Report on IEA Bioenergy Tasks' Activities 2013-2015

IEA Bioenergy

IEA BIOENERGY: EXCO: 2016:04

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Published by IEA Bioenergy

Foreword

This report presents the results of the work in the triennium 2013-2015 of all Annexes or Tasks in the IEA Bioenergy Technology Collaboration Program (TCP).

The IEA Bioenergy TCP is the main initiative under the auspices of the IEA to develop and deploy bioenergy in a sustainable way. During the last triennium 23 countries participated in the collaboration, and contributed financially to the programme resulting in a budget of about 1.7 million US$ per year to carry out the work. The collaboration is managed by the Executive Committee which is composed of a member from each participating country.

The work is divided into 10 different annexes, also called Tasks and the results from each Task are presented in this report. It shows a wide variety of results and allows our countries to remain on top of technology development and deployment in the area of bioenergy. Collaboration in the Tasks also enables cost reduction compared to isolated innovation by each country separately. A great number of experts – scientists and industrial representatives from the participating countries – have joined this collaborative work in the Tasks and contributed to the results. We are grateful to all Task Leaders and experts for carrying out the work programme and creating the results that have been achieved.

The results show steady progress, although a number of complicated issues need to be addressed. More sustainable production is possible and efficient conversion in new processes in a cost effective way offers opportunities for market deployment.

The IEA Bioenergy Technology Collaboration Programme will continue to develop and improve efficient and cost-effective biomass technologies and support the deployment of bioenergy in a sustainable way to realise a low carbon economy.

On behalf of the Executive Committee,

Kees Kwant
Chairman IEA Bioenergy

Introduction

Key achievements Triennium 2013-2015

The work within IEA Bioenergy is structured in a number of Tasks, which have well defined objectives, budgets, and time frames, which are agreed per period of three years (triennium). 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 10 ongoing Tasks during this triennium:

- Task 32: Biomass Combustion and Co-firing
- Task 33: Thermal gasification of Biomass
- Task 34: Pyrolysis of Biomass
- Task 36: Integrating Energy recovery into Solid Waste Management
- 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 International Bioenergy Trade – Securing Supply and Demand
- Task 42: Biorefining – Sustainable Processing of Biomass into a Spectrum of Marketable Bio-based Products and Bioenergy
- Task 43: Biomass Feedstocks for Energy Markets

This overview shows a short summary of key achievements of the Tasks in the Triennium 2013-2015.

Task 32: Biomass Combustion and Co-firing

Task 32 aims to stimulate the expansion of cost effective and clean biomass combustion and co-firing for the production of heat and power. Some key reports published in the previous triennium:

- *Status overview of Torrefaction Technologies – A review of the commercialisation status of biomass torrefaction.* Commercialisation of torrefaction technologies has been more difficult than anticipated a few years ago. However, companies involved have significantly improved their ability to produce high quality torrefied biomass products, with pellets of comparable durability and supply costs to conventional wood pellets, yet with superior handling and combustion characteristics.
- The technical report *Sensitivity of System Design on Heat Distribution Costs in District Heating*, shows that district heating networks are generally overdimensioned, and should be installed with smaller diameters as the resulting increment in pumping energy is more than compensated by reduced investment costs, particularly in a situation where load densities are only reducing further due to better insulation.
- The publication '*The status of large scale biomass firing – The milling and combustion of biomass materials in large pulverised coal boilers*' describes the practical experiences and commonly accepted approaches for biomass co-firing in pulverised coal fired power stations, including a number of case studies.

Task 33: Thermal gasification of Biomass

In the 2013-2015 triennium Task 33 monitored and reported on the status of new and existing commercial biomass gasification processes, identified technical hurdles limiting broader deployment, and explored opportunities to improve operational reliability and costs associated with biomass gasification systems. Main achievements:

- A Status report on thermal *biomass gasification in the countries participating in Task 33* provides an overview of 86 commercial, demonstration and pilot facilities in these countries. Details about these thermal biomass gasification facilities are also available via an interactive online database.
- A *performance test protocol (PTP) for small scale biomass gasifiers* was developed and published. As a guideline during a project for a gasifier CHP unit, this white paper can help improve project execution by providing guidance for objectively measuring performance after commissioning.
- A *series of eight 1- to 2-page factsheets about biomass gasification* was developed and published on the Task 33 website. The factsheets provide an overview of gasification technology, opportunities, challenges and development status and are targeted towards non-experts interested in knowing more about biomass gasification.
- Five public workshops were organized in this triennium on lessons learned, system and integration aspects, small scale gasification, liquid biofuels, and energy and products from biomass and waste.

Task 34: Pyrolysis of Biomass

The objective of Task 34 is to improve the rate of implementation and success of fast pyrolysis for fuels and chemicals by contributing to the resolution of critical technical areas and disseminating relevant information, particularly to industry and policy makers.

The Task members undertook a *review of the potential applications for bio-oil* within existing markets. The group identified the leading applications and the technical and non-technical barriers to commercialization.

A *Round Robin* was organized to understand the consistency of bio-oil as it is produced in the diverse group of laboratories involved in process research and development. Twenty laboratories in the participating countries received three biomass feedstocks for processing in their respective systems.

Newsletters were published at 6-monthly intervals including several technical articles on the topic of pyrolysis oil.

Task 36: Integrating Energy recovery into Solid Waste Management

The aim of Task 36 in the 2013-2015 triennium was to examine issues that are important to policy development and implementation of energy recovery systems for solid wastes. Various workshops were organized as well as specific studies of key importance: small scale energy from waste, waste gasification, impact of changes in policy on energy recovery and mass/energy balance of RDF compared with MSW.

Waste-to-Energy will still play an important role when it comes to sustainable waste management in a circular economy. The role will be especially important during the transition period when products and waste containing hazardous substances should be phased out and not recirculated. For most of these streams energy recovery is the most efficient way to handle it.

Policy and legislation are extremely important when developing technologies. Long term policies and stable conditions regarding incentives or taxes are creating an environment that can foster innovations and stimulate new technologies, while short sighted changes will make it harder to raise the needed capital when developing something.

Small scale Energy-from-Waste can be viable despite the clear disadvantage regarding costs. Policy, local opinion, decreased transport and security of supply are some factors that can offset the economic disadvantages.

Task 37: Energy from Biogas

The main objectives of the 2013-2015 work program of Task 37 were to support sustainable development and exploitation of technologies used in the biogas production and utilisation process chain.

The technical report "*Process monitoring in biogas plants*" divides monitoring in two groups: the first group are early indicators of a process imbalance and allow the biogas plant operator to react in time before process imbalance occurs; the second characterise the process and can help to detect and eliminate the cause of the imbalance.

The report "*A perspective on the potential role of biogas in smart energy grids*" highlighted how biogas systems could facilitate increased proportions of variable renewable electricity on the electricity grid through a combination of demand driven biogas systems and power to gas systems.

The report "*A perspective on algal biogas*" investigated generation of biogas from macro-algae (seaweed) and micro-algae; it concluded that the technology was not mature and sustainable processes would require circular economy applications.

The *Biogas Handbook* was published in February 2013 and marked the end of a large collaborative effort towards the end of the previous work program. The handbook has since become the leading reference work in the field of AD and biogas utilisation.

Task 38: Climate Change Effects of Biomass and Bioenergy Systems

Task 38 considers questions of GHG estimation in agriculture, forestry and the energy sector, with application to GHG accounting for bioenergy under renewable energy schemes and the Kyoto Protocol, and contributes to the work of the Intergovernmental Panel on Climate Change (IPCC). During the 2013 – 2015 period, Task 38 has focussed on addressing methodological challenges in quantifying climate change effects of bioenergy, and encouraged discussion amongst the research community on the role of bioenergy in climate change mitigation. Task 38 has discerned that one of the major reasons for diverging results between studies on climate change effects of bioenergy is the different methods applied. Studies vary, for example, in key assumptions regarding reference systems, system boundaries, temporal and spatial scale, life cycle stages and emissions sources included. A further important difference relates to the LCA modelling approach employed – attributional or consequential. During the 2013-2015 triennium, Task 38 members published several papers on aspects of methodology for climate change assessment, and the Task is nearing completion of papers to guide selection of reference systems and metrics.

Task 39: Commercialising of Conventional and Advanced Liquid Biofuels from Biomass

Task 39's work is focused on accelerating the commercialisation of liquid biofuels, both conventional and advanced biofuels, including algal and 'drop-in' biofuels.

A significant achievement of the Task during the 2013-2015 triennium was publishing the comprehensive report "*The Potential and challenges of Drop-in Biofuels*". The report provided a well-researched, objective evaluation of existing and emerging drop-in biofuels conversion technologies and the various companies that are trying to commercialise the various pathways and technologies.

Nine Newsletters were published during the triennium, each highlighting the latest news in the biofuel area, with a specific focus on one of Task 39's member countries.

An updated *Implementation Agendas* report was published in 2014. This report, based on input from all of the Task 39 country representatives, primarily compares and contrasts the policies that have been used to implement biofuels production, development and market penetration for 19 different countries. The report highlights details of biofuel policies and assesses the extent to which these biofuels policies have been successfully implemented.

Task 40: Sustainable International Bioenergy Trade – Securing Supply and Demand

The core objective of Task 40 is to support the development of sustainable, international bioenergy markets and international trade, recognising the diversity in resources and biomass applications. Several publications and workshops were prepared, including the following:

- A book on "*International Bioenergy Trade: History, status & outlook on securing sustainable bioenergy supply, demand and markets*" was published by Springer in 2014, and is in essence a synthesis of 10 years work of Task 40. For this period, Task 40 has monitored the developments in international bioenergy trade, including the organization of about 20 workshops on trade-related topics, and the publication of over 100 studies, country reports, newsletters, etc.
- A technical report on the *impact of promotion mechanisms for advanced and low-iLUC biofuels on markets*. In this report, four case studies are presented where promotion mechanisms for advanced biofuels have had an impact on markets and trade (used cooking oils and animal fats, sugarcane ethanol), or may be anticipated to impact markets and trade in the future (straw, wood pellets). However well intentioned these policy measures, some may create unintended effects.
- A book entitled "*Developing the global bio-economy. Technical, market and environmental lessons from bioenergy*" brings together expertise from three IEA Bioenergy Tasks on international trade, biorefineries and pyrolysis to review the bioenergy sector and draw useful lessons for the full deployment of the bioeconomy.

Task 42: Biorefining – Sustainable Processing of Biomass into a Spectrum of Marketable Bio-based Products and Bioenergy

The aim of Task 42 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.

Task 42 started its activities by the set-up of a biorefinery definition, i.e.: biorefining is the sustainable processing of biomass into a portfolio of marketable biobased products and bioenergy. Then the Task developed an understandable biorefineries classification system based on raw materials, platforms, and products. A method to calculate a biorefinery complexity-index (BCI) and a biorefinery-complexity-profile (BCP) was developed to give industry, policy makers and investors some additional information to assist them in developing biorefinery implementation strategies at minimal technical and economic risks. A biorefinery fact sheet (BFS) methodology/set-up was developed/defined with the goal to clearly present the advantages of biorefining in a uniform way to help overall understanding of the principle and final market deployment. Meanwhile 13 biorefinery factsheets have been produced.

Biorefining/bio-cascading is always the approach to use to maximise full sustainability. Bioenergy can be the main driver (biofuel/energy-driven biorefinery approach) or a secondary product (product-driven biorefinery approach), but will always be part of the optimised biomass valorisation path.

Task 43: Biomass Feedstocks for Energy Markets

The role of Task 43 is to envisage and contribute to the development of competitive bioenergy supply chains that use sustainably produced feedstocks. This is accomplished by linking promising feedstocks with energy markets, addressing logistical and technical challenges, and through the identification and quantification of socioeconomic and environmental consequences of feedstock production.

A central part of the work of Task 43 is to investigate and communicate how dedicated biomass production systems can be expanded and how land, water and other resources can be used sustainably to produce biomass for energy. Considering the on-going public debate about bioenergy, the work of the Task has progressed in response to the need for science-based information that can inform the evolving public debate about bioenergy sustainability and provide guidance for policymaking and strategic planning in the industry.

During the 2013-2015 triennium, Task 43 provided leadership to an inter-Task Strategic Project titled "Mobilizing Sustainable Bioenergy Supply Chains". This project involved over 70 collaborators associated with different IEA Bioenergy Tasks. The project concluded that significant opportunities exist to reduce greenhouse gas emissions, increase domestic energy security, boost rural economies, and improve local environmental conditions through the deployment of sustainable bioenergy and bio-based product supply chains. However, challenges will exist to large-scale implementation in many regions.

Contents

TASK 32: Biomass Combustion and Cofiring

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Introduction

Task 32 aims to stimulate the expansion of the use of Biomass Combustion and Cofiring for the production of heat and power to a wider size range. This objective is to be reached by generating and disseminating information on technical and non-technical barriers and solutions.

Background

Some general trends for the different combustion applications are as follows:

- Manually fired stoves and boilers using firewood logs are still widely deployed in both OECD countries and non-OECD countries. Health issues related to combustion aerosols are one of the main concerns
- Fully automated combustion technologies for wood pellets and wood chips are widely applied and continuously improving in terms of reliability, costs and environmental performance. Significant development work is ongoing to enable the use of locally available, low grade biomass residues
- Biomass CHP plants based on grate combustion are widely deployed in Scandinavian countries, Austria, Switzerland, Italy, Germany and to a lesser extent the USA and France. These systems are generally of increasing scale and have increasing electrical efficiency due to better understanding of superheater corrosion mechanisms
- CHP plants based on fluid bed combustion in the size range 20-100 MWe can be considered as well established technology, deployed especially in Finland and Sweden but increasingly in other countries as well
- The co-firing of biomass with coal is widely deployed in a number of European countries and is of increasing interest worldwide. There is also a trend towards the conversion of existing coal-fired boilers to 100% biomass firing.

Task 32 has contributed to further development and implementation of biomass combustion and cofiring systems in its member countries through exchange of information during semi-annually organised Task meetings, Task organised workshops on particular topics (with active industry involvement and also organised with other tasks or networks), as well as Task initiated studies on certain specific combustion related topics such as aerosols' emissions and cofiring. In these activities, Task 32 seeks industrial participation, interaction with other IEA Bioenergy Tasks, other IEA Technology Collaboration Programmes (TCPs) and European bioenergy industry organisations. A memorandum of understanding for collaboration exists with the industrial biomass power group, VGB Powertech (the European branch organisation of power producers). Several joint workshops and studies were carried out with such groups, as shown in this report.

Task objectives and work carried out

Overview

In the triennium 2013-2015, Task 32 addressed most of the issues listed above in specific workshops or publications. The following specific activities were undertaken:

Task meetings

Seven Task meetings were held, to effectively communicate progress and results of both national R&D programmes and task initiated projects described in this end-of-task report. Each task meeting was combined with plant visits and/or a task organised workshop on a specific combustion related topic.

Workshops

Five workshops were organised, typically in combination with a task meeting. Through the hyperlinks in the table below, detailed information can be obtained from the Task 32 website.

Nr.	Topic	Hyperlink
D2	Expert workshop on CFD for design of industrial biomass combustion technologies, 6 June 2013, Copenhagen, Denmark	Individual presentations
D9	Torrefaction workshop at the Central European Biomass Conference, 17 Jan 2014, Graz, Austria	Individual presentations Summary report
D6	High Temperature Corrosion in Biomass Combustion Installations, 4 June 2014, Jönköping, Sweden	Individual presentations
	Expert workshop on Opportunities for Bioenergy in South Africa, 4 Nov 2014, Johannesburg, South Africa	Individual presentations
D16	Expert workshop on Highly Efficient and Clean Wood Log Stoves, 29 Oct 2015, Berlin, Germany	Individual presentations
	Key results of Task 32 in the triennium 2013-2015, Berlin, 28 Nov 2015	Individual presentations

Compared to the original workplan, some deviations occurred. A planned workshop on biomass cofiring was cancelled, while an additional workshop was organised on opportunities for bioenergy in South Africa. Furthermore, Task 32 co-organised or provided input to conference sessions initiated by others such as:

- Presentations on combustion of challenging fuels and health and safety at a VGB Powertech conference on key challenges in biomass power production, 13-14 November 2013.
- A presentation on the commercial status of torrefaction at the World Bioenergy Conference, 27 January 2015
- A conference session in the IEA Bioenergy Conference 2015, Berlin, November 2015 displaying the key results of the triennium 2013-2015.

Task studies:

Task 32 prepared a number of specific publications in which recent R&D developments were collated in order to address the actual market issues identified. An overview of these specific activities that were performed by task 32 in the triennium 2013-2015 is given in the table below. A detailed description per activity is included after the table.

Nr.	Deliverable
D11	Developments in commercialisation of torrefaction technologies, Marcel Cremers, DNV-GL, Netherlands
D13	Advanced characterisation methods for solid biomass fuels, Ingwald Obernberger, Thomas Brunner, TU Graz, Austria
D17	The status of large scale biomass firing – The milling and combustion of biomass materials in large pulverised coal boilers. W.R. Livingston, J. Middelkamp, W. Willeboer, S. Tosney, B. Sander, S. Madrali, M.T. Hansen, J. Koppejan and M.F.G. Cremers
D18	Sensitivity of System Design on Heat Distribution Costs in District Heating, Thomas Nussbaumer and Stefan Thalmann, Verenum, Switzerland
	Status Report on District Heating Systems in IEA Bioenergy T32 member countries, Thomas Nussbaumer and Stefan Thalmann, Verenum, Switzerland
D19	Techno-economic evaluation of selected decentralised CHP applications based on biomass combustion with steam turbine and ORC processes, Alfred Hammerschmid, Bios Bioenergiesysteme GmbH, Austria
D20	Database on cofiring experiences

Detailed description

The key results of projects carried out by Task 32 in the triennium 2013-2015 as summarised in this report were presented at the IEA Bioenergy Conference 2015, Berlin, 28 Nov 2015. This provided an opportunity to display the work of Task 32.

Workshops

A summary of the results of the workshops is provided below; reports on all workshops can be downloaded from the Tasks website www.ieabioenergytask32.com.

1. Fuel characterisation, pretreatment, and supply

A workshop on progress in commercialisation of torrefaction technologies was held jointly with Task 40 and the EU project 'SECTOR' at the Central European Biomass Conference, 17 Jan 2014, Graz, Austria. It was concluded there that in 2010-2014, expectations concerning the commercialisation rate of torrefaction technologies were unrealistically high. It takes several years to develop a new thermal processing technology from technology concept to full-scale production and to have a substantial impact on the world market. Nevertheless, significant progress has been achieved, as a number of technology suppliers are now able to produce high quality torrefied material and offer commercial turnkey torrefaction plants at full scale. The progress in commercialisation of torrefaction was also examined in a separate Task 32 report, see below.

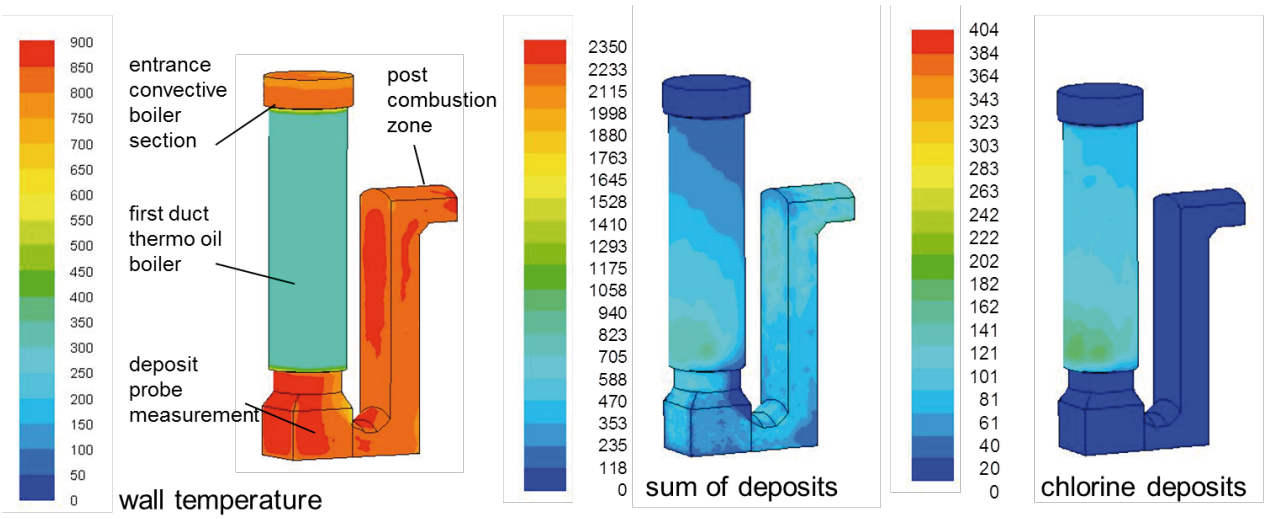
2. CFD based furnace and boiler design

On June 6, 2013 a workshop was held as a side event of the EU Biomass Conference to share experiences and address the current opportunities and limitations of CFD based design of industrial biomass combustion appliances. CFD aided design tools are becoming increasingly available to translate the improved fundamental understanding of the combustion process into better practical designs. At the workshop it was concluded that such CFD tools could be very effective in improving the design of such equipment, as it could lead to much better combustion quality, avoid the need of a 'trial and error' approach and reduce development expenses. The application of such tools however is relatively costly and it is doubtful whether smaller stove producers can afford this at the moment, so that currently this approach is more applied for larger scale industrial boilers.

3. Improvement in woodstove designs

A workshop at the IEA Bioenergy Conference 2015, in October 2015, addressed recent technical developments in the design of domestic woodstoves. Wood stoves continue to be sold on the European market and contribute significantly to renewable energy use. However, where obsolete technologies are applied or the stove is not properly operated, there may be significant adverse effects on public health. Some important conclusions from this event are as follows:

- Good combustion starts with a properly designed combustion chamber (if possible using CFD tools). Only in the second stage, should manufacturers design an attractive casing around it (currently the design process often takes place the other way around).
- Very positive results have been achieved with stoves equipped with automatic combustion control, to optimise the combustion parameters through the various phases of the combustion process. For the validation of such improvements new test procedures are required, which better reflect real life operational behaviour; such methods are currently being developed.
- Recently, positive results have also been achieved for the application of catalysts in stoves. In Germany, stove catalysts with a proven long life are now commercialised. The effect of foam ceramic elements without catalyst, aimed at extending the reaction time and thereby reducing the emission of particles, seems only marginal.

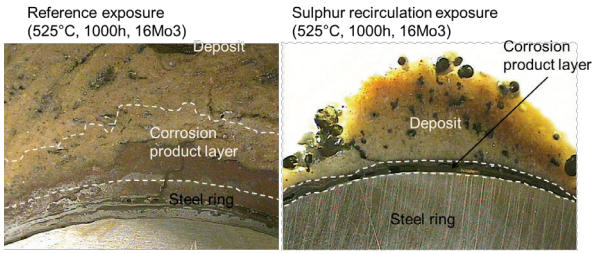


Example of CFD applications: Simulation of deposit formation in a 10 MW thermal oil boiler (Robert Scharler, Bioenergy2020+)

- Other major influencing factors on emissions are the use of wood with suitable moisture content, proper user behaviour and an adequate installation and integration of the stove into the building. These factors should be addressed by user training organised by stove suppliers and by quality certification schemes for installers.

4. High Temperature Corrosion in Biomass Combustion Installations

On 4 June 2014, a workshop was organised at the World Bioenergy Conference in Jönköping, Sweden on high temperature corrosion in biomass boilers. This topic continues to be relevant as industry wants to use inexpensive but therefore often challenging biomass types at the highest possible steam (and therefore metal) temperatures and the lowest CAPEX and OPEX costs. The workshop provided an overview of the fundamental mechanisms behind high temperature corrosion, as well as a number of practical ways to mitigate the corrosion to acceptable levels, such as fuel additives, furnace additives, wall cladding, superheater configurations, etc.



Experiments to evaluate the protective effect of sulphur recycling on metal corrosion (Prof L.G. Johansson, Chalmers University)

5. South African national workshop on opportunities for biomass based power generation

On the 4 November 2014, IEA Bioenergy Task 32 and ESKOM jointly organised an expert workshop on the opportunities for bioenergy in South Africa. The workshop aimed at discussing the potential for applying various bioenergy technologies in the South African economy. After various presentations and an open discussion, it was concluded that biomass cofiring in particular could make a significant impact in South Africa, but landfill gas and anaerobic digestion could also be very relevant.

Studies

A summary of Task 32 studies carried out in the triennium 2013-2015 is provided below. The full reports are available on the Task 32 website.

Task 32 Study 1: Status overview of Torrefaction Technologies – A review of the commercialisation status of biomass torrefaction, Marcel Cremers et. al., DNV-GL, Netherlands (D11)

This report provides an update of the Status overview of torrefaction technologies, which was produced by IEA Bioenergy Task 32 in 2012. The reason for this action was the observation that commercialisation of torrefaction technologies had been more difficult than anticipated in 2012, when it was expected that a significant fraction of the biomass pellets supplied today could have been replaced by torrefied pellets. It has been hard to fully prove the earlier claims made on product characteristics, and several companies have gone bankrupt due to the inability to produce good quality product or due to a lack of buyers.

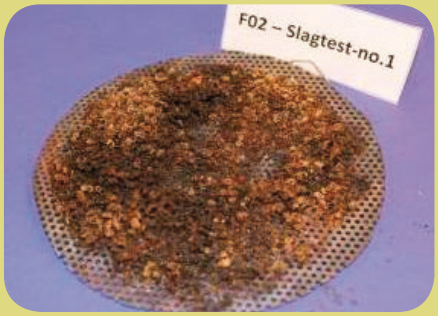
Nevertheless, it is clear that the companies involved have significantly improved their ability to produce high quality products, with pellets of comparable durability to conventional wood pellets. The torrefied pellets exhibit comparable supply costs. However end users need to be convinced that the superior handling and combustion characteristics claimed do translate into an economic advantage that can counterbalance the perceived risk.

As in the case of conventional wood pellets, price parity with coal is essential to enable commercial market introduction of torrefied biomass for co-firing. In the absence of a substantial price penalty for CO_2 emissions and with the low price of coal, this implies that typically additional subsidy schemes should be in place.

Task 32 Study 2: Advanced characterisation methods for solid biomass fuels, Ingwald Obernberger, Thomas Brunner, TU Graz, Austria (D13)

In this project a comprehensive questionnaire regarding advanced biomass fuel characterisation methods was distributed to different organisations active in this field. Based on this feedback as well as on information and experience gained from recent European projects (EU FP7 and ERA-NET Bioenergy), a summary and evaluation of different advanced fuel characterisation methods has been made. The advanced methods concerned are TGA analyses, fuel indices, chemical fractionation, SEM/EDX analyses, TGA/DSC analysis and thermodynamic equilibrium calculations. In addition test runs at batch and continuously working reactors have been carried out. All of these methods show their specific advantages and disadvantages and therefore, in many cases a combination of different methods is envisaged.

It can generally be recommended to apply the evaluation of fuel indices as a first step in fuel characterisation in order to gain a qualitative pre-evaluation of conversion related problems which could be expected.



A slag analyser used to predict slagging behaviour of a fuel (DTI, Denmark)

In a second step, test runs in batchwise or continuously operated lab-scale reactors are recommended in order to gain quantitative data. The selection of the reactor, the test run setup and the measurement and analysis programme have to be adjusted to the specific problems expected from the utilisation of the fuel (derived from the interpretation of fuel indices) as well as account taken of the constraints of the process as it is be applied. TGA, chemical fractionation, SEM/EDX analysis, STA-tests as well as TEC can be used as supporting tools to gain deeper insights into specific aspects as well as to gain basic data (e.g. kinetic data) for process modelling. If a new fuel has been positively evaluated by these methods with regard to an application in real-scale, it is recommended to perform a pilot-scale test run with this fuel. In this way, the plant settings can already be optimised based on the results gained from the advanced fuel characterisation.

Task 32 Study 3: The status of large scale biomass firing – The milling and combustion of biomass materials in large pulverised coal boilers. W.R. Livingston, J. Middelkamp, W. Willeboer, S. Tosney, B. Sander, S. Madrali, M.T. Hansen, J. Koppejan and M.F.G. Cremers, jan 2016 (D17)

This report provides a status update on biomass cofiring activities. It describes the practical experiences and commonly accepted approaches for biomass cofiring in pulverised coal fired power stations, including a number of case studies.

Firing and co-firing biomass as a replacement for coal in large pulverised coal boilers is a very attractive option for generating electricity from biomass, offering various technical and commercial advantages, such as:

- The capital investment requirements of power plant conversion projects are very much lower than the investment costs of a new build power plant,
- The reliability and security of the supply of the power generated are higher than most other forms of renewable energy, and
- The power generation efficiency and the generation costs are much better than those associated with industrial scale biomass power plants.

The report shows how the key technical options for the conversion of large pulverised coal boilers to the firing and co-firing of biomass have been successfully demonstrated, principally in projects in Northern Europe, over the past 10-15 years. A number of the plants converted to biomass firing and co-firing are currently in operation, and there are a small number of further conversion projects currently at the proposal stage.

The general experience from these projects has shown that the technical risk areas have been managed successfully and that the plant availability and efficiency levels after conversion have been acceptable.

It has been found that the storage and handling of the biomass materials, particularly due to the tendency of the biomass to generate significant dust levels, have presented the most significant problems. It is fair to say, however, that the fuel suppliers and the materials handling equipment supply industry have learned many lessons over the past few years, and that the solutions currently being offered for biomass projects represent a significant improvement over previous practice.

Aerial view of de converted Drax power station, showing the coal stockpile on the bottom left and the four biomass silos on the bottom right

Task 32 Study 4: Sensitivity of System Design on Heat Distribution Costs in District Heating, Thomas Nussbaumer and Stefan Thalmann, Verenum, Switzerland (D18a)

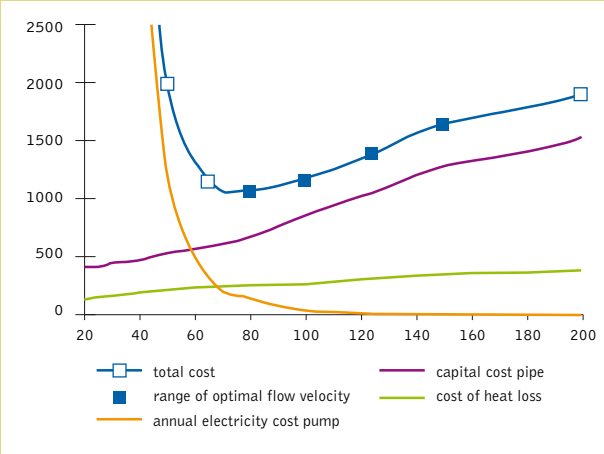
District heating (DH) offers interesting opportunities to use biomass heat to replace decentralised fossil heating. The additional cost and energy losses caused by the heat distribution network however can be significant in comparison to the benefits. In close collaboration with the IEA District Heating and Cooling TCP, a study was performed to evaluate how biomass combustion based district heating networks could be optimally designed. The project resulted in two separate reports.

The first report comprises a sensitivity analysis for a virtual DH network in Switzerland with 1 MW heat output, a pipeline length of 1 km, and a heat consumption during 2000 annual full-load hours corresponding to a linear heat density of 2000 MWh per year and meter of pipeline length.

The economic assessment evaluates influences of capital costs, electricity prices, interest rates, fuel prices, insulation, supply and return temperatures, full load hours, etc. It clearly indicates that for the case analysed, capital costs are most relevant for the total costs of heat supply, representing a share of 62%, while the fuel costs at a fuel price of 4.0 c/kWh contribute a 25% share and the electricity costs for pumping at a power price of 16.5 c/kWh the remaining 13%. An assessment of the connection load reveals that at constant linear heat density, the heat distribution costs increase with increasing network size. Consequently, strong economy of scale in the heat production is necessary to justify large DH systems. This pre-condition is typically fulfilled by automatic biomass combustion plants and even amplified for applications with combined heat and power (CHP).

Since the capital costs dominate the total cost, minimisation of the heat distribution costs generally implies the use of the smallest, technically feasible pipe diameter without cavitation pitting, while respecting the maximum allowable specific pressure drop up to 300 Pa/m, since this only occurs at a short peak time. For the investigated model network, an oversizing by one diameter resulted in 9% higher heat distribution cost while two diameters caused 30% higher cost.

Besides the pipe diameter, it is essential to minimise the flows by obtaining the lowest possible return temperatures. Further, the insulation class has only a minor influence on the economy and high insulation is not economically favourable at today's fuel prices.



Heat distribution losses indicated as total cost and divided in capital cost, heat loss costs, and electricity costs as a function of the nominal diameter for a reference case.

Task 32 Study 5: Status Report on District Heating Systems in IEA Bioenergy T32 member countries, Thomas Nussbaumer v and Stefan Thalmann, Verenum, Switzerland (D18b)

The second report evaluates district heating systems in Task 32 member countries based on characteristic parameters such as annual heat losses, linear heat density and the connection load. Data was evaluated from 800 district heating systems from Austria, Denmark, Finland, Germany and Switzerland.

As the evaluation illustrates that heat losses can increase significantly with reducing linear heat density, a minimum linear heat density of 1.8 MWh/m is recommended. The survey also shows that the heat losses vary by more than a factor of three with a given linear heat density. This is caused by various factors:

Applying pipes with diameters that are too large strongly affects the capital costs and heat distribution losses and should be avoided.

Other key parameters that determine heat supply costs are network layout, temperature spread and level, insulation class, and the utilisation of the network.

While the costs of heat production generally benefits from a strong economy of scale, the heat distribution is characterised by diseconomy of scale. Consequently, larger district heating systems as e.g. in Denmark, are only economically feasible due to the large economy of scale in the generation unit.

A detailed analysis of individual line sections for a selected number of district heating systems in Switzerland revealed that 80% of the line sections are oversized mostly by one or two and maximally up to four nominal diameters. This results in heat distribution losses and costs of up to 20% to 30% higher than necessary.

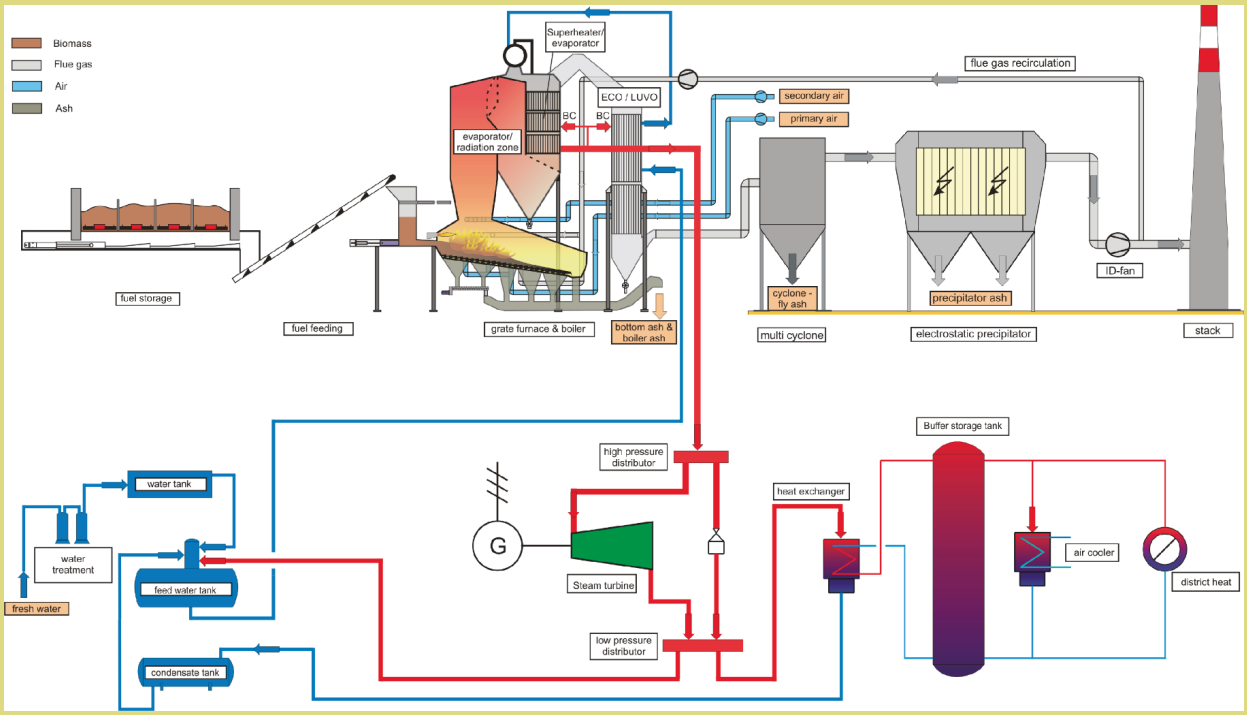
Task 32 Study 6: Techno-economic evaluation of selected decentralised CHP applications based on biomass combustion with steam turbine and ORC processes, Alfred Hammerschmid, Bios Bioenergiesysteme GmbH, Austria (D19)

Since the first CHP plant based on biomass combustion was launched, several technological developments and demonstration activities have taken place. This report provides an update of a Task 32 project carried out in 2004, covering three actual plants that were recently taken into operation, based on steam turbine and Organic Rankine Cycle (ORC) processes:

- In steam turbine based systems, the main issue within the last ten years was an increase in electric efficiency by increasing the live steam temperatures through the use of better materials that could withstand high temperature corrosion. In the present study the economics of a steam turbine based CHP plant of 5.7 MWelgross, from Austria was evaluated.
- ORC based CHP plants have been operational since 1999, and today over 200 ORC units are in operation with continuously improved electric efficiency and reduced investment costs. A typical ORC plant of 2.4 MW_e in Estonia was evaluated in this study.
- A third plant evaluated was based on the so-called direct exchange ORC system. This technology is based on an ORC system which does not need an intermediate circuit (e.g. a thermal oil cycle) and can be seen as a promising future approach to reduce the investment costs of the technology. A case study based on the direct exchange ORC system in a biomass plant in Slovakia with an electric capacity of 130 kWelgross, has been investigated.

The analysis of the CHP technologies covers the technology as well as an economic performance evaluation based on real life figures of the case studies selected. This includes the process flow sheets with mass and energy balances, and the specific differences between the technologies concerning operational behaviour, personnel demand and process control.

The report showed that the heat generation costs of the different CHP plants investigated vary between 44 €/MWh_{th} (steam turbine) to 25 €/MWh_{th} (direct exchange ORC system) and the electricity generation costs are in a range of 150 €/MWh_e (direct exchange ORC) and 99 €/MWh_{el} (steam turbine). The main cost factors are the capital costs and the fuel costs. The economy of scale effect is obvious when comparing the specific investment costs of the 130 kWel,gross ORC with the 2.4 MWel,gross ORC. This illustrates that higher feed in tariffs or investment subsidies would be required in order to make the smaller CHP technologies economically viable. The study further shows that heat utilisation and correct dimensioning of the CHP plant is crucial in order to achieve a large number of full load operating hours in heat controlled operation.



Schematic diagram of the evaluated biomass CHP plant based on steam turbine in Austria
source: BIOS BIOENERGIESYSTEME GmbH, Graz, Austria; www.bios-bioenergy.at

Task 32 Study 7: Updated database on biomass co-firing with expert tool (D20)

On the Task 32 website, a database exhibiting experiences with biomass cofiring is operational since 2003. Currently approximately 250 coal fired power plants with experience in cofiring biomass are identified. In 2015, the database was incorporated into the joint IEA Bioenergy Technology database.

Geographical detail of entries in the Task 32 cofiring database.

Conclusions and recommendations

Task 32 has a unique role in providing an independent platform for hands-on information exchange amongst both manufacturers and operators of biomass combustion plants, and in translating findings of fundamental and applied R&D work to industry and policy makers.

In the period 2013-2015, Task 32 organised several expert workshops and produced a number of topical reports. The work of Task 32 is greatly appreciated by market actors (end users, equipment suppliers and policy makers), as indicated in the interaction in the workshops organised and from the feedback on reports published. One success factor is the provision of publications with detailed insights on key technical performance figures on costs, reliability, efficiencies, and emissions from various technology concepts such as torrefaction, CFD analysis tools, low emission stoves and boilers, new particle removal technologies, or mitigating high temperature corrosion.

The work of Task 32 will continue in the triennium 2016-2018, with an increased number of participating member countries and a new work programme that reflects the actual research priorities in the area of biomass combustion and cofiring.

TASK 33: Thermal Gasification of Biomass

Prepared by:

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Participating countries:

Austria, Denmark, Finland, Germany, Italy, The Netherlands, Norway, Sweden, Switzerland, USA

Website: http://www.ieatask33.org/

Introduction

IEA Bioenergy Task 33 is a forum for National Team Leaders (NTLs) representing member countries to exchange, review and evaluate information about biomass gasification research, development and demonstration (RD&D) programmes and operating commercial, demonstration and pilot plants. Task activities assist the development of national bioenergy programmes and aim to help advance the state-of-the-art of biomass gasification.

The objectives of Task 33 are to foster cooperation among the participating countries and industry to eliminate technological impediments to the advancement of thermal gasification of biomass. The ultimate objective is to promote commercialisation of efficient, economical, and environmentally preferable biomass gasification processes, for the production of electricity, heat, and steam, for the production of synthesis gas for subsequent conversion to chemicals, fertilisers, hydrogen and transportation fuels, and also for co-production of these products. Information sharing and advocacy is achieved through regular meetings and correspondence of National Team Leaders, organisation of public workshops on biomass gasification issues and development of special projects and reports on matters associated with technical or market aspects of biomass gasification.

In recognition of the potential to produce fuels and chemicals via synthesis gas, in the 2013-2015 triennium the Task expanded its role to address issues related to synthesis gas in addition to combined heat and power (CHP) and power. The Task continued its interaction with industrial and academic experts to coordinate technology and product development. These activities were useful for participating countries to refine national bioenergy plans as well as to explore cooperative RD&D projects with other NTLs.

This report provides a summary of Task 33 activities during the triennium 2013-2015, including the special projects and workshops arranged through the task.

Background

The scope of work for the 2013-2015 triennium was 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 programme of work that addresses the needs of the participating countries.

The Task monitored the current status of the critical unit operations and unit processes that constitute the biomass gasification (BMG) process, and identified hurdles to further development, operational reliability, and reduction of the capital cost of biomass gasification systems. The Task meetings provided a forum to discuss the technological advances and issues critical to scale-up, system integration, and commercial implementation of biomass gasification processes. Generally, 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 meetings to present their practical experiences and to discuss the options for development of critical process components to advance state-of-the-art biomass gasification systems. The interaction with industry provides the opportunity for the National Team Leaders to evaluate refinements to existing product lines and/or processes. Academic experts are also invited when the need arises to seek information and cooperation in order to address research needs.

The work programme included the following elements:

- Task 33 planned and conducted semi-annual Task meetings including workshops on sub-task studies selected by the NTLs, and addressed matters related to the Task mission and objectives. Meeting locations, dates, and topics of the associated workshops are given below. Discussions of workshops are presented later.

Meeting	Associated Workshop	Dates and Location
1st Task meeting	WS1: "Lessons Learned"	7-9 May 2013 Denver, USA
2nd Task meeting	WS2: "System and Integration Aspects of Biomass-based Gasification" – Joint with IEA Industrial Energy-related Technologies and Systems	19-21 Nov 2013 Gothenburg, Sweden
3rd Task meeting	WS3: "Thermal Biomass Gasification in Small Scale"	13-15 May 2014 Ischia, Italy
4th Task meeting	WS4: "Liquid Biofuels"	3-5 Nov 2014 Karlsruhe, Germany
5th Task meeting	WS5: "Symposium on Renewable Energy and Products from Biomass and Waste"	11-13 May 2015 Ponferrada, Spain
6th Task meeting	WS6: IEA Bioenergy 2015; end of triennium conference jointly with all tasks	27-29 Oct 2015 Berlin, Germany

- NTLs surveyed the current biomass and waste gasification RD&D programmes in member countries, commercial operations and market opportunities for BMG, and identified the technical and non-technical barriers to commercialisation of the technology. NTLs used the survey results to prepare and update Country Reports for information dissemination. Summary country report presentations and supporting reports were posted on the Task website (www.ieatask33.org).
- The Technical University of Vienna maintained and updated the Task 33 Website, including country reports from member countries, workshop summaries and presentations, selected gasification publications, and meeting schedules.
- Task 33 developed a database of gasification facilities in collaboration with Task 39. The structure of the database is similar to that for Task 32, 33, 34 and 39.

Task objectives and work carried out

Task Meetings and Workshops

Five workshops were organised by Task 33 throughout the triennium. In addition, Task 33 organised a session on commercial success of biomass gasification at the IEA Bioenergy Conference 2015. Content and outcomes from the workshops are described below.

Workshop 1: Lessons Learned

The workshop was held in Denver on May 8, 2013 and was attended by Task NTL's and outside guests representing the National Renewable Energy Laboratory (NREL). NREL is the principal research laboratory for the U.S. Department of Energy's (DoE) Office of Energy Efficiency and Renewable Energy (EERE). The laboratory is managed for EERE by the Alliance for Sustainable Energy, LLC (limited liability company), a partnership between Battelle and MRIGlobal. NREL also conducts research for DoE's Office of Science and Office of Electricity Delivery and Energy Reliability.

The objective was to summarise the NREL achievements in the biomass gasification area. At the beginning of the workshop the possibilities of cooperation between Tasks 33 and 34 (Pyrolysis) were discussed. Presentations given at the workshop are listed below.

Author	Presentation Title
Richard Bain **NREL, USA**	Integrated Pilot Operations for Production of Mixed Alcohols
Kim Magrini **NREL, USA**	Development of Reforming Catalysts
Jesse Henley **NREL, USA**	Development of Mixed Alcohol Catalysts
Abhijit Dutta **NREL, USA**	Techno-economics of Biomass Gasification Followed by Mixed Alcohol Production and Alcohol Separation
Michael Talmadge **NREL, USA**	Techno-economic and Market Analysis of Pathways from Syngas to Fuels and Chemicals,
Douglas Elliott, Task 34 Leader **Pacific Northwest National Lab, USA**	Task 34 Overview

Presentations from the workshop can be found online at the Task 33 website.

Workshop 2: System and Integration Aspects of Biomass-based Gasification

A joint Workshop between IEA Bioenergy, Task 33, and IEA Industrial Energy-related Technologies and Systems took place in Gothenburg 19-20 November 2013, with the theme "System and Integration Aspects of Biomass-based Gasification." The workshop was organised because there are several national and international initiatives in the area of biomass-based gasification, and such aspects are addressed at different levels, e.g. in both the IEA Bioenergy and the IEA Industrial Energy Related Technologies and Systems (IETS) Technology Collaboration Programmes (TCPs). The main focus of the Bioenergy TCP is the technical development status of individual technologies such as gasification, pyrolysis, torrefaction etc. and biorefinery systems as well as the technical and economic potential of such developments. The IETS TCP is more directed towards biomass usage by such technologies within a larger industrial system, i.e. a system integration context, also including the societal level. There is an obvious strong interlink between these two levels, requiring the exchange of data and results, but also for understanding the underlying methodologies used in both areas to correctly interpret this information between the levels.

The aim of this workshop was to initiate a dialogue across the technology/system interface, as well as on methods and results for technical, economic and environmental evaluations of integrated biomass-based gasification systems. Over 50 experts participated in the workshop, which was divided into 4 sessions. Presentations are listed below.

Author	Presentation Title
Session 1: Biomass Gasification to Fuel Gas; Integration into Power and CHP	
H. Wagner TU of Hamburg-Harburg, Germany	Gasification of Urban Biomass Residues – Possibilities in Hamburg/Germany
M. Möller DONG Energy, Denmark	Status of DONG Energy´s Pyroneer Gasification Technology for High Alkaline Fuels
C. Breitholz Metso Power, Sweden)	Gasification of Biomass and Waste for Production of Power in Lahti and Vaasa
Session 2: Biomass Gasification into Syngas Part I – Upstream and Internal Integration	
Henrik Thunman Chalmers Univ of Technology, Sweden	Beyond 80% Efficiency for Standalone Production of Bio-methane from Wet Biomass
Thomas Kolb KIT, Germany	Biomass gasification for BtL – The Bioliq Process
Ingvar Landälv Luleå Univ of Technology, Sweden	Methanol as Energy Carrier and Bunker Fuel
Session 3: Biomass Gasification into Syngas Part II – Downstream and Product Integration	
Reinhard Rauch Vienna Univ of Technology, Austria	Dual Fluidised Bed Gasification from CHP and Production of Advanced Biofuels
Bram van der Drift ECN, The Netherlands	Chemicals from Gasification
Ilkka Hannula VTT, Finland	Production of Synthetic Methanol and Light Olefins from Lignocellulosic Biomass
Session 4: Methodologies for Assessing Techno-economic Performance and Climate Impact	
S. Harvey Chalmers Univ of Technology, Sweden	Assessing the Performance of Future Integrated Biorefinery Concepts based on Biomass Gasification
Eric D. Larson Princeton University, USA	Techno-Economic Systems Analysis of Jet Fuel and Electricity Co-Production from Biomass and Coal with CO_2 capture: An Ohio River Valley Case Study
Michael Talmadge NREL, USA	Techno-economic and Market Analysis of Pathways from Syngas to Fuels and Chemicals
A. Faaij University of Utrecht, The Netherlands	Bio-CCS: Negative Emissions to Meet the Global Carbon Budget

The highlights of the workshop were summarised in a workshop report, which is available on the Task 33 website, www.ieatask33.org

Workshop 3: Thermal Biomass Gasification in Small Scale

The workshop was held in Ischia, Italy on May 14, 2014 and was attended by Task 33 representatives and about 20 outside participants. The focus of the workshop was gasification of biomass at small scale.

Combined heat and power generation (CHP) or cogeneration has been considered worldwide as the major alternative to traditional systems in terms of significant energy saving and environmental conservation. The most promising target in the application of CHP lies in energy production for buildings, where small-scale CHP is usually installed. Small-scale CHP systems are particularly suitable for applications in commercial buildings, such as hospitals, schools, industrial premises, office building blocks, and domestic buildings of single or multi-family dwelling houses. Small-scale CHP systems can help to meet a number of energy and social policy aims, including the reduction in greenhouse gas emissions, improved energy security, investment savings resulting from the avoidance

of the electricity transmission and distribution network, and the potentially reduced energy cost to consumers. Generally speaking, the concept "small-scale CHP" means combined heat and power generation systems with electrical power less than 100 kW.

The workshop offered interesting information in this field, from research organisations as well as industry. Furthermore, new contacts and areas of cooperation were identified. Presentations from the workshop are listed below.

Author	Presentation Title
Marco Fantacci Bio&Watt Gasification S.R.L., Italy	Energy Conversion of Biomass Through Pyrogasification: Presentation of an Industrial Solution
Andrea Duvia Gammel Duvia Engineering Srl, Italy	Biomass Cogeneration: Activities and Experience With Plants Based on Biomass Gasification
Marcel Huber Syncraft, Austria	The Floating-Fixed-Bed – Status of a Unique Staged Gasification Concept on its Way to Commercialisation
Giovanna Ruoppolo CNR – National Research Council, Italy	Fluidised Bed Gasification and Co-Gasification of Biomass and Wastes
Paola Ammendola CNR – National Research Council, Italy	Development of Catalytic Systems for Tar Removal in Gasification Processes
Paola Ammendola CNR – National Research Council, Italy	Relevance of Biomass Comminution Phenomena in Gasification Processes
Osvalda Senneca CNR – National Research Council, Italy	Gasification Kinetics of Biogenic Materials and Wastes
Simeone Chianese University of Naples, Italy	H_2 for Industries
Simeone Chianese and Nadia Cerone ENEA, Italy	Gasification of Fermentation Residues from Second Generation Ethanol for Production of Hydrogen Rich Syngas in a Pilot Plant

The workshop offered a good overview and important information on small scale biomass gasification in Italy and Austria. The research organisations as well as the representatives of industrial companies active in this field participated in the workshop. All the presentations, as well as a report about the workshop, can be found at the Task 33 website (www.ieatask 33.org).

Workshop 4: Liquid biofuels

The workshop was held at KIT in Karlsruhe, Germany on November 4, 2014 and was attended by Task NTLs and about 60 outside participants representing the German bioenergy industry and academia. The objective was to present updates on the status of liquid biofuels developments.

Fuels from biomass have great potential. In the short term, they will be able to replace part of our fossil energy sources and will contribute to an efficient mix of renewable energies. Covering a wide range of different fuels such as kerosene, diesel, and gasoline, BTL (biomass-to-liquid) fuels of the second/third generation offer various advantages over bioethanol or biodiesel. Almost any kind of biomass, whose origin and needs need not compete with those of plants grown for the food industry, can be used for biofuel production. Dry, cellulose-rich residual biomass from agriculture, forestry production, and landscaping is particularly suited for use in fuels. The synthetic biofuels produced from biomass are fully compatible with the already existing, conventional fuels and can be used as drop-in, but also as stand-alone products. The quality of the high performance fuels or fuel components should improve the combustion properties and emissions significantly.

A tour of Karlsruhe Institute of Technology's Bioliq® pilot plant was conducted in association with the workshop. The Karlsruhe BTL concept combines decentralised production of energy-rich BioliqSynCrude® by means of rapid pyrolysis and central processing with final industrial-scale refinement. Since the energy density of BioliqSynCrude® is more than one order of magnitude higher than dry straw, it is evident that the method's efficiency is enhanced by decentraliszed energy densification.

The workshop presentations, listed below, provide a comprehensive overview of opportunities and technologies for liquid biofuel production through biomass gasification.

Author	Presentation Title
Manfred Wörgetter Bioenergy 2020+, Austria	Introduction IEA Task 39: Commercialising Liquid Biofuels
Thomas Wurzel Air Liquide Global E&C, Germany	2nd Generation Biofuels – The Bioliq Technology and Economic Perspectives
Rikard Gebart Luleå Univ of Technology, Sweden	Conversion of Forest Industry By-products to Methanol and DME
Holger Kittelmann Linde Engineering GmbH, Germany	Carbo-V – Biomass Gasification Technology
Malin Hedenskog Göteborg Energi, Sweden	GoBiGas Project – Experiences and Operational Progress

Author	Presentation Title
Ralf Abraham, Norbert Ullrich UHDE GmbH, Germany	An Update on the BioTfueL Project and Other Activities of TKIS-PT in the Area of Biomass Gasification
John Bøgild Hansen Haldor Topsøe, Denmark	Haldor Topsøes Biobased Sustainable Fuel Production Technologies
Jörg Sauer KIT, Germany	Modified MtG Processes for BtL and Power-to-Fuels
Thomas Bülter EVONIK Industries AG, Germany	Speciality Chemicals from Syngas Fermentation
Peter Pfeiffer KIT, Germany	Technology for Fischer-Tropsch Synthesis of Liquid Fuel in Small Scale

The workshop offered a very good overview and important information on liquid biofuels from biomass; a large attendance at the workshop has shown that this topic is very relevant and has significant potential for the future. All the presentations as well as a workshop report are available on the Task 33 website. (www.ieatask 33.org).

Workshop 5: Symposium on Renewable Energy and Products from Biomass and Waste

The symposium was held in Ponferrada, Spain on May 12, 2014, and was attended by Task representatives and about 30 external participants.

The symposium was organised together with the University of Seville in the framework of the BIOTER (Thermochemical Biorefineries based on DME) project.

Invited speakers selected from the IEA Bioenergy Task 33, Academia and Industry gave presentations in the symposium, Attendees were both senior researchers and PhD students from academy, industry and governments. There was a poster session in parallel with the presentations.

The following table gives an overview of the workshop presentations

Author	Presentation Title
Session 1: Gasification, CO_2 capture and synthesis	
Bo Leckner Chalmers Univ of Technology, Sweden	Thermal Conversion of Wastes: The Separation of Steps
Jose Maria Sanchez Hervas CIEMAT, Spain	Process Developments for CO_2 Capture and Valorisation Methods at CIEMAT
Sylvie Valin CEA, France	CO_2 Valorisation in a Biomass to Fuel Process: Experimental Gasification Study and Process Evaluation
Leif Gustavsson Linnaeus University, Sweden	Time-integrated Greenhouse Gas Emissions in the Thermochemical Conversion of Municipal Waste and Forest Residues
Session 2: Design of new concepts of thermochemical biorefineries	
Judit Sandquist SINTEF, Norway	Advanced Biorefinery Concept Based on Cultivated Macroalgae
Pedro Haro University of Sevilla, Spain	Thermochemical Biorefineries with Multiproduction: Hydrocarbonylation of DME into Fuels and Chemicals
Ilkka Hannula VTT, Finland	Doubling of Synthetic Biofuels Production via Hydrogen from Renewable Electricity
Session 3: Demonstration and commercialisation	
Juan Luis Cruz INERCO, Spain	INERCO Technology for Biomass Gasification
Juhani Isaksson Valmet, Finland	Progress in Commercial Scale CFB Gasification for Waste and Biomass
Bram van der Drift ECN, The Netherlands	Commercialisation of WtE through Gasification Technology Developed by ECN
Miguel Angel Delgado CIUDEN, Spain	Carbon Capture Challenges and CIUDEN
Manuel Silva Perez CTAER, Spain	Development and Demonstration of Solar-Biomass Hybridisation Technologies
JJ Leahy University of Limerick, Ireland	Biomass and Waste Valorisation in an Irish Perspective
Carlos de la Paz Life, EU Commission	The Life Programme as a Driver for the Development of More Efficient Technologies for Carbon Capture and Biomass/ Waste Utilisation

The highlights of the workshop were summarised in a workshop report, which is available on the Task 33 website (www.ieatask33.org).

During this triennium the task website was updated to provide an enhanced user experience and to make navigation more intuitive and effective.

Biomass Gasification Database

A Google-map based interactive database of applications of gasification plants was incorporated in the Task website during this triennium. Currently, there are 86 gasification facilities in member countries and 33 in other countries registered in the database, of which there are 62 in operation, 5 under construction, 2 planned, 16 on hold and 1 whose status is not really clear. All the important information including location, technology, raw material used, input and output data, products, facility type, partners, total investment (if known), status and start up is displayed. Also a short technology brief or a flow sheet is given. If more information is required, a contact person for the facility is given. The database is interactive, meaning that one can filter for the technology, type, and status of the gasifiers for all the gasification facilities registered in the database. The database is updated regularly and provides a good overview of gasifiers throughout the world.

Special projects

During the last Triennium three special projects were completed by Task 33:

- Fact sheets on biomass gasification
- Performance Test Protocol for Small Scale Gasifier
- Status report on thermal biomass gasification in member countries

The results of the projects were published on the Task 33 website and are available in the section "Publication and reports."

Fact sheets on biomass gasification

The 8 fact sheets describe the following topics:

- What is biomass gasification?
- Gasification in numbers
- Gasification technologies
- Biomass as gasification feedstock
- Gas cleaning and tars
- Gas engines
- Co-firing
- New developments

The aim of the Fact sheets was to inform the general public about thermal biomass gasification technology, its advantages, uses of the product gas and about biomass as a renewable energy carrier.

Performance test protocol for small scale biomass gasifiers

In recent years more small scale commercial gasifiers have become available on the market. Under this special project, a performance test protocol was developed that is specific to small scale biomass gasification systems. As a guideline during a project for a gasifier CHP unit, this protocol can help to improve the project quality and the achievement of successful proof of performance after commissioning. The handover of a gasifier CHP unit from the supplier to the client will be facilitated, if an accurate performance test protocol is available.

A Performance Test Protocol [PTP] for commercial Small Scale Gasifier CHP units helps the parties involved to minimise differences and unrealistic expectations. PTP can be useful in a project during evaluation, ordering of equipment, commissioning and tests. For the final tests PTP is the "tool" for the handover to the client. PTP inclusion in a commercial project is a necessity. In a bioenergy project it is especially necessary because of the variety of the input fuel types and quality. It is also recommended to consider PTP already in the first steps of projects evaluation. It is important to have a PTP at least before the procurement begins and it should be part of the purchase of equipment. A PTP is always a specific individual document and is different for each project. It should be included in the contract suite of documents. This ensures that the purchaser and the supplier agree on the specific items that should be validated during the performance tests, and by which methods the validation should be implemented.

The effect of using PTP will be the achievement of:

- Satisfaction for parties involved in small scale gasifier projects
- Small differences between expectations and reality
- Verification of the guaranteed values, performance and warranties
- Verification of meeting authorities regulated emissions, noise and other permits' criteria
- The gasifier CHP installation targets such as environmental benefits, economic benefits, stable long-term operation and stable long-term financial goals
- Long term effect: Increasing the trust and credibility of the thermal gasification technology

Status report on thermal biomass gasification in countries participating in IEA Bioenergy Task 33

This report gives an overview of the thermal biomass gasification technology, projects/facilities in countries participating in IEA Bioenergy Task 33, their status, size and technology applied as well as detailed information concerning e.g. feedstock, output, etc. The report is based on Country reports from member countries and an interactive online database of thermal biomass gasification facilities, which is a part of the IEA Bioenergy Task website (www.ieabioenergytask33.org).

This report gives a detailed overview of 86 commercial, demonstration and pilot facilities in IEA Bioenergy member countries. It was not possible to include all facilities because of the large number of small-scale facilities (e.g. there are over 140 Burkardt CHP gasifiers in operation at this time). Highlights from the report are:

- Of the 86 thermal gasification facilities, there are 62 in operation, five under construction, two planned, 16 on hold and one whose status is not really clear.
- Most of the facilities (53) are in combined heat and power (CHP) applications. Eighteen are for synthesis and 15 are for other purposes such as fuel gas for heat.

The report begins with a description of the technology, types of gasifiers, product gas cleaning and upgrading and product gas applications. There is also a chapter about the most well known gasification facilities. All the gasification facilities in member countries are also listed and described there.

Success story

The most notable biomass gasification plant commissioned during the 2013-2015 triennium was the GoBiGas plant operated by Göteborg Energi in Gothenburg, Sweden. GoBiGas represents a significant step forward in biomass gasification. It is the first industrial-scale plant to produce substitute natural gas (SNG) from biomass in a continuous process integrating gasification, syngas cleaning and catalytic synthesis, and is the largest facility to use biomass syngas for synthesis rather than heat or power. The GoBiGas plant produces 20 MW of substitute natural gas, and was built as the first phase of a larger project that would ultimately produce 100 MW natural gas from biomass.

Development of the GoBiGas plant took many years. The idea for the project was launched in 2005, when a feasibility study for thermochemical production of biomethane was launched. The project engineers evaluated a number of biomass gasification technologies before finally settling on the dual fluidised bed gasification technology of Repotec, originally developed by Vienna University of Technology. The dual bed gasifier design has been successful in the Güssing, Austria 2 MW_{el} power plant that has operated since 2002. Chalmers University of Technology in Gothenburg played a key role providing technical and R&D support for the GoBiGas plant. Part of that industry-university collaboration involved modifying an existing 11 MW circulating fluidised bed biomass boiler on the Chalmers campus to include a 2-4 MW fluidised bed biomass gasifier. Construction of the GoBiGas plant began in 2011 and startup of the various systems progressed through 2014. In December 2014, the first bio-SNG was delivered to the grid. The plant has been operating relatively consistently since then, delivering SNG to the Swedish natural gas system.

Task 33 has been a strong supporter of the GoBiGas project. In November 2013, Task 33 had its task meeting at Chalmers University of Technology in Gothenburg and co-hosted a workshop on System and Integration Aspects of Biomass Gasification with IEA Industrial Energy-related Technologies and Systems (IETS). During the tours associated with the workshop, participants got to visit both the GoBiGas plant, which was in the final stages of construction at the time, and the Chalmers gasifier. Representatives from GoBiGas also attended workshops throughout the triennium, provided updates on the GoBiGas project and received input from Task 33 members and other workshop participants. Reports and presentations from Task 33 highlighted the technical achievements of the GoBiGas project during the triennium. The success of the GoBiGas project was reported during the first session, organised by Task 33, of the IEA Bioenergy Conference 2015 in Berlin.

Conclusions and recommendations

Task 33 has been primarily a technical task whose objective is 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. The activities of the Task have been very effective. The Task monitored the current status of the critical unit operations and unit processes that constitute the biomass gasification (BMG) process, and identified hurdles to further development, operational reliability, and reduction of the capital cost of BMG systems. These were reported throughout the triennium and remain the basic foundations for developing and implementing a programme of work that addresses the needs of the participating countries.

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 BMG 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 were also invited to provide information and cooperate to address research needs.

In summary, Task 33 has played a useful role for technology providers, end users and other interested parties. The workshops, reports, facilities database and web site have proven to be valuable resources, and the national team leaders are recognised as leading experts on gasification technology.

Attachments

Participation in Major Events

Task 33 was visible as a participant and organiser in various workshops and conferences throughout the triennium. These are listed below.

- Workshop "Lessons Learned about Biomass Gasification," 7-9 May 2013, Denver, Colorado, USA.
- Symposium "System and Integration Aspects of Biomass-Based Gasification," 19-21 November 2013, Gothenburg, Sweden
- Symposium "Thermal Biomass Gasification in Small Scale," 13-15 May 2014, Ischia, Italy
- Workshop "Liquid Biofuels through Biomass Gasification," 3-5 November 2014, Karlsruhe, Germany
- Symposium on Renewable Energy and Products from Biomass and Waste, 11-13 May 2015, Ponferrada, Spain
- Session "Commercial Success of Biomass Gasification" at the IEA Bioenergy Conference 2015, 27-29 October 2015, Berlin, Germany.

In addition to these events, many of the national team leaders represented Task 33 at local or national meetings in their respective countries.

Deliverables

Many deliverables resulted from Task 33 activities during the 2013-15 triennium. These are listed below.

- **Workshop Reports.** These reports provide a summary of the workshops coordinated by Task 33 during the triennium. They are available on the Task web site.
  - Workshop "Lessons Learned about Biomass Gasification," 7-9 May 2013, Denver, Colorado, USA.
  - Symposium "System and Integration Aspects of Biomass-Based Gasification," 19-21 November 2013, Gothenburg, Sweden
  - Symposium "Thermal Biomass Gasification in Small Scale," 13-15 May 2014, Ischia, Italy
  - Workshop "Liquid Biofuels through Biomass Gasification," 3-5 November 2014, Karlsruhe, Germany
  - Symposium on Renewable Energy and Products from Biomass and Waste, 11-13 May 2015, Ponferrada, Spain

  Note that PDF copies of most of the presentations from the workshops are also available on the Task website
- **Performance Test Code for Small Scale Gasifiers.** This document is useful for parties purchasing small gasifiers for power and/or heat, and is available from the Task web site.
- **Status Report on Thermal Gasification of Biomass in Member Countries.** This end-of-triennium report summarises the state of biomass gasification, including notable plants and statistics on installations. The report is available from the Task web site.
- **Fact Sheets on Biomass Gasification.** These 1-2 page documents distil aspects of biomass gasification into a form digestible by a non-technical audience and answer many of the questions regarding biomass gasification. Several fact sheets were developed, all of which are available on the Task web site:
  - What is biomass gasification?
  - Gasification in numbers
  - Gasification technologies
  - Biomass as gasification feedstock
  - Gas cleaning and tars
  - Gas engines
  - Co-firing
  - New developments

- **Newsletters.** Several newsletters regarding activities in Task 33 and member countries were prepared during the triennium. The newsletters are available on the Task web site.
- **Web Site.** The Task 33 web site hosts all information relating to the Task, including reports, workshop proceedings and the facilities database. The web site was redesigned during the triennium to make it more user friendly and navigable http://www.ieatask33.org/.
- **Gasification Facility Database.** Task 33 maintains a database of gasification facilities within member countries and in some non-member countries. Facilities can be identified using a map interface and detailed information regarding status, scale, feedstock and products is given.
- **Country Reports.** National team leaders provided updated reports on the status of biomass gasification in their respective countries throughout the triennium. The most up-to-date report from each country is available on the Task 33 web site.
- **Task Meeting Minutes.** Minutes from Task 33 business meetings are posted on the Task web site.
- **Reports for ExCo Meetings.** Several status reports and an end-of-triennium report were prepared for the IEA Bioenergy Executive Committee over the course of the triennium.

Coordination with Other Tasks within IEA Bioenergy

Several projects were coordinated with other IEA Bioenergy Tasks during the triennium. The joint activates are listed below.

- The project "Advances in Biomass Characterisation" was carried out with Tasks 32 and 34, and included distributing a survey to researchers and end-users to learn about their experience with biomass and novel techniques for characterisation. Task 33 contributed by distributing the survey to appropriate parties in the contact network.
- Biomass combustion and syngas co-firing was discussed with Task 32, since combustion or co-firing of biomass gasification syngas is an indirect means of utilising energy from biomass. One of the fact sheets developed by Task 33 addresses this issue, and its development was carried out in consultation with Task 32.
- Task 34 (biomass pyrolysis) and Task 33 had several interactions relating to the idea of using biomass pyrolysis as a means of creating a biomass-based feedstock suitable to feed into gasification systems. This is the strategy used by e.g. Karlsruhe Institute of Technology in their Bioliq process. Representatives of Task 34 also attended some of the workshops organised by Task 33.

Coordination with Other Bodies Outside IEA Bioenergy

During the 2013-15 triennium, several activities were coordinated with bodies outside IEA Bioenergy. These are summarised below.

- A workshop on Lessons Learned from Biomass Gasification was organised jointly with the National Renewable Energy Laboratory (USA). The workshop was held in May 2013.
- A workshop entitled "System and Integration Aspects of Biomass-Based Gasification" was organised jointly with IEA Industrial Energy-related Technologies and Systems (IETS) in November 2013 in Gothenburg, Sweden.
- The first workshop of 2014, focused on Gasification of Biomass in Small Scale, was organised with INEA, Italy.
- Representatives from a variety of national research organisations and governmental bodies were present at the various workshops during the triennium.

Industry Participation

Task 33 has strong participation from industry. Nearly all of the national team leaders in the Task have background in industrial biomass gasification, and many have either worked in industry or are currently working with an industrial company associated with biomass energy. The focus and direction of the Task is driven largely by the experience of the Task leaders and their familiarity with current and past biomass gasification projects.

Throughout the triennium, individuals representing industrial scale gasification technology providers, small-scale gasification technology providers, catalyst development and technology providers, syngas cleaning technology providers, feedstock suppliers, end-users, electric utilities, energy consultants and environmental consultants all contributed to the Task by providing input to reports, participating in workshops, attending Task business meetings or presenting at Task 33-organised conference sessions.

TASK 34: Pyrolysis of Biomass

Prepared by:

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Operating Agent:

Jim Spaeth, US DoE, USA

Participating countries:

Finland, Germany, The Netherlands, Norway, Sweden, United Kingdom, USA

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Introduction

This is the final report of Task 34 (Pyrolysis of Biomass) of the IEA Technology Collaboration Programme (TCP) on Bioenergy. This report covers the triennium of 2013-2015.

The overall objective of the continuing Task was to facilitate commercialisation of biomass pyrolysis and particularly fast pyrolysis to maximise liquid product yield and production of renewable fuel oil and transportation fuels by contributing to the resolution of critical technical areas and disseminating relevant information particularly to industry and policy makers. The scope of the Task was to monitor, review, and contribute to the resolution of issues that would permit more successful and more rapid implementation of pyrolysis technology, including identification of opportunities to provide a substantial contribution to bioenergy. This would be achieved by all the activities described below.

The existing structure of Topic Groups has proved very successful in promoting a very high level of member participation, attracting a high proportion of industrialists to meetings, and providing a stimulating and lively forum. The topics included in the Task for this triennium are shown in Table 1. These were derived from a list originally identified from Task discussions and refined by iterative polling of the Task participants and potential participants. This final list was reviewed and confirmed at the Task meeting in April 2012.

Table 1: Priority Topics for Task 34 Prolongation

Review of bio-oil applications
Bio-oil standardisation
Round robin for analytical method validation
TEA of thermochemical liquefaction technologies
Collaboration with Task 32, Task 33, Task 38, and Task 40

A more detailed overview of these topics is provided below:

Background

The work programme for Task 34 was similar to that of the previous Task 34, however with more emphasis on overcoming barriers to commercialisation of fast pyrolysis of biomass for liquid fuel production. The plan for the triennium was discussed during 2012 and revised over the year in order to be prepared for the new triennium. With the start of the new triennium in 2013, Canada withdrew and Sweden joined the task.

As stated in the Introduction, the overall objective of the Task was to improve the rate of implementation and success of fast pyrolysis with the emphasis on fuels production but also to include chemicals where this complemented the energetic considerations. By contributing to the resolution of critical technical areas and disseminating relevant information particularly to industry and policy makers the Task was expected to play an important role in this new industry. The scope of the Task was to monitor, review, and contribute to the resolution of issues that would permit more successful and more rapid implementation of pyrolysis technology, including identification of opportunities to provide a substantial contribution to bioenergy.

Pyrolysis comprises all steps in a process 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 byproduct. 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 covers optimisation, alternatives, economics, and market assessment.

The work of the Task addressed the concerns and expectations of the following:

- Pyrolysis technology developers
- Bio-oil applications developers
- Equipment manufacturers
- Bio-oil users
- Chemical producers
- Utilities providers
- Policy makers
- Decision makers
- Investors
- Planners
- Researchers

Industry was actively encouraged to be involved as Task participants, as contributors to workshops and working meetings, as consultants, or as technical reviewers of Task outputs to ensure that the orientation and activities of the Task matched or met their requirements. This involvement was a key factor in the value of the Task outputs as industrial involvement was high, including regular meeting participation by two of the leading industrial developers for fast pyrolysis of biomass with attendance at one of the task meetings by the third.

Task objectives and work carried out

1. Review of bio-oil applications

The Task members undertook a review of the potential applications for bio-oil within existing markets. The group identified the leading applications and the technical and non-technical barriers to commercialisation. One deliverable from this effort was a journal article to update the Oasmaa, Gust, Peacocke et al. publication on *Norms and Standards for End User Specifications* from 2005. In addition, the information was formatted and placed on the Task website to update information already in place. Thus the information was made broadly available.

2. Bio-oil standardisation

The Task supported the implementation of standard methods for the use of bio-oil, specifically the efforts to establish CEN standards as required for use of bio-oil as a burner fuel, both heavy and light grades, internal combustion engine fuel, as well as feedstock to gasification and refinery co-processing, as specified in the recent Draft Mandate from the EC. Support and input toward the ASTM specifications and standards development were placed to the side pending the European standards being put in place. Following that, an effort would be made to facilitate transfer of the EU developed standards to the ASTM process in order to coordinate standards.

Technical input to the REACH (http://echa.europa.eu/regulations/reach) process for registering bio-oil for commercial use in Europe was also provided, including SIEF (substance information exchange forum), assistance to companies in pyrolysis oil data collection and processing, and completion of the registration process. These efforts are important support to the commercialisation of bio-oil as a marketable product.

3. Round Robin for bio-oil analysis methods validation

A Round Robin was organised to understand the consistency of bio-oil as it is produced in the diverse group of laboratories involved in process research and development. The Round Robin process included a preparatory step as part of the confirmation process of a review by the organisers of the details of the required information from each Round Robin participant in order to validate their operation.

The Round Robin arranged for three biomass feedstocks to be prepared and distributed to the participants. Twenty laboratories in the participating countries received the three biomass feedstocks for processing in their respective systems. The Round Robin included actual participation by 16 of the laboratories, which provided bio-oil samples to a central laboratory for analysis and comparison.

The results of the Round Robin were drafted into a technical journal manuscript under the authorship of the Task members. From this round robin, the research community could learn about the consistency of the bio-oil produced in the participating laboratories, and the participating laboratories could learn how their products compared to those produced elsewhere without the complication of feedstock effects.

4. Techno-economic assessment (TEA) of biomass thermochemical liquefaction technologies

Two participating countries, Finland and the U.S., undertook to update the techno-economic assessment of biomass liquefaction technologies in light of new developments in finished fuel production as well as changes in the economic climate since the earlier reports from the 1980s. This effort was initially proposed as a special project for ExCo funding to be initiated in 2012; however, such support was lacking and the effort has now been fully incorporated into Task 34.

The comparative TEAs for fast pyrolysis and upgrading and hydrothermal liquefaction and hydrotreating were derived from an initial review of potential process options for transformation of biomass to transportation fuels through pyrolytic routes. The representative process models were developed including detailed process flow diagrams, mass and energy balances, equipment sizing and costing with

overall operating and capital cost calculations performed on a uniform basis, which allowed useful internal comparison. This TEA allowed environmental impacts to be judged and Life-Cycle Analyses to be completed.

5. Meetings

Meetings were held at approximately six-month intervals and comprised a regular Task meeting in conjunction with a seminar and/or technical tour. Seminars featured speakers with an emphasis on industrial and commercial organisations. This approach resulted in an excellent two-way interaction between participants of the Task and external organisations. Each meeting devoted a portion of the session to country reports to facilitate exchange of research developments among the participants. The meetings were open to those countries participating in the Task and usually included a number of visitors. In addition, observers from non-participating countries also attended on occasion.

6. Interaction with industry

Fast pyrolysis is a new technology that offers the unique advantage of producing a liquid fuel directly from biomass in high yield. Though much of the recent activity in this area has been at a research level, more companies are becoming interested in the potential of producing and using a biomass derived liquid fuel and the technology is at an early stage of market penetration. There has been extensive interest by industrialists in the fast pyrolysis seminars, and this interest continued to develop over the triennium as commercial fast pyrolysis plants came on stream in Finland and the Netherlands, joining the expansion of the operational plant in Canada.

The Task worked with pyrolysis technology developers and providers to help identify and define their problems, and help to provide solutions both from within the group and externally. Similarly the Task co-operated with applications' developers and equipment manufacturers to help them understand more about bio-oil and its properties and requirements. This close co-operation is considered the most effective way of identifying and promoting opportunities for bio-oil to make a significant impact on renewable energy supplies.

7. Publications

The newsletter was published at approximately six-month intervals in electronic format to reduce costs and improve timeliness. Information was gathered from the Task participants and their contacts throughout the world.

In addition, the Website was maintained and regularly updated. An additional feature that was implemented was a database of fast pyrolysis demonstration plants around the world.

Much of the work in Task 34 in the past has been published in technical journals. During the triennium there were 3 journal publications by Task participants, which were derived from the collaborations and round robins.

Success story

Clearly, the success story for pyrolysis in the past three years has been the first significant market penetration of bio-oil as a fuel oil. Fast pyrolysis plants were built and started up in Finland (Fortum) and the Netherlands (BTG-BTL), while a demonstration plant in Canada (Ensyn) was upgraded to allow extended operation to fulfil commercial contracts for bio-oil in the U.S. These plants are operating at a scale of 100 to 250 tons per day producing bio-oil at about a 60% mass yield from woody feedstocks, ranging from flooring/furniture manufacturing waste and wood pellet crumbs to forestry residue. The bio-oil product is being used to displace fossil oil fuels in modified boiler systems. In all cases the byproduct solids and gases are burned within the plant for additional heat as boiler fuel. The bio-oil products meet the ASTM standards as developed with the input of Task 34 in 2009.

Conclusions and recommendations

Task 34 has continued to play an active role in supporting the market penetration of fast pyrolysis of biomass to produce bio-oil. The support has included major roles in standards development, organisation of round robins to validate important bio-oil analytical methods, and providing a source of useful information to interested parties who might want to get involved in biomass pyrolysis. The Task has successfully disseminated the results of its work in technical journals and on the Task website. Furthermore the Task has played a role in informing the technical community through the organisation of a symposium of the leading industrial participants in the field, as a session of the IEA Bioenergy Conference 2015 in Berlin and in the development of a demonstration plants database, which is currently active on the Task website and is searchable by interested parties.

Attachments

Participation in major events

tcbiomass 2013 and 2015
(the biennial conference on biomass thermochemical conversion in Chicago, Illinois, USA)

Task members participated in both conferences.
A presentation on stability of fast pyrolysis bio-oils was made in 2013. A poster describing the results of the round robin on bio-oil production was presented in 2015.

tcs 2014
(biomass thermochemical conversion science conference in Denver, Colorado, USA)

Two Task members participated as presenters and session chairs.

IEA Bioenergy Conference 2015

(end of triennium conference)-Berlin, Germany

Task 34 arranged the speakers for the session on pyrolysis and the Task Leader acted as the session chair.

BEST - Helsinki, Finland

Finnish stakeholders gathered on October 30, 2014, and the Task members participated in the BEST (Sustainable Bioenergy Solutions for Tomorrow) seminar at Pörssitalo in central Helsinki. The morning agenda included presentations given on IEA Bioenergy Task 34 by Task Leader Doug Elliott, the Joensuu plant by Joakim Autio of Valmet, the status of the Empyro plant in the Netherlands by Bert van de Beld, Green Nordic Fuels by Jerkko Starck, Bio-oil combustion by Oilon and CEN standardisation by Pia Saari of Fortum, who chairs the Working Group. There then followed a Question and Answer session.

EMPYRO opening - Hengelo, Netherlands

An international symposium was organised on May 21 2015 and included 75 participants from 15 different countries for the official opening of the EMPYRO fast pyrolysis plant. In the morning session of the first day Kyriakos Maniatis – Principal Administrator in the Directorate General for Energy of the European Commission – informed the audience of the latest developments from the Renewable Energy Directive and the Fuel Quality Directive, and also addressed new developments related to the 2030 Roadmap and the Energy Union. Doug Elliott introduced IEA Bioenergy Task 34 and the role of the Task in supporting the further development of fast pyrolysis technology and products. A number of presentations followed on the development and implementation of the EMPYRO project, and at midday delegates were able to visit the EMPYRO plant for its opening ceremony and a tour.

Northwest Wood Energy Team Forum - Stevenson, Washington, USA

A workshop and technology demonstration was organised by several state agencies in Washington and Oregon on May 7, 2014. Commercialisation of fast pyrolysis was discussed and two demonstration reactors of small-scale technology were operated for the participants to evaluate. As part of the seminar, the Task 34 leader gave an overview of IEA Bioenergy and Task 34 on Pyrolysis.

CED pyrolysis workshop - North Conway, New Hampshire, USA

A site visit to Memorial Hospital was made as part of the Technical Information Exchange on Pyrolysis Oil Combustion meeting on March 30-31, 2015. This meeting was held as part of the US-Canada Clean Energy Dialogue Program. Memorial Hospital is a 115,000 ft_2 regional facility heated with 2 oil-fired, Cleaver-Brooks, 150 HP fire-tube boilers. In 2014 a conversion was implemented on one of the boilers to enable firing of 100% bio-oil imported from Ensyn's commercial fast pyrolysis plant in Renfrew, Ontario, Canada. As part of the seminar, the Task 34 leader gave an overview of IEA Bioenergy and Task 34 on Pyrolysis.

Deliverables for 2013-2015

Deliverables for the triennium 2013-2015 for Task 34 were:

- Task document describing Bio-oil properties and applications.

  This information was developed and posted on the Task website.

- Round Robin report published in a technical journal.

  The Round Robin was completed and the results drafted into a manuscript for publication.

- Techno-economic assessments of biomass liquefaction processes (at least two).

  This deliverable was met through the efforts of Task members from Finland and the US with participation from other colleagues at the respective laboratories. Fast pyrolysis and bio-oil upgrading was compared with hydrothermal liquefaction and biocrude hydrotreating with model development and cost assessment. The results were published by PNNL as report #PNNL-23579.

- Updated and normalised MSDS (material safety data sheet) for bio-oil for international use.

  The Finnish version of the MSDS was distributed to the members of the Task.

- Electronic newsletter (twice a year).

  Two issues of the newsletter were prepared, distributed, and posted on the Task website in each of the three years (Issues from #33 in June 2013 to #38 in December 2015).

- Regularly updated website.

  The website was discussed in each Task meeting and regular improvements were implemented as needed.

- Task meetings and minutes (twice a year).

  The Task met two times during each of the three years and minutes were prepared, reviewed and distributed to the members.

- Annual reports to ExCo.

  Annual reports were presented at ExCo 72, 74, and 76 including progress description and budget information.

- Progress reports to ExCo (at alternate meetings from annual reports).

  Progress reports were prepared for ExCo 71, 73, and 75 including budget information and website statistics.

- State of the Art review of the Task participating countries.

  Country reports were prepared for each Task meeting and presented to the members. The state of the art of bio-oil applications was prepared (see first bullet) and was posted to the Task website.

- Collaborative journal publications (at least two).

  A collaborative article was prepared by Oasmaa, A.; van de Beld, B.; Saari, P.; Elliott, D.C.; Solantausta, Y. 2015 "Norms, Standards & Legislation for Fast Pyrolysis Bio-Oils." Energy & Fuels 29, 2471-2484, web published: March 18, 2015, DOI:10.1021/ acs. energyfuels.5b00026.

  A second article has been drafted describing the round robin results.

  A third article on what is bio-oil and what is not bio-oil is undergoing a final draft for publication.

- Final report, containing the output from the Task participants as well as any commissioned work.

  This document is the deliverable.

Further accomplishments performed within the Task 34 activities:

- The state of the art (SOTA) of pyrolysis technology, drafted into a journal manuscript in the preceding triennium, was published in *Renewable and Sustainable Energy Reviews,* **2013**, *20, 619-641.*
- The results of the round robin undertaken during the current triennium were presented in a poster at the *tcbiomass 2015* The International Conference on Thermochemical Conversion Science held in Chicago, Illinois, USA, November 2-5, 2015.

Coordination with other Tasks within IEA Bioenergy

In order to address the direction to increase inter-Task collaboration, four topic areas were identified for cooperation with Tasks 32, 33, 38 and 42. The expectation was that the Task should be able to undertake the first two collaborations within existing manpower and budgets. The third and fourth would be dependent on the level of participation in Task 34.

1 Techno-Economic Assessment of Bio-oil Gasification

To collaborate with Task 33 it was proposed to complete a TEA of bio-oil gasification as a means to compare with solid biomass gasification. The Task 34 leader attended a meeting of Task 33 in May 2013 to develop this idea further. Bio-oil gasification is being studied in Germany by the Karlsruhe Institute of Technology as a means of making use of the processing advantages of a liquefied biomass in subsequent utilisation. This option was being assessed and it was determined that a comparative study with the required model development was too large an effort to be completed without a significant funding effort from outside the Task.

2 Techno-Economic Assessment of Bio-oil Combustion for CHP

To collaborate with Task 32 a TEA of bio-oil combustion for CHP as a means to compare with direct biomass combustion for CHP was proposed. This collaboration was expected to involve Finland in the development of comparative bio-oil combustion cost models. Early in the triennium a change in Finnish participation delayed this effort. Later in the triennium the Netherlands undertook to develop this information, but the effort has not yet been completed.

3 Use of TEAs for LCAs

As a point of collaboration with Task 38 a process LCA developed by two of the participants (Finland and the U.S.) was made available to Task 38 for review, and the Task 38 participants provided feedback to the LCA developers.

4 Biorefinery TEA Development

The proposed effort to work collaboratively on process TEAs to determine the added value of valuable byproducts from fast pyrolysis was not undertaken. In its stead, a Fact Sheet developed by Task 42 on a pyrolysis-based biorefinery concept was critiqued by German participants in Task 34. A second spin-off effort also involved German participants wherein a written chapter on fast pyrolysis was contributed to the book being prepared by Task 42 and Task 40 on Logistics of a Biobased Economy.

An additional collaboration with Task 39 led to an expanded effort to provide a web-based bioenergy demonstration plant database. The existing databases from Task 39 and Task 33 were used as the structure for the development of a pyrolysis demonstration plant database. Task 34 funds were expended in a contract to Bioenergy 2020+ in Austria to develop the searchable database which is now in place on the Task website and incorporated into an overall IEA Bioenergy demonstration database.

Plans were developed with Tasks 32 (with others) and 42 for the coming triennium.

Industrial participation

Task 34 maintains a strong connection to industrial leaders in biomass fast pyrolysis for bio-oil production. A key contributor is Anja Oasmaa from VTT in Finland who provides the direct connection to the consortium in Finland, including Valmet, Fortum, and VTT, that opened a commercial biomass fast pyrolysis plant in Joensuu while operating a scaled-up demonstration plant in Tampere. The other industrial connection, Bert Van de Beld from BTG, represents the other commercially operating fast pyrolysis plant in Europe, in Hengelo, Netherlands. Bert and Anja have played a strong role as well in the CEN standards development Working Group.

The Task as a whole worked with and through these participants to address the commercialisation barriers. The Task supported the development in Europe of the CEN standard for bio-oil. The Task provided continuing input to the REACH registration process for bio-oil, which was completed in the past triennium.

In addition, as part of Task 34 meetings, the Task maintained a presence in the seminars involving biomass fast pyrolysis commercial stakeholders in both Finland and the Netherlands. The presentations by these industrial leaders at the End-of-Triennium conference were organised by Task 34.

TASK 36: Integrating Energy Recovery in to Solid Waste Management

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Participating countries:

France, Germany, Italy, The Netherlands, Sweden, United Kingdom

Website: http://www.ieabioenergytask36.org/

Introduction

This is the final report for IEA Bioenergy Task 36 – Integrating Energy Recovery into Solid Waste Management for the period 2013-15.

In this period, the Task aimed to examine issues that were important to policy development and implementation of energy recovery systems for solid wastes.

In the period 2013-15 Task 36 aimed to:

- Continue to inform decision makers on issues that were important to their decisions;
- Understand how policy decisions impact on the opportunities for and efficiency of energy recovery; and
- Continue to inform the IEA Bioenergy Technology Collaboration Programme (TCP) Executive Committee on progress of the Task.

The objectives of the Task in the period 2013-15 were to:

- Hold a series of workshops alongside Task 36 meetings, centred on topical issues for energy from waste. The proceedings from these workshops have been published on the website.
- Undertake specific studies in areas of key importance to participating countries, which have been published as summary papers on the website.
- Work with Task 37 on areas of overlapping interest.
- Seek opportunities to publicise the work of the Task through national dissemination mechanisms.
- Seek opportunities to publicise the work of the Task through presentations at national/international events.

This report summarises the work and results of the Task over the 2013-15 triennium, evaluating the work carried out and the significance of the findings.

Task 36 members with participants in BREF working group, Karlsruhe, March 2014

Background

The proposal of work for the 2013-15 Triennium included four key activities to deliver the aims and objectives of the Task:

- Task meetings, with associated workshops
- Collaborative work with Task 37 and 32
- Reports on key topics
- Communication through presentation of results on the website and via international conferences.

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

The workshops held in the 2013-15 triennium were:

1. A joint workshop with Task 37 exploring relevant developments in anaerobic digestion (AD) and areas of synergy between Task 36 and Task 37. *Stockholm, May 2013*
2. A workshop focussed on Solid Recovered Fuels. *Milan, November 2013*

3. A workshop held in association with the German BREF Working group on efficiency of energy from waste. *Karlsruhe, March 2014*
4. A workshop on Advanced Thermal Treatment of waste and emerging technologies, *Harwell, October 2014*
5. A workshop focussed on factors influencing the development of energy from waste, including public perception, legislation and policy changes, and health issues. *Bordeaux, June 2015*
6. A joint workshop with the International Solid Waste Association (ISWA) Waste to Energy working group on the role of energy recovery in a Circular Economy, *Berlin, October 2015*.

In addition to the workshops outlined above, the Task also delivered three topic reports – *Small Scale Energy from Waste, Gasification in the UK,* and *RDF/MSW Mass Balance*.

Task 36 collaborated with Task 37 on the preparation of a report on the source separation of organic wastes from MSW and with Task 32 on a report on the health and safety aspects of solid biomass storage, transportation and feeding.

The work of the Task was also presented at a number of international conferences and workshops, including:

- Factors Influencing the development of Small-scale EfW – paper presented at ISWA Annual Congress, Antwerp, September 2015
- Opportunities for Solid Recovered Fuel in a Circular Economy – presentation at the European Recovered Fuels Organisation (ERFO) Workshop, Brussels, April 2015
- An Evaluation of arising and markets for waste derived fuels – paper presented at the Fifth International Symposium on Energy from Biomass and Waste, Venice, November 2014

Task objectives and work carried out

This section reports on the Task's objectives and whether or not they have been achieved. In order to do this, the section is divided into a series of sub-sections dedicated to each specific objective, and the programme of work that was delivered as part of meeting the objective.

Objective 1: Hold a series of workshops alongside Task 36 meetings centred on topical issues for energy from waste. The proceedings from these workshops will be published on the web site.

This objective was clearly met through the delivery of 6 workshops, summarised in Table 1. Presentations and summary reports from all workshops are published on the Task 36 website.

Table 1 : Summary of workshops delivered by Task 36 in 2013-15.

WORKSHOP 1: A joint workshop with Task 37 exploring relevant developments in anaerobic digestion (AD) and to explore areas of synergy between Task 36 and Task 37. Stockholm, May 2013
Aims/Content
This workshop was designed to update Task 36 on relevant developments in AD and to investigate the areas where there were synergies in the two areas, where the work of Task 37 might overlap with the work of Task 36 and where there could be useful joint projects.
Outcome/Conclusions:
▪ Source separation is important to AD of waste and one of the major costs is collection systems ▪ Substrates can make a major difference to economics, but local conditions are also important. ▪ There is evidence that source separation for AD is energy and carbon efficient, but the use of nutrients in the residue is important to this finding. If the residue cannot be used and is burnt in EfW or buried in landfill this important advantage is lost. ▪ Microbiology is complex and important in influencing the yields. In particular inhibition can make a big difference to performance. Trace elements (e.g. Co, Ni, Se) are key, but so is understanding exactly what is happening within the digester. Methodologies are now available to rapidly identify the microbial population. ▪ Quality control of source separation is important.
WORKSHOP 2: Which future for the Solid Recovered Fuels (SRF) market? Milan, November 2013
Aims/Content
This workshop discussed end of waste for solid recovered fuels, the results of the EU supported Recombio project and experience with the use of solid recovered fuel in Italy.

WORKSHOP 2: continued

Outcomes/Conclusions

The following conclusions were drawn at the workshop:

- The standards body, CEN/TC343, has produced useful definitions for SRF and tests for the characteristics of SRF, enabling evaluation of the quality of SRF and its management.
- Work is still needed to increase confidence in SRF, both for users and for public perception.
- Over 1 million tonnes of SRF are produced in Italy alone, signifying the increasing interest in SRF in Europe.
- It is not possible to classify SRF on the basis of a single sample, and an agreed monitoring and sample protocol is necessary.
- A mature market for SRF requires transparency, data sharing and accepted procedures.
- End of waste for SRF has been achieved in Italy. The requirements are challenging but should lead to easier transport, handling and the development of market for a true waste derived fuel.
- Users called for SRF characteristics that decrease polluting emissions, improve combustion characteristics, increase the sustainable use of biomass contained in waste, develop high quality SRF and reduce management costs

WORKSHOP 3: A workshop held in association with the German BREF Working group on the efficiency of energy from waste. Karlsruhe, March 2014

Aims/Content

This workshop was held in association with the German BREF Working group on Efficiency of energy from waste. The workshop discussed issues about energy efficiency and the upcoming revision of the WI BREF in Europe.

Outcomes/Conclusions

Key workshop conclusions were:

- The most efficient EfW plants are those supplying district heating. These may achieve over 60% efficiency, providing that the heat load is reliable. For this reason it is best to site the plant in an urban area where reliable heat loads are available.
- Although it is possible to achieve higher efficiencies as presented at the meeting, this may make operation more complicated and increase costs. In reality operators have to achieve a balance between efficiency and costs. In addition any alterations should not result in corrosion in the superheaters, or costs will increase significantly.
- There is a need to examine why electrical efficiency is so important. Are incentives resulting in this trend? Could we do more to encourage the use of CHP?
- Operators also need to be convinced that there are no significant impacts on running costs, although the plant designers pointed to Amsterdam as an example where running costs have been controllable and there has been no need to replace the superheaters to date.

WORKSHOP 4: Advanced Thermal Treatment of waste and emerging technologies, Harwell, October 2014

Aims/Content

The workshop examined the development of technologies that would allow flexible integration of energy into solid waste management and the circular economy, including issues of funding and incentives to bring these technologies into commercial operations.

Outcomes/Conclusions

- Advanced thermal conversion of waste has come a long way over the past few years and a lot of money has been invested, resulting in some full scale plants being established.
- In the UK a number of policies have supported the development of waste infrastructure and commercialisation of advanced thermal conversion options for waste.
- Changes or shifts in government energy policy can be unsettling as advanced conversion technologies are still not commercially proven and continue to require development.
- The overall conclusion from this discussion is that government renewable energy policy and regulation are important in developing advanced conversion options. Speakers asked for long term stability in policy and support for innovation to enable commercialisation of advanced thermal conversion of waste to renewable energy and other products.
- Some speakers pointed out that the long term nature of the development needs for advanced conversion technologies is important. Speakers discussed the need to adapt feed mechanisms, gasifiers and clean up to suit the waste fuel used (or alternatively to treat the waste fuel so that it is suitable for advanced thermal conversion).
- There were some questions about the comparison of efficiencies with conventional plants, with a plea that we ensure that information on feedstocks is provided when comparing efficiencies – particularly on the combustion properties of the feedstocks.

WORKSHOP 5: Factors influencing the development of energy from waste, including public perception, legislation and policy changes, and health issues. Bordeaux, June 2015

Aims/Content

The workshop examined the impact of government policy on the development of EfW in different member countries, and the impact this has on technology, application and outputs.

Outcomes/Conclusions

- Whilst recycling of waste continues to increase in developed economies, the demand for treatment of residual waste continues to grow. The EfW technologies adopted in any one place are very much linked to what is driving their development in policy terms. The outcomes of the workshop included updates from all Task 36 members on how policy, public perception, legislation and health issues were impacting the development of EfW in member countries.

WORKSHOP 6: The role of energy recovery from waste in a Circular Economy, A joint workshop with the ISWA Waste to Energy working group, Berlin, October 2015
Aims/Content
The aim of the workshop was to facilitate discussion between Task 36 and the ISWA Energy recovery working group on the role of EfW in a Circular Economy. The workshop consisted of presentation by Task 36, ISWA, and facilitated workshops sessions.
Outcomes and significance
The workshop consisted of facilitated sessions that concluded: ■ Energy Recovery from waste is an integral part of a Circular Economy ■ There is an opportunity to include EFW as an essential part of the Circular Economy ■ It is likely that homogeneous waste will be recycled or upgraded, but EfW systems will need to be able to deal with increasingly heterogeneous residues. ■ Circular economy initiatives are too focused on recycling rather than materials use. Countries that are already having issues with diversion from landfill may find it difficult to adapt to the circular economy without clear strategies that enable this. ■ Terminology relating to the circular economy is vague and needs clearer definition. ■ The circular economy should aim for climate neutrality. ■ It will be important that Circular Economy initiatives do not result in export of problems, e.g. packaging mountains in emerging economies.

Objective 2: Undertake specific studies in areas of key importance to participating countries, which will be published as summary papers on the web site.

The planning of the 2013-2015 work programme identified a number of key priority areas for member countries. These topics included:

1. Small scale energy from waste;
2. Gasification;
3. Impact of changes in policy on energy recovery;
4. Mass /energy balance for refuse derived fuels (RDF) compared with MSW.

It was agreed that these topics would be explored in further detail depending on the number of members who subsequently joined the task and on the available budget. Subsequently, the Task has undertaken studies into Small Scale EfW, Gasification, and Mass/energy balance of RDF versus MSW. The work on impact of changes in policy on energy recovery was covered in Workshop 5 as outlined above. The specific studies undertaken are summarised below:

Small Scale EfW: The objectives of this study were to collate information on selected small scale waste treatment systems and to produce a status report on the technical and economic potential of such systems for waste treatment. A report was prepared and presented at the IEA Bioenergy Conference2015 in Berlin.

Gasification: a study was undertaken to investigate the apparent growth in the use of Advanced Conversion Technologies (gasification and pyrolysis) for the treatment of waste in the UK, to identify the number of projects in development and in operation, and to state the reason for the growth experienced. A report was prepared and presented at the IEA Bioenergy Conference 2015 in Berlin.

RDF/MSW mass balance: a study has been completed on the mass balance of RDF production compared to MSW production in the UK. This showed that increasing amounts of RDF were being produced from residual waste (i.e. waste after recycling). An additional trend was the increase in export of this RDF from the UK. The exported RDF was being used as a fuel in other European countries, notably Sweden, the Netherlands and Germany.

Objective 3: Work with Task 37 on areas of overlapping interest.

This objective was achieved through the delivery of both a joint workshop and the publication of a joint report. The joint Task 36/37 workshop is detailed above and contained presentations made by both Task 36, Task 37 and invited speakers, and included:

- Strategies for collection of organic waste in Stockholm, Johanna Nilsson (City of Stockholm)
- Biogas production in Sweden – role of nutrient composition and effects on microbial composition, degradation capacity and rheology, Professor Bosse Svensson (Linköping University)
- Biogas from organic residues and outlook to hetero-fermentative alcohol production, Günther Bochmann (Task 37)
- Update on Joint Task 36/37 report on international practices on the source separation of organics, Kathryn Warren (Task 36) & David Baxter (Task 37)
- Valorgas project: Collection and AD of Food Waste, Sonia Heaven, (University of Southampton)
- WRAP Organics Programme, Nina Sweet (WRAP)
- Trends influencing energy recovery from waste, Pat Howes (Task 36).

In 2014, a report was authored jointly by Task 36 and Task 37 on the Source Separation of MSW. The report presented an overview of the source separation and separate collection of the digestible fraction of household waste, and of other similar wastes from municipalities, with the aim to use this waste as feedstock for anaerobic digestion in biogas plants.

Objective 4: Seek opportunities to publicise the work of the Task through national dissemination mechanisms.

This objective has been met by the policy of Task 36 to invite key national stakeholders to our workshops. This has the benefit of both inputting key stakeholder knowledge into the work of the Task and disseminating the work of the Task to the stakeholders themselves. Invited stakeholders have included people from academia, industry representatives, trade organisations representatives and government officials.

Where possible, we have sought joint working and engagement of national stakeholders in the delivery of our workshops. For example, our workshop on Solid Recovered Fuels in Milan in 2013 was supported by RegioneLombardia and Energia Ambiente. The Task's workshop in Karlsruhe in 2014 was organised in conjunction with the BREF working group. Most recently, the joint workshop delivered in conjunction with ISWA was attended by representatives from 20 countries, all of whom had an interest in energy from waste.

In addition to this, presentations were delivered during all site visits to inform our hosts of the work of the Task. Information sheets were also provided.

Objective 5: Seek opportunities to publicise the work of the Task through presentations at national/international events

This objective was met by presentations made by Task 36 members at the following workshops, seminars and international conferences:

Workshops and seminars

- ISWA joint working group – presentation and workshop on the role of EfW in the Circular Economy. Berlin, October 2015
- Opportunities for Solid Recovered Fuel in a Circular Economy, presentation at the European Recovered Fuels Organisation Workshop, Brussels, April 2015
- End of waste for SRF – presentation to the workshop in Milan, 2013, following Italian legislation in this area.

International conferences

- Gasification of waste in the UK – IEA Bioenergy Conference 2015, Berlin
- Factors Influencing the development of Small scale EfW – paper presented at ISWA Annual Congress, Antwerp, September 2015
- An Evaluation of arising and markets for waste derived fuels. Paper presented at the Fifth International Symposium on Energy from Biomass and Waste, Venice, November 2014

Success story

In 2004, the International Energy Agency Bioenergy Task 36 – 'Integrating Energy Recovery in to Solid Waste Management Systems' (Task 36) published a topic report "*Review of small scale Waste to energy conversion systems*". The objectives were to collate information on selected small scale waste treatment systems and to produce a status report on the technical and economic potential of such systems for waste treatment. However, there were many other aspects that were of interest when considering the development of small scale energy from waste in general, and not just the technologies used. Therefore, in the 2013-2015 work programme, the Task decided to revisit this topic and to provide an update to that report, focusing in more detail on the reasons behind the decision to build a small scale plant and exploring further the different drivers and limitations and how these could impact positively or negatively on the viability of small scale EfW. This included a review of drivers and barriers such as legislation, policy, public acceptance, and financing and technical data such as plant size – both in terms of the input and thermal capacity, and the output of heat and electricity.

Key conclusions

While the study identified clear policy drivers which were influencing EfW development in general, the decision to develop facilities on a small scale were more relevant to local politics and situation. The costs, both operational and capital, were higher for small scale EfW facilities, but, there were often other drivers which took precedence over economics. Whilst it might be challenging in some cases to demonstrate value for money, other benefits would support a case for small scale EfW.

In the future, financial incentives, and energy and resource drivers might further drive the development of smaller scale EfW facilities using Advanced Conversion Technologies. These technologies enabled flexibility in the way in which outputs from EfW were used, and were likely to be at a smaller scale. Some examples included the conversion of syngas for use as a fuel in dedicated gas engines, conversion to liquid fuels, use as ammonia or methanol, which can be used in transport fuels, and a chemical feedstock. Energy and resource drivers would also be factors, in addition to waste management and landfill diversion targets.

Why has this been highlighted as a success story?

The finding of the study help demonstrate that whilst the costs, both operational and capital, are higher for small scale EfW facilities, there are often other drivers which take precedence over economics alone, making small scale EfW a preferred option in some cases. Whilst it may be challenging in some cases to demonstrate value for money, other benefits will support a case for small scale EfW. Geography can be a driving factor for small scale EfW, but in many cases there are additional drivers. The advantages offered by small scale EfW, such as the treatment of waste close to the point of generation, the generation of jobs in the local community, and lower transport distances, all serve to increase the public acceptance of such facilities. With their smaller footprint, smaller scale EfW facilities can be more easily integrated in to existing industrial areas.

The final report is available on the website, and the findings were presented at the ISWA Annual Congress in Antwerp, 2015 and at the IEA Bioenergy Conference 2015 in Berlin.

Other success factors:

- Participation from all Task 36 member countries, including:
- Development of data collection templates
- Contributing to data collection
- Visiting case study sites to undertake interviews

Conclusions and recommendations

The six workshops delivered were an excellent way to maximise the output of the limited budget of the small Task. The workshops allowed member countries to take ownership of the workshops and their content, and to leverage additional input from stakeholders within each country, hence maximising the outreach and visibility of the Task.

The workshops were well attended, with over 50 delegates at the SRF workshop in Milan, the Advanced Treatment Technology workshop in the UK, and the ISWA joint workshop on the circular economy in Berlin.

The major outcomes of the Task are:

- six key priority issues have been explored by the Task through the delivery of workshops
- three topic reports
- increased level of stakeholder involvement and co-operation
- increased level of dissemination of work of the Task
- working relationships established with ISWA and ERFO

SRF workshop, Milan 2013

Study tour, Sweden 2013.

The delivery of the work of Task 36 is always a challenge due to the small number of members and therefore limited budget. However, the number of strategic proposals that the Task was invited to participate in shows the relevance of the work of the Task to other Tasks in the IEA Bioenergy TCP.

Our conclusions for the Executive Committee of the IEA Bioenergy TCP from this work are as follows:

- The development of energy from waste is relevant to the majority of countries in the world. Globally the amount of waste produced is increasing, particularly in regions where there is rapid urbanisation. Increasingly regulation of waste management takes the nature of the waste into account and aims to maximise resource recycling and to optimise energy recovery from residues. This means that energy from waste is and will remain a key issue globally. Our work in this triennium leads us to recommend that IEA Bioenergy concentrates its efforts on providing information that allows decision makers to make the right decisions concerning integration of energy into solid waste management, in particular regarding the most appropriate technology for their local needs.
- Related to the above, there are many opportunities to reach out to countries that are not in IEA Bioenergy. This may be done initially by joining forces with other international groups (such as the International Solid Waste Association (ISWA) or Asian international waste groups). Ultimately the aim of such work should be to draw more countries into the IEA Bioenergy TCP, by demonstrating the advantages of membership.
- In the past triennium there have been a number of important trends that have impacted on the integration of energy recovery in solid waste management. These include the integration of energy from waste with targets for increased recycling in Europe. This has resulted in increased recycling in Europe and increased production of refuse derived fuel (RDF) from residual waste (as shown in our report on the mass balance of RDF versus municipal waste in the UK). We have also identified trends towards improved development of waste as a fuel for specific purposes, through our work on Solid Recovered Fuel (SRF) (see, for example, our workshop on SRF in Italy).
- Trends towards recycling and the circular economy mean that lower quantities of residual waste are being produced for energy from waste plants and that this residual waste is usually heterogeneous. Treatment of this residual waste requires flexibility, smaller scale energy plants or integration of residual waste management between areas and technologies. Decision makers are looking for novel solutions to the management of residual waste, and need information on small scale energy from waste plants, the integration of recycling, anaerobic digestion and energy from waste, or on novel technologies that are applicable at all scales and that allow for flexibility in the use of the products of conversion (e.g. gasification). We have examined these issues in our gasification and small scale energy from waste reports, but further information is required on operational performance, costs and materials and energy recovery as these options develop.
- Related to the above we have recommended that the Task builds on the gasification work in the current Triennium by working with Task 33 to review gasification worldwide in the forthcoming Triennium.
- Energy from waste is a mature technology and there are many examples of grate combustion worldwide. We covered this area in our end of triennium report in 2009, where we reviewed the available technologies. However, as indicated above, the nature of its application is changing and there are new technologies that could be game changers. We recommend that work supported by the IEA Bioenergy TCP on the integration of energy into solid waste management should aim to provide transparent information on the changing application of energy in solid waste

management (such as how it fits into the circular economy); and on the status of new technologies that could be game changers (such as the stage of development, costs, efficiencies, etc., achieved by these new technologies).

- Dissemination of this information remains a problem for the Task. We recommend that more use is made of modern communication methods, but that this is co-ordinated by the ExCo Communication Group to ensure optimal use of funds. For example, greater use of webinars would help reach a wider audience.
- The Task is small with limited funds. Many of the strategic projects supported by the ExCo are not relevant to the Task as they concern virgin biomass rather than waste feedstock. We recommend, therefore, that the Task contribution to the strategic fund is decreased, or that, alternatively, the strategic fund is used to assist the Task in dissemination (such as the update of the website, or assistance in the costs of attending the end of triennium conference).

Attachments

- Participation in major events is included in this report. The presentations at events are published on the web site
- Deliverables (conference papers, seminar proceedings, technical notes, newsletters, Industry Days, scientific publications, books, etc.), including website address or reference of the publication. These publications are on the Task 36 web site (www.IEAbioenergytask36.org).
- Co-ordination with other Tasks within IEA Bioenergy – information on co-ordination with other Tasks is included in this report. Reports produced as a result of this co-ordination are on the Task 37 and Task 32 websites and our website links to these.
- Industry participation: We have discussed co-ordination with industry in this report. Most of this co-ordination was done through our workshops, but we also organised study tours of industrial sites.

Appendix 1 Publications and industrial participation

Publications in this Triennium

2013

- Integration of thermal energy recovery into solid waste management – published in the IEA Bioenergy Annual report, 2013.
- Summary of the Workshop on Solid Recovered fuel. (http://www.ieabioenergytask36.org/vbulletin/showthread.php?29-Workshop-on-SRF-Milan-20th-November-2013)
- Proceedings of Workshop on Anaerobic Digestion of Solid Waste, Stockholm 8th May 2013 (http://www.ieabioenergytask36.org/vbulletin/showthread.php?28-Proceedings-of-Workshop-on-Anaerobic-Digestion-of-Solid-Waste-Stockholm-8th-May-2013)
- Health and Safety Aspects of solid biomass storage, transportation and feeding (http://www.ieabcc.nl/)

2014

- Karslruhe: IEA Task36-/ BREF AG3 Meeting, 10-12 March 2014 (http://www.ieabioenergytask36.org/vbulletin/showthread.php?33-Karslruhe-IEA-Task36-BREF-AG3-Meeting-10-12-March-2014)
- Energy from waste – the next generation (http://www.ieabioenergytask36.org/vbulletin/showthread.php?38-Workshop-on-Energy-from-Waste-%EF%BF%BD-The-Next-Generation-29th-October-2014-Harwell-UK&p=38#post38)
- Source separation of MSW (http://www.ieabioenergytask36.org/vbulletin/showthread.php?32-Source-separation-of-MSW&p=32#post32)
- An Evaluation of arising and markets for waste derived fuels. Paper presented at the Fifth International Symposium on Energy from Biomass and Waste, Venice, November 2014

2015

- The Growth of Advanced Conversion Technologies for the Treatment of Waste in the UK (http://www.ieabioenergytask36.org/vbulletin/showthread.php?39-Report-on-The-Growth-of-Advanced-Conversion-Technologies-for-the-Treatment-of-Waste-i&p=39#post39)
- Factors influencing EfW (http://www.ieabioenergytask36.org/vbulletin/showthread.php?41-IEA-Bioenergy-Task-Meeting-Bordeaux-2-4-June-2015&p=41#post41)
- Factors Influencing the development of Small scale EfW – paper presented at ISWA Annual Congress, Antwerp, September 2015 Small scale Energy from waste report – to be added to Website
- An Assessment of the Export of Municipal Solid Waste from the UK as Refuse Derived Fuel using a Mass Balance Technique – to be added to Website.
- Papers presented as part of the IEA Bioenergy Conference 2015. (https://mediathek.fnr.de/band-53-iea-bioenergy-conference-2015-realising-the-world-s-sustainable-bioenergy-potential.html)

Industrial participation in Task.

Name of Body	Industry (association)/ International body	Area of focus	Type of collaboration* (existing or planned)
International Solid Waste Association (ISWA)	Waste Management association	Transition to circular economy, waste-to-energy role in circular economy, revision of the WtE BREF	Meeting between task 36 and the Working group on energy recovery. The chair of that working group has also participated at the triennium conference as well as at workshop held on advanced thermal treatments.
SIVOM des Canton du pays de Born	Waste management consortia/association of municipalities	Waste-to Energy /small scale W-t-E	Technical visit in association with the Task meeting 2nd quarter 2015
Tiru	W-t-E operation active in UK and France	Waste-to Energy /small scale W-t-E	Technical visit in association with the Task meeting 2nd quarter 2015
Europlasma	Supplier of technology for gasification, vitrification	gasification of waste together with vitrification of ashes/hazardous waste	Technical visit in association with the Task meeting 2nd quarter 2015
Umweltbundesamt	German EPA	Technologies for gasification/pyrolysis of waste as a background for revision of BREF	Gave a presentation on the Task meeting in Berlin, 4th quarter 2015
The National Environmental Agency of Singapore		Waste management in a circular economy	Invited to be present in a Task meeting during 2016
Skövde värmeverk	Swedish owner/operator of W-t-E and district heating	Small scale WtE	Participated as a case study in a Task report on Small Scale EfW
Viridor	UK owner/operator of WtE facility	Small scale WtE	Participated as a case study in a Task report on Small Scale EfW
European recovered fuels organisation – ERFO	Association for SRF-producers	SRF/RDF	Task 36 made a presentation in one of their meetings

TASK 37: Energy from Biogas

Prepared by:

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Participating countries:

Australia, Austria, Brazil, Denmark, European Commission, Finland, France, Germany, Ireland, Korea, The Netherlands, Norway, Sweden, Switzerland, United Kingdom

Website: http://www.iea-biogas.net/

Introduction

The production of biogas by anaerobic digestion (AD) is generally considered a mature technology although there are many challenges to improve economic performance to a level that would allow direct competition of bioenergy or biofuel production with fossil energy and provide an overall improvement in resource efficiency. Hence, the main objective of Task 37 is to assess technical improvements and to identify best practices in the field of AD applications. Based on the technical knowledge and expertise of its members, technical studies are carried out and reports produced for the benefit of the main stakeholders that include technology developers, biogas plant operators and policy makers.

In the period from 2013-2015 there was a high rate of growth in numbers of biogas plants in IEA Bioenergy member countries, although the rate slowed dramatically in Germany following a reassessment of a key subsidy scheme in 2014. Overall, in other member countries and elsewhere in the world biogas plant numbers increased steadily in most sectors where AD is applied, particularly on farms to deal with animal residues, in municipalities to deal with food waste and for waste water treatment. Following years of use of biogas for electricity generation and heat utilisation where possible, the period of the last work programme saw a marked shift to the production of biomethane for use as a transport fuel and for injection into natural gas grids to replace natural gas. The shift to biomethane production was prompted in large part by a combination of avoiding low energy conversion efficiency from feedstock to energy due to low utilisation of waste heat from electricity generation and the local and global benefits of low CO_2 and pollutant emissions from use of biomethane as a vehicle fuel compared with diesel, especially in urban areas. Also, it has become widely acknowledged by policy makers that AD can play an important role in the treatment of wastes and residues in sustainable agriculture, municipal waste management and renewable energy/biofuel production from sustainable biomass feedstocks. For example, AD is applied in agriculture to reduce eutrophication of water in areas of intense animal rearing by facilitating the capture of plant nutrients, while at the same time providing a source of energy and an alternative source of income to the farm.

During the 2013-2015 work programme Task 37 started a study on the environmental performance of biogas plants in order to provide support to both policy makers and biogas plant operators on this topic. The work included a study of methane emissions from all steps of the biogas production and utilisation process chain and a start of life cycle assessment of biogas process chains.

In general, the Task disseminated technical information through technical reports and case studies to people involved in the technical deployment of economic and environmentally sustainable biogas installations. While aiming at a high technical level, the intention of most publications was to enable easy understanding by both technical and non-technical people and indeed the general public using a combination of website and technical fora. Publication of a new all-encompassing biogas handbook was completed in 2013.

Background

The main objectives of the 2013-2015 work programme of Task 37 were to support sustainable development and exploitation of technologies used in the biogas production and utilisation process chain. There were three main objectives of the work programme:

- Assessments for improvements in the economic performance of the biogas/biomethane value chain and efficient product utilisation, focussing on AD process optimisation, feedstock properties, including pretreatments and algae and MSW, biomethane upgrading, biogas utilisation in smart grids and nutrient recovery from digestate.

- Measurement and assessment of emissions from biogas production facilities and the mitigation of methane emissions.
- Support to policy makers through provision of technical input for preparation of standards for biomethane injection in natural gas grids and utilisation as a transport fuel, for environmental assessment of biogas production through information on process chain emissions, for identifying best practices in feedstock selection and carrying out small scale AD at farm level and for providing technical information for AD users and the general public.

In all cases, the aim of Task 37 has been to identify best practices applied in the exploitation of biogas technologies. The two main challenges of the biogas sector are the costs of investment and operation and maintenance while maintaining high levels of environmental sustainability.

There is an overall need to improve resource efficiency. There is potential for reducing both investment and operation and maintenance costs by fine tuning a number of processes. These include feedstock selection and pretreatment, followed by process monitoring and control. Task 37 set out to publish technical reports on these topics as well as on the economics of small-scale farm biogas production and the measurement of methane emissions from biogas plants. In terms of products utilisation, there is increasing interest in the use of digestate as a recognised biofertiliser product, in expansion of the possibilities for biomethane production and the role of biogas in balancing electricity grids that are increasingly fed from variable (solar and wind) renewable energy sources. Overall, resource efficiency in the sector is high, but there is still potential for more improvement.

Task objectives and work carried out

A. Biogas production

Feedstocks must be carefully selected and pretreated before effective anaerobic digestion. A study on pretreatments for feedstocks was carried out to assess methods to optimise methane yield and methane production kinetics, since any significant increase in the proportion of the methane potential able to be recovered and/or the rate at which methane is produced would improve the efficiency of the AD process and thus have a positive impact on costs. The published report [3] addresses a wide range of pretreatments for feedstocks and an attempt was made to judge their respective performances, energy consumption and maintenance needs. In practice, pretreatment is becoming more common as plant operators become more confident in the ability of technologies to provide positive results. This work was led by Austria.

A study on process monitoring was carried out in order to provide the state-of-the-art of process monitoring techniques and how the techniques available can be applied to improve the stability and performance of biogas plant operation and to assess possible opportunities for process optimisation by individual plant operators. The final report [2] contains a review of process monitoring techniques that can be applied at various stages of the biogas production and utilisation process. This work was led by Austria.

For the first time, Task 37 addressed the growing interest of high efficiency AD in wastewater treatment plants. An outline study was carried out to assess options and approaches for integration of AD into modern wastewater treatment plants, primarily in developed countries. The final report [9] considers energy performance, nutrient recycling and the effects of selection of different process options and their potential impacts on performance. This work was led by Switzerland and was linked to two Case Studies [17, 21]

Also for the first time, the Task carried out a study to assess the prospects of the use of algae as a feedstock for AD. The final report [7] contained a review of the production and properties of both microalgae, mainly from cultivation using open ponds or enclosed photobioreactors, and macroalgae, mainly derived from seaweed that is often associated with troublesome growths in open waters enriched by the run-off of excess fertilisers used in agriculture, for example as described in a Case Study [23]. While algae is widely considered a potentially attractive feedstock for AD, the report highlights a range of challenges that must be overcome before either type of algae can be used in a cost-effective manner. This work was led jointly by Austria and Ireland.

While over the last two decades there has been a trend to build large-scale biogas plants, this has often led to logistical difficulties in feedstock supply and utilisation of the energy content of the biogas. As a consequence, there is growing interest in small-scale biogas plants on farms to address animal slurry management, as for example in the Task 37 Case Study for family farms in Brazil [16]. This approach is in contrast to large-scale biogas plants in areas of intense animal rearing, for example in Denmark and described in Success Stories [11,14] and Case Studies [15,19,22]. The final report [10] presents the challenges and possible solutions for achieving viability at small scale in terms of investment costs and practical operation and maintenance. This report was led by the United Kingdom.

B. Biogas product utilisation

To complete the planned series on digestate management, the Task prepared a publication on nutrient recovery by digestate processing in which processes for separation of individual fractions of digestate are described and compared. Digestate processing and nutrient recovery are important practices particularly in areas of intense

animal rearing in order that problems associated with eutrophication are avoided and that utilisation of valuable nutrients is maximised. The publication on nutrient recovery [6] complements earlier publications in the 2010-2012 work programme on utilisation of digestate as biofertiliser and quality management of digestate. This report was led jointly by Austria and Denmark.

Biogas up-grading technologies were monitored and plant lists for operating plants and equipment suppliers were maintained on the Task website. The Task last produced a detailed report on biogas up-grading to biomethane in 2009 and during the period 2013-2015 produced a Success Stories on membrane upgrading [12] and a Case Study on retrofitting an existing plant for biogas upgrading to biomethane [18]. Production of biomethane for utilisation as a gaseous transport fuel was described in a Success Story for a plant in Sweden treating food waste [14]. With the growing use of liquefied natural gas (LNG) opportunities have been taken to adopt liquefaction technology in the biogas sector, as described in a Case Study for a project in Sweden in a remote production location without access to a gas grid [20]. Reporting on biogas upgrading and biomethane production and utilisation for transport was led by Sweden.

Through its members, Task 37 provided technical input to work on the preparation of standards for gas grid injection of biomethane and utilisation of biomethane as a transport fuel in Europe.

With the growth of electricity generation from intermittent power sources (solar and wind) there is growing demand for flexible power generation to meet demand. The ability to store methane presents biogas operators with an interesting new possibility to feed electricity into the grid only when needed and at the same time enhance the income received from power fed into the grid. A new Task 37 report [5] describes the possibilities not only of biogas storage, but upgrading to biomethane and using the natural gas grid for storage as well as flexible operation of the biogas process itself to regulate gas output. This report was led jointly by Sweden and Ireland.

C. Emissions from biogas installations

Methane is the primary product of anaerobic digestion and has a global warming potential 25 times higher than carbon dioxide. Therefore there is strong incentive to minimise leakage losses for both economic and environmental reasons. The Task published its first assessment of methane losses from biogas plants in a chapter in *The Biogas Handbook, science, production and applications*, prepared by the Task and published within the 2010-2012 work programme [31]. Subsequently, during 2014 and 2015 the Task participated in a national project involving an assessment of methane emissions' measurement techniques and in making field measurement on a commercial biogas plant. Combined with life cycle assessment methods, the practical implications and impacts of methane emissions will be considered in a new technical report scheduled for publication in 2016.

D. Topics Supporting Dissemination and Collaboration

The Task contributed to three key joint Task reports. These are summarised below.

In the area of municipal waste management, a study was carried out in collaboration with Task 36 on methods for source separating the digestible fraction of municipal solid waste (MSW). The aim was to identify best practices that would produce feedstock which could be used efficiently for AD. The final report [1] contains an assessment of methodologies developed over the last decades and in different parts of the world and refers to three case studies to illustrate successful approaches in Sweden, South Korea and the United Kingdom. The work was led by the UK for Task 36 and Denmark for Task 37.

On the topic of the availability of sustainable biomass that could be used for bioenergy, the Task contributed to a multi-Task study led by Task 43 on mobilising sustainable bioenergy supply chains. The final report was published in 2015 [8]. One chapter of the report is dedicated to the biogas supply chain and considers the cases of municipal solid waste, oil palm residues for AD and co-digestion as a means of benefitting from available local feedstocks and of optimising AD process performance.

With the steadily increasing injection of biomethane into natural gas grids, potential challenges in relation to trade of biomethane have arisen. The topic of biomethane trade has been addressed in a study led by Task 40 and to which Task 37 contributed information on the technical options, opportunities and limitations relating to methods for producing biomethane, injection into the natural gas grid and biomethane utilisation in the final report [4].

Country reports had previously been published in the form of raw information from individual member countries. For 2013, the first consolidated Task 37 annual country report was published [24]. This exercise was repeated in succeeding years, and with the needs of policy makers in mind, the layout was adapted to make key information clearer and to more readily facilitate inter-country comparisons [25].

National workshops were held in conjunction with three Task meetings:

- Biogas Process Optimisation, Bern, Switzerland, April 18, 2013 [26]
- Renewable Energy Biogas Technologies, Seoul, Korea, November 14, 2013 [27]
- Brazil joint biogas workshop with CIBiogas, Foz do Iguaçu, Brazil, April 4, 2014 [28]

In addition, the Task organised one session at each of two conferences:

- Green Gas Research Outlook Sweden (GGROS) 2015", Örnsköldsvik, Sweden, March 24, 2015 [29]
- IEA Bioenergy Conference 2015 – Biogas Session, Berlin, Germany,October 28th 2015 [30]

Contacts with industry and research projects are maintained wherever appropriate. Collaboration with international networks and projects has been maintained (e.g. European Biogas Association, EU and national projects, etc.) as well as with the various biogas mirror groups in member countries. Industrial organisations participated in workshops organised jointly by Task 37 and Task meetings' hosts. At all six Task meetings in the triennium visits were made to biogas facilities for the purpose of data collection and dissemination of the Task's output. Biogas plant operators provided all the information needed for the four Success Stories and all nine Case Studies published.

The biogas newsletter is produced in cooperation with the European Biogas Association. Task 37 publishes a minimum of 4 newsletters each year on biogas production and utilisation. The newsletter is published on the Task website and distributed to more than 800 organisations worldwide.

It is standard practice to provide a short version of Task meeting minutes with action points soon after each meeting. Extended meeting minutes are provided at a later date as required. All meeting minutes are circulated only within the IEA Bioenergy membership.

The Task Leader contributed to review of the IEA How2Guides which build on the global energy technology roadmaps. Task members contributed economic data for IEA Headquarters.

The Biogas Handbook was published in February 2013 [31] and marked the end of a large collaborative effort towards the end of the previous work programme. The handbook has since become the leading reference work in the field and AD and biogas utilisation.

Success story

This success story concerns the portfolio of studies that have been carried out over the period of the 2013-2015 work programme and the period before. With an established international core of expertise the Task was invited by a well-known publisher to produce a new handbook on biogas science, production and utilisation. While the bulk of the work was carried out pre-2013, publication was completed in February 2013 and led to increased collaboration involving Task projects and increased visibility for IEA Bioenergy. Topics in the handbook covered all steps in the biogas production and utilisation chain. The book was written to address the needs and interests of researchers addressing the basic concepts of AD, process and equipment developers, biogas plant operators, maintenance organisations and last but not least policy makers. Three topics are highlighted below to illustrate the external impacts the Task has had.

Publications on digestate use as a biofertiliser and quality management had earlier been used in the preparation of national legislation and were subsequently used in European Union legislative work to determine criteria for end-of-waste [32]. End-of-waste criteria were required within the Directive on Waste, originally adopted in 2008. The important contributions from the Task 37 studies concerned allowable levels of contaminants in digestate and methods for ensuring minimum quality requirements. The importance of variation due to local conditions was a key aspect in the Task 37 study and how those conditions could affect the limits set for contaminants. Subsequently, the Task published an additional report on nutrient recovery from digestate in 2015 [6], a process important in the management of nutrients both in terms of avoiding ground water contamination in areas of intense animal rearing and in managing nutrients from the point of view of resource efficiency.

Upgrading of biogas to biomethane has been the focus of Task 37 work for more than a decade and biomethane injection into the natural gas grid or utilisation as a vehicle fuel has been addressed. Through national representatives, expertise in these areas has been used to support the drafting of standards for the European standards organisation, CEN. Drafts for three standards, gas grid injection, use of biomethane as a vehicle fuel after transport through the gas grid and direct use of biomethane after production without use of the gas grid are expected to be ready by 2017.

Finally, assessment of methane emissions from biogas plants that started in the previous work programme led to involvement in a national study that eventually included three Task member countries in an evaluation of measurement methodologies and the measurement of emissions in real time on a large plant operating under normal commercial conditions. The final report from the Task is expected to be published in 2016. In the meantime participants in the small project have been awarded funding from a European Union research programme to extend the work with the aim of establishing best practices for biogas plant operators and finally enabling quantitative assessments of the life cycle impacts of methane losses on the biogas value chain.

Conclusions and recommendations

Task 37 has provided substantial input to plant designers, to plant operators and to policy makers during the 2013-2015 work programme. The main objective of the Task is to provide support for improvement of the economic performance of biogas plants while maximising environmental sustainability. Optimising the technical performance along the whole biogas process chain is the key to achieving good economic performance. Through optimisation with a careful eye on environmental impacts, the best results should be achieved in terms of overall resource efficiency.

Throughout the course of the 2013-2015 work programme the Task has worked to produce a matrix of publications that cover key aspects of technical and economic sustainability. This matrix covers feedstock selection and pretreatment, including feedstocks from agriculture, wastewater treatment, algae and municipal waste, AD process monitoring, maximising utilisation of the energy content of biogas, for example through upgrading to biomethane, and innovative ways to improve income while at the same time contributing to electricity grid stability. Reports have been written with both plant operators and policy makers in mind. The individual reports complement the key biogas handbook publication made at the end of the previous work programme.

Task members were invited to make various presentations at a number of key conferences and project events. These invitations collectively indicate the high level of expertise the Task represents.

It is suggested that ExCo continues to play an active coordinating role that facilitates the widest possible dissemination of Task output so that the maximum benefit can be gained.

Attachments

- Deliverables: All deliverables mentioned earlier in this report are listed in the deliverables and publications below.
- Co-ordination with other Tasks within IEA Bioenergy: Task 37 started work with Task 36 in the previous triennium on source separation of waste feedstocks for anaerobic digestion; and published the final report in 2013. The Task was also involved in a joint study on biomethane trade with Task 40 (publication in September 2014) and with Task 43 on mobilising sustainable bioenergy supply chains (publication in November 2015). Contribution to a joint study on algal biofuels with Task 39 was started in 2015 (publication scheduled in 2016) and there was contact with Task 38 concerning life cycle assessment on the effects of methane leakage during biogas production (report scheduled for publication in 2016).
- The Task participated in the end of triennium conference held in Berlin in October 2015 and organised a parallel session within the conference. In addition, the Task participated in national workshops and conferences, all of which are mentioned earlier in this report.

Deliverables and Publications

IEA Bioenergy Task 37 website: http://www.iea-biogas.net/

Technical and Policy Reports

(http://www.iea-biogas.net/technical-brochures.html)

1. "Source separation of municipal solid waste: An overview of the source separation and separate collection of the digestible fraction of household waste, and of other similar wastes from municipalities, aimed to be used as feedstock for anaerobic digestion in biogas plants", Teodorita Al Seadi, Nia Owen, Hanna Hellström, Ho Kang, November 2013, ISBN 978-1-910154-01-4
2. "Process monitoring in biogas plants", Bernhard Drosg, December 2013, ISBN 978-1-910154-03-8
3. "Pretreatment of feedstock for enhanced biogas production", Lucy Montgomery, Günther Bochmann, February 2014, ISBN 978-1-910154-05-2
4. "Biomethane – Status and factors affecting market development and trade", Daniela Thrän, Eric Billig, Tobias Persson, Mattias Svensson, Jaqueline Daniel-Gromke, Jens Ponitka, Michael Seiffert, John Baldwin, Lukas Kranzl, Fabian Schipfer, Julian Matzenberger, Nathalie Devriendt, Mathieu Dumont, Jonas Dahl, Günther Bochmann, September 2014 (in cooperation with Task 40), ISBN 978-1-910154-10-6
5. "A perspective on the potential role of biogas in smart energy grids", Tobias Persson, Jerry D Murphy, Anna-Karin Jannasch, Eoin Ahern, Jan Liebetrau, Marcus Trommler, Jeferson Toyama, December 2014, ISBN 978-1-910154-13-7
6. "Nutrient recovery by biogas digestate processing", Bernhard Drosg, Werner Fuchs, Teodorita Al Seadi, Michael Madsen, Bernd Linke, August 2015, ISBN 978-1-910154-16-8
7. "A perspective on algal biogas", Jerry D Murphy, Bernhard Drosg, Eoin Allen, Jacqueline Jerney, Ao Xia, Christiane Herrmann, September 2015, ISBN 978-1-910154-18-2
8. "Mobilising sustainable bioenergy supply chains", IEA Bioenergy ExCo: 2015:04, ISBN 978-1-910154-20-5
9. "Sustainable biogas production in municipal wastewater treatment plants", Nathalie Bachmann, October 2015, ISBN 978-1-910154-22-9

10. Exploring the viability of small scale anaerobic digesters in livestock farming", Clare Lukehurst, Angela Bywater, December 2015, ISBN 978-1-910154-25-0

Success Stories

(http://www.iea-biogas.net/success-stories.html)

11. "Lemvig biogas: an example of successful centralised co-digestion in Denmark", Teodorita Al Seadi, Lars Albæk Kristensen, February 2013

12. "Bruck an der Leitha (Austria) membrane up-grading of biogas to biomethane for grid injection", BOKU University and Biogasanlage Bruck/Leitha GmbH, April 2013

13. "LINKO GAS: a reference plant for centralised co-digestion of animal manure and digestible wastes in Denmark", Teodorita Al Seadi and Linko Gas Biogas Plant, November 2013

14. "More than 10 years production of fossil-free automotive fuel and certified digestate from food waste: VERA Park in Helsingborg, Sweden", Tobias Persson and Nordvästra Skånes Renhållnings AB, October 2014

Case Studies

(http://www.iea-biogas.net/case-studies.html)

15. "The first organic biogas plant in Denmark: demonstration project at Bording organic farm", Teodorita Al Seadi, Michael Tersbøl, Bjarne Viller Hansen, June 2013

16. "Bio-energy in family farming a new sustainable perspective for the rural sector in Brazil", Cicero Bley & Barbara Amon, September 2013

17. "Biowaste and sewage sludge recovery: separate digestion, common gas upgrading and heat supply: Biogas Zürich – An innovative energy concept", Nathalie Bachmann & Biogas Zürich AG, April 2014

18. "Fredericia biogas upgrading: the first full scale upgrading plant in Denmark opens the way for use of biogas for biomethane fuel production", Teodorita Al Seadi & Lars Markdal Johansen, May 2014

19. "Maabjerg biogas plant: operation of a very large scale biogas plant in Denmark", Teodorita Al Seadi & Maabjerg Bioenergy A/S, June 2014

20. "Non-grid biomethane transportation in Sweden and the development of the liquefied biogas market", Tobias Persson & Mattias Svensson, September 2014

21. "REVAQ certified wastewater treatment plants in Sweden for improved quality of recycled digestate nutrients", Tobias Persson, Mattias Svensson & Anders Finnson, April 2015

22. "Ringkøbing-Skjern, Denmark – Decentralised Biogas Network Model", Teodorita Al Seadi & Ringkøbing-Skjern Forsyning A/S, May 2015

23. "Solrød Biogas – Towards a circular economy", Teodorita Al Seadi & Mikkel Busck, December 2015

Country Reports

(http://www.iea-biogas.net/country-reports.html)

24. "Task Country Overview – Country Reports", edited by Tobias Persson & David Baxter, January 2014

25. "IEA Bioenergy Task 37 – Country Reports Summary 2014", edited by Tobias Persson & David Baxter, January 2015, ISBN 978-1-910154-11-3

National Workshops

(http://www.iea-biogas.net/workshops.html)

26. " Biogas Process Optimisation", Bern, Switzerland, April 18, 2013

27. "Renewable Energy Biogas Technologies", Seoul, Korea, November 14, 2013

28. "Brazil joint biogas workshop with CIBiogas", Foz do Iguaçu, Brazil, April 4, 2014

29. "IEA Task 37 Session at Green Gas Research Outlook Sweden (GGROS) 2015", Örnsköldsvik, Sweden, March 24, 2015

30. "IEA Bioenergy 2015 Conference – Biogas Session", Berlin, Germany,October 28th 2015

Reference Book

31. "The Biogas Handbook: Science, Production and Applications", edited by A. Wellinger, J. Murphy and D.Baxter, Woodhead Publishing, 2013 (ISBN 978-0-85709-498-8 (print); ISBN 978-0-85709-741-5 (online))

Other Reference

32. "End-of-waste criteria for biodegradable waste subjected to biological treatment (compost & digestate): Technical proposals", Hans Saveyn, Peter Eder, European Commission, EUR 26425 EN, ISBN 978-92-79-35062-7 (pdf), 2014

TASK 38: Climate Change Effects of Biomass and Bioenergy Systems

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Introduction

IEA Bioenergy Task 38 brings together the research work of national programmes in participating countries, on climate change effects of a wide range of biomass systems, bioenergy technologies and terrestrial carbon sequestration. The Task considers questions of GHG estimation in agriculture, forestry and the energy sector, with application to GHG accounting under the Kyoto Protocol, and contributes to the work of the Intergovernmental Panel on Climate Change (IPCC). Emphasis is placed on the development of state-of-the-art methodologies for assessing climate change effects that demonstrate the application of established methods and support decision-makers in implementing effective GHG mitigation strategies.

For the 2013-2015 Triennium, Task 38 continued to work on the climate change effects of biomass and bioenergy systems, with the specific emphasis on:

1. the impacts of timing of emissions and removals related to bioenergy systems, especially those based on existing forestry systems
2. the appropriate metrics for quantifying the climate effects of bioenergy
3. the appropriate reference systems against which to compare a bioenergy system
4. approaches for Life Cycle Assessment of bioenergy systems.

The objectives of Task 38 are:

1. to promote the sustainable use of biomass and bioenergy through increased understanding of the climate change impacts of biomass production and utilisation for energy
2. to revise and promote the "standard methodology" for the calculation of life cycle climate change impacts, incorporating new issues, technologies and topics as they emerge
3. to work in cooperation with other IEA Bioenergy Tasks to assess the climate change impacts of bioenergy technologies and production systems
4. to aid decision makers in devising policy and selecting mitigation strategies that optimise climate change benefits of bioenergy.

This report summarises the activities, deliverables, progress on objectives, and successes and difficulties during the Triennium 2013-2015.

Background

The urgent need for effective action on climate change was stressed by the IPCC in their 5th Assessment Report, released in 2013-14, and the Paris Agreement of 2015. Bioenergy has been promoted as a component of climate-change policies in many countries, as an alternative to fossil fuels, delivering renewable electricity, heat and transport fuels, and with the potential to mitigate climate change. However, over the past decade, bioenergy has come under increasing scrutiny for its environmental impacts, and its climate-change benefits have been questioned. There has been ongoing debate on the magnitude of indirect Land Use Change (iLUC) and the timing of climate change benefits from bioenergy. The use of Life Cycle Assessment (LCA) in informing climate change policy emerged as a new topic of debate, suggesting inconsistency between the application of LCA for bottom-up assessments and the use of top-down scenario modelling of aggregated results. The debate in the scientific literature and the popular media raised increasing doubts about the benefits of bioenergy in addressing climate change, and policy-makers began to question support for the bioenergy industry. As a result, the majority of the emphasis of Task 38 during the 2013-2015 Triennium was on the topics of timing and LCA methodology, with the aim to assist decision-makers in government and industry to recognise the role of bioenergy in renewable energy systems.

Bioenergy is often considered "carbon neutral" because it is assumed that the biomass is produced sustainably so that the amount consumed is regrown, and over the life cycle there are no net biospheric CO_2 emissions. However, there are various sources of emissions along the supply chain, and additional climate warming factors, such as albedo, that need to be quantified to determine the climate change effects of a bioenergy system. Direct and indirect land use change can also be important due to the carbon (C) stocks in biomass and soil, which may increase or decrease. For example, energy crops planted on marginal land may increase both biomass and soil carbon, while biomass residues extracted from existing forestry systems may reduce C stocks in the forest. Thus, climate impacts of bioenergy are sensitive to a range of case-specific factors, but also to the methodological choices and assumptions adopted: biomass feedstocks, reference energy system displaced (e.g. fossil), delimitation of spatial system boundary, procedures for dealing with co-production, time horizon, metrics applied and climate forcers considered. Task 38 has developed standard methodology to assist researchers to quantify the net climate change effects over the life cycle of bioenergy products. Task 38 worked with other IEA Bioenergy Tasks to evaluate the climate change effects of specific technologies and bioenergy supply chains.

There has been increasing recognition that bioenergy systems based on existing managed forests may incur a "carbon debt" if their carbon stock is reduced by biomass harvest. The difference in average carbon stock between the with- and without-bioenergy cases reflects the carbon cost of bioenergy, that needs to be repaid through avoided emissions of fossil fuels before the bioenergy system delivers net benefits. Task 38 has focused on explaining this topic, and worked with Task 43 to engage in dialogue with researchers and decision-makers, to enhance understanding of the issue.

The scientific literature proposes many different metrics to quantify the climate effects of GHG emissions, so Task 38 is working on guidance to assist researchers to choose appropriate metrics. Similarly, Task 38 is developing guidance on selection of the appropriate reference system against which to evaluate bioenergy systems, with particular focus on the reference land use.

Task 38 has contributed to the debate on alternative approaches to life cycle assessment, and the use of LCA in informing policy development. Two alternative LCA approaches are recognised: attributional (in which a share of total impacts due to all human activities is attributed to a specific bioenergy product) and consequential (in which the impacts, both direct and indirect, of a change – e.g. in production of bioenergy – are quantified). Attributional LCA is commonly applied in product labelling and has been used for many past studies, but it is increasingly recognised that consequential LCA is the more appropriate approach to inform policy development and research into implications of expansion of bioenergy.

Task objectives and work carried out

The following tables summarise the work conducted during the 2013-2015 Triennium in meeting Task 38's objectives, including the major deliverables and activities and their relevance. Most activities contribute to more than one objective, so the relevant Objectives are listed with the title of each. Much of the work of Task 38 has been undertaken in collaboration with other IEA Bioenergy Tasks.

Table 2: Publications

Item	Description	Relevance/Status
ExCo – Strategic Paper On the Timing of Greenhouse Gas Mitigation Benefits of Forest-Based Bioenergy (*Cowie, Berndes, Smith and others, 2013*) 01, 03, 04	The report addresses a much debated issue – the impacts of timing of emissions and sequestration on the climate change effects of bioenergy. Available at http://www.ieabioenergy.com/wp-content/uploads/2013/10/On-the-Timing-of-Greenhouse-Gas-Mitigation-Benefits-of-Forest-Based-Bioenergy.pdf	▪ Completed ▪ The purpose of the report is to produce an unbiased, authoritative statement on this topic aimed especially at policy advisors and policy makers
Workshop statement and Report Copenhagen workshop on Forests, bioenergy and climate change mitigation 01, 03, 04	This statement and report are outcomes of the workshop on "Forests, bioenergy and climate change mitigation", held May 19-20, 2014 in Copenhagen (see below). Available at http://www.task38.org/html/body_copenhagen_2014.html The statement summarises the (few) areas where the diverse workshop participants reached consensus. The report summarises the results of a preliminary survey and the workshop discussions, including a summary of areas of convergence and divergence, and the bases for different perspectives.	▪ Completed ▪ Advanced scientific understanding of the topic and clarified divergent views on the role of forest-based bioenergy in climate change mitigation, and identifies knowledge gaps and priorities for future research and data collection, in order to improve scientific understanding and support policy development for forest-based bioenergy
2014 Annual report special feature Quantifying the Climate Effects of Forest-Based Bioenergy: Dealing with spatial and temporal boundaries *(Cowie AL, Soimakallio S and Brandão M)* 01, 04	This feature for the 2014 Annual report of IEA Bioenergy presents the key issues in quantifying the climate change effects of bioenergy and provides recommendations for undertaking appropriate and comprehensive assessments of climate change impacts of forest-based bioenergy systems.	▪ Completed ▪ Provides an overview of the state of the art relevant for researchers and decision-makers.
Case study: Greenhouse Gas (GHG) and energy analysis of a bioethanol oriented biorefinery concept in Austria *(Cherubini, Jungmeier and Bird, 2013)* 01	This case study deals with a Life Cycle Assessment (LCA) of a conceptual biorefinery system which produces ethanol, other energy carriers (electricity, heat, biomethane) and chemicals (phenols) from softwood forest residues.	▪ Completed ▪ Demonstrates the GHG benefits of a biorefinery, particularly in the medium-long term
Case study: Greenhouse gas and oil use impacts of Fischer-Tropsch diesel and DME production integrated with pulp and paper mills *(Joelsson and Gustavsson, 2013)* 01	This case study analyses the resource efficiency and the reductions in CO_2 emissions and oil use when motor biofuels are produced in an integrated pulp and paper mill, under Swedish conditions, and used to replace fossil motor fuels. Integration of motor biofuel production with a pulp mill is more efficient than stand-alone motor biofuel production, but larger reductions in CO_2 emissions or oil use can be achieved if biomass replaces coal or oil directly in stationary energy applications.	▪ Completed ▪ Optimisation of resource use and importance of displaced fossil energy in assessing the CO_2 emissions saved
Case study: Life cycle assessment of greenhouse gas mitigation benefits of biochar in Australia *(Cowie and Cowie, 2013)* 01	This study evaluates the GHG impacts of a range of biochar systems, made from different biomass feedstocks, at different pyrolysis conditions, and applied to different crops.	▪ Completed ▪ Demonstrates the relative benefits of using biomass for bioenergy and biochar, and emphasises the importance of the reference system

Item	Description	Relevance/Status
Case study: EU biofuel targets, costs and GHG balance of the Finnish energy sector and forests. *(Forsström, Pingoud, Pohjola and Vilén, 2013)* 01, 04	The study analyses a biodiesel strategy based on domestic forest biomass, using an integrated modelling framework. A market-oriented approach is applied to estimate the potential impacts on greenhouse gas (GHG) emissions of achieving a national transport biofuel target (of 10% or 20% of total consumption) under the current climate and energy policy obligations.	▪ Completed ▪ Demonstrates the importance of including market-mediated impacts in an assessment ▪ Demand for forest biomass for biofuel reduced the forest carbon sink and diverted biomass from electricity and industry.
Case study: Alternatives to Use Sugarcane Residues to Reduce GHG Emissions *(Leal et al, 2013)* 01	Studies alternative uses of sugarcane residues, bagasse and straw, aiming at the maximum GHG reduction. Alternative uses evaluated are: surplus power generation, second generation biochemical ethanol and F-T biofuels, pellets to displace coal in EU thermal power plants (co-firing), biochar as a way to fix carbon in the soil and to improve soil fertility.	▪ Completed ▪ Demonstrates how GHG outcomes from use of sugarcane residues can be optimised. ▪ Highest net emissions reductions route was bagasse pellets co-fired in EU thermal power plants
Inter-task project "Monitoring Sustainability Certification of Bioenergy" 01, 03, 04	Tasks 38-40-43 collaborated in this project led by Task 40. Outputs comprise four reports, summary report and scientific papers, as well as presentations to a workshop at the World Biofuels Markets conference, Rotterdam, *How can sustainability certification support bioenergy markets?* Task 38 provided input to development of project plan, development design and dissemination of survey to stakeholders, reviewed survey results, reviewed existing schemes and provided a visual summary highlighting the relationships amongst schemes, contributed to the reports and presentations.	▪ Completed ▪ Highlighted the plethora of schemes and gathered valuable data on views of stakeholders. ▪ Created a foundation for future studies on improving governance of bioenergy
Inter-task project "Mobilising sustainable bioenergy supply chains" 01, 03	Led by Task 43, this large project involving Tasks 43/42/40/38/29 reviewed the sustainability of various bioenergy supply chains.	▪ Synthesis report published and many papers and reports published or in press for each of the specific chains
Scientific Paper: Updating the Standard Methodology for Comparing the Greenhouse Gas Balances of Bioenergy Systems and Fossil Energy Systems 01, 02	The "standard methodology" requires updating to address issues that have emerged since its first publication (e.g. timing of flows, indirect land use change, non-GHG climate forcers).	▪ In preparation ▪ Will be completed after publication of the reference system and metrics papers as these are important aspects of the standard methodology
Scientific Paper: Metrics for assessing the climate change effects of bioenergy systems *(Brandão et al)* 01, 02	A paper that arose from the two expert meetings in 2012, it discusses how to handle the time component of climate impacts of bioenergy systems.	▪ Close to submission ▪ Comparison of more than 10 metrics for climate change that yield different results ▪ Recommendations given
Scientific Paper: Reference Systems for evaluating climate effects of bioenergy *(Koponen et al)* 01, 02	A paper that arose from the two expert meetings in 2012, it recognises that one of the most important factors for evaluating the climate effects of bioenergy is understanding, and properly assessing what would have occurred in the absence of bioenergy (the reference system).	▪ Close to submission ▪ Provides guidance on selection of the appropriate reference system for evaluation of the effects of bioenergy ▪ Focuses on the land use reference
Proof of concept Approach developed to compare three available LCA GHG emissions tools used by regulatory systems 01, 03	Harmonised assumptions methodology developed and presented at the 2015 IEA Bioenergy Conference for ethanol from corn in the U.S.	▪ Initial model comparison completed. Joint proposal T38 and T39 to continue comparisons approved by Task 39. Brazilian collaborators will be co-sponsored by T39.

Table 3: Meetings and conferences organised

Item	Date	Description	Relevance/Status
Business/expert meeting	12-13 March 2013	Task meeting, Rotterdam	Update, progress work plan
Business/expert meeting	28-29 November 2013	Task meeting, Sydney	Update, progress work plan
Business/expert meeting	21 May 2013	Task meeting, Copenhagen	Update, progress work plan
Business/expert meeting	8 December 2014	Task meeting, Helsinki	Update, progress work plan
Business/expert meeting	25 May, 2015	Task meeting, Växjö (Sweden)	Update, progress work plan
Business/expert meeting	29 October, 2015	Task meeting, Berlin	Update, progress work plan
Conference session: Bioenergy Australia 2013 Conference	25-27 November, 2013	Bioenergy Australia 2013 Conference, Hunter Valley, NSW Task 38 led the session "Quantifying Climate Change Effects of Bioenergy" Seven Task members gave presentations	Presentations highlighted several aspects of importance to quantifying climate change effects of bioenergy, and demonstrated the application of Task 38 methodology to a range of different bioenergy systems.
Joint Workshop Forests, bioenergy and climate change mitigation Copenhagen	19-20 May, 2013	Tasks 38, 40, 43 collaborated with JRC, IINAS and EEA, to organise and present the workshop that brought together experts with diverse views on bioenergy. ■ Dialogue between experts on climate change effects of forest-based bioenergy ■ Workshop statement articulating key points of agreement	The workshop identified key points of convergence and divergence between experts on the role of forest-based bioenergy in climate change mitigation, clarified the basis for alternative perspectives, and agreed appropriate approaches for assessing the climate effects of bioenergy.
Expert Workshop Forest-based Bioenergy Helsinki	9 December 2014	Workshop with invited Finnish and Swedish forest modelling experts on "Forest-based Bioenergy". The ten presentations covered both economic and ecological approaches to model forest carbon impacts.	The climate impacts of forest bioenergy are highly dependent on the selection of the baseline scenario, choice of the time horizon, parameter setting and metrics applied.
Task 38 Workshop Climate Change Effects of Biomass and Bioenergy Systems Växjö, Sweden	26-27 May 2015	Hosted by Linnaeus University, Task 38 held a workshop on "Climate Change Effects of Biomass and Bioenergy Systems". The presentations were on climate effects of managed forest systems, wood products and bioenergy, including presentations from four Task 38 members. It included an excursion to the Växjö Energy AB, visit CHP-plant, Limnologen Wood-frame apartment buildings and Södra Climate Arena.	Ten presentations about the climate effects of bioenergy systems helped the debate that ensued around the relevant issues in estimating the climate change effects of biomass and bioenergy systems.

Item	Date	Description	Relevance/Status
International conference: Session at IEA Bioenergy Conference 2015, Berlin	27-28 October 2015	End of triennium conference of IEA Bioenergy Task 38 presented the session: "Quantifying climate change effects of bioenergy" at the conference "Realising the world's sustainable bioenergy potential". Four members of Task 38 presented papers.	Five presentations about the climate effects of bioenergy systems supported stakeholders' views (including those of policy makers) regarding the climate effects of bioenergy systems.
Joint workshop Task 38 and Task 43 Quantifying climate change effects of forest-based bioenergy	30 October 2015	Presentations covered: ■ studies on quantifying climate effects of forest-based bioenergy from member countries ■ quantifying and managing iLUC ■ Policy development in GHG accounting ■ Economic and energy system modelling	Highlighted areas of common interest, differences in methodological approaches, provided opportunity to plan future collaboration.

Table 4: Collaboration with other Tasks

Item	Description	Relevance/Status
Joint Task 38/40/43 Workshop Copenhagen	Structured discussion between experts with divergent views on climate effects of bioenergy – see above.	Part of ongoing dialogue with researchers and policy-makers on the sustainability of bioenergy.
Collaborative project *"Monitoring Sustainability Certification of Bioenergy"*	Project led by Task 40. Members of Task 38 (Helena Chum) provided significant inputs to the collaborative project	Completed with significant publications record and impact
Inter-task strategic project: *"Mobilising Sustainable Bioenergy Supply Chains"*	Project led by Task 43. Task 38 contributed to and reviewed the case studies	Completed. Summary report published and other materials in press.
Review of Algal Biofuels	Task 38 contributed review of the environmental effects of algal biofuels (major focus on GHG balance, with brief review of water and nutrient issues)	Report nearing completion Reviews technical potential and barriers to expansion.
Review of GHG tools for biofuels Collaborative project with Task 39	Task 38 developed a methodology to compare different attributional life cycle assessment studies in use by regulatory instruments in various countries and applied to one commercial biofuel route.	Approach for comparison developed and demonstrated. The work seeded the collaboration, with Task 39 co-funding Brazilian collaborators to jointly continue the assessment for multiple commercial biofuels routes. It then expands to advanced systems as commercial operations data become available.

Table 5: Networking and contributions outside IEA Bioenergy

Item	Description	Relevance
SCOPE Report: Bioenergy and Sustainability; Bridging the gaps	SCOPE (Scientific Committee on Problems of the Environment, http://www.scopenvironment.org/) Bioenergy and Sustainability: Bridging the Gaps, led by the Brazilian Research Foundation. Task 38 contributed as follows: ■ Chapter 1. SCOPE Bioenergy and Sustainability Technical Summary, pp. 8-26. (Chum) ■ Chapter 2. Bioenergy Numbers, pp. 28-57 (Chum, Regis Leal) ■ Chapter 6. Sustainable development and Innovation, pp. 184-217 (Chum, Leal) ■ Chapter 11. Feedstock Supply Chains, pp.348-373 (Leal) ■ Chapter 12. Conversion Technologies to Biofuels and Their Use, pp. 374-468 (Chum) Chapter 14. Case Studies, pp. 450-527 (Leal) ■ Chapter 17. Greenhouse Gas Emissions of Bioenergy, pp. 482-617 (Annette Cowie)* ■ Chapter 18. Soils and Water, pp. 618-659 (Cowie) ■ Policy Brief, SCOPE, (2015) (Chum)	The publication is a handbook on bioenergy and sustainability with various levels of information from synthesis report, technical report, and a summary for policymakers. **Outreach** Launch (1) Sao Paulo, Brazil at FAPESP, (4/2015), (2) European Union Sustainable Energy Week (6/2015), (3) World Bank, Washington DC, USA States (9/2015) (Johnson), discussed at the Global Bioeconomy Summit, Berlin, Germany (11/2015); BIO World Congress on Industrial Biotechnology (4/2016). Presented to 2015 International Student Energy Summit (ISES), Bali, Indonesia: "Connecting the Unconnected"(Chum)
IPCC (Intergovernmental Panel on Climate Change)	Contributing authors of Chapter 11 Agriculture, Forestry and Other Land Use (AFOLU). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Bright, Cherubini, Chum, Strømman); Chum lead author of the Energy Systems Chapter 7 and contributed to Transport Chapter 8 Coordinating lead author on Harvested wood products in Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014) (Rüter) for the Task Force on National Greenhouse Gas Inventories (TFI)	IPCC reports underpin the development of international climate change policy and are commonly applied at national level in policy formulation and implementation for renewable energy and GHG mitigation. Recommendations from the report and the interactions in the IEA Bioenergy task between the climate change Working Group and the Task Force on National Greenhouse Gas Inventories enable improved understanding and methodologies
ISO	Member of ISO PC248 which prepared ISO 13065 Sustainability criteria for bioenergy. Task 38 made major contribution to the chapter on GHG assessment and the Annex on system expansion. (Cowie and Brandão)	ISO standards facilitate industry development and international trade. ISO 13065:2015(E) was published in 2015.
Global Environment Facility and UNCCD	Member of the Scientific and Technical Advisory Panel of the Global Environment Facility (Cowie)	Provides opportunities to enhance understanding of the appropriate methods to evaluate bioenergy systems, potential benefits of bioenergy as part of a renewable energy strategy, with benefits for land management.
UNCCD (UN Convention to Combat Desertification)	Member of the Science Policy Interface of the UNCCD (Cowie)	Opportunities to promote the role of biomass production for bioenergy as component of sustainable agricultural and forestry production systems.
GBEP (Global Bioenergy Partnership)	Task 38 activities, one example of Intertask "Mobilising Sustainable Bioenergy Supply Chains" and the SCOPE Bioenergy and Sustainability were discussed at the GBEP 3rd Bioenergy Week (Chum)	Increases awareness of the activities related to climate change mitigation of bioenergy systems to a Southeast Asia audience

Item	Description	Relevance
Finnish research programme BEST (Sustainable Bioenergy Solutions for Tomorrow), Espoo	Discussed current issues in climate impact assessment of bioenergy systems with participants from Ministry of Employment and the Economy, private companies and Finnish research institutes.	Outreach to decision-makers in government and industry
IRENA (International Renewable Energy Agency)	Workshop on Liquid Biofuels/IRENA (International Renewable Energy Agency)-INER (National Institute of Energy Efficiency and Renewable Energy of Ecuador) for Latin America and Caribbean countries in Quito, Ecuador (11/5/2015)	Discussed technology development, commercialisation efforts, and GHG emissions. Provided input to the ongoing update of 'IRENA's Innovation Technology Outlook for Advanced Biofuels', a global technology outlook for advanced liquid biofuels for transport from 2015 to 2045, which focuses on the role of innovation on advanced production pathways which have not yet reached large scale commercialisation.

Success story

Key mitigation measures from the IPCC 5th Assessment Synthesis Report are (1) More efficient use of energy; (2) Greater use of existing or in-development low-carbon and no-carbon energy technologies; (3) Improved carbon sinks by (a) reduced deforestation and improved forest management and planting of new forests and (b) bioenergy with carbon capture and storage (BECCS), and (4) Lifestyle and behavioural changes. Bioenergy has thus been recognised as playing a significant role in low-carbon energy systems of the future. Researchers undertaking global modelling of scenarios to meet the <2-degree warming challenge have identified a key role for BECCS technologies to deliver negative emissions. These top-down models of the global economy are interlinked with a variety of other models in order to create an integrated assessment of global climate, using more than 70 models that have various capabilities to express land use.

Regulation for biofuels was established based on bottom-up calculations of bioenergy projects based on LCA studies and most have relatively narrow boundaries around the products. Kyoto signatories use national accounting (i.e. all GHG emissions arising from within a country's territory in a given year) while LCA studies are consumption-based and therefore focus on a functional unit of the bioenergy product. National emissions are better reflected by the inventories of carbon stocks and flows (i.e. emissions and removals) across the countries' economies, as reported by countries, according to methods established and improved by the IPCC Task Force on Greenhouse Gases Inventories. Task 38 has been active in contributing to the ongoing debate on reconciling top-down and bottom-up analytical frameworks, seeking to convey a science-based balanced perspective on the role of bioenergy in climate change mitigation. Task 38 has sought to stimulate discussion within IEA Bioenergy, in the scientific literature and through workshops with experts external to IEA Bioenergy. Task 38, together with Task 43, aims at identifying 1) best-practice in agricultural and forest management, as well as 2) the most efficient biomass uses for climate-change mitigation, including long- and short-lived products for food, feed, fibre and energy. A sustainable bioeconomy aided by innovation and big-data developments in agriculture, forestry, waste and residue management, and in the chemicals and biotechnology industry, will be able to produce substitutes or better performing materials, chemicals, and fuels.

The issue of timing of benefits of bioenergy has been a major focus of the triennium. Concerns have arisen over the impacts of bioenergy systems on forest carbon stocks. This is not a new issue for Task 38, having been addressed in earlier papers and case studies. In response to scientific papers and attention in the media, the Task organised a series of workshops and expert meetings during the previous triennium (2010 – 2012) to discuss the issue and formulate potential solutions and, in 2010, Task 38 produced an internal statement to raise awareness of the issue at ExCo. Based on this early work Task 38 worked with Task 43, Task 40 and ExCo to devise a statement On the Timing of Greenhouse Gas Mitigation Benefits of Forest-Based Bioenergy, which presents an overview of the issue and provides a balanced perspective on the role of forest-based bioenergy in climate change mitigation. The statement was published by ExCo (http://www.ieabioenergy.com/wp-content/uploads/2013/10/On-the-Timing-of-Greenhouse-Gas-Mitigation-Benefits-of-Forest-Based-Bioenergy.pdf), and has been presented in several workshops and conferences.

Task 38 has continued to enhance its standard methodology for assessment of climate effects, including incorporation of biogeophysical effects that need to be taken into account. The Task contributed to raising the importance of site (project)-specific albedo effects, which can offset or increase the climate effects of GHG emissions.

To reach this range of impacts and dissemination of very complex policy-relevant knowledge, members of Task 38 are involved in various international bodies, and in these roles they have been able to apply the learnings of Task 38 and its preceding Tasks, communicating the work of Task 38 to a broad audience of researchers and decision-makers, and influencing development of climate-change and renewable-energy policies. Task 38 members are involved in the IPCC, ISO, Roundtable on Sustainable Biomaterials, GBEP, and the Global Environment Facility.

Conclusions and recommendations

Conclusions

During the 2013 – 2015 period, Task 38 has focused on addressing methodological challenges in quantifying climate change effects of bioenergy, and encouraged discussion amongst the research community on the role of bioenergy in climate change mitigation. Task 38 has maintained its position as an authority on this topic, through publications in the scientific literature, involvement in international bodies and hosting of workshops. As deliverables, Task 38 National Team Leaders finalised and produced 5 case studies, 2 policy briefs/policy statements, 2 draft papers and contributed to 5 joint reports with other tasks. Task 38 held 6 business meetings and organised 3 international meetings. In addition, task members published 37 papers related to the work of Task 38.

Task 38 has discerned that one of the major reasons for diverging results between studies on climate change effects of bioenergy is the different methods applied. Studies vary, for example, in key assumptions over reference systems, system boundaries, temporal and spatial scale, life cycle stages and emissions sources included. A further important difference relates to the LCA modelling approach employed – attributional or consequential. During the 2013-2015 triennium, Task 38 members published several papers on aspects of methodology for climate change assessment, and the Task is nearing completion of papers to guide selection of reference systems and metrics. Subsequent to their publication, these recommendations will be incorporated in an updated version of the standard Task 38 methodology that Task 38 will be producing. This comprehensive guidance will assist researchers and policy–advisors to identify bioenergy systems that offer the greatest climate change mitigation benefits. Such methods, tools and data are of great value to sustainability assessments that go beyond climate change effects: biodiversity, resource use, ecosystem services, and a variety of economic and social costs and benefits. Exploring these dimensions is necessary to reach the Sustainable Development Goals of the UN Agenda 2030 for Sustainable Development approved in 2015 (see Figure 1). The Climate Action (goal #13) is led by the UNFCCC, the initiative Sustainable Energy for All that started in 2011 is Goal #7, and a key related goal is the responsible consumption and production (Goal #12), spurred by UNEP's International Resource Panel (IRP). Sustainable land management (Goal #15) also plays a central role, underpinning many of the SDGs. These goals are interlinked as shown in Figure 2. Bioenergy can play a key role in supporting sustainable land use and energy systems, to deliver sustainable livelihoods.

Figure 1. Sustainable Development Goals of the UN Agenda 2030 for Sustainable Development

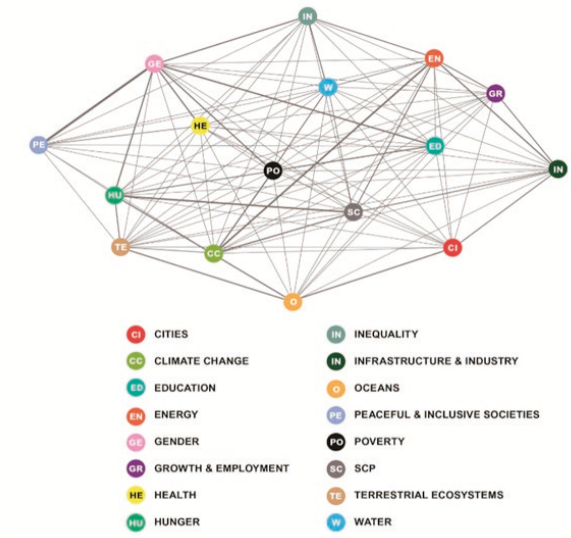

Figure 2. 2015 UN Global Sustainable Development Report shows the interlinkages of the various goals and measures proposed, as well as the 72 models employed, about half on the climate goals.

Policy support for bioenergy has diminished in recent years due to the publication of studies that claim that bioenergy does not contribute to climate change benefits in the required time frame, and that GHG accounting for bioenergy is flawed. It is unfortunate that bioenergy as a whole has been tainted as a result. Task 38 has been working to promote understanding that bioenergy systems vary widely, from those with very short – or even negative – payback times, to others that provide benefits only in the long term. Task 38 focuses on promoting understanding of the appropriate methods to quantify the climate change effects of different bioenergy systems, so that decision-makers will be better able to identify the most beneficial bioenergy systems, and devise measures to promote these systems.

Considering the many co-benefits that bioenergy has within the framework of a sustainable bioeconomy, and building on our understanding of desirable land-use changes to achieve climate change benefits, Task 38 could, working with other IEA Bioenergy tasks, expand the analyses to consider multiple goals simultaneously – seeking to optimise resources in order to maximise climate-change mitigation and achieve the greatest net benefit across these goals.

Recommendations

Anticipation of climate change mitigation benefits is one of the major reasons for the recent expansion of the bioenergy industry world-wide. Loss of confidence in bioenergy amongst policy-makers is likely to erode policy support, although support for an integrated bioeconomy already exists in many countries[1] and is expanding across the world. The work of Task 38 is critical in providing a balanced understanding of the climate effects of different bioenergy systems, assisting policy-makers to understand the need for more nuanced policy measures that provide support for those bioenergy systems that provide significant climate change benefits.

Task 38 addresses a cross-cutting topic that is of relevance to other Tasks. The methods being developed by Task 38 should be applied within the technology-focused Tasks to evaluate these technologies.

Task 38 is uniquely poised to contribute to the understanding of the relationship between the country inventories of GHG and issues of direct and indirect land use change. This knowledge and the demonstrated collaborations with many multilateral organisations that impact bioenergy can benefit all countries in better making use of such compiled data, and derive bioenergy-specific information. However, support from IEA Bioenergy member countries for Task 38 has diminished, and it is increasingly difficult for Task 38 to play an active role in the debate on climate change effects of bioenergy and to work with other Tasks to advise on assessment of climate change effects of new technologies. Task 38 currently has no capacity to pursue the opportunities raised above, of working to demonstrate how bioenergy and the bioeconomy can contribute to meeting the world's sustainable development challenges.

Task 38 therefore encourages ExCo to consider the important role played by Task 38 in maintaining support for bioenergy, and look for opportunities to support Task 38, particularly in its collaboration with other Tasks and in attracting additional countries to join Task 38.

Attachments

Participation in major events

See Table 3: Meetings and conferences organised

Co-ordination with other Tasks within IEA Bioenergy

See Table 4: Collaboration with other Tasks

Task 38 collaborated with Task 40 and 43 in completing and communicating results of the inter-task project *Monitoring Sustainability Certification of Bioenergy*

Task 38 collaborated with Task 40 and 43 in presenting the workshop *Forests, bioenergy and climate change mitigation*

Task 38 collaborated with Task 43 in the inter-Task project – *Mobilizing Sustainable Bioenergy Supply Chains*

Task 38 collaborated with Task 39 by reviewing the GHG savings associated with algal biofuels.

Task 38 collaborated with Task 39 by reviewing GHG assessment tools for liquid biofuels.

Co-ordination with other bodies outside of IEA Bioenergy

See Table 5: Networking and contributions outside IEA Bioenergy

Industry participation

Presentations were made by the Task Leader and several National Team Leaders at various events that were attended by industry members. Members of industry have interacted with Task 38 members to better understand the debate on climate effects of bioenergy and the role of bioenergy in emissions trading. The Task Leader engaged closely with bioenergy industry representatives during the development of the International Standard on Sustainability Criteria for Bioenergy. Petroleum refining companies are increasingly interested in routes that can use biomass (e.g., pyrolysis oils or derivatives) to reduce their fossil emissions and utilise their biomass resources.[2]

1 United States FEDERAL ACTIVITIES REPORT ON THE BIOECONOMY, February 2016, http://www.biomassboard.gov/pdfs/farb_2_18_16.pdf. German Bioeconomy Council reviewed the bioeconomy policies and strategies of G7 countries at http://gbs2015.com/fileadmin/gbs2015/Downloads/Bioeconomy-Policy_Part-I.pdf and of an 45 additional countries at http://gbs2015.com/fileadmin/gbs2015/Downloads/Bioeconomy-Policy_Part-II.pdf

2 Pertamina, Indonesian Oil Company interest in the direct coprocessing of pyrolysis oils and vacuum gas oil described at the GBEP Bioenergy Week meeting, Medan, Indonesia based on 2015 DOE BETO Project Peer Review meeting http://www.energy.gov/sites/prod/files/2015/04/f21/thermochemical_conversion_chum_242303.pdf

Reports to ExCo

Progress reports

- Task 38 Progress report for ExCo71, Capetown, South Africa. May 2013.
- Task 38 Progress report for ExCo 72, Jeju, South Korea. November 2013.
- Task 38 Progress report for ExCo73, Copenhagen, Denmark, May 2014
- Task 38 Progress report for ExCo74, Brussels, Belgium, October 2014
- Task 38 Progress report for ExCo75, Dublin Ireland, May 2015
- Task 38 Progress report for ExCo76, Berlin, Germany, October 2015

Reports from Inter-Task project Monitoring sustainability certification of bioenergy (available from Task 40 website):

1. Examining sustainability certification of bioenergy
2. Survey on governance and certification of sustainable biomass and bioenergy
3. Impacts of sustainability certification on bioenergy markets and trade
4. Recommendations for improvement of sustainability certified markets

Policy brief: On the timing of GHG mitigation benefits of forest-based bioenergy. Task 38, 43 and 40 collaborated to produce an ExCo report. IEA Bioenergy: ExCo: 2013:04.

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TASK 39: Commercialising Conventional and Advanced Liquid Biofuels from Biomass

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Website: http://task39.org/

Introduction

Overview

Task 39's work is focused on accelerating the commercialisation of liquid biofuels from biomass, both conventional (so-called first generation) and advanced (sometimes called second generation) biofuels, including algal and 'drop-in' biofuels. Through coordinated policy and technical activities, Task 39 assists participants in their efforts to develop and deploy biofuels such as ethanol from lignocellulosics, Fischer-Tropsch fuels, biomass-to-liquid (BTL), biosyndiesel (biodiesel made from synthesis gas), etc. It also continues to identify opportunities for comparative technical assessments and improved information and support for policy development. The success of the Task has been, in large part, a direct result of providing a forum for these types of integrated discussions and the excellent participation of network members from industry, government and academia.

Task Objectives

- Catalyse cooperative technical research, development and demonstration projects to help participants:
  - commercialise improved, cost-effective bio-based processes for the generation of conventional and advanced biofuels such as lignocellulosic biomass to ethanol and biodiesel
  - work with other Tasks to help develop and commercialise improved, cost-effective thermochemical-based processes, such as the Fischer-Tropsch process, for converting syngas to synthetic biodiesel and other advanced biofuels
  - help in the development of other advanced liquid biofuel technologies, including biomass-to-hydrogen, algae-to-biofuel processes and the development of so-called 'drop-in' biofuels.
- Provide information and analyses on policy, markets, and implementation issues (including regulatory and infrastructure development) that will help in the commercialisation of liquid biofuels as a replacement for fossil-based biofuels, by continuing the deployment of conventional biofuels and the development and deployment of advanced biofuels
- Provide information and outreach to stakeholders and coordinate with related groups both within IEA Bioenergy and externally.

Report Contents

This report summarises Task 39's achievements over the past triennium, highlighting key results and recommendations arising from the work of Task 39 members. A background to the Task's is first provided, followed by a discussion of the Task's work.

Background

Biofuels offer a renewable alternative to fossil fuel-based transportation fuels. Global biofuel production in 2014 was about 127 billion litres (IEA MTRMR 2015), mainly comprised of conventional (first generation) biofuels such as ethanol (77.4%) and biodiesel, derived from food-based crops, (primarily corn and sugarcane for ethanol and vegetable oils for biodiesel). The development of biofuels has been based on two main drivers, energy security and climate change mitigation, with climate change mitigation becoming the more prominent driver in recent years. Achieving global GHG emission reduction targets by 2050 will require

significant growth in biofuel production and consumption. The IEA's projections under their 450 ppm CO_2 (2°C increase) scenario suggest that biofuels will need to grow to represent 18% of transportation fuels by 2040 from a current level of 3% (equivalent to 9.4 mboe/d) (World Energy Outlook 2015). While many renewable alternatives exist for replacing stationary energy applications (e.g., hydro, wind, solar, etc.), limited alternatives are available for transportation, especially for sectors such as aviation, shipping and long distance trucking. The IEA projects an increase in aviation biofuels to 1.8 mboe/d by 2040 in order to meet the climate objectives described under the 450 scenario (this would amount to about 100 billion litres per year of aviation biofuels).

Task 39 plays a critical role in facilitating international research, development, commercialisation and deployment of biofuels. While the vast majority of current commercial biofuels are produced from food-based feedstocks such as edible sugars/starch and vegetable/seed oils, the GHG emissions savings from these biofuels are limited due to the emission-intensive inputs that are required (e.g., emissions associated with fertiliser production and application, feedstock collection, conversion processing, as well as from potential land use change). Another issue is that the current major biofuels, ethanol and FAME biodiesel, do not make full use of the existing petroleum infrastructure because they are not fully fungible. Thus, they are most typically only blended up to a few percent (5-10%) in petroleum fuels (but higher in Brazil). In order to achieve significant expansion of biofuels that are fully fungible and more sustainable, advanced technologies based on non-food feedstocks have to be developed. As these types of advanced biofuels have not yet reached full commercialisation, the Task serves an important role by monitoring and evaluating new technologies and progress towards commercialisation, as well as in assessing the policy, markets and economic, social and environmental sustainability considerations of biofuels. This is carried out by commissioning highly relevant reports on technologies such as drop-in biofuels and algal biofuels while also maintaining an international online database describing many of the world's advanced biofuel facilities. The Task 39 business meetings, newsletters and various commissioned reports are all activities that help the larger Task 39 liquid biofuels network assess and monitor "advanced" biofuel developments around the world.

The overall sustainability of biofuels and their GHG emission reduction potential continues to grow in importance. This is evident in routes to biofuels increasingly being assessed through life cycle analysis (LCA) of their respective feedstock and conversion technology pathways using different LCA models such as BioGrace, GREET and GHGenius. The Task, in collaboration with other IEA Bioenergy Tasks such as Task 38, continues to assess LCA and emission reduction potentials of biofuels, as reflected in the Task's current and future programme of work.

Globally, biofuels development and expansion has come about as a result of extensive policy support from governments in the form of mandates, tax credits, funding, etc., and has resulted in the growth of the biofuels industry to its current, significant, size. It is apparent that a combination of policy/environmental and technical/economic parameters will impact the commercialisation potential of both conventional and advanced biofuels. Task 39 is fortunate to benefit from the active participation of many individuals from industry, government and academia who together have expertise across the many technology, market and policy issues that have and will continue to influence the economic, environmental and social uptake of biofuels. Task 39's specific contributions during the 2013-2015 triennium are described in the following sections.

Task objectives and work carried out

To achieve the objectives of the Task, the work of the Task focuses on three broad areas: (1) Technology and commercialisation; (2) Policy, markets, implementation and sustainability; and (3) Information dissemination/communication.

Technology and commercialisation

While conventional biofuels production is based on mature technologies, advanced biofuel conversion technologies are still maturing. Keeping abreast of developments in conversion technologies forms an important part of the Task's work. The Task provides a critical, independent and objective analysis of the potential and challenges of technologies, both technical and non-technical. The vast majority of current biofuels are ethanol and biodiesel that can only be used in limited blends within existing infrastructure and engines. The Task continues to monitor expansion of these biofuels, including cellulosic ethanol commercialisation based on non-food/feed feedstocks. However, during the 2013-2015 triennium, there was an increasing focus on the production of drop-in biofuels, i.e., biofuels that are functionally equivalent to fossil-based fuels. A significant achievement of the Task during the triennium was issuing a comprehensive 210-page report on "*The Potential and challenges of Drop-in Biofuels*", which, provided a well-researched, objective background and evaluation of existing and emerging drop-in biofuels conversion technologies. Some of the key findings of this report are that, in the near term, advanced biofuels primarily will be based on oleochemical technologies using oils and fats as a feedstock. In the longer-term, thermochemical technologies based on lignocellulosic feedstocks are likely to supply increasing commercial volumes of drop-in biofuels,. Key challenges that may limit the expansion of this latter route are the increasing requirement for hydrogen for upgrading to produce fully deoxygenated drop-in biofuels and the significantly higher economic challenge of achieving cost competitive production in an era of low petroleum prices and an insufficient price on carbon.

The potential of algal biofuels as a next-generation biofuel has been under investigation by Task 39 for a number of years, with an initial report published in 2010. Some of the potential benefits of algal biofuels are their limited requirement for arable land and the ability to use wastewater or salt water for growth, at least for some species of algae. An update to the original 2010 report began during the second half of the triennium. The objective of this update is to review more recent assessments of the potential for algal biofuels based on technology and commercialisation progress published since the first report was issued, as well as to expand the assessment scope to consider non-liquid biofuel bioenergy products (e.g., biogas) as well as the potential of multiproduct algal-based biorefineries to provide an economically viable means of bringing algal biofuels to market. Unforeseen personnel issues resulted in a substantial delay in completing this report during 2015. A plan to complete this report under different leadership was implemented at the end of the triennium and this report is now expected to be completed in the first half of 2016. While it is still being finalised at the time of this writing, the report documents the substantial progress in understanding and advancing algal biomass cultivation and algal-based biofuel production that has occurred since the first report published in 2010. While final conclusions are not yet available to report, the prospects for algal biofuels are more challenging today than they were in 2010. This is primarily the result of the substantial decline in petroleum prices that has occurred since August 2014. As a result, the economic challenge of bringing cost competitive algal-based biofuels to market has significantly increased in light of much lower petroleum prices, despite substantial improvements in the underlying core algal cultivation and upgrading technologies achieved since 2010. As a consequence, companies that were leading commercial development of algae-based biofuels have been increasingly redirecting their commercial focus towards production of higher value food, feed and specialty products. Primary strategies for liquid biofuels production from algae will need to rely on a biorefinery approach where the production of higher value products can subsidise co-production of algal biofuels.

Collaboration with other Tasks is another important component of Task 39's work.

Deliverables/reports published during the triennium and ongoing projects:

- Report on The Potential and challenges of Drop-in Biofuels.
- Report on the Status of Advanced Biofuel Demonstration facilities in 2012 and ongoing annual updates of the interactive database as maintained by Bioenergy 2020+.
- Update on Algal Biofuels Report – this work was initiated in the 2013-2015 triennium but finalisation of the report was delayed due to unforeseen personnel issues such that this report will now be completed in the first half of 2016. This project is a multi-Task activity led by Task 39.
- Advanced Fuels for Advanced Engines – this project was proposed in the 2013-2015 triennium but the majority of actual work will occur in the new triennium. Task 39 is collaborating with IEA AMF TCP on this effort, and Task 39's initial work will also contribute to AMF's new Annex 52 "Fuels for Efficiency" effort initiated in 2015.
- Task 39 contributed a chapter to the inter-Task project "Mobilizing Sustainable Bioenergy Supply Chains". This project was led by Task 43 (Feedstocks).

Policy, Markets, Implementation and Sustainability

Policy support in the form of national mandates, incentives, funding, etc., has created a market for biofuels and facilitated expansion to its current levels. It will also play an ongoing role in the future to facilitate development of advanced drop-in biofuels. During this triennium, the Task primarily monitored policies and their implementation through Task participant country reports. These individual reports are compiled into an Implementation Agenda report every triennium. In addition, the introduction of new policies and their implementation at a global scale is monitored via the web, reports, press releases, etc., and this is reported through the Task's website and three times a year Newsletters. The sustainability of biofuels has been an ongoing area of investigation for the Task, particularly the ability of biofuels to decarbonise the transportation sector through GHG emission reductions. The assessment of GHG reduction potential of different feedstock/technology pathways is ongoing. In the last year of the triennium the Task initiated a new project which sets out to rigorously compare major LCA models used to assess the carbon and energy balance of various biofuels in North and South America and the European Union. This project is continuing into the next triennium.

Deliverables/reports published or initiated during the triennium:

- Advanced Biofuels – GHG Emissions and Energy Balances published in 2013. This report compared the energy and GHG emissions profiles of leading conventional and advanced biofuel pathways. This assessment highlighted the importance of different bases and methods being used in different LCA models and created increased interest in this topic within the Task. Ultimately, this motivated growing collaboration with Task 38 and the formation of the follow-up joint project on LCA model comparisons started late in the triennium by Tasks 38 and 39.

- Update to Implementation Agendas published in 2014. This report *compares and contrasts* developments in biofuels production and market penetration for 19 different countries. These countries include the Task 39 member countries as well as important emerging economies such as China and India (for completeness and comparison). The report includes details of biofuel policies and assesses the extent to which these biofuels policies have been successfully implemented. The report also reviewed the measures taken by member countries to develop or stimulate their respective biofuels industries, including incentives and investment in research. As mentioned earlier, this report is based on information provided in the country reports made by Task members on an annual basis at Task 39 business meetings.
- Comparison of LCA models (ongoing into the next triennium). This project extends and broadens the work reported in 2013. It is a new Task 39 funded and led joint effort between Tasks 38 and 39. While initiated late in this triennium, its deliverables will be reported in the next triennium. An overall 3-year effort is planned in 3 approximately 1-year phases.

Information dissemination/communication

Information dissemination is a key objective of the Task to keep members, external organisations and governments, as well as the general public informed about the Task's work, the status of developments in liquid biofuels technology/policy, key conclusions and recommendations from Task reports. As this is a rapidly developing and changing area, the Task's close contact with industry ensures that its work remains relevant and at the forefront of opportunities and challenges. The following table lists the Task's activities in this area.

Business meetings	2013 – 1 formal business meeting (Stellenbosch, South Africa March 2013) and two informal meetings (Portland, Oregon April 2013 and Nanjing, China October 2013) 2014 – 2 business meetings (Berlin Jan 2014 and Copenhagen May 2014) 2015 – 2 business meetings (Gwangju, South Korea March 2015 and Berlin October 2015) plus an informal meeting at the 37th Symposium on Biotechnology for Biofuels and Chemicals (SBFC) (San Diego April 2015)
Conferences	The Task leadership, Jim McMillan and Jack Saddler, are frequently invited to speak at international conferences and this is used as an opportunity to promote Task 39 and IEA Bioenergy. Efforts continued to be made to recruit countries such as China, India and Chile, to join IEA Bioenergy and Task 39. Task 39 is frequently asked to arrange a dedicated Task 39 session(s) at international conferences. 20th International Symposium on Alcohol Fuels (ISAF) March 2013 – Stellenbosch, South Africa – 2 half-day sessions with 10 speakers, and also 4 plenary talks. 35th SBFC held in Portland, USA in May 2013 – The Task organised a special session entitled "International Demonstrations and Commercialisation Updates" featured leading biorefining and cellulosic ethanol companies (Borregaard, Catchlight, Chemtex, DuPont and Lignol). "International Conference on Biomass Energy and Chemicals" October, 2013 in Nanjing, China – Several Task 39 members gave presentations at the conference. This meeting was used as an opportunity to show representatives from the Chinese government, industry and academia about the benefits of being part of IEA Bioenergy. The government officials from the Chinese central government were encouraged to contact the Chair/Secretary of IEA Bioenergy to see about being invited as observers to a future IEA Bioenergy Executive Committee meeting. "Fuels for the Future" conference Berlin, Jan 2014 was attended by participants from around the world and included two dedicated sessions organised by Task 39. These sessions featured 10 presentations given by Task 39 members; one session focused on policy tools used to help develop biofuels and the other focused on advanced biofuels technical and commercialisation progress.

Conferences	March 2015 in Gwangju, Korea, 21st International Symposium on Alcohol Fuels (ISAF). The Task organised two 'IEA Bioenergy Task 39' sessions within this symposium, which included 7 speakers from Task 39. "International Commercialisation Progress" at the 37th SBFC in San Diego, USA, comprising 6 invited speakers from 6 companies at the forefront of commercial development of advanced biofuels and sustainable bio-based chemical production: Iogen, Novozymes, Abengoa, Borregaard, Genomatica and Katzen International. This session was extremely well attended (estimated attendance of 300), reflecting strong on-going interest in Task 39 activities within the renewable fuels and chemicals stakeholder community. IEA Bioenergy Conference 2015, October 2015. Task 39 organised a session within the IEA Bioenergy conference that profiled several leading companies active in advanced biofuels development and utilisation (Boeing, UPM Biofuels, SkyNRG, Biochemtex). Invited speakers from each of these companies presented at the IEA Bioenergy Conference 2015 in the session entitled, *Progress in the development and use of advanced liquid biofuels*.
Workshops	Workshops held and workshops attended: Berlin Jan 2014 – joint workshop with Task 42 (Biorefineries) Copenhagen May 2014 – Workshop entitled, "Infrastructure compatible transportation fuels", was jointly organised by IEA Bioenergy and the Advanced Motor Fuels (AMF) implementation agreements (IA). Two Task 39 colleagues, Oliver May (DSM) and Sergios Karatzos (UBC/Steeper Energy) gave presentations, respectively providing an industrial perspective and summarising the Task's recently released report on drop-in biofuels.
Newsletter	9 Newsletters were published during the triennium, each highlighting the latest news in the biofuel area, plus featuring a country profile from one of Task 39's member countries. These newsletters are distributed via an email list and are also available on the Task 39 website.

Website	The Task 39 website is well-maintained and informative, providing information about the Task and country representatives. All reports and publications from the Task are published on the Task website (www.Task39.org) and can be downloaded by the public after a short embargo period (during which they are only available to Task 39 members). The website also serves as a secure portal for dissemination of minutes and presentations from business meetings, as access to the area of the website where these documents are posted is limited to Task 39 country representatives and their respective ExCo members. In addition, the website also provides links to the latest IEA Bioenergy and IEA AMF newsletters.
Database	Task 39 with Bioenergy 2020+ maintains a database on facilities for piloting, demonstrating and commercially producing advanced liquid and gaseous biofuels for transportation. This database (http://demoplants.bioenergy2020.eu/) is updated on an annual basis.
Review of reports	The expertise of Task 39 in the liquid biofuels space is recognised internationally and Task leaders and members are often requested to review draft reports and provide input on the status of biofuels technology research and commercialisation. During the latter part of the triennium, the Task provided critical guidance and review to IEA RETD for their development of a report entitled, "Towards advanced biofuels: Options for Integrating Conventional and Advanced Biofuel Production Sites". This report was published in January 2016.
General	ExCo Progress Reports; IEA Bioenergy Annual Reports; Contributions to IEA Bioenergy Newsletter; Handling of queries via email

Success story

Conventional biofuels (formerly called "first generation" biofuels) such as sugar- and starch-derived ethanol and vegetable/seed oil-derived fatty acid methyl esters (FAME) have limited compatibility with the existing petroleum/oil refining, distribution and use infrastructure. Blend walls, storage instability and lower energy content are some of the disadvantages that these conventional biofuels (bioethanol/FAME biodiesel) have compared to petroleum fuels. These fuels are also unsuitable for applications such as aviation. In response to these shortcomings, coupled with recent advances in microbe engineering and catalyst science, new processes to produce longer chain alcohols and hydrocarbon biofuels containing little to no oxygen are being developed, fuels that exhibit functionality like fossil fuels. These so-called "drop-in" biofuels represent a major area of development/interest globally, specifically in the aviation, marine and long distance haulage sectors. Various conversion technologies are actively being researched and developed by many research labs and companies around the world. However, commercialisation has been slow and many technical and economic challenges still remain. The Task 39 report, "*The potential and challenges of drop-in biofuels*", provided a comprehensive assessment of the technical and commercial potential of a variety of "drop in" biofuels. The report reviewed leading technology platforms and company strategies as well as relevant market and policy trends. The various technological issues and knowledge gaps that must be overcome to realise the commercialisation potential of various prospective drop-in biofuels were assessed and described. The Task also took a lead in trying to better define what was meant by a "drop-in biofuel". Drop-in biofuels are defined in this report as "liquid bio-hydrocarbons that are functionally equivalent to petroleum fuels and are fully compatible with existing petroleum infrastructure".

The full 210 page report, as well as a 20 page executive summary, were completed in 2014 and then made publicly available for download from the Task 39 website (www.task39.org). The key conclusions can be summarised as follows: Due primarily to the significant processing and resource requirements (e.g., sufficient hydrogen supply and effective catalysts) needed to make drop-in biofuels as compared to "conventional" oxygenated alcohols or FAME biofuels, large scale, large volume production of cost-competitive drop-in biofuels is expected to remain challenging in the near-to-midterm. While tremendous technical progress and commercialisation activity have taken place over the past several years, only relatively small amounts of drop-in biofuels, functionally equivalent to petroleum-derived transportation fuels, are commercially available today. In the same way conventional (so-called "first generation") bioethanol from sugar and starch was used to establish the infrastructure and "rules" for subsequent production and use of advanced (so-called "second generation") bioethanol, it is likely that oleochemical derived drop-in biofuels will initially be used to establish the markets and procedures for use of drop-in biofuels. This is exemplified by the many Hydrotreated Vegetable Oil (HVO)-based biofuel flight trials and refinery co-processing trials undertaken over the last few years and by the recent ASTM approval of oleochemical derived jet fuel blendstocks. However, significant expansion of the oleochemical platform will be limited by the cost, availability and sustainability of food grade (vegetable oil) or animal oil/fat based feedstocks. The challenge of developing emerging thermochemical based drop-in technologies can be viewed as analogous to cellulosic ethanol, which uses more plentiful, non-food lignocellulosic biomass as feedstock but entails larger technology risks and higher capital costs. In this context, thermochemical technologies are well positioned to account for a considerable component of drop-in biofuel capacity growth over the near-to-midterm. This is primarily because biochemical and hybrid based drop-in biofuel processes typically provide lower yields of higher value oxygenated intermediates (e.g. organic dialcohols and diacids) that can command higher value in the rapidly growing bio-based chemicals markets. It is also likely that future biorefineries will utilise biomass in much the same way that current petroleum refineries use crude oil by converting the raw feedstock into a diverse range of fuels and chemical products in a single highly integrated facility.

The high visibility and acclaim of this report encouraged the Task to maintain an assessment of ongoing technical and policy developments for drop-in biofuels as well as close monitoring of emerging processes and companies. The structure and format of the original report will form the basis for continuing this assessment in the new triennium, incorporating the latest research studies as well as commercial and policy developments.

Conclusions and recommendations

Biofuels offer a needed renewable alternative to fossil-based transportation fuels and will continue to play an important role in achieving energy security and meeting climate change mitigation targets. Global biofuel production in 2014 was 127 billion litres, mainly comprised of conventional (or first generation) biofuels such as ethanol (77.4%) and FAME biodiesel, derived from food-based crops, (corn and sugarcane for ethanol and vegetable/seed oils for biodiesel). In the US, expansion of conventional biofuels capacity has slowed down, primarily due to the blend wall limit for ethanol being reached. However, more and more countries are implementing ethanol and biodiesel mandates and opening new facilities. Advanced biofuels, using non-food biomass or algal feedstocks, potentially offer greater expansion opportunities based on using potentially much cheaper and more abundant feedstocks. They should also offer greater climate change mitigation potential. Although the development of advanced biofuels based on lignocellulose biomass has been slow, the 2013-2015 triennium period encouragingly saw the opening of several commercial scale lignocellulosic ethanol facilities worldwide (e.g., in Italy, USA, Brazil, etc).

Biofuels development and commercialisation was particularly challenged in the last half of the triennium due to steadily decreasing and unexpectedly low oil prices. This has hindered investment and has highlighted the increased role of policy needed to achieve significant expansion of biofuels. According to IEA projections (based on keeping global atmospheric CO_2 levels below 450 ppm), biofuel consumption will have to increase significantly from its current 3% level to 18% of total transportation fuel by 2040 (amounting to 9.4 mboe per day).

Task 39 has remained at the forefront of assessing and communicating technology and commercialisation developments through publications such as the comprehensive Drop-in biofuels report and the updated database on Advanced Biofuel demonstration facilities. The Task participated in many conferences over the triennium and, based on on-going strong industry participation, the Task arranged many conference sessions featuring companies at the forefront of advanced biofuel technology commercialisation. In addition, the Task helped in the review of reports from other organisations (such as IEA-RETD and IRENA). In a rapidly developing industry that often must deal with excessive hype and unsubstantiated claims and conflicting projections from multiple reports authored by different institutions, the members of Task 39 have continued to provide an unbiased, objective and realistic evaluation of advanced biofuels technologies and their commercialisation potential.

Task 39 played an important role in facilitating communication through its newsletters, business meetings, conference sessions and publishing reports/reviews on the Task 39 website. The business meetings and conference sessions provide a unique opportunity for leading world experts to interact and address priorities for accelerating the commercialisation of biofuels. Inter Task collaborations have greatly facilitated some of these meetings, such as the joint meeting with Task 42 in Berlin in 2014 and participation of other Tasks in meetings to discuss collaboration opportunities (e.g., Tasks 38 and 43). The Task 39 newsletter keeps its more than 3000 registered readers up-to-date on the latest international developments. This helps decision makers, investors and companies in both member and non-member countries with their strategic planning.

The reports produced by Task 39 are prepared by highly qualified and experienced experts in the field of biofuels. They are highly cited and provide insights into the threats to and opportunities for positive biofuel technology and policy developments. Over the last triennium, the Task has continued to address critical issues such as drop-in biofuels, GHG emissions of emerging routes to advanced biofuels, advanced biofuel demonstration facilities and algal biofuels development.

In the next triennium, the Task will continue to facilitate communication and provide high quality information to the liquid biofuels stakeholder community. It will leverage previous years' work to further support the biofuel sector. Biofuels remain a unique renewable alternative for many transport sectors including marine, aviation and long distance lorries/trucks, contributing to climate change mitigation and improved energy security.

Task 39's communication vehicles (website, newsletter, meetings) as well as its technical and policy report deliverables will remain invaluable to the biofuels community and it is planned that they all will be continued. IEA Bioenergy provides an effective portal for inter-Task collaboration and Task 39 is fortunate to operate within this highly recognised international and multidisciplinary network.

Attachments

Newsletters:

(Available on the Task website (www.task39.org)

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 41, December 2015.

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 40, August 2015.

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 39, April 2015.

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 38, December 2014.

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 37, August 2014.

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 36, April 2014.

Van Dyk, JS (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 35, December 2013.

Karatzos, S. (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 34, September 2013.

Karatzos, S. (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 33, April 2013.

Business Meetings:

(Available on the Task website (www.task39.org)

Minutes from the Task meeting in Berlin, Germany, October 2015.

Minutes from the Task meeting in Gwangju, Korea, March 2015.

Minutes from the Task meeting in Copenhagen, Denmark, May 2014

Minutes from the Task meeting in Berlin, Germany, January 2014

Minutes from the Task meeting in Stellenbosch, South Africa, March 2013

ExCo:

Progress report for ExCo76, Berlin, Germany, October 2015.

Progress report for ExCo75, Dublin, Ireland, May 2015.

Progress report for ExCo74, Brussels, Belgium October 2014.

Progress report for ExCo73, Copenhagen, Denmark, May 2014.

Progress Report for ExCo72, Jeju, Korea, November 2013.

Progress Report for ExCo71, Cape Town, South Africa, May, 2013.

Reports:

Karatzos, S., McMillan, J., Saddler, J. (2014) The Potential and challenges of Drop-in Biofuels.

Bacovsky, D., Ludwiczek, N., Ognissanto, M., Wörgetter, M. (2013) Report on the Status of Advanced Biofuel Demonstration facilities in 2012

O'Connor, D. (2013) Advanced Biofuels – GHG Emissions and Energy Balances

Van Dyk, JS, Mabee, W., Saddler, J. (Eds) (2014) Update to Implementation Agendas

Contributions:

Cadham, W. Van Dyk, J.S., Kumar, L., Saddler, J. "Challenges and opportunities for the conversion technologies used to make forest biomass based bioenergy/ biofuels" Chapter contribution to "Mobilizing Sustainable Bioenergy Supply Chains"

Collaborations:

Task 39 works closely with a number of other Tasks in IEA Bioenergy, including Tasks 34, 37, 38, 42, (Algal Report); Task 43 ("Mobilizing Sustainable Bioenergy Supply Chains"); Task 38 (LCA). Task 39 also collaborates with the IEA-AMF TCP on advanced biofuels in advanced engines. The Task also works with IEA RETD and IRENA on liquid biofuels-related technology and policy assessments.

Industry participation:

Task 39 maintains strong ties with industry involved in liquid biofuels development and production. Many companies participate in the Task or in conference sessions arranged by the Task. These companies include: Borregaard, DSM, Iogen, Catchlight, Chemtex, DuPont and Lignol, Novozymes, Abengoa, Genomatica, POET-DSM, Katzen International, Boeing, UPM Biofuels, SkyNRG, GoodFuels Marine, Biochemtex, Licella, and Steeper Energy.

TASK 40: Sustainable bioenergy markets and international trade: Securing Supply and Demand

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Website: http://www.bioenergytrade.org/

Introduction and Background

Bioenergy is one of the largest current renewable energy sources. Due to its versatility to produce electricity, heat, and liquid fuels for transport, and its storability and ability to follow demand, it is also generally expected to contribute significantly to the future energy mix. However, it is also clear that while currently most world regions are self-sufficient in biomass use for energy, some world regions will have to import biomass, while others may be able to export a surplus. Therefore, developing an international sustainable bioenergy trade remains a vital priority. In order to meet the expected strong growth in demand for biomass across the world in the coming decades, mobilisation of resources, investments in infrastructure and transport capacity, pre-treatment and final conversion are crucial. Investments are, however, faced with unusual risks with respect to changing policy frameworks, on-going societal debate about the sustainability of biomass use and market conditions in energy, agriculture and forestry (as well as CO_2 prices). This means that developing and expanding business and investments in national and international biomass supply chains and markets deserves special attention to deal with those risks and accelerate developments. The core objective of Task 40 for the 2013-2015 triennium was: 'to support the development of sustainable, international bioenergy markets and international trade, recognising the diversity in resources and biomass applications'

To achieve this objective the 2013-2015 work programme consisted 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.

In the next section, an evaluation of the work carried out during the triennium and how it meets the initial targets of the Task is presented.

Task objectives and work carried out

Below, the various written reports belonging to the five objectives are briefly described. The references to the reports are listed in the appendix. All reports can be found on the Task 40 website[3]. In addition, almost all of the reports were presented and disseminated at international workshops. These are described in detail in the appendix, and are therefore not repeated in this section, unless they are not linked to one of these deliverables.

1. Mobilisation of sustainable biomass resources for the international market across different regions in the world.

On this topic, the inter-Task project "Mobilising sustainable bioenergy supply chains" was carried out. This project involved Task 38, 39, 40, 42 and 43. The purpose of the project was to identify sustainable biomass systems and promote their implementation through a series of case studies. Utilising the expertise from across the Tasks and focusing on issues specific to bioenergy, the case studies highlight successful systems and challenges requiring further consideration. This project was very successful

3 http://bioenergytrade.org/publications.html

and the outputs included a book on the mobilisation of biomass from boreal and temperate forests (led by Evelyne Thiffault, Task 43), of which Task leader Martin Junginger is co-editor. The book is due to be published in the second quarter of 2016. Other case studies included agricultural crop residues, biogas, lignocellulosic crops, and cultivated grasslands and pastures in Brazil. These case studies have confirmed that feedstocks produced using logistically efficient production systems can be mobilised to make significant contributions to achieving global targets for bioenergy. However, the very significant challenges identified in this report indicate that changes by all key members of society in public and private institutions and along the whole length of supply chains from feedstock production to energy product consumption are required to mobilise adequate feedstock resources to make a sustainable and significant contribution to climate change mitigation and provide the social and economic services possible. Notably, this report reveals that all globally significant bioenergy development has been underpinned by political backing, which is necessary for legislation in the form of mandates, renewable energy portfolios, carbon trading schemes, and the like. The mobilisation potential identified in this report will depend on even greater policy support than achieved to date internationally.

Due to the comprehensiveness of this study, and the involvement of several Task 40 members in various case studies, Task 40 did not develop any additional deliverables for this objective.

2. Analysis of the future market demand for biomass from the broader biobased economy perspective.

Task 40 published a number of studies on different future markets:

Biomethane – Status and Factors Affecting Market Development and Trade, published in September 2014, was prepared jointly by Task 40 and Task 37 to address the status and emerging challenges of dealing with the rapid growth in the production of biomethane, by either anaerobic digestion or thermal gasification, the developing biomethane market and trade of the gaseous biofuel. The aim of this study was to provide an up-to-date overview of the status of biomethane (including upgraded biogas and bio-SNG) production, grid injection and use in different countries, and to illustrate the options and needs for the development of larger biomethane supply strategies. The focus was on technical, economic and management- related hurdles to inject biomethane into the natural gas grid and to trade it transnationally. The study provides insights into the current status of technologies, technical requirements and sustainability indicators as well as cost of biomethane production and use in general and especially in selected countries. It also assesses implementation strategies, market situations and market expectations in selected countries, and proposes actions to be taken to reduce barriers and to develop the market step-by-step.

Large Industrial Users of Energy Biomass: The objective of the study was to obtain a global overview of biomass use in the industrial and transport sectors and to compose lists of the largest users of energy biomass in the world. Various statistics, databases, reports, and reviews, most of them publicly available, have been utilised during the study to examine plants that either refine biomass for use in transportation and for heating purposes or plants that convert biomass into heat and power. The plant lists presented are based on the prevailing situation at the end of the year 2012; due to a lack of comprehensive and accurate plant-specific information and the rapidly changing situation, the results should be used with care.

Finally, a study was also commissioned on "**Biomass Trade and Supply System Opportunities for a Global Bio-Based Economy**". This resulted in a book, and is described in the section under "success stories". In addition, two workshops were held on this topic in Jonkoping (2013) and Sassari (2015).

3. Sustainability and certification.

This topic was covered by several reports (and workshops):

An Inter-Task Strategic Project "**Sustainability of certified solid wood bioenergy feedstock supply chains: Ecological, operational and international policy perspectives**" was performed to provide background information on the operational and scientific aspects of sustainability criteria for solid woody bioenergy feedstocks. The information is intended for policymakers and other stakeholders for the development and possible extensions of the EU RED, certification systems, and national sustainability schemes. This project involved Task 40 and 43, and is published as a report and as a peer-reviewed article in BioFPR[4].

Impact of promotion mechanisms for advanced and low-iLUC biofuels on markets. With current discussions on indirect effects of biofuels, and the aim to broaden feedstocks to non-food biomass, policies are trying to put focus on biofuels from waste, residues and lignocellulose materials, so called 'advanced' biofuels. Next to the general biofuel incentives, these biofuels get extra support through specific promotion mechanisms. Examples are the double-counting mechanism for advanced biofuels in the EU, and the specific targets for advanced biofuels in the US. In this study, some typical cases are presented where promotion mechanisms for advanced biofuels have had an impact on markets and trade (used cooking oils and animal

4 Evelyne Thiffault, Jody Endres, James S.N. McCubbins, Martin Junginger, Miren Lorente, Uwe Fritsche, Leire Iriarte (2015). Sustainability of forest bioenergy feedstock supply chains: Local, national and international policy perspectives. Biofuels, Bioproducts and Biorefining, 9(3) 283-292, DOI: 10.1002/bbb.1547

fats, sugarcane ethanol), or may be anticipated to impact markets and trade in the future (straw, wood pellets). General conclusions and summaries of the four case studies can be found in a summary report.

In addition to these studies, the workshop jointly organised with, amongst others, the Pinchot Institute in Savannah in November 2013, and with Biotrade2020+ in October 2014 focused on the importance of sustainability assurance of globally traded woody biomass feedstocks. Both involved policy makers from both sides of the Atlantic.

4. Support of business model development for biomass supply and value chains.

Originally, three studies were planned under this objective. The first study on "torrefaction" has been carried out. The project produced a live technology database with new updates and the latest market information, included a workshop in Graz organised jointly with Task 32 and IBTC, and a comprehensive report, in which future markets for torrefied biomass are discussed as well as possibilities for business model development of torrefied biomass supply chains.

Originally, Task 40 also intended to carry out two studies on trade in biomass technologies and the required investments (and linked business models) to develop international biomass supply and value chains. Both projects were ultimately not carried out due to the preference of the Task 40 members to spend the available budget on other studies, but also due to man-power constraints to carry-out these additional studies.

5. Assisting the development and deployment of advanced analysis tools to improve the understanding of potential future market developments, implications and impacts of policies.

Two studies were commissioned for this topic:

Future Perspectives of International Bioenergy Trade: this study aimed to provide insights into "possible futures" of bioenergy trade and to discuss implications and challenges related to different developments. The sub-objectives of this study were to investigate to which extent various global energy models and scenarios took into account bioenergy trade, identify the implications of different global bioenergy scenarios on bioenergy trade, and summarise the range of results into 3-5 storylines on future international bioenergy trade. The insight into future scenarios and perspectives of bioenergy trade revealed that substantial challenges for the future development of global and international bioenergy trade may be expected in the coming decades, if a low carbon energy system is to be developed. The theoretical and technical biomass potentials in many models are often quite optimistic, and traded biomass volumes often reach several hundred million tonnes by 2050, but sustainable biomass potentials are only included to a limited extent, as these are often hard to quantify and are also not the main aim of the models. It remains to be seen how global, stringent, mandatory sustainability requirements (e.g. on water use, biodiversity, forest carbon accounting and iLUC) would limit the production, trade and use of feedstocks in the first place, but also how practical certification of biomass would affect bioenergy trade. The work has been published both as a Task 40 report, chapter 8 in the Task 40 trade book (see next section) and as a peer-reviewed article[5].

A second study focuses on **biomass prices as drivers for trade**: International trade streams of solid and liquid bioenergy commodities exhibited significant growth in the past decade. While the main drivers for their absolute increases are policy induced, drivers for particular developments of trade streams between regions have to be examined in more detail. Assuming the Pareto efficiency concept playing a major role in resource allocation between countries, in this project we will develop a model in order to explain the role of regional biomass price differences as a driver for trade between those regions. Statistical import and export data is correlated with commodity prices within the investigated regions, taking into account interregional transport costs. The key objective is to investigate biomass price differences as drivers for trade, taking into account interregional transport costs. The study was not finished in 2015, and final results (including a report) are expected to be presented at the next Task 40 meeting in May in Sweden.

5 Matzenberger, J., Kranzl, L., Junginger, M., Vassilis, D., Tromborg, E. (2015), Future perspectives of international bioenergy trade, Renewable and Sustainable Energy Reviews 43 (May 2015) 926 941.

Success story

As a particular success story for the 2013-2015 triennium, Task 40 has/is going to publish two books. The first one, **International Bioenergy Trade: History, status & outlook on securing sustainable bioenergy supply, demand and markets** has been published by Springer in 2014, and is in essence a synthesis of 10 years work by Task 40. For this period, Task 40 has monitored the developments in international bioenergy trade, with activities including the organisation of about 20 workshops on trade-related topics, and the publication of over 100 studies, country reports, newsletters, etc. The amount of material produced over these years and insights gained, concerning how biomass markets and international trade of biomass and biofuels has developed, is impressive. Besides that, the group has produced overviews and insights; also a large amount of practical experience has been brought together concerning what works and what doesn't. Finally, based on all of this, there are clear(er) views on how to proceed with building working sustainable international biomass markets in the future. This book compiles those lessons and insights into an easily accessible publication. Since its publication, (parts of) the book has been sold several hundred times, and the combined chapter downloads have surpassed 6000 downloads in early 2016.

The second book, led by Patrick Lamers (1st editor and US Task 40 member) focuses on **Biomass Trade and Supply System Opportunities for a Global Bio-Based Economy** (in a cooperation of Task 40 with Task 34 & 42). The book is almost finished and should be published in the second quarter of 2016 by Elsevier. The future vision for global bioenergy trade sees it developing over time into a real 'commodity market'. Investigating the requirements (pre-conditions) for commoditisation of biomass and biofuels will be a central theme in this report. It specifically covers (1) an in-depth historical analysis of the developments of existing key commodity markets, e.g., of the energy (e.g., coal) or food/feed sector (e.g., corn), and (2) an exploration of how conditions can be created and enhanced to achieve similar development for biomass resources and biofuels. This book assesses the potential international supply, trade, and demand of biomass for energy, fuels, and chemicals applications within a competitive (energy) market, including the identification of improved and new value chains (e.g., conversion technologies and end uses). The assessment includes current state-of-the-art overviews of the markets for power, heat, and fuels/chemicals, and the identification and characterisation of emerging biomass demand regions. The ultimate aim is to integrate the market demand assessment and specification analysis to form a larger picture of the implications of developing a bio-based economy for biomass supplies and trade at the international level. This includes the identification of new or improved value chains and the integration of biomass into existing large-scale logistics infrastructure.

Both books illustrate the relevance of the work of Task 40 in the developing bioeconomy, providing a sound basis for further work in the years to come.

Conclusions and recommendations

As illustrated above, Task 40 has delivered many contributions in various arenas over the past three years:

On the scientific level, Task 40 members have published scientific articles based on Task 40- commissioned work on topics such as the potential import streams and supply costs to North-West Europe under different sustainability constraints; future perspectives of international bioenergy trade; lignocellulosic feedstock supply systems with intermodal and overseas transportation; and monitoring of sustainable biomass flows in a bio-based economy. These articles have all been frequently cited (older Task 40 work from previous triennia even more than 100 times in Google scholar), illustrating the usefulness to the scientific community. Task 40 members have been involved in discussions with inter alia the JRC and modelling teams developing the integrated assessment models for IPCC scenarios, and have participated in many scientific conferences. Task 40 could reasonably be considered as the recognised leading authority on bioenergy trade.

For the bioenergy industry, Task 40 has organised a large number of workshops and participated in numerous conferences, covering issues as diverse as future bio-methane markets, overviews of large industrial users of biomass and the role of torrefaction as an enabler for international bioenergy trade. Industry participation in Task 40 is high, and frequently events are organised in cooperation with industry associations such as Aebiom, IBTC and USIPA. In many ways, the analyses of Task 40 provide the statistical proof for entrepreneurs, such as investors, that bioenergy trade is a reality and is needed to develop the bioeconomy further.

Finally, Task 40 members have given policy advice and interacted with policy makers on numerous occasions, especially in cooperation with other Tasks (notably task 38 and 43). Advice has frequently focused on the assurance of sustainable biomass feedstock production for international trade, but has also included many other aspects such as an evaluation of the unintended impacts of policies aiming to

stimulate 2nd generation biofuels, or the need for policies to support the development of international biomethane markets. It would appear that the work is noted and used by policy makers both on the national level of the country members and on the international level (e.g. GBEP, European Commission). Task 40 will continue to pursue information dissemination to the institutions.

In conclusion, Task 40 has had a significant impact on all of these arenas, and will continue to do so in the coming years. At this time, the future of bioenergy is at a crossroads: while governments globally have agreed to limit global warming to a maximum of 2 degrees in Paris last year, the contribution of bioenergy – the importance of which is evident from almost all scenario studies and model runs – is heavily debated by many stakeholders, due to sustainability concerns, but also due to debate on the optimal use of biomass and the prioritisation of material use over energy use. Through such work as the inter-task project on sustainable supply chains and an ongoing Task 40 study on the cascading of biomass, Task 40 will continue to address the issues and inform stakeholders in order to continue to promote the development of sustainable, international markets and international trade of biomass, while recognising the diversity in biomass resources and applications for bioenergy and bio-materials in the biobased economy.

Attachments

Participation in major events

Below, all major events (co-)organised by task 40 between 2013 and 2015 are listed. This also includes all joint activities with other IEA Bioenergy Tasks, and all other cooperations with international bodies and projects such as GBEP, the Pinchot Institute, the EU-funded projects SECTOR and Biotrade2020+, and various bioenergy conferences.

In March 2013, the first workshop took place at the 8th Annual World Biofuels Markets (WBM) Conference in Rotterdam. During the workshop, the strategic study by IEA Bioenergy Tasks 40, 43 and 38 was presented and discussed. This study aimed to monitor the actual implementation process of sustainability certification of bioenergy, and to obtain a view on how certification schemes were operating and impacting markets, taking into account the point of view of different stakeholder groups. Based on input from over 200 stakeholders, recommendations were made on how sustainability certification could work in bioenergy markets and actually support further deployment. This event attracted 60-70 attendees from different sectors, including industry, government, academics and NGOs. During the workshop, the main findings were presented and discussed with the audience. The panel debate (roundtable) confirmed most of the conclusions. The interaction and communication between different sectors have further improved the understanding of the systems. The participants indicated that certification systems were not easy, but they had a clear purpose and the markets could work with them. Nevertheless it was agreed that there was still a lot to do to improve their functioning and various issues were still to be resolved. The project leader, Luc Pelkmans, made a closing remark, noting that it was important to use the lessons beyond the energy sector, and then to translate these to land use, agriculture, forestry and other biomass applications.

In October 2013, a workshop "The Transatlantic Trade in Wood for Energy: A Dialogue on Sustainability Standards" was held in Savannah, GA, USA, jointly with Task 43 and the Pinchot Institute. The Savannah workshop explored the potential application of sustainability criteria being developed by European governments and industry in the context of U.S. forests. Sponsors of the dialogue included the IEA Bioenergy Executive Committee and Tasks 40 and 43, Sustainable Forestry Initiative Inc. (SFI), Programme for the Endorsement of Forest Certification (PEFC), E.ON, Georgia Forestry Commission, Weyerhaeuser, MeadWestvaco Foundation, and Plum Creek. Representatives of US pellet producers, European purchasers, US, Canadian and European policy makers, and conservation organisations met over two days to analyse and debate complex sustainability issues. Participants toured industrial timberlands certified to SFI's Forest Management standard, a non-industrial family forest, and the Georgia Biomass LLC pellet mill. The field tour showcased several tools to mitigate environmental risks along the biomass supply chain. A summary report from the workshop was published in 2014.

In November 2013, a Task 40 technical workshop was held at the 3rd Annual Exporting Pellets Conference on 29 October 2013. The workshop was divided into two sections. Section 1 covered safety issues related to biomass from production, transportation and storage to handling at the furnace. The speakers included Harold Arnold, the chairman of USIPA, Mieke Vandewal from Control Union, Peter-Paul Schouwenberg from RWE Essent and Jonas Dahl from the Danish Technological Institute. Section 2 focused on torrefaction of biomass. The speakers included Jacob Jacobson from INL, Doris Thamer from Andritz, Jesse Dickerman from Zilkha and Michael Wild from Wild & Partner. The workshop attracted about 80 participants. The programmes, presentations, and summaries are available on the Task website.

In January 2014, Task 40, Task 32 and SECTOR jointly organised a workshop "*Torrefaction of Biomass*" at the 4th Central European Biomass Conference in Graz, Austria. The workshop attracted 70 attendees to the discussion of economic and technological developments in the field of biomass torrefaction. The workshop started with an overview of the developments in torrefaction, followed by several technical presentations on the torrefaction process, and also included topics on international trade and market perspectives. The workshop concluded with a round table discussion on future perspectives from the viewpoints of technology suppliers, biomass producers, traders and consumers.

In May 2014, Task 40 contributed to the organisation of the two-day joint workshop on "Forests, bioenergy and climate change mitigation" in Copenhagen, Denmark, with Tasks 38, 43, IINAS, EEA and JRC (see tasks 38 and 43 for further details).

In June 2014, a workshop was organised by Task 40 on "*Biomass trade & supply system opportunities in a world-wide bio-based economy*" at the World Bioenergy Conference 2014 in Jonkoping, Sweden. This workshop was framed by the growing worldwide interest in the transition from fossil energy resources such as oil and coal to renewable, bioenergy resources. The shift is complex, and the process varies depending on many influences, such as regional resource availability, logistics and distribution infrastructure, and specific product opportunities/demand. Depending on the type and size, biorefineries may be placed either near the feedstock, or near demand centres. The workshop discussed the potential international supply, trade, and demand for biomass for energy, fuels, and chemicals within a competitive energy market, including the impact/opportunities associated with improved and new value chains (e.g. conversion technologies and end uses).

In October 2014, the International workshop *Towards sustainable international biomass trade strategies* in Brussels, Belgium was organised jointly by Task 40 and Biotrade 2020+. Today in the European Union, the cost-effective achievement of existing and future bioenergy targets in the legislation implies that in addition to using domestic sustainable and cost-competitive biomass potentials, European markets will also (partly) rely on sustainable and cheap(er) imports of biomass. Some well-positioned regions of the world are already playing a role in supplying biomass to the European markets and could become increasingly relevant in the near future. One of the objectives of the BioTrade2020+ project is to propose appropriate long-term strategies and support frameworks which can form a basis for a balanced approach between promoting the use of domestic biomass, while also keeping markets open for sustainable imports of biomass. This workshop brought experts together to initiate discussions on how these trade strategies could be framed. The central points of discussion were (1) how to define sustainable export potentials, (2) which opportunities and risks were connected with biomass trade and how these could be addressed, and (3) which were the key principles that sustainable biomass trade should fulfil – one important point was the interaction between local use and exports in the sourcing regions.

On 20 January 2015, the 4th "Biomethane International"-Session was carried out within the conference "Fuels of the Future" in Berlin. The event was organised in close cooperation between the DBFZ and IEA Bioenergy Task 40. The session was chaired by Professor Dr. Daniela Thrän. The aim was to engage international experts and stakeholders from economy, science and politics. Approximately 40 experts joined the session while presentations were given by international experts from five countries. They provided insights into the global and national status and trends for biomethane production and trade. The workshop summary and presentations are available on Task 40 website.

In April 2015, the session "Visions for bio-energy trade in the Baltic Sea region in a ten year perspective" was organised and led by IEA Bioenergy, Task 40 (Sustainable International Bioenergy Trade) at the Nordic Baltic Bioenergy Conference, Riga, Latvia. The discussion focused on the key questions including how bioenergy trade would develop in the Nordic Baltic region in the coming ten years, and what were the driving forces, taking the perspective of the North European region on the potential of biogenic raw materials, woodchips, pellets and liquid biofuels as important sources of income to producers and traders. All presentations are available on the Task 40 website.

On the 5th of May 2015, under the banner of "Biomass Trade and Supply in a Global Bio-Based Economy", IEA Bioenergy Tasks 40 and 42, together with the European Commission funded project DiaCore, hosted a workshop in Sassari, Italy. Many governments across the globe have defined national 'bioeconomy' strategies. However, it remains unclear how the current economy will shift towards a future bioeconomy where chemicals, materials, transport fuels, and other high-value products are derived from non-food materials. Draft findings of a recent Intertask study between Tasks 34, 40, and 42, as well as results of DiaCore on the same topic were presented. The viewpoints of policy makers and representatives from the biofuels, biopower, and logistics industry were heard and discussed. The workshop was connected to Italian research perspectives in the afternoon on May 5 and included a site-visit to the MATRICA Biorefinery (a Versalis-NOVAMONT joint venture). In association with the workshop, Task 40 also had an internal meeting in Sassari to discuss the progress of Task activities.

In August 2015, a workshop was organised by The Global Bioenergy Partnership (GBEP) and IEA Bioenergy 43 and 40 on 'Examples of Positive Bioenergy and Water Relationships' in Stockholm, Sweden. GBEP Activity Group 6 ("Bioenergy and Water") aims to identify and disseminate ways of integrating bioenergy systems into agricultural and forested landscapes to improve sustainable management of water resources, including wastewater. The Activity includes sharing knowledge and experiences on landscape identification and design, best management practices and policies and instruments supporting bioenergy implementation that contribute positively to the state of water. With the support of the IEA as a GBEP partner, IEA Bioenergy Task 43, assisted by Task 40, is co-chairing the Activity Group and contributing to the work defined in the workplan. In this framework, GBEP Activity Group 6 launched the Call for Examples of Positive Bioenergy and Water Relationships. This initiative aims to showcase innovative examples of how bioenergy systems (in both the feedstock production and conversion phases) can produce positive impacts on the status of water and to serve as a way to inspire and build on this knowledge and experience with other bioenergy producers. The submissions received in response to the Call for Examples were reviewed by the Activity Group and the most relevant among them were selected to be presented at the workshop organised by GBEP and IEA Bioenergy, in collaboration with the Royal Swedish Academy of Agriculture and Forestry (KSLA) and Chalmers Energy Area of Advance, in Stockholm (Sweden). The workshop was broadcast on the web and a DVD will be made available by GBEP, as well as a web link for direct streaming if technically feasible. More details are available on the Task 43/Task 40 website.

At the IEA Bioenergy Conference 2015 in October 2015, Task 40 hosted a workshop to discuss lessons from international bioenergy trade for the development of the bio-based economy and their implications. The workshop attracted about 100 attendees, both from European countries and from outside Europe, including Canada, the US and South Korea. The workshop offered information on bioenergy trade, particularly from the perspective of standardisation, sustainability and logistics. It covered the latest developments in technical standardisation and sustainability certification of liquid biofuels, biogas and solid biomass, as well as opportunities and challenges in terms of logistics. All presentations are available on the Task 40 website. Task 40 members also met internally in association with this event to discuss the Task activities and exchange information.

Publications

Newletters

Goh CS, Junginger M, Faaij A and Schouwenberg P-P. (Eds) Task 40 Newsletter. Issue 1, September 2013.

Goh CS, Junginger M, and Schouwenberg P-P. (Eds) Task 40 Newsletter. Issue 1, September 2014.

Goh CS, Junginger M, and Schouwenberg P-P. (Eds) Task 40 Newsletter. Issue 1, September 2015.

Books

Junginger M, Goh CS, Faaij APC (Eds.) International Bioenergy Trade: History, status & outlook on securing sustainable bioenergy supply, demand and markets. November 2013. 233 p. ISBN 978-94- 007-6982-3. Springer, Dodrecht. Available at: http://www.springer.com/energy/policy%2C+economics%2C+management+%26+transport/book/97 8-94-007-6981-6

Articles in peer-reviewed journals

Stupak I, Joudrey J, Smith CT, Pelkmans L, Chum H, Cowie A, Englund O, Goh CS, Junginger M. (2016) A global survey of stakeholder views and experiences for systems needed to effectively and efficiently govern sustainability of bioenergy. WIREs Energy Environ 2016, 5:89–118. doi: 10.1002/wene.166.

Patrick Lamers, Ric Hoefnagels, Martin Junginger, Carlo Hamelinck, André Faaij (2015) Global solid biomass trade for energy by 2020: an assessment of potential import streams and supply costs to North-West Europe under different sustainability constraints. Global Change Biology Bioenergy, Volume 7, Issue 4, pages 618–634, July 2015 DOI: 10.1111/gcbb.12162.

Evelyne Thiffault, Jody Endres, James S.N. McCubbins, Martin Junginger, Miren Lorente, Uwe Fritsche, Leire Iriarte (2015). Sustainability of forest bioenergy feedstock supply chains: Local, national and international policy perspectives. Biofuels, Bioproducts and Biorefining, 9(3) 283-292, DOI: 10.1002/bbb.1547

Matzenberger, J., Kranzl, L., Junginger, M., Vassilis, D., Tromborg, E. (2015), Future perspectives of international bioenergy trade, Renewable and Sustainable Energy Reviews 43 (May 2015) 926–941.

Ric Hoefnagels, Erin Searcy, Kara Cafferty, Thijs Cornelissen, Martin Junginger, Jacob Jacobson, André Faaij (2014). Lignocellulosic feedstock supply systems with intermodal and overseas transportation. Biofuels, Bioproducts & Biorefining, 8(6), 794–818, November/December 2014

Goh, C.S, Junginger, M., Faaij, A., Monitoring sustainable biomass flows in a bio-based economy: General methodology development (2014), Biofuels, Bioproducts and Biorefining, Volume 8, Issue 1, January 2014, Pages 83-102. DOI: 10.1002/bbb.1445;

Presentations

IEA Bioenergy Task 40, 43 and 38 workshop at 8th WBM Conference, Rotterdam, The Netherlands

- **Kees Kwant, NL Agency.** Goals of the Workshop and the Strategic IEA Bioenergy Study
- **Luc Pelkmans, VITO.** Implementation of Schemes for Biomass and Bioenergy Sustainability – What are the Main Differences?
- **Peter-Paul Schouwenberg, Essent.** IWPB, Working Towards a Common System for Wood Pellets to Facilitate Trade
- **Chun Sheng Goh,** UU. Can We See an Impact of Sustainability Requirements on Markets?
- **Luc Pelkmans, VITO.** Overall Findings and Recommendations from the IEA Bioenergy Study.

Savannah Sustainability Workshop, Savannah, GA, US

- **Martin Junginger, Utrecht University/IEA Bioenergy Task 40.** The strategic importance of the Southeast US in global biomass trade.
- **Uwe Fritsche, IINAS.** Meta-study on energy wood certification.
- **Mieke Vandewal,** Control Union. Application of the Green Gold Label.

IEA Task 40 & USIPA Safety, Logistics & Torrefaction Workshop at USIPA conference, Miami, FL, US

- **Martin Junginger, UU.** Overview of IEA Task 40 and Its Initiatives
- **Mieke Vandewal, PCU.** Lessons from 10 years of wood pellet exports from North America to Europe
- **Peter-Paul Schouwenberg, Essent.** Safe handling of wood pellets at the furnace. How the lessons learned from Tilbury will be used for the next generation of co-firing plants.
- **Jonas Dahl, DTI.** Main Outcomes of the LUBA Safe Pellets projects
- **Jake Jacobson, INL**. Global Trade Study: The Importance of Pretreatment Technologies to Enable Commoditisation & Long-Distance Trade of Solid Biomass.
- **Michael Wild, Wild & Partners.** Expected Impacts of Torrefaction on Wood Pellet Trade and Logistics.

IEA Bioenergy Task 40, 42 and SECTOR workshop on torrefaction in Graz, Austria – 17 Jan 2014:

- **Michael Wild, Wild and partners.** Torrefaction– International Overview of Developments in this Novel Technology

Workshop Biomass trade & supply system opportunities in a world-wide bio-based economy, Jonkoping, Sweden – 4 Jun 2014:

Anders Evald, HOFOR. One million tonnes of wood: considerations on feedstock price versus quality issues and supply options for a large scale biomass project

Martin Junginger, UU. International trade and supply opportunities of processed stable biomass intermediates for biopower and other emerging large-scale markets.

Patrick Lamers, INL. Biomass trade and supply system opportunities for a worldwide bio-based economy

International workshop: Towards sustainable international biomass trade strategies, Brussels – 24 October 2014:

Uwe R. Fritsche, Leire Iriarte, IINAS. Assessing sustainable biomass export potentials: methodological considerations

Uwe R. Fritsche, Leire Iriarte, IINAS. Case study: Woody biomass from South-East U.S. Approach and preliminary results

Martin Junginger, UU. Biomass trade for energy: history & future expectations

Thuy Mai-Moulin & Martin Junginger, UU. Sustainable Lignocellulosic Biomass Potentials in Mozambique and Kenya – preliminary results.

Patrick Lamers, INL. Export vs. local biomass use – a dilemma?

Others:

Martin Junginger, UU. Overview of IEA Task 40. IEA Bioenergy National workshop, Utrecht, the Netherlands, November 2013.

Peter-Paul Schouwenberg, Essent. International development within TKI-BBE. IEA Bioenergy National workshop, Utrecht, the Netherlands, November 2013.

Reports

Goovaerts L, Pelkmans L, Goh CS, Junginger M, et al. Monitoring Sustainability Certification of Bioenergy (Task 1): Examining Sustainability Certification of Bioenergy. March 2013.

Stupak I, Joudrey J, Smith CT, Pelkmans L, et al. Monitoring Sustainability Certification of Bioenergy (Task 2): Survey on governance and certification of sustainable biomass and bioenergy. March 2013.

Goh CS, Junginger M, Chum H, Joudrey J, et al. Monitoring Sustainability Certification of Bioenergy (Task 3): Impacts of sustainability certification on bioenergy markets and trade. March 2013.

Pelkmans L, Goovaerts L, Smith CT, Joudrey J, et al. Monitoring Sustainability Certification of Bioenergy (Task 4): Recommendations for improvement of sustainability certified markets. March 2013.

Pelkmans L, Goovaerts L, Smith CT, Joudrey J, et al. Monitoring Sustainability Certification of Bioenergy – Short Summary. June 2013.

Thiffault E et al. The Science-Policy Interface on the Environmental Sustainability of Forest Bioenergy.

Bradley D, Hektor B, Wild M, Deutmeyer M, et al. Goh CS and Junginger M (Eds) Low cost, Long Distance Biomass Supply Chains. August 2013.

Kranzl L, Matzenberger J, Junginger M, Daioglou V, Tromborg E, Keramidas K. Future Perspectives of International Bioenergy Trade – Summary. August 2013.

Vakkilainen E, Kuparinen K, Heinimö J. Large Industrial Users of Energy Biomass. September 2013.

Gawor et al. 2014. Impact of promotion mechanisms for advanced and low-iLUC biofuels on biomass markets: Straw for bioenergy. IEA Bioenergy Task 40. August 2014.

Iriarte et al. 2014. Impact of promotion mechanisms for advanced and low-iLUC biofuels on biomass markets: Wood Pellets from the US to the EU. IEA Bioenergy Task 40. August 2014.

Pelkmans et al. 2014. Impact of promotion mechanisms for advanced and low-iLUC biofuels on biomass markets: Trade of ethanol between Brazil and the US. IEA Bioenergy Task 40. August 2014.

Pelkmans et al. 2014. Impact of promotion mechanisms for advanced and low-iLUC biofuels on biomass markets: Summary report. IEA Bioenergy Task 40. August 2014.

Pelkmans et al. 2014. Impact of promotion mechanisms for advanced and low-iLUC biofuels on biomass markets: Used cooking oil and animal fats for biodiesel (case study). IEA Bioenergy Task 40. August 2014.

Thiffault et al. 2014. Ecological sustainability of wood bioenergy feedstock supply chains: Local, national and international policy perspectives. IEA Bioenergy Task 40. August 2014.

Daniela Thrän, Eric Billig, Tobias Persson, Mattias Svensson, Jaqueline Daniel-Gromke, Jens Ponitka, Michael Seiffert, John Baldwin, Lukas Kranzl, Fabian Schipfer, Julian Matzenberger, Nathalie Devriendt, Mathieu Dumont, Jonas Dahl, Günther Bochmann, Editors Martin Junginger (Task 40) and David Baxter(Task 37). 2014. Biomethane – status and factors affecting market development and trade. A joint Study on behalf of IEA Bioenergy Task 40 and Task 37. September 2014.

In 2015, Task 40 compiled country reports. These country reports identify domestic biomass resources in each member country, and their current use, trends, and main users. In the reports, policy support and expected biomass use in 2020 (and beyond) is also described, together with biomass prices and international biomass trade for energy. Finally, discussions on drivers, barriers & opportunities are also presented. The following reports have been published

F. Schipfer, L. Kranzl, Task 40 Country reports 2014: Austria

A. Walter, P. Dolzan, Task 40 Country reports 2014: Brazil

W. Stelte, J. Hinge, J. Dahl, Task 40 Country reports 2014: Denmark

A. Karhunen, J. Heinimö, T. Ranta, E. Alakangas, Task 40 Country reports 2014: Finland

D. Thrän. C. Hennig, N. Rensberg, V. Denysenko, U.R. Fritsche, U. Eppler, Task 40 Country reports 2014: Germany

C.S Goh, M. Junginger, Task 40 Country reports 2014: Netherlands

E. Trømborg, Task 40 Country reports 2014: Norway

B. Hektor, L. Bruce, K. Andersson, Task 40 Country reports 2014: Sweden

P. Lamers, J.R. Hess, M.S. Roni, J. J. Jacobson, B. Heath, Task 40 Country reports 2014: US

TASK 42: Biorefining – Sustainable Processing of Biomass into a Spectrum of Marketable Bio-based Products and Bioenergy

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Website: http://www.iea-bioenergy.task42-biorefineries.com/en/ieabiorefinery.htm

Introduction

In a future Bio-Economy sustainable production and valorisation of biomass for both food and non-food applications will be the framework of operation. Sustainably produced biomass (crops, algae, residues) should be used as efficiently as possible – using bio-cascading and biorefining[6] approaches – to meet future demands for food, feed, bio-based products (chemicals, materials) and bioenergy (fuels, power, heat).

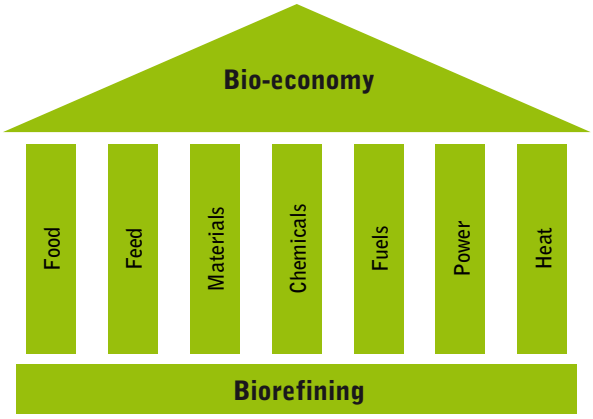

Figure 2. Biorefinery as a base for the Bio-Economy.

Biorefineries have been applied for some considerable time in for example the food and pulp/paper industries. Large-scale implementation of biorefineries for non-food (including bioenergy) applications, however, is still lacking. Major reasons for this include: some of the key technologies (fractionation & product separation) which are part of integrated biorefinery plants are still not mature enough for commercial market implementation; there is still no level-playing-field for sustainable biomass use for food and non-food applications; market sectors that should co-operate (food, feed, agro, chemistry, energy, fuels, logistics, etc.) for the development and commercialisation of full sustainable biomass value chains, including highly-efficient biorefinery processes, are often not yet working together, and there is still a lack of knowledge/expertise on the advantages of biorefinery processes for optimal sustainable biomass use at both industrial, small and medium enterprise (SME) and (regional) governmental level.

The aim of Task 42 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. Task 42 provides an international platform for collaboration and information exchange between industry, SMEs, government organisations (GOs), non-government organisations (NGOs), research and technology organisations (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 are addressed to successfully promote sustainable biorefinery systems market implementation.

6 Biorefining is the sustainable processing of biomass into a spectrum of marketable biobased products (food, feed, chemicals, and/or materials) and bioenergy (biofuels, power and/or heat) [IEA Bioenergy Task 42].

Background

The objectives for Task 42 in this triennium were to collect, analyse, share, and disseminate strategic technical and non-technical information – including best-practices – on biorefinery-based sustainable value chains, and to support and train industrial/SME, governmental and non-governmental stakeholders with a view to establishing their position in a future BioEconomy. The Task participants have worked on the following topics in the work programme of the 2013 – 2015 triennium.

Table 1. Work programme IEA Bioenergy Task 42 2013 – 2015.

1.	Assessing the market deployment aspects for integrated Biorefineries
1.1	Technical and non-technical critical success factors
1.2	Disruptive/game changing technologies
1.3	Central vs. decentral processing
1.4	Biorefinery-Complexity-Index
2.	Supporting industrial/SME stakeholders establishing their position in a future BioEconomy
2.1	Role involved market sectors: i.e. energy sector. biofuel sector. agro sector. chemical sector. food/ feed sectors
2.2	Upgrading strategies of existing industrial infrastructures to biorefineries, improving overall sustainability
2.3	Factsheets major biorefineries|National case-studies
2.4	Added-Value products to be co-produced in energy-driven biorefineries
3.	Analysing optimal sustainable biomass valorisation approaches for food and non-food (incl. energy/ fuels)applications within a market-pull approach
3.1	Sustainable bioenergy supply chains (joint Task43, 42, 40, 39, 38, 29 initiative)
3.2	Future market demand for biomass from the broader BioEconomy perspective (joint Task40 and 42 initiative)
3.3	Optimal sustainable biomass valorisation co-producing food/feed, chemicals/materials, fuels and energy
4.	Preparing policy advice on further needs (regulation, research ...)
4.1	'Roadmap' Biorefinery (vision & strategic research agenda) - Joint Activity with IEA Headquarters
4.2	Biorefinery (related) policies in participating countries
4.3	Country reporting
5	Organising - knowledge dissemination activities
5.1	Bi-annual Task meetings, incl. industrial stakeholder meetings and excursions in participating countries
5.2	Annual Task meetings at national level
5.3	Task website: incl. data-base biorefineries
5.4	Task newsletters
5.5	Task reports, brochures & leaflets
5.6	International conferences and workshops
6.	Developing and organising training activities
6.1	Annual training- / summer school on biorefining, incl. making lectures available for teaching outside the EC

The synergetic international co-operation within the IEA Bioenergy framework will potentially decrease the time-to-market of highly-efficient integrated biorefineries by tackling major technical and non-technical critical success factors at the appropriate international level.

Task objectives and work carried out

The full deliverables of the different 2013-2015 topics can be found at the Task 42 website:

www.IEA-Bioenergy.Task42-Biorefineries.com

1. Assessing the market deployment aspects for integrated Biorefineries

1.1 Technical and non-technical critical success factors (coordination USA)

In spite of the fact that there are already operating commercial examples available, large-scale implementation of highly-efficient integrated biorefinery facilities is still lacking. This is the result of a variety of non-technical (policies/regulations, level-playing-field, full chain stakeholder involvement, etc.) and technical barriers. In this activity an assessment is made of existing major critical success factors, and the way these are handled. The U.S. was taken as a reference-case, mainly because of its leading role in the demonstration of large-scale advanced biofuel production facilities, and because of the implementation trajectory monitoring activities of Department of Energy/ Bioenergy Technologies Office (DOE/BTO), identifying major success factors and "show stoppers".

Figure 3. INEOS New Planet Biorefinery [DOE/BET, 2014].

It has been identified that, for successful implementation, key challenges in the full value chain – feedstock production and logistics, refining, products distribution and end-use – have to be taken into account and de-risked. Sound policies, effective integrated proven technologies based on versatile test facilities, adequate capital investments/financing instruments, and partnerships covering the full chain and markets are identified to be major key success factors.

Deliverables (and further information provided):

- Challenges to Successful Integrated Biorefineries/ Best Practices and Lessons Learned, DOE/BTO, January 2014.
- Demonstration and Deployment Strategy Workshop Summary, DOE/BTO, May 2014.
- Integrated Biorefineries Critical Success factors, DOE/BTO, June 2014.

1.2 Disruptive/game changing technologies (coordination Netherlands)

An assessment is made of potential game changing (technology) developments in both the participating countries and others, that potentially will make it possible to significantly improve the overall sustainable processing of biomass for food and non-food applications. The goal of identifying these new developments, and disseminating knowledge on them, is to accelerate support for them, shortening the time-to-market of highly-efficient sustainable value chains.

Biofuels and biobased chemicals – both the products and the production technologies – are identified as potentially disruptive and fundamental to the circular (bio)economy, with significant geopolitical, military, economic, cultural/ social cohesion and industrial impacts. The biorefining approach is necessary to make these products genuinely disruptive, i.e. fully sustainable. The key enabling technologies/products that have been identified to make biorefining a disruptive technology are: genetic engineering, separation technology, nanoparticles, conversion technology, small-scale/ decentralised technology, chemicals from CO_2, brand new functionalities, cell wall disruption, energy storage and energy from residues/waste heat.

Deliverable:

Disruptive – Game Changing Technologies (slide-deck), Avantium Chemicals, December 2015.

1.3 Centralised vs. decentralised processing (coordination Netherlands)

Biomass can be converted at large-scale (centralised processing), and at smaller-scales (decentralised/regional processing). Relatively high-temperature thermal processes (combustion, gasification) are applied mostly at large-scale because of economy-of-scale aspects. On the other hand, the general opinion is that low-temperature (bio)chemical processes (fermentation, digestion, etc.) can be applied in an economically favourable way at smaller scales, reducing necessary initial investment costs, and potentially making use of the economy-of-duplication. This together with other regional advantages (such as biomass availability, reduced logistics, the possibility to recirculate minerals to the biomass cultivation area, stakeholders from the full chain that know and trust each other, etc.) potentially makes the market implementation at regional smaller-scale easier.

This topic was originally brought into the work programme by France. Since France ultimately decided not to join Task 42 for this triennium, the topic was not dealt with within the Task 42 framework. However, Wageningen UR (NL) worked on this aspect within several projects supported by the Dutch Government. From these projects it can be concluded that small-scale regional biorefining is specifically advantageous if the transport of raw materials and (intermediate) products can be minimised (in particular for relatively wet perishable raw materials like grass, sugar beet, etc.), intermediate trade can be taken out, the process is applied in rural areas, and several modular units can be applied in decentralised mode with one centralised processing station. Furthermore, while small-scale dewatering is advantageous, drying is not.

More information is available in publications: *Opportunities for small-scale biorefinery for production of sugar and ethanol in the Netherlands* (Kolfschoten et al), *Small-scale processing of biomass for biorefinery* (Bruins et al), and *Low-cost small scale processing technologies for production applications in various environments-Mass produced factories* (Bramsiepe et al).

See also: www.kleinschaligebioraffinage.nl (in Dutch).
Deliverable: none.

1.4 Biorefinery-Complexity-Index (coordination Austria)

Based on the Task 42 biorefinery definition and classification system, a biorefinery-complexity-index (BCI) – based on the Nelson's complexity-index for oil refineries – is developed. The BCI gives an indication on the complexity of the biorefinery facility, i.e. on the time-to-market, the amount of stakeholders to be involved, the initial investment and final operational costs.

A high BCI has the disadvantage that the initial investment costs will be high and that a variety of stakeholders will be involved, potentially increasing the time-to-market. However, the advantages are that, when an implementation decision is taken, it will be clearly possible to co-produce significant amounts of bio-based products and bioenergy in a profitable way. The BCI was calculated for 7 different biorefinery concepts to demonstrate its applicability. It was shown that the BCI is directly linked to the number of process units of which the refinery is composed and their Technology Readiness Level (TRL). The higher the BCI, the further beyond the state-of-the-art the biorefinery facility is.

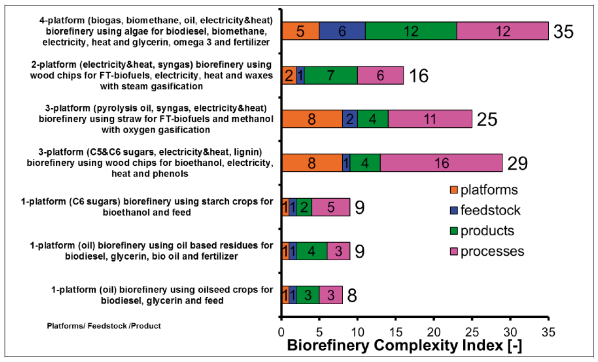

Figure 4. BCI of some selected biorefineries [Joanneum Research/IEA Task42, 2014].

In addition, the Biorefinery Complexity Profile (BCP) shows the most relevant features contributing to the complexity of a biorefinery, and gives an indication of the technical and economic risks. Both the BCI and BCP might give industry, policy makers and investors some additional information to assist them in developing biorefinery implementation strategies at minimal technical and economic risk.

Deliverable:

- The Biorefinery Complexity Index, Joanneum Research (Austria)/Task 42, July 2014.

2. Supporting industrial/SME stakeholders finding their position in a future BioEconomy

2.1 Role involved market sectors; i.e. energy sector, biofuel sector, agro sector, chemical sector, food/feed sectors (coordination Denmark)

In the transition to a future Bio-Economy – an economy in which biomass is used for both food and non-food applications – the roles of stakeholders currently operating in more or less distinct market sectors will potentially change to a role of being an integral part of the development and implementation of integrated sustainable biomass valorisation chains. In this new role, stakeholders who are currently operating in separate markets will have to co-operate in the joint Bio-Economy.

Task 42 carried out a short questionnaire-based study to review the general opinion among stakeholders concerning the challenges and the role they foresaw for themselves in the transition towards a Bio-Economy, and to identify factors that these stakeholders saw as critical for increased cross-sector collaboration. The major findings were: both the chemical and biofuel sectors are expected to be the main industrial stakeholders to initiate the transition to a Bio-Economy; the main barriers in the transition (and cooperation) as identified are profitability and a lack of appropriate policies, a competitive market and a need for trust between stakeholders; governmental support that facilitates/ encourages collaboration across traditional market sectors will stimulate the overall deployment; and IEA Bioenergy Task 42 can play a serious role by monitoring and communicating the progress in demonstration of biorefining technologies and highlighting success stories.

Deliverable:

- The role of industry in a transition towards the Bio-Economy in relation to biorefinery, DTU(Denmark)/ Task42, May 2015.

2.2 Upgrading strategies for existing industrial infrastructures to biorefineries improving overall sustainability (coordination Austria)

Existing industrial infrastructures are a starting point for upgrading to highly-efficient sustainable biorefineries, i.e. for biorefinery deployment in the short-term. Promising biomass conversion processes could potentially be integrated directly upstream (power plants, oil refineries) or downstream (biofuel, pulp/paper) of conventional industrial infrastructures, converting these infrastructures to highly-efficient sustainable multi-product biorefineries. Task 42 assessed the integration options for biorefineries in the existing infrastructures of 10 industrial sectors using its previously developed classification system to identify their potential advantages. The most relevant features identified for synergetic integration are: specific feedstock and product handling experience; dealing with specific platforms (sugars, syngas, etc.); and the availability of specific processes. A specific case-study for the Austrian situation was performed in which integration options for the co-production of biofuels/bio-chemicals in the pulp/paper and wood industry at 12 sites were identified; options for the additional co-production of energy carriers in the food/ feed industry were identified for 60 sites; biogenic resource use for potential bio-chemicals production was identified for 20 sites; and the option to co-produce biofuels in an existing oil refinery was identified for one site. Demonstrating these integration opportunities will potentially help interested stakeholders to start promising biorefinery initiatives with minimal technical and financial risks.

Deliverable:

- Upgrading strategies for industrial infrastructures – integration of biorefineries in existing industrial infrastructure, Joanneum Research (Austria)/IEA Task 42, December 2014.

2.3 Factsheets major biorefineries/National case-studies (coordination Austria)

Thirteen factsheets of major biorefinery facilities were developed, including the following information/data: classification, mass/energy balances, capacities, costs, major sustainability aspects. The type of facilities dealt with were:

1. 4-platform biorefinery using grass silage and food residues for bio plastic, insulation material, fertilizer, electricity
2. 3-platform biorefinery using wood chips for pulp, paper, turpentine, tall oil, bark, electricity and heat
3. 1-platform biorefinery using starch crops for bioethanol and feed
4. 3-platform biorefinery using wood chips for bioethanol, electricity, heat and phenols
5. 1-platform biorefinery using oilseed crops for biodiesel, glycerine and feed
6. 1-platform (oil) biorefinery using oil based residues for biodiesel, glycerine, bio oil and fertilizer
7. 2-platform biorefinery using wood chips for Fischer-Tropsch (FT)-biofuels, electricity, heat and waxes
8. 3-platform biorefinery using straw for FT-biofuels and methanol
9. 2-platform biorefinery using wood chips for FT-diesel, FT-gasoline, heat and waxes
10. 3-platform biorefinery using straw for FT-diesel and methanol
11. 3-platform biorefinery using wood for renewable gasoline/diesel, biochar and pyrolysis oil
12. 3-platform biorefinery using wood chips for bioethanol, electricity and phenols
13. 4-platform biorefinery using grass silage and food residues for bioplastic, insulation material, fertilizer and electricity

Joanneum Research (Austria) and Task 42 are very interested to further extend the number of biorefining factsheets, because in our view it is an excellent way of communicating biorefining to a wider audience. Those interested in making a factsheet of their own biorefinery facility or concept should contact gerfried.jungmeier@joanneumresearch.at. A data-input sheet for the preparation of these type of factsheets is available on the Task 42 website.

Deliverables:

- The Biorefinery Fact Sheet (incl. 8 factsheets), Joanneum Research (Austria)/IEA Task 42, September 2014.
- Biorefinery Fact Sheets (methodology & 5 factsheets), Joanneum Research (Austria)/IEA Task 42, Q1 2016.

2.4 Added-Value products to be co-produced in energy-driven biorefineries (coordination Netherlands)

By the end of 2012 Task 42 had published the report "Biobased Chemicals". This report was very successfully received within the biorefinery market sector. This report was expected to be updated during this triennium. However, in 2014 E4Tech (UK), RE-CORD (Italy), and Wageningen UR (Netherlands) were contracted by the European Commission (EC) to prepare a report on the perspectives of the sugar-platform for the production of biobased chemicals and fuels. These parties took the 2012 Task 42 report as a basis, and made an updated elaboration of it.

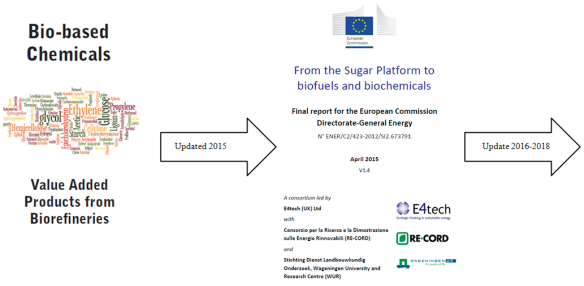

Figure 5. Progress Biobased Chemicals Report Task42.

Therefore, a new update by Task 42 has been postponed to the new 2016-2018 triennium. In the same triennium, the same type of reports will also be published by Task 42 on:

- Proteins for Food, Feed and Bio-based Applications – Biorefining of Protein Containing Biomass (1st half 2016)
- Biobased Fibrous Materials (2017)

3. Analysing optimal sustainable biomass valorisation approaches for Food and Non-food (incl. Energy/Fuels) applications within a market-pull approach

3.1 Sustainability Assessment Toolbox Testing (coordination Canada)

This activity was replaced early in 2013 by a Canadian activity concerning the development of the LEEAFF-indicators (Land-use, Environment, Employment, Acceptability, Finances, Feedstock) sustainability assessment methodology for biorefineries. The main reason for this was that the PROSUITE sustainability toolbox (Utrecht University) was not ready for the assessment of integrated biorefinery processes. This methodology was

applied in the inter-Task project "Mobilising sustainable bioenergy supply chains" to assess the corn stover (cellulosic sugar) to bioethanol chain in comparison to corn grain (starch sugar) bioethanol production in Southwestern Ontario.

Deliverable:

- LEEAFF sustainability assessment methodology, Agriculture and Agri-Food Canada, to be delivered 1st-half 2016.

3.2 Sustainable bioenergy supply chains (joint Task 43, 42, 40, 39, 38, 37 initiative) (coordination Task 43)

Task 42 participated in the Strategic Fund Project (SFP) Mobilising Sustainable Bioenergy Supply Chains. In this project global sustainable bioenergy supply chains were analysed that were also sustainable according to international standards. Task 42 contributed to this project by direct involvement in the assessment of two cases: the corn stover case (Canada) and the biogas case (Germany). The overall SFP-results have been published in a final report that was distributed at ExCo76 in Berlin in Q4 2015 (http://www.ieabioenergytask43.org/mobilizing-supply-chains/). More detailed reports on the separate value chains are expected to be published in the 1st-half of 2016.

Deliverables:

- Mobilizing Sustainable Bioenergy Supply Chains – Inter-Task Project Synthesis Report, IEA Task43, Q4 2015.
- Biogas Case Study and Corn Stover Case Study Reports, to be delivered by IEA Task43 1st-half 2016.

3.3 Future market demand for biomass from the broader Bio-Economy perspective (joint Task 40 and 42 initiative) (coordination Task 40)

In this joint Task project the potential international supply, trade and demand for biomass for energy and fuel applications in a competitive Bio-Economy market is assessed, including the identification of improved and new value chains. Task 42 contributed to this project by providing information on: which types of biorefineries are expected to be implemented as a function of time, which feedstocks they will use, and where they will be located. In addition to desk study activities, a workshop is organised to incorporate real market data in the project analysis, to present preliminary results, and to obtain feedback from stakeholders from the countries participating in the Tasks.

Deliverables:

- Contribution to workshop "Biomass Trade and Supply in a Global Bio-Based Economy", Sassari, Sardinia, Italy, 5 May 2015.
- Book Chapter "Biorefineries in a Global Bio-based Economy"), H. Stichnothe et al. on behalf of Task 42 ; coordination final book publication (1st-half 2016) by Task 40.

3.4 Optimal sustainable biomass valorisation co-producing food/feed, chemicals/materials, fuels and energy (coordination Netherlands)

At the request of ExCo (Kwant/Sipila), this activity was replaced by the development of an overview of Bio-Economy Strategies in IEA Bioenergy Implementing Agreement participating countries. This assessment was performed by Austria//Italy in Q3 2014, and the results were presented at ExCo74.

A poster based on the results of the work was presented at 23rd European Biomass Conference and Exhibition in Vienna, Austria, and was nominated for the Poster Award within the topic Biomass Policies, Markets and Sustainability.


G. Jungmeier, V. Pignatelli, M. Monni, M. Beermann, K. Kwant, K. Sipilä, R. Van Ree

have been nominated by the official jury for the Poster Award for the topic "Biomass Policies, markets and sustainability"

The Poster entitled "BioEconomy Strategies in the Member Countries of the IEA Bioenergy Implementing Agreement - Current Status, Approaches and Opportunities "

was deemed to be a particularly valuable contribution to the 23rd European Biomass Conference and Exhibition Vienna, Austria, 1 - 4 June 2015

Ingwald Obernberger, Conference General Chairman | David Baxter, Technical Programme Chairman | Dimitrios Sidiras, Poster Awards Coordinator | Peter Helm, Executive Committee | Angela Grassi, Executive Committee

Figure 6. Poster Award at EUBC&E Conference

In addition, selected Task 42 2013-2015 triennium results on sustainable biomass valorisation using biorefineries were used as a starting point of a workshop on "The future role of biorefining in the BioEconomy" that was organised as an integral part of the Global Bio-Economy Summit: Innovation, Green Growth and Sustainable Development, Berlin, Germany, 25/25 November 2015 (http://gbs2015.com/programme/).

Figure 7. Stakeholder Dialogue on The Future Role of Biorefining in a Bio-Economy at Global Bio-Economy Summit, Berlin, November 2015

Deliverables:

- BioEconomy Survey 2014 – National Bio-Economy Strategies in IEA Bioenergy Implementing Agreement Countries, IEA Task 42, October 2014.
- The Future Role of Biorefining in the Bio-Economy – A Stakeholder Dialogue, minutes Task 42 workshop at the Global Bio-Economy Summit, Berlin, November 2015.
- PDFs of lectures (introducing Task 42, Novamont, SCAR, Joanneum Research/Task 42, DTU/Task 42) given at stakeholder dialogue.

4. Preparing policy advice on further needs (regulation, research, ...)

4.1 'Roadmap' Biorefinery (vision & strategic research agenda) – Joint Activity with IEA Headquarters (coordination Netherlands)

IEA Headquarters was planning to set-up and perform a Project (Roadmap) on Sustainable Biomass Valorisation by the Biorefining Approach. Task 42 planned to participate in this initiative, to be further specified during this 2013-2015 triennium. However, the observer from IEA Headquarters advised the ExCo72-meeting in Korea that they were not planning such an activity within the short-term. As a result, this activity was removed from the work programme. However, at the start of 2016 IEA Headquarters made a new request to Task 42, as the former want to include a short feature article on biorefining in this year's medium-term renewable energy market report. Task 42 will prepare this feature article, that can hopefully be used as a first attempt for a more regular cooperation with IEA Headquarters in the near term. Deliverable: none.

4.2 Biorefinery (related) policies in participating countries (coordination Austria)

In September 2014 Wageningen UR on behalf of the Dutch Ministry of Economic Affairs hosted an EC Research & Innovation – Standing Committee on Agricultural Research (SCAR) Collaborative Working Group (CGB) – Integrated Biorefineries Meeting, in which the current state-of-the-art of biorefinery initiatives in various European countries was presented and discussed with the goal to analyse which joint research & innovation programmes and supporting policy measures could be effective to promote further deployment. This and other information (Task 42 activities 1.1, 2.1, 3.4, 4.3, etc.) was used to set the framework for the workshop on "The future role of biorefining in the Bio-Economy", see activity 3.4. Policy assessment was an important part of the workshop.

Deliverable: see 3.4, Minutes workshop at Global Bio-Economy Summit, Berlin, November 2015.

4.3 Country reporting (coordination Netherlands)

In recent years the following countries were participants of Task 42: Austria, Australia, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Turkey, UK, USA. All have prepared Country Reports describing: overall (bio)energy production and use; biomass use for non-energetic applications; mapping of biorefineries, including commercial facilities, demonstration and pilot plants, major R&D projects and regional initiatives; Bio(based) Economy strategies; policy goals and instruments, and major national stakeholders (industry, SMEs, GOs, NGOs, RTOs, UNIs). These Country Reports are updated every three years. During this triennium all participating countries – except Ireland – have prepared country reports on the status and developments of biorefineries in their respective countries.

These country reports – in the form of slide-decks – are available at the Task website. Ireland will produce their report in the next triennium, during the next round of updating.

5. Organising knowledge dissemination activities

5.1/5.2 Bi-annual Task meetings and annual meetings at national level (coordination Netherlands)

In this triennium bi-annual internal Task 42 meetings were organised for both management of the Task activities and informing each other on the biorefinery developments in the participating countries. These internal Task 42 meetings were coupled with an industrial stakeholder meeting/ conference/ workshop and/or an excursion to a operating biorefinery facility, to gain knowledge and for dissemination purposes. In some of the partnering countries (Netherlands, Austria, Italy, etc.) IEA type meetings at national level also took place. The following meetings/activities occurred:

Table 2. Overview bi-annual Task events during the 2013-2015 triennium.

When	Where	What
2013	Wageningen, the Netherlands	■ 13th Task 42 Progress Meeting ■ Biorefinery for Food, Fuel and Materials Symposium (BFF2013)
2013	Graz, Austria	■ 14th Task 42 Progress Meeting ■ Austrian Stakeholder Workshop "The Role of Biorefining in a Future Bio-Economy"
January 2014	Berlin, Germany	■ 15th Task 42 Progress Meeting ■ Joint Task 42 & Task 39 Workshop on Biofuel-driven Biorefineries
June 2014	Hamburg, Germany	■ 16th Task 42 Progress Meeting
December 2014	Guelph / Toronto, Canada	■ 17th Task 42 Progress Meeting ■ Contribution to Bio-Economy Conference "Biofuels to Bio-Economy" – 6 lectures by Task 42 ■ Site Visit and dinner with Canadian Stakeholders
May 2015	Sassari/ Porto Torres, Sardinia, Italy	■ 18th Task 42 Progress Meeting ■ Joint Task 40/Task 42 Workshop "Biomass Trade and Supply in a Global Bio-Based Economy ■ Italian (industrial) stakeholder meeting
October 2015	Berlin, Germany	■ 19th Task 42 Progress Meeting ■ IEA Bioenergy End-of-Triennium Conference "Realising the world's sustainable bioenergy potential". Task 42 contributed to this conference by organising a specific biorefining session, incl. 4 lectures
Coming up April 2016	Dublin, Ireland	■ 20th Task 42 Progress Meeting ■ Irish stakeholder meeting to exchange info

Figure 8. Compilation Task 42 members in action at Task 42 Progress Meetings and linked events.

5.3 Task website (coordination Netherlands)

The Task 42 website – www.IEA-Bioenergy.Task42-Biorefineries.com – was successfully upgraded during 2014. All Task 42 deliverables and major general biorefinery information can be found at this website.

5.4 Task newsletters (coordination Netherlands)

No Task 42 newsletters were produced during this triennium. A new newsletter set-up and dissemination procedure has been developed, and will become active in the new triennium. This newsletter will contain biorefinery news from partnering countries (presented at the roundtable Task Progress meetings), such as: new commercial/demonstration/pilot plants, new projects, new regional initiatives, policy issues, new publications, and biorefinery related events from the international calendar. The Netherlands will prepare the newsletters, and will transfer them to the national country representatives for dissemination within their respective countries. A first newsletter will be published in Q2 2016, directly after the 20th Task 42 Progress Meeting in Dublin, and will include information on the Task 42 Work Programme and participating countries for the 2016-2018 triennium.

5.5 Task reports/brochures (coordination NL)

A Glossy Task 42 Brochure was published in September 2014 and included: country specific biorefining challenges; vision of and contribution by IEA Bioenergy Task 42; definition, classification and factsheets; sustainability issues; biofuel-driven biorefineries; value-added products from biorefineries; training activities; website; commercial, demonstration and pilot plants in participating countries: more than 35 one-page descriptions; activity plan 2013 – 2015; and a table with a full overview of biorefinery plants in participating countries. This brochure is available in HR and LR on the Task 42 website at News, and Publications – Reports.

New/Updated reports on: Bio-based Chemicals; Proteins for Food, Feed and Bio-based Applications – Biorefining of Protein Containing Biomass, and Biobased Fibrous Materials are scheduled for the new triennium (see also 2.4).

5.6 International conferences and workshops (coordination Netherlands)

During this triennium, Task 42 both (co)organised and contributed to a variety of international workshops and conferences. Some examples are the workshops/sessions directly related to the Task 42 Progress Meetings, see Table 2. In addition the workshop "The role of industry in a transition towards the Bio-Economy in relation to biorefinery" at i-SUP2014 Conference, Antwerp, Belgium (2014) has been organised.

A variety of lectures have been given at international conferences and workshops – for a full list see attachment.

In addition, IEA Bioenergy Task 42 is continuously contributing its international biorefining expertise and Task results to some very important European Bio-Economy related platforms, such as: the European Biofuel Technology Platform (EBTP), the European Biobased Industries Consortium (BBI/BIC), and the European COST Action (EUBIS) on Food Waste Valorisation by biorefining. Information that becomes available in these platforms is disseminated to the Task 42 members.

6. Developing and organising training activities

In the past Task 42 was involved in the establishment and organisation of several biorefining training courses – (RRB5/Ghent/2009, BVC/Amsterdam/2010, Summer School/Paris-France/2011 (1st European training school), 2nd European Training School/Wageningen-NL/2012) both for students, industrial/SME representatives and policy makers. In this 2013-2015 triennium a contribution was given to the 3rd European Biorefinery Training School, Budapest, Hungary, July 2014. In 2016 a small training support will be given to an international students-4-students initiative organised at Wageningen UR (Netherlands) where students will organise a Biorefinery-based Bio-Economy Event: International Bio-Based Economy Student SymbioSUM (IBBESS):

http://www.iea-bioenergy.task42-biorefineries.com/en/ieabiorefinery/show-8/IBBESS-Conference-2015.htm

Success story

Biorefining – from definition, classification, complexity-index to factsheets

Task 42 initiated its activities by the establishment of a biorefinery definition, i.e.: biorefining is the sustainable processing of biomass into a portfolio of marketable biobased products and bioenergy. It then developed an understandable biorefineries classification system based on raw materials, platforms, and products with the overall goal to make the principle and advantages of biorefining clear to industrial/SME stakeholders and GOs/NGOs, with the aim to accelerate the market deployment of biorefineries. A method to calculate a biorefinery-complexity-index (BCI) and a biorefinery-complexity-profile (BCP) was developed to give industry, policy makers and investors some additional information to assist them in developing biorefinery implementation strategies at minimal technical and economic risk. A biorefinery fact sheet (BFS) methodology/set-up – including description/classification biorefinery (part A), results sustainability assessment (part B) and an Annex (documented input-data) – was developed/defined with the goal to clearly present the advantages of biorefining in a uniform way in order to aid overall understanding of the principle and final market deployment.

Biorefinery Fact Sheet (BFS) shortened example: 4-platform biorefinery using grass silage and food residues for bioplastic, insulation material, fertilizer and electricity

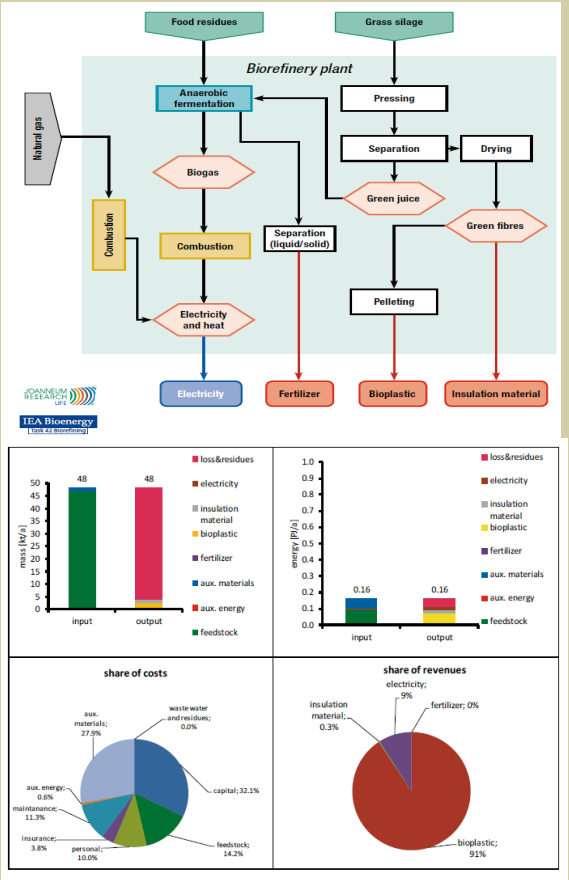

Figure 9. Part A: Biorefinery plant

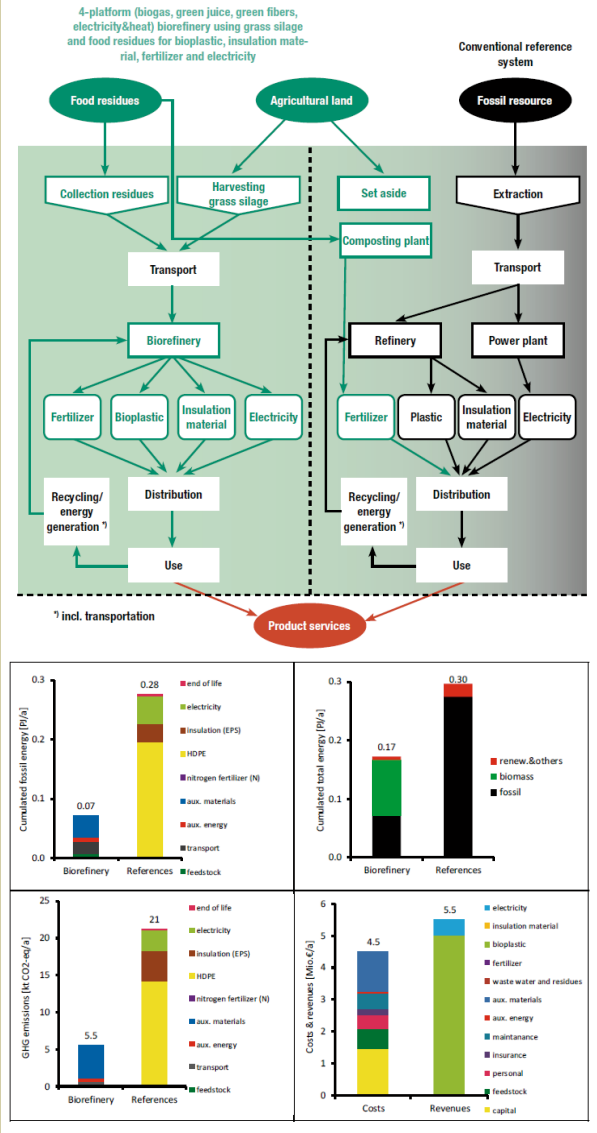

Figure 9. Part B: Value chain sustainability assessment

The biorefinery classification system (BCS) developed by Task 42 was already used by several international stakeholders in various publications, for examples see below.

Figure 10. BCS use by other international stakeholders.

Conclusions and recommendations

Conclusions

1. Concerning the assessment of the market deployment aspects of integrated biorefineries, it can be concluded that there are still many technical and non-technical barriers to be solved before large-scale implementation of biorefineries in the circular (bio)economy will become a reality. IEA Bioenergy Task 42 can make an important contribution to overcoming these barriers by knowledge dissemination concerning international best-practices, bringing together stakeholders involved in the full value chain and stakeholders normally operating in different market segments, providing clear Biorefinery Fact Sheets, and producing reports on added-value products (chemicals, proteins, fibrous materials) that can potentially be coproduced with bioenergy to improve its overall sustainability.
2. Industrial/SME stakeholders can be best supported in finding their way in a future Bio-Economy by showing them the international developments and clear facts on biorefinery technology opportunities as part of full sustainable value chains.
3. Optimal sustainable biomass valorisation approaches to food and non-food (including energy/fuels) are plentiful; however, biorefining/bio-cascading is always the approach to use to maximise sustainability. Bioenergy can be the main driver – biofuel/energy-driven biorefinery approach – or a secondary product (product-driven biorefinery approach), but it will always be part of the optimised biomass valorisation path.
4. Policy advice on further biorefinery deployment should be formulated taking into account the market point-of-view. IEA Bioenergy Task 42 could provide the platform to bring together market players to discuss implementation barriers and potential policies to be developed. These recommendations can be transferred to the IEA Bioenergy Executive Committee for discussion with the international/national governmental organisations.
5. Both knowledge dissemination and training are very important for further expertise capacity building and technology development in order to provide the (technical) foundation for further biorefinery deployment and in this way feed the circular (bio) economy.

Recommendations to the ExCo

Biorefining (and bio-cascading) is the most efficient approach to meet future food and non-food market demands of a Circular Bio-Economy. In spite of the fact that biorefineries are already being applied for some considerable time in, for example, the food and pulp/paper industries, further facilitation is still required to realise its full market potential. In the short-term **BIOENERGY** (fuels, power, heat) is expected to play an initiating role in the transition to a Circular Bio(based) Economy by providing biomass mobilisation and certification expertise, facilities and infrastructure, and a value chain covering stakeholders that potentially can be used to kick-start biorefinery deployment. The aim is to use the available biomass potential in a sustainable way to co-produce both food/feed ingredients, biobased products (chemicals, materials) and energy (fuels, power, heat). In the medium to longer-term **BIOENERGY** is expected to play a central role as part of efficient bio-cascading/biorefining approaches in the Circular Bio(based) Economy by:

- Providing sustainable biofuels – biofuels sustainably produced from non-food biomass sources – to sectors where they are the only alternative fuels available to reduce those sectors' GHG emissions, i.e. aviation, shipping and heavy duty transport – **biofuel-driven biorefinery approach**.
- Valorisation of primary (agro), secondary (process) and tertiary (post-consumer) chain residues for both power and heat to be used to meet internal product-driven biorefinery-based process energy requirements or for external use, and for sustainable biofuels to meet (part of) the logistical energy requirements for biomass sourcing and product delivery purposes – **product-driven biorefinery approach**.
- Valorisation of biomass residues and non-food biomass sources for power and heat in high-efficiency co-firing and stand-alone conversion facilities with upstream value-added products extraction and/or valorisation of process residues – **energy-driven biorefinery approach**.

IEA Bioenergy Task 42 on Biorefining should be continued for another 3 years with the main focus on: analysis/assessment of biorefineries in full value chains; product quality issues (including standardisation/certification); development of a circular (bio)economy; and communication, dissemination and training. The main added-value deliverables, specifically for Task 42 to produce, are: biorefinery fact sheets; overview of international developments on biobased product quality; biorefinery country reports; waste management strategies in a circular (bio)economy; thematic workshops together with other international organisations (FAO, OECD, etc.); reports on biobased chemicals, proteins for food, feed and industrial application, and biobased fibrous materials, and biorefinery training activities.

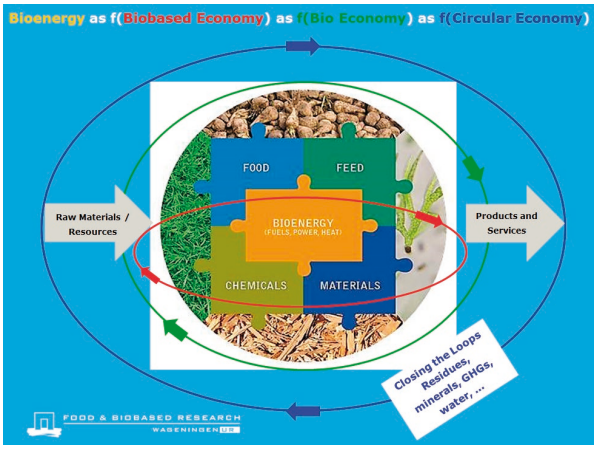

Figure 11. Bioenergy within the Circular Economy [Wageningen UR, IEA Bioenergy Task 42]

Attachments

Participation in major events, lectures and publications

- van Ree R., co-organisation and chairing of the Biorefinery Platforms Day at the World Biofuels Markets Conference (WBM-2013) (including a short Task 42 lecture), Rotterdam, the Netherlands on 12 March 2013.
- Stichnothe H., IEA Task 42 Overview Lecture at 52th Tützing Symposium "One year on: Germany's Biorefinery Roadmap in an International Context", Tützing, Germany, 11 June 2013.
- Jungmeier G. et al., "A Biorefinery Fact Sheet for the Sustainability Assessment of Energy Driven Biorefineries – Efforts of IEA Bioenergy Task 42 "Biorefining", 21th EU BC&E, Copenhagen, Denmark, 3-7 June 2013.
- Jungmeier G., "Possible Role of a Biorefinery´s Syngas Platform in a Bio-based Economy – Assessment in IEA Bioenergy Task 42 Biorefinery", ICPS 13 – International Conference on Polygeneration Strategies, Vienna, Austria, 3-5 September 2013.
- Jungmeier G., "Facts & Figures of Producing Biofuels in Biorefineries – Current Status and Future Perspectives", 8th A3PS Conference Eco-Mobility 2013, Vienna, Austria, 3-4 October 2013.
- Jungmeier G., "The Austrian Participation in IEA Bioenergy Task 42 Biorefining", Austrian Stakeholder Meeting, Graz, Austria, 24 October 2013.
- Van Ree R., "Achievements of IEA Bioenergy Task 42 Biorefining", Austrian Stakeholder Meeting, Graz, Austria, 24 October 2013.
- Stichnothe H., "Update of the German Biorefinery Roadmap", Austrian Stakeholder Meeting, Graz, Austria, 24 October 2013.
- Jorgensen H., "Using Straw and MSW for Biorefineries in Denmark – Technical Developments and Demonstration Activities", Austrian Stakeholder Meeting, Graz, Austria, 24 October 2013.
- De Bari I., "Biorefineries and Green Chemistry in Italy – Overview of Applied R&D, Demo and Industrial Breakthroughs", Austrian Stakeholder Meeting, Graz, Austria, 24 October 2013.
- Wellisch M. et al, "Building Sustainable Biomass Supply Chains", International Forest Biorefinery Symposium, Montreal, QC, 3-4 February 2014.
- de Jong Ed, Task 42/Avantium Lecture at Tomorrow's Biorefineries Event, Brussels, Belgium, 11-12 February 2014.
- Van Ree R., chairing of 2 Biorefinery Sessions at the World Bio Markets Conference (WBM-2014) (including a short Task 42 lecture), Amsterdam, the Netherlands, 4-6 March 2014.
- Van Ree R., The role of industry in a transition towards the Bio-Economy (BE) in relation to biorefinery – Overview Task 42, Task 42 Workshop at i-SUP Conference, 3 September, Antwerp, Belgium.
- Jungmeier G., "Approach for the Integration of Biorefineries in the Existing Industrial Infrastructures", Task 42 Workshop at i-SUP Conference, 3 September, Antwerp, Belgium.
- BioEconomy Strategies in the 22 IEA Bioenergy Member Countries – Current Status, Approaches and Opportunities for Bioenergy, bmvit Bioenergie Fachgespräch, Wien 21. November 2014.
- Introduction to IEA Bioenergy and Task 42 Biorefining, Ed de Jong, Canadian Bioeconomy Conference (CRFA), Toronto/Canada, December 1 – 3, 2014.
- Maximising Revenues and Minimising waste in Fuel and Feed-based Biorefineries, Geoff Bell, Canadian Bio-Economy Conference (CRFA), Toronto/Canada, December 1 – 3, 2014.
- The "Biorefinery Fact Sheet" of IEA Bioenergy Task 42 "Biorefining", Gerfried Jungmeier, Canadian BioEconomy Conference (CRFA), Toronto/Canada, December 1 – 3, 2014.
- Biorefinery Evolution in the Netherlands, Bert Annevelink, Canadian Bio-Economy Conference (CRFA), Toronto/Canada, December 1 – 3, 2014.
- Biorefinery Evolution in the US, Steven R. Thomas, Canadian Bio-Economy Conference (CRFA), Toronto/Canada, December 1 – 3, 2014.
- Biorefinery Evolution in Japan, Satoshi Hirata, Canadian Bio-Economy Conference (CRFA), Toronto/Canada, December 1 – 3, 2014.

- Working Document „Upgrading Strategies for Industrial Infrastructures – Integration of Biorefineries in Existing Industrial Infrastructure", Gerfried Jungmeier, Martin Buchsbaum with contributions from Rene van Ree, Henning Jørgensen, Ed de Jong, Heinz Stichnothe, Maria Wellisch, Isabella di Bari, Geoff Bell, James Spaeth, auf der Task 42 webpage veröffentlicht am 22.12. 2014.
- Heinz Stichnothe, Dietrich Meier, Isabella de Bari, Martin Beermann, Gerfried Jungmeier, Steven Thomas, Biorefineries in a Global Bio-based Economy", book/report chapter, to be published.
- Ed de Jong and Gerfried Jungmeier, Biorefinery Concepts in Comparison to Petrochemical Refineries, Industrial Biorefineries and White Biotechnology, Elsevier, Amsterdam, the Netherlands, June 2015.
- Gerfried Jungmeier and Task 42, Assessing Biorefineries Using Wood for the BioEconomy – Current Status and Future Perspective of IEA Bioenergy Task 42 "Biorefining", 18th ISWFPC 2015, 9-11 September 2015, Vienna, Austria.
- Gerfried Jungmeier and Task 42, The Biorefinery fact Sheet and its Application to Wood Based Biorefining – Case Studies of IEA Bioenergy Task 42 Biorefining, Nordic Wood Biorefinery Conference (NWBC), Helsinki, Finland, 20-22 October 2015.
- René van Ree and Task 42, Contribution to Handbook of Biofuels' Production: Processes and Technologies (Second Edition), A VOLUME IN THE WOODHEAD PUBLISHING SERIES IN ENERGY) edited by Prof Rafael Luque, Prof James Clark, Prof Karen Wilson and Dr Carol Lin, Q4 2015.
- Gerfried Jungmeier and Task 42, Implementing Strategies of Biorefineries in the Bio-Economy using a Life Cycle Sustainability Approach developed in IEA Bioenergy Task 42 Biorefining, to be presentedat the European Biomass Conference, Amsterdam, The Netherlands 2016.

Deliverables

Subject	Progress
Act.1 Assessment of the market deployment potential of integrated biorefineries	
Technical and non-technical critical success factors	Delivered (US) [Q1, 2014] – slide-deck with major results
Disruptive/game changing technologies	Delivered (NL) [Q4, 2015] – slide-deck with major results
Centralised vs. decentralised processing	None. Originally brought-in the WP by France who finally decided not to join Task 42; info provided by Wageningen UR
Biorefinery-Complexity-Index (BCI)	Delivered (AT) [Q3, 2014]
Act.2 Support of industrial/SME stakeholders finding their position in a future BioEconomy	
Role involved market sectors in the transition to a BioEconomy	Delivered (DEN) [Q2, 2015] – report with results workshop i-SUP 2014 conference and questionnaire
Upgrading strategies for existing industrial infrastructures	Delivered (AT) [Q4, 2014] – slide-deck with major results
Factsheets on major biorefineries/ national case studies	Delivered (AT) [Q4, 2015] – factsheet methodology (A and B part + Annex), and 13 mainly biofuel-based factsheets fully filled-in
Updating of bio-chemicals report	None. It was decided to postpone the update of the 2012 Task 42 report till the next triennium to be able to build on EC report ENER/C2/423-2012/S12.673791 (April, 2015) that used the Task 42 2012-report as starting point
Preparation Report "Proteins for Food and Non-food Applications"	A first draft report has been prepared (NL) [Q4, 2015]. The report will be finalised and upgraded for external dissemination in the 1st half of 2016
Act.3 Analysis optimal sustainable biomass valorisation in market-pull perspective approach	
Sustainability assessment toolbox	Activity replaced by CAN LEEAFF-indicators sustainability assessment. To be delivered (CAN) [1st half 2016]
Mobilising sustainable bioenergy supply chains	Delivered (GER, CAN) [2015] – contributions to reports inter-Tasks project coordinated by Task 43
Future market demand for biomass from a BioEconomy perspective	Delivered (GER et al) [2015] – contribution to workshop and report (book chapter "Biorefineries in a Global Bio-based Economy") coordinated by Task 40

Optimal sustainable biomass valorisation	Replaced on ExCo-request by Assessment National Bio-Economy Strategies in IEA Bioenergy countries; delivered (AT, IT, NL) [2014] – slide-deck with major results; workshop at Global Bio-Economy Summit 2015
Act.4 Preparation advice policy makers on current status, future potential and priority needs	
Biorefinery Roadmap	None. Originally suggested for the WP by IEA HQ who finally did not put it on their agenda for the 2013-2015 period
Biorefinery (related) policies in participating countries	Delivered (AT, IT, NL) [2014] as part of Assessment National Bio-Economy Strategies in IEA Bioenergy countries – slide-deck with major results, and workshop at Global BioEconomy Summit, Berlin 2015
Country reporting	Delivered (all, except IL) [2013-2015] – slide-decks with up-to-date national biorefinery info
Act.5 Biorefinery knowledge dissemination	
Bi-annual task and stakeholder meetings, incl. excursions	Delivered, minimally 2 a year
Annual task meetings at national level	Delivered in some (AT, IT, NL, ...) of the partnering countries
Task website (public internet and closed members area)	Delivered, will be updated for the new 2016-2018 triennium
Task newsletters	Not delivered. For the new triennium minimally 2 Task 42 newsletters a year will be prepared directly after the Progress Meetings, and widely distributed by the NTLs using their own distribution channels
Glossy task brochure, poster, leaflet	Delivered (all) [Q4, 2015]
Contributions international workshops and conferences	Delivered (all), incl. contributions to EC (BBI/EBTP, ...) [2013-2015]
Act. 6. Delivery of biorefinery training activities	
Annual training school on biorefining	Contribution to 3rd European Biorefinery Training School, Budapest, Hungary, July 2014; None in 2015.

Co-ordination with other Tasks within IEA Bioenergy and bodies outside IEA Bioenergy

In this triennium co-operation was established with international activities, such as: other Tasks (Task 39 and 34 on Biorefinery Factsheet Data, Task 40 on biomass supply for the BE, and Task 43 et al. within the multi-tasks strategic project on sustainable bioenergy chains), European-based Technology Platforms (EBTP), EC Specific Support Actions, and EC FP7 Integrated Projects. This co-operation will be enhanced in 2016 – 2018 by organising joint events, e.g. workshops and meetings, with international organisations (FAO, OECS, IEA-IETS).

Industry participation

Industry was heavily involved in the activities of the Task, by for example: sub-coordination of the Task (Avantium Chemicals BV, NL), providing technical data-input for the set-up of the Biorefinery Fact Sheets, active participation in events (stakeholder meetings, workshops), organised by Task 42, data provision and data checking of Biobased Products market reports (biobased chemicals, proteins) prepared by Task 42, plant descriptions/info for brochures and the website, and participation in the training activities.

TASK 43: Biomass Feedstocks for Energy Markets

Prepared by:

Göran Berndes, Task Leader, Chalmers University of Technology, Sweden

Tat Smith, Associate Task Leader, University of Toronto, Canada

Operating Agent:

Åsa Forsum, Swedish Energy Agency, Sweden

Participating countries:

Australia, Canada, Croatia, European Commission, Denmark, Finland, Germany, Ireland, The Netherlands, Norway, Sweden, United Kingdom, USA

Website: http://www.ieabioenergytask43.org/

Introduction

The role of Task 43 is to envisage and contribute to the development of competitive bioenergy supply chains that use sustainably produced feedstocks. This is accomplished by linking promising feedstocks with energy markets, addressing logistical and technical challenges and identifying and quantifying the socioeconomic and environmental consequences of feedstock production. The Task takes global, regional and local approaches when investigating sustainable supply chains and considers commercial, near-commercial and promising agricultural and forestry production systems coupled with conversion technologies. Aquatic resources have not been included. Throughout the triennium, the Task has addressed environmental, economic and social opportunities and barriers relating to bioenergy supply chains. Based on the work carried out, timely and topical analyses, syntheses, and conclusions have been provided to relevant actors on matters concerning biomass feedstock and markets, including socio-economic and environmental consequences of feedstock production and supply.

Work in the 2013-2015 triennium was based on the premise that biomass demand for energy would increase rapidly in many countries as governments implement policies to address climate change and energy security concerns. Organic consumer waste, residue flows in agriculture and forestry (e.g. logging residues and straw) as well as dedicated biomass production systems could become plausible energy sources if production systems were economically, socially and environmentally attractive. It was expected that simplistic and polarising views on priorities for bioenergy-food-fibre-environment values would gradually become replaced by more nuanced and holistic considerations, and that this development would make it easier to move beyond polarised debates to address the bigger, more pertinent, question about how the increasing demands for food, fibre and bioenergy could be met in the future. Task 43 consequently established as a central part of its work to investigate and communicate how dedicated biomass production systems could be expanded and how land, water and other resources could be used sustainably to produce biomass for energy.

However, throughout the triennium, there has been much debate and concern about possible negative impacts associated with bioenergy and the view that bioenergy represents an attractive alternative to conventional energy options is still being challenged. Much attention has been directed to the possible consequences of land-use change (LUC), referring to effects of forest management and cropland expansion into previously uncultivated areas, possibly resulting in biodiversity losses, GHG emissions and degradation of soils and water bodies. Sustainability concerns relating to the feedstock supply systems also include direct and indirect social and economic impacts, including land-use conflicts, human rights violations and food security.

The work of the Task has progressed in response to the need for science-based information that can inform the evolving public debate about bioenergy sustainability and provide guidance for policymaking and strategic planning in the industry. The science-policy interaction has become more intensive during the 2013-2015 triennium. Through NTLs and other participating colleagues, the Task has contributed to the development of governance systems including legislation, sustainability standards and certification schemes. Through Task participants, Task 43 has also contributed to many publications, as documented in the attached list of Task deliverables (Appendix A).

Background

During the preparations for the 2013-2015 triennium it was decided that Task 43 should merge with Task 29 – Socio-economic Drivers for Implementing Bioenergy Projects. The Task 43 work plan for the 2013-2015 period was therefore prepared in collaboration with colleagues in Task 29. The technical and governance view on biomass production systems and supply chains – improving and adapting these systems to local conditions and existing supply chains, markets, and policies – was complemented with views on technological innovation systems, economics, financing options, and producers' willingness and ability to change behaviour. The complementary perspective of producers and the obstacles they face in changing from conventional production systems or integrating biomass production for energy into conventional production systems, added an integrated view on feedstock production and energy markets including policies and other factors that can shape market development and economic opportunities.

The work in the Task necessitates involvement of colleagues from many disciplines employing a variety of approaches, and interdeciplinary collaboration. The work programme for the 2013-2015 triennium was developed around three key work areas:

1. Land use and sustainable bioenergy feedstock supply systems
2. Assessment and certification of sustainability
3. Socio-economic drivers in implementing sustainable bioenergy production and supply.

Based on these three areas, more specific work areas and topical questions were formulated:

- how to overcome technical, economic and policy barriers to mobilisation of existing and new biomass resources
- how to mitigate negative impacts and avoid irreversible degradation of ecosystems and essential natural resources such as soil, water and biodiversity
- how to integrate new bioenergy feedstock production systems into existing agricultural and forestry landscapes in ways that promotes environmental, social and economic sustainability of the overall agricultural and forestry production
- how to develop governance models that provide sound operating conditions for the agriculture and forestry sectors, and also properly address societal concerns about various risks associated with bioenergy.

The Task also highlighted in the prolongation proposal for the 2013-2015 triennium that – since the Task worked within a dynamic area undergoing rapid change – it was essential to have a significant degree of flexibility and capacity to respond constructively to unforeseen developments and propose new and unforeseen work (emerging issues).

The Task engaged in the development and evaluation of methods and tools for sustainability assessment of bioenergy feedstock supply systems and provided expert advice concerning criteria and indicators for sustainable biomass production, including information on biomass supply systems and their performance in relation to sustainability criteria. Here, critical assessments of how regulatory measures influence the conditions for rational forestry and agriculture operations represented important work. Through specific Task and inter-Task projects, workshops, and collaboration with other Tasks and organisations outside IEA Bioenergy, experts have been brought together to evaluate alternatives across sectors and to identify trade-offs and synergies between food, fibre and bioenergy production systems. One important aim for the Task has been to achieve strong outreach, both within the scientific community and in the rest of society. Major activities have taken place around the inter-Task project "Mobilization of sustainable bioenergy supply chains".

Task objectives and work carried out

The key work areas were achieved through arrangement of seminars and workshops, and publication of reports in collaboration with other Tasks and organisations. The Task has arranged and co-organised several dissemination events where only those Task colleagues with direct involvement in the addressed work area have participated. The Task has at the same time maintained the same meeting frequency as in earlier periods regarding regular Task business meetings for planning of Task activities. There has been extensive collaboration among Tasks and several Task NTLs have worked in other networks and, in this way, have brought collaboration opportunities to the Task. Consolidation and development of such opportunites for the Task as a whole will continue in the next triennium.

Developing a flexible work plan was justified by events; several requirements for publications, workshops and seminars on emerging issues were identified in response to developments taking place during the triennium, in areas where the Task has expertise. It is our judgment that the flexibility and ability to mobilise capacity to respond promptly to arising demands has helped the Task to establish a position in relation to important ongoing processes and to influence the conditions for bioenergy feedstock production.

It is difficult to assign different Task activities and publications to a specific key work area since these in many ways overlap and are inter-linked. However, the table below, which presents selected major publications, workshops and other events organised by Task 43 during the 2013-2015 triennium, indicates how the various deliverables have addressed the key work areas. The organised events have served the purposes of gathering international expertise, as dissemination events, or events to create dialogue among a large range of stakeholders on conflicting matters.

Examples include sustainability of the North American-European wood pellet supply chains, and the question of the existance and timing of the climate change mitigation benefits. The events also provided opportunities for meeting and planning further work with representatives from the collaborating organisations that Task 43 has engaged with during the triennium. Several of the events have also served the purpose of initiating or coordinating report writing processes aiming at joint publications as well as scientific publications. A more extensive list of deliverables is attached (Attachments).

Several additional publications will be available in the 2nd quarter of 2016 that represent the outcome of work mainly carried out in the 2013-2015 triennium. For example, an Elsevier book is in process, which focuses on mobilising boreal and temperate forest biomass supply chains. The work on the book has been coordinated by Evelyne Thiffault at Laval University who is also the book editor, supported by Tat Smith, Jack Saddler (Task 39), Martin Junginger (Task 40), and Göran Berndes as co-editors. In addition, several other publications are being published as outcomes or spin-offs from the inter-Task project "Mobilization of sustainable bioenergy supply chains". This projecct also facilitated new collaboration and networks relating to the included case studies, for example North American–European collaboration on bioenergy supply chains based on agriclutural residues. Furthermore, two reports are in the review stage, which are the outcome of two projects initiated jointly by Task 38 and Task 43. One of the reports is an overview of literature on the Albedo effects of biomass production, which can significantly affect the climate effect of bioenergy implementation. The other report concerns the influence of the choice of decomposition model for estimated forest carbon balances after harvesting of different forest bioenergy feedstock. A third example is a Task 43 report on sustainable biomass recovery technology/supply chain in forest operations, which is soon to be available on the Task 43 website. It was coordinated by the Australian Task 43 NTL with contributions from an international team of experts.

When	Activity/deliverable	Work area	Description/comment
March 2013	Publishing and other Dissemination within the inter-Task project 'Monitoring Sustainability Certification of Bioenergy'.	2, 3	Four reports and a summary were published and also several scientific articles and book chapters. A dissemination workshop "How Can Sustainability Certification Support Bioenergy Markets?" was organised at the World Biofuels Markets conference, in Rotterdam, by the involved Tasks, including Task 43. The workshop was well attended, with approximately 60 participants from the energy sector, environmental NGOs, certification and auditing organisations. The discussion came to a number of conclusions on the proliferation of schemes, importance of convergence and mutual recognition, the complementarity to legislation, and the importance of a common language among sectors. It is anticipated that this discussion will help further the ongoing developments towards harmonisation and a common language for certification, reflecting both the need for certification and the need to decrease the burden facing bioenergy producers from complex governance measures.
March 2013	1-day conference session, 'Governing water quality and quantity in bioenergy feedstock production at the World Biofuels Markets conference', in Rotterdam.	1, 2	Organised by Task 43, which covered many important aspects associated with the session theme. Presenters represented the industry, governments as well as academia in a broad geographical coverage. After the session, a follow-up meeting was held where the participants planned future cooperation. The event was a follow-on from events in the previous triennium where Task 43 engaged with other organisations to develop constructive approaches to address water related issues of biomass feedstock production.
May 2013	Report: Economic Sustainability of Biomass feedstock Supply IEA Bioenergy: Task43: 2013:01	1, 3	This report addressed key factors contributing towards economic sustainability and more economically viable bioenergy development and use, such as increasing operational efficiency and integration into traditional supply chains. It was concluded that economic, environmental and social dimensions of sustainability are highly interconnected and that bioenergy value chains must generate profits also for biomass suppliers in order to create sustainable feedstock supplies for growing biomass markets.
May, 2013	Report: "Science-policy interface on issues of environmental sustainability of forest bioenergy". IEA Bioenergy ExCo:2013:03.	1, 2, 3	This report was the outcome from an ExCo-sponsored workshop and field tour in Quebec, Canada, in October 3-5, 2012. It was organised by Task 40 and Task 43 in collaboration with the Faculty of Forestry, Geomatics and Geography of Laval University and Natural Resources Canada, with collaboration from the Global Bioenergy Partnership and the Canadian Council of Forest Ministers. The workshop gathered key European, Canadian and American experts involved in bioenergy research, industry and policy development, and it was very successful in addressing science, policy, NGO and industry concerns, with an open dialogue among participants.
July, 2013	Workshop: Developing a binding sustainability scheme for solid biomass for electricity and heat under the EU-RED, Arona, Italy.	1, 2	Organised by JRC and IINAS with support from Task 40 and Task 43. The workshop was part of a series of workshops dedicated to methodology development supporting policy and regulation in the bioenergy area. It was followed by several other events, including the May 2014 workshop in Copenhagen, as described below.

When	Activity/deliverable	Work area	Description/comment
July, 2013	Report: On the timing of GHG mitigation benefits of forest-based bioenergy. IEA Bioenergy: ExCo: 2013:04.	1, 2	This report was produced by Task 43 in collaboration with Task 38 and it addresses the timing of greenhouse gas emissions and carbon sequestration when biomass from existing managed forests is used for energy to displace fossil fuels. The purpose of the report, which is aimed at policy advisors and policy makers, is to explain the essence of the timing debate and to propose a perspective that considers the broader context of forest management and the role of forest bioenergy in climate change mitigation.
October, 2013	Workshop: The transatlantic trade in wood energy: a dialogue on sustainability standards, in Savannah, GA, USA	1, 2, 3	This ExCo-sponsored workshop in Savannah, GA, USA, was organised by the Pinchot Institute, Task 40 and Task 43. The aim was to continue the dialogue from the Quebec 2012 workshop described above. A webinar in February 2014 contributed further dissemination of this event. A bioenergy study tour organised by US-DOE with Task 38 and Task 43 is an example of an event in the new 2016-2018 triennium that uses a similar format to create dialogue on feedstock production and sustainability among stakeholders along the supply chains and across the Atlantic.
February, 2014	Workshop: Bioenergy and Water: Developing strategic priorities for sustainable outcomes, Paris, France	1, 2, 3	Organised by Task 43, UNEP, IINAS, Winrock International. Well attended workshop that provided the basis for involving additional organisations in a co-ordinated and common approach to addressing and communicating water-related issues for bioenergy. Both FAO and GBEP participated in the workshop and it can be considered a step towards the establishment of GBEP-AG6. Selected contributions to the workshop are available in an 'In Focus' section in the scientific journal BioFPR, see Attachments.
May, 2014	Workshop: Forests, bioenergy and climate change mitigation, Copenhagen, Denmark	1, 2	Organised by Task 38, Task 40, Task 43, IINAS, EEA, and JRC. This workshop aimed to facilitate dialogue between scientists on the topic of climate effects of forest-based bioenergy, to advance understanding of the topic and to determine the causes behind diverging views. The workshop identified converging views and views that are still diverging. Points of convergence related to the appropriate approaches for assessing the climate effects of bioenergy, and priorities for research. Areas of divergence related to both objective and subjective aspects of research approaches, and different perspectives were explained mainly by different worldviews or reference points, rather than scientific aspects. It is a topic that needs yet further clarification through dialogue and publication.
January, 2015	Report: Assessing the environmental performance of biomass supply chains. IEA Bioenergy Task43 TR2015:01.	1, 2	This report presents state of the art information on environmental impacts of biomass supply chains including how to assess them and identify the environmental challenges and limitations to mobilisation. It provides an introduction to the application of LCA to biomass production systems, identifying factors to be taken into account for assessing these biological systems.
April & August, 2015	Call for contributions, workshop, report and webinars: Positive examples of bioenergy-water relationships	1, 2, 3	The call was part of the GBEP-AG6 initiative to collect, analyse and showcase innovative examples of how bioenergy systems (in both the feedstock production and conversion phases) can produce positive impacts on the status of water. The examples should also serve as a way to inspire and build on this knowledge and experience among other bioenergy producers. The submitted examples were reviewed by AG6 members and the most relevant among them were selected to be presented at the workshop. Based on the contributions and the workshop, a publication was published by GBEP and IEA Bioenergy. A number of webinars in 2016 contribute to further dissemination.

When	Activity/deliverable	Work area	Description/comment
May, 2015	Conference: Mobilisation of woody biomass for energy and industrial use – Smart logistics for forest residues, prunings and dedicated plantations, Rome, Italy	1, 3	The conference, which was co-arranged with Task 43, provided an overview and summarised the key outcomes of three European projects INFRES, LogistEC and EuroPrunning that aimed at accelerating technological development and opening new paths to Europe's renewable energy targets by producing research-based knowledge, technological solutions and service innovations for increased biomass feedstock supply from forestry residues, agricultural residues, and dedicated energy crop plantations.
October, 2015	Report: Mobilizing Sustainable Bioenergy Supply Chains -- Inter-Task Project Synthesis Report. IEA Bioenergy ExCo: 2015:04.	1, 2, 3	This report summarises and synthesise the results from the five case studies of the inter-Task project "Mobilizing Sustainable Bioenergy Supply Chains". The project was one of the larger efforts in the 2013-2015 triennium, which resulted in a substantial amount of outputs, see Attachments.
December, 2015	Book: Advances in Bioenergy: The Sustainability Challenge. 560 pp. Wiley & Sons Inc., ISBN: 978-1-118-95787-5	1, 2, 3	This book provides a wide-ranging scientific overview of the technology, economics and policy of bioenergy. It draws upon articles published in WIREs – Energy and Environment under the editorship of Task 43, including 12 articles authored by Task 43 associates.

Success story

During the 2013-2015 triennium, Task 43 provided leadership to an inter-Task Strategic Project titled "Mobilizing Sustainable Bioenergy Supply Chains". This project involved over 70 collaborators associated with Tasks 37 (Energy from Biogas), 38 (Climate Change Effects of Biomass and Bioenergy Systems), 39 (Commercialising Conventional and Advanced Liquid Biofuels from Biomass), 40 (Sustainable International Bioenergy Trade: Securing Supply and Demand), 42 (Biorefining – Sustainable Processing of Biomass into a Spectrum of Marketable Bio-based Products and Bioenergy), and 43 (Biomass Feedstocks for Energy Markets) with many decades of experience in all aspects of sustainable bioenergy production systems. The purpose of the collaboration was to analyse prospects for large-scale mobilisation of major bioenergy resources through five case studies that determine the factors critical to their sustainable mobilisation. The following bioenergy opportunities were analysed, with special focus on selected countries and regions that represent different supply chain conditions:

- forest biomass in temperate and boreal ecosystems, including a broad range of countries and conditions;
- agricultural crop residues focusing on supply chains in Denmark, the United States of America and Canada;
- biogas production from municipal solid and liquid waste, oil palm residues, and co-digestion of agricultural crops and residues and animal wastes;
- lignocellulosic crops in agricultural landscapes, with special attention to their place in sustainable landscape management and design; and
- bioenergy involving feedstock cultivation on pastures and grasslands, with special focus on sugarcane ethanol in Brazil.

These studies determined where opportunities lay, as well as barriers that needed to be overcome to realise the mobilisation potentials on a wider scale.

The project concluded that significant opportunities existed to reduce greenhouse gas emissions, increase domestic energy security, boost rural economies, and improve local environmental conditions through the deployment of sustainable bioenergy and bio-based product supply chains. There was currently a wide selection of possible feedstocks, a variety of conversion routes, and a number of different end products that could be produced at a range of scales. However, economic slowdown, low oil prices, lack of global political will, and lingering questions regarding land use change, timing of climate change benefits, and the overall sustainability of bioenergy production systems provided a challenging global context to speed the pace of investment. The study confirmed that feedstocks produced using logistically efficient production systems could be mobilised to make significant contributions to achieving global targets for bioenergy. At the same time, significant barriers to large-scale implementation existed in many regions. The mobilisation potential identified in the study would depend on both increases in supply chain efficiencies and profits, and strong policy support to increase stakeholder and investor confidence.

This project was, in a sense, a model for inter-Task collaboration and community-building involving experts in deriving novel solutions to complex problems and options for mitigation of climate change through significant bioenergy supply chain mobilisation. The results of the project have been widely disseminated, and continue to drive priorities for IEA Bioenergy RD&D in the 2016-2018 triennium. Written outputs to date are included in the attached list of Task 43 deliverables.

Conclusions and recommendations

The objective of Task 43 during the 2013-2015 triennium has been to "promote sound bioenergy development that was driven by well-informed decisions in business, governments and elsewhere". The Task has maintained a global scope and included commercial, near-commercial and promising production systems in agriculture and forestry. The Task has been primarily concerned with issues related to the linking of sustainable biomass feedstocks to energy markets, explicitly considering environmental and socioeconomic trade-offs and synergies among a variety of bio-based products, including blended feedstocks derived from a variety of feedstock production sectors.

The Task has sought to move the discussion beyond the simplistic bioenergy vs. food/fiber debate to address the bigger, more pertinent, question about how the increasing demands for food, fiber and bioenergy could be met in the future. Recognising the competition for input resources and alternative land uses, the Task has focused its work on investigating and communicating how dedicated biomass production could be sustainably expanded. Central in this work has been advancing the knowledge about how different systems for producing biomass feedstocks interact with food and fiber production; how to mitigate negative impacts and avoid irreversible resource degradation; and how to integrate bioenergy feedstock production systems into the agriculture and forestry landscapes so as to shape more sustainable agriculture and forestry production in tune with local and strategic needs.

It has been the ambition of Task 43 to promote a holistic perspective on bioenergy and land use, and to propose governance models that provide sound operating conditions for the agriculture and forestry sectors while addressing concerns about various risks associated with bioenergy. A primary driver of the work in the Task has been the desire to create competitive business cases that are efficient along the entire supply chain, from feedstock production to energy markets.

To this end, the inter-Task project on "Mobilizing sustainable bioenergy supply chains" was conducted successfully in the 2013-2015 triennium, as reported in the Success Stories section above. Task 43 also collaborated with other IEA Bioenergy Tasks and such external organisations as JRC, EEA, GBEP, IINAS, and UNEP on a series of events related to critical issues such as the timing of greenhouse gas mitigation benefits of forest-based bioenergy and the water-bioenergy nexus (see outputs summarised above), and has contributed to organising a series of trans-Atlantic trade events primarily focused on wood pellet trade.

However, it can be concluded that the expectations described in the introduction – that more favourable conditions for rational deployment of sustainable bioenergy systems would become establisheds – have not been fulfilled; during the 2013-2015 period there has been a continuous animated scientific, societal and political discussion concerning potential impacts of bioenergy on sustainable development. Opponents have continuously raised concerns over multiple risks, e.g., potential disruption to food security and rural livelihoods, greenhouse gas emissions and ecological impacts due to direct and indirect land use change, and displacement of small-scale farmers. Proponents on the other hand have pointed out the opportunities for new land use options and benefits such as employment creation, climate change mitigation, and reduced dependency on oil and natural gas.

Both sides in the debate face the challenge that they cannot refer to unequivocal support from science since there are considerable disagreements among scientists and other experts concerning bioenergy's contribution to energy, climate and other objectives. Often disagreements exist due to diverging views on how bioenergy systems should be evaluated relative to specific objectives, on uncertain baseline assumptions or on effectiveness of different regulations in guiding bioenergy development towards better fulfilment of the objectives.

Policy makers need to strike the proper balance between specific energy and food needs, and more broad social and economic development and environmental sustainability goals. This is a challenge fraught with uncertainties: we cannot know how and to what extent biodiverse life would be disturbed under different utilisation scenarios; and we do not know clearly whether or not social changes (e.g., diets, family formation) or international efforts to significantly alleviate poverty and hunger will succeed in enabling greater use of bioenergy of certain kinds and on certain scales. Risks embedded in these uncertainties are large.

When confronted with highly complex issues such as these, it is common to counsel adherence to the precautionary principle in actions and aspirations, and this principle plays a large role in shaping policy options. Accordingly, ambitions in the bioenergy area have been reformulated in ways that align policy makers with the side espousing application of the precautionary principle and governance of bioenergy has increasingly focused attention on risks as opposed to opportunities.

In parallel, there has been growing scientific activity as well as stakeholder interest in more holistic sustainable landscape management systems for the provision of biomass and other ecosystem services. Analytical methods and frameworks for assessing impacts on biodiversity and provision of ecosystem services are becoming more widely recognised and are also used in stakeholder collaboration processes associated with land use decisions. During the 2013-2015 triennium the Task has arranged events and

managed activities supporting progress in this area and intends to further engage in this development, which is considered critical for ensuring that the transition to a bio-based economy is supported by strategies for efficient use of biomass from sustainably managed landscapes. A crucial role for the Task will be to ensure that emerging frameworks promote the mobilisation of competitive bioenergy systems that are efficient along the entire supply chain, from feedstock production to energy markets.

In short, our judgment is that Task 43 has – together with other Tasks – made important contributions by providing science-based information and advice in support of well-informed decisions in business, governments and elsewhere. It is our expectation that the 2016-2018 triennium will also see animated debates and simplistic messages, but a growing awareness of the need for holistic perspectives as well with sustainable landscape management for multiple products and services becoming an increasingly strong paradigm. The Task aims to continuously offer science-based advice and alternative perspectives to balance and, as much as possible, to reconcile polarised assertions (negative and positive) about bioenergy systems, in general, and feedstock production in agriculture and forestry, in particular.

Attachments

A.1. Task business/planning meetings

2013

- Rotterdam, Netherlands, March 13 &15 (March 13: meeting, inter-task project "Mobilizing sustainable bioenergy supply chains", March 15: Task 43 business meeting)
- Copenhagen, Denmark, June 5: meeting, inter-task project "Mobilizing sustainable bioenergy supply chains"
- Tuheljske toplice near Zagreb, Croatia, October 2: Task 43 business meeting

2014

- Uppsala, Sweden, January 21-22: Task 43 planning meeting for activities related to carbon
- Copenhagen, Denmark, May 21-23: Task 43 business meeting and planning meetings in inter-task project "Mobilizing sustainable bioenergy supply chains"
- Brussels, Belgium, October 23-24: Task 43 business meeting and planning meeting

2015

- Dublin, Ireland, May 21-22: Task 43 business meeting and planning meeting for next triennium. Also planning meeting for the inter-task project "Mobilizing sustainable bioenergy supply chains"
- Berlin, Germany, Oct 29: Task 43 business meeting and end-of-triennium meeting

A.2. Participation in major events

This list is limited to events where Task 43 was involved as organiser or co-organiser.

2013

- Dissemination workshop (with Task 38 and Task 40): *How Can Sustainability Certification Support Bioenergy Markets?* at the World Biofuels Markets conference, Rotterdam, March 12
- 1-day conference session: *Governing water quality and quantity in bioenergy feedstock production* at the World Biofuels Markets conference, Rotterdam, March 14
- Workshop: *Developing a binding sustainability scheme for solid biomass for electricitiy and heat under the RED*, Arona, Italy, July 1-2 (organised by JRC and IINAS with support from T40 and T43)
- Half-day conference session: *Biomass energy markets – financing perspective* at COENEREGY 2013 – Sustainable Energy Finance and Investment Summit, Tuheljske toplice, Zagreb, Croatia, October 2-4
- Workshop: *The transatlantic trade in wood energy: a dialogue on sustainability standards*, Savannah, GA, USA, October 23-24 (organised in collaboration with The Pinchot Institute and Task 40)

2014

- *Bioenergy and water: Developing strategic priorities for sustainable outcomes*, joint workshop with UNEP, IINAS and Winrock International, Paris, France, Feb 21-22
- *Forests, bioenergy and climate change mitigation, joint workshop* with Task 38, Task 40, IINAS, EEA, JRC, Copenhagen, Denmark, May 19-20
- *Use of agricultural residues for energy, joint workshop* with JRC, the Scientific Engineering Centre "Biomass", and the Bioenergy Association of Ukraine
- *Forest Biomass Supply Chains: Practice, Economics, and Carbon Balance*, conference session organised by Swedish Task 43 NTL Gustaf Egnell at 24th IUFRO World Congress – Sustaining forests, sustaining people. The role for research. Salt Lake City, Utah, USA, Oct 5-11
- Through TL:s Berndes and Smith, the Task also contributed to the ExCo74 workshop *Bioenergy: Land use and mitigating iLUC*, Brussels, Belgium, Oct 23

2015

- *Mobilization of woody biomass for energy and industrial use: Smart logistics for forest residues, prunings and dedicated plantations.* Conference organised with INFRES, LogistEC, EuroPrunning, FAO, USDA-FS, AEBIOM, EUBIA, ITABIA, FederUnaCome. Rome, Italy, May 19
- *Examples of positive bioenergy and water relationships.* Workshop organised with GBEP-AG6, Chalmers Energy Area of Advance, and The Royal Swedish Academy of Agriculture and Forestry. Stockholm, Sweden, Aug 25-26
- *Biomass feedstocks for Energy markets.* Conference session at IEA Bioenergy Conference 2015. Berlin, Germany, Oct 27
- *Forests, bioenergy and climate change mitigation*, joint workshop with Task 38. Berlin, Germany, Oct 30

A.3. Webinars

- *The Transatlantic Trade in Wood for Energy*, February 27, 2014, webinar following the ExCo sponsored event The Transatlantic Trade in Wood for Energy: A Dialogue on Sustainability Standards, in Savannah, USA, Oct 2013
- *Assessment of the Risks Associated with Certain Biomass Fuel Sourcing Scenarios -- Canadian Stakeholder feedback to the DECC North American Wood Pellet Survey: An opportunity to discuss key findings tested with forestry experts*, organised with Canadian Institute of Forestry and UK Department of Energy and Climate Change (DECC), 2015
- *Joint Task 38-Task 43 Webinar Forest Biomass – Climate and Wider Environmental Issues*, organised with Bioenergy Australia, 2015

A.4. Task 43 Reports

The reports are available from the Task 43 website.

de Jong, J., Akselsson, C., Berglund, H., Egnell, G., Gerhardt, K., Lönnberg, L., Olsson, B., von Stedingk, H. 2014. Consequences of an Increased Extraction of Forest Biofuel in Sweden. IEA Bioenergy Task43 TR2014:01

Graudal, L., Nielsen, Schou, E., Jellesmark Thorsen, B., Hansen, J.K., Bentsen, N.B., Joha, V.K. (2016). The contribution of Danish forestry to increase wood production and offset climate change 2010-2100. IEA Bioenergy Task 43 TR2016:01

Ikonen, T., Asikainen, A. (2013). Economic Sustainability of Biomass Feedstock Supply. IEA Bioenergy Task43 TR2013:01

Neary, D.G. (2015). Best Practices Guidelines for Managing Water in Bioenergy Feedstock Production. IEA Bioenergy Task 43 Report 2015:02

Nordborg, M., Cederberg, C., Berndes, G. (2015). Modeling potential freshwater ecotoxicity impacts due to pesticide use in biofuel feedstock production: the cases of maize, rapeseed, Salix, soybean, sugarcane and wheat. IEA Bioenergy Task 43 Report TR2015:04

Richards, K.M., Pearce, C., Domac, J., White, W., Elbe, S., Hohle, E.E. (2015). Fuel poverty and bioenergy – discussion paper. IEA Bioenergy Task 43 Report TR2015:03

Schweinle, J., Rödl A., Börjesson, P., Neary, D.G., Langevel J.W.A., Berndes, G., Cowie, A., Ahlgren, S., Margni, M., Gaudreault, C., Verschuyl, J., Wigley, T.B., Vice, K., Titus, B. (2015). Assessing the Environmental Performance of Biomass Supply Chains. IEA Bioenergy Task 43 Report TR2015:01

Snowdon, K., McIvor, I., Nicholas, I. (2013). Short rotation coppice with willow in New Zealand. IEA Bioenergy Task 43 Report PR2013:01

A.5. Other Task and ExCo Report

Task 43 Progress report for ExCo73, Copenhagen, Denmark, May 2014

Task 43 Progress report for ExCo74, Brussels, Belgium, October 2014

Task 43 Progress report for ExCo75, Dublin, Ireland, May 2015

Task 43 Progress report for ExCo76, Berlin, Germany, October 2015

Reports from Inter-Task project Monitoring sustainability certification of bioenergy (available at the Task 40 website):

- Task 1 – Examining sustainability certification of bioenergy
- Task 2 – Survey on governance and certification of sustainable biomass and bioenergy
- Task 3 – Impacts of sustainability certification on bioenergy markets and trade
- Task 4 – Recommendations for improvement of sustainability certified markets

On the timing of GHG mitigation benefits of forest-based bioenergy. Task 38-43 collaboration to produce an ExCo state-of-the-art report on the topic. IEA Bioenergy: ExCo: 2013:04.

Forests, bioenergy and climate change mitigation. Workshop Statement from the workshop organised by Task 38, Task 40, Task 43, IINAS, EEA, JRC in Copenhagen, Denmark, May 19-20, 2014. Available at the Task 38 website

Mobilizing Sustainable Bioenergy Supply Chains. Inter-Task Project Synthesis Report. IEA Bioenergy ExCo: 2015:04

Science-policy interface on issues of environmental sustainability of forest bioenergy. Strategic discussion paper from the workshop organised by IEA Bioenergy Task 40, Task 43 and Pinchot Institute. IEA Bioenergy ExCo:2013:03

Examples of Positive Bioenergy and Water Relationships. Outcome report from the work in 2015 in GBEP AG6 – Bioenergy and Water. Joint publication GBEP and IEA Bioenergy, 2016. Available from www.ieabioenergy.com/publications/examples-of-positive-bioenergy-and-water-relationships/

A.6. Books

Lund,P., Byrne, J., Berndes, G., Vasolos, I. (Eds.) (2016). *Advances in bioenergy – the sustainablity challenge*. Wiley & Sons. Ltd. The book includes 13 chapters involving authors from Task 43.

Thiffault, E., Berndes, G., Junginger, M., Saddler, J., Smith, T. (Eds.) (2016). *Mobilisation of Forest Bioenergy in the Boreal and Temperate Biomes*. Elsevier. (in press)

A.7. Publications in Wiley Interdisciplinary Reviews – Energy and Environment

The list restricted to contributions from Task 43 associates and publications associated with Task 43 activities. T43 in addition has editorial responsibility

Cintas, O., Berndes, G., Cowie, A. L., Egnell, G., Holmström, H., Ågren, G. I. (2015). The climate effect of increased forest bioenergy use in Sweden: evaluation at different spatial and temporal scales. WIREs Energy Environ. doi: 10.1002/wene.178

Englund, O., Berndes, G. (2014). How do sustainability standards consider biodiversity? WIREs Energy Environ. 2015, 4: 26-50. doi: 10.1002/wene.118

Garg, K.K., Wani, S.P., Rao A.V.R.K. (2013). Crop coefficients of *Jatropha* (*Jatropha curcas*) and *Pongamia* (Pongamia pinnata) using water balance approach. WIREs Energy Environ. 2014, 3: 301-309. doi: 10.1002/wene.88

Gaudreault, C., Wigley, T.B., Margni, M., Verschuyl, J., Vice, K., Titus, B. (2016). Addressing Biodiversity Impacts of Land Use in Life Cycle Assessment of Forest Biomass Harvesting. WIREs Energy Environ. 2016. doi: 10.1002/wene.211

Gusciute, E., Devlin, G., Murphy, F., McDonnell, K. (2014). Transport sector in Ireland: can 2020 national policy targets drive indigenous biofuel production to success?. WIREs Energy Environ. 2014, 3: 310-322. doi: 10.1002/wene.84

Hall, P. (2013). Bioenergy options for New Zealand: key findings from five studies. WIREs Energy Environ. 2013, 2: 587-601. doi: 10.1002/wene.60

Neary, D.G. (2013). Best management practices for forest bioenergy programmes. WIREs Energy Environ. 2013, 2: 614-632. doi: 10.1002/wene.77

Stupak, I., Joudrey, J., Smith, C.T., Pelkmans, L., Chum, H., Cowie, A., Englund, O., Goh, C.S., Junginger, M. (2016). A global survey of stakeholder views and experiences for systems needed to effectively and efficiently govern sustainability of bioenergy. WIREs Energy Environ 2016, 5:89-118. doi: 10.1002/wene.166

Stupak, I., Raulund-Rasmussen, K. (2016). Historical, ecological, and governance aspects of intensive forest biomass harvesting in Denmark. WIREs Energy Environ. 2016. doi: 10.1002/wene.206

Talbot, B., Helmer, B. (2014). Performance of small scale straw to heat supply chains in Norway. WIREs Energy Environ. 2014, 3: 400-407. doi: 10.1002/wene.107

Thiffault, E., Bechard, A., Pare, D., D. Allen, D. (2014). Recovery rate of harvest residues for bioenergy in boreal and temperate forests: A review. WIREs Energy Environ. 2014. doi: 10.1002/wene.157

Walter, A., Galdos, M.V., Scarpare, F.V., Leal, M.R.L.V., Seabra, J.E.A., Cunha, M.P., Picoli, M.C.A., Oliveira, C.O.F. (2014). Brazilian sugarcane ethanol: developments so far and challenges for the future. WIREs Energy Environ. 2014, 3: 70-92. doi: 10.1002/wene.87

A.8. Selected other conference papers and publications

Only including publications directly associated with Task 43 activities.

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A.9. Collaboration with other Tasks within IEA Bioenergy

Task 43 collaborated with Task 38 and 40 in the finalisation and subsequent dissemination of results in the inter-task project proposal *Monitoring Sustainability Certification of Bioenergy*

Task 43 collaborated with Task 38 and Task 40 in the organisation of the workshop *Forests, bioenergy and climate change mitigation*

Task 43 collaborated with several other Tasks in the inter-Task project *Mobilizing Sustainable Bioenergy Supply Chains* which runs during the period 2013-2015 and is coordinated by Task 43

A.10. Collaboration with other bodies outside of IEA Bioenergy

This includes for example other Implementing Agreements and other organisations.

Bioenergy Australia

- Webinar (with Task 38)

Canadian Institute of Forestry/Institut forestier du Canada (CIF/IFC)

- Coordination of Canada's involvement in Task 43 for 2013 2015
- Dissemination

Chalmers Energy Area of Advance

- Workshop and associated publications

EC – Joint Research Center (JRC)

- Workshop and associated publications

European Environment Agency (EEA)

- Workshop and associated publications

Focali

- Policy Brief, dissemination

Food and Agriculture Organization of the United Nations (FAO)

- 1-day conference (other collaborators in this conference: INFRES, LogistEC, EuroPrunning, USDA-FS, AEBIOM, EUBIA, ITABIA, FederUnaCome).

Global Bioenergy Partnership (GBEP)

- Activities within GBEP AG6 – Bioenergy and Water

International Institute for Sustainability Analysis and Strategy (IINAS)

- Workshop and associated publications

Pinchot Institute

- Workshop with study tour and webinar

Royal Swedish Academy of Agriculture and Forestry (KSLA)

- Workshop and associated dissemination

Stockholm International Water Institute (SIWI)

- Policy Brief

UK Department of Energy and Climate Change (DECC)

- Webinar

United Nations Environment Progremme (UNEP)

- Workshop and associated dissemination

Winrock Institute

- Workshop and associated dissemination

A.11 Industry participation

This section answers the question: how was the industry involved in the Task activities? How did it influence the work carried out by the Task? Which industries participated and what activities did they participate in?

Industry involvement has taken place indirectly via NTLs engaging with industry in their normal work capacity. Many Task 43 NTLs and associates are for example involved with the development of sustainablity certification and standards and this provides plenty of opportunities for interaction with industry where one can provide information about Task reports and events and bring the views and perspectives of industry for consideration in the planning of Task work.

Industry is also involved in Task events, such as the recent dissemination event within the inter- Task project "Monitoring sustainabilty certification of bioenergy" at the World Biofuel Markets conference in Rotterdam, and events promoting dialougue among a range of stakeholders, with an example being the workshop and field tour organised in Savannah in Oct 2013.

Acknowledgements

This report was produced with detailed input from all Task Leaders and their colleagues and is gratefully acknowledged.

Luc Pelkmans, the Technical Coordinator of IEA Bioenergy, prepared the introduction to the report. Pearse Buckley, the IEA Bioenergy Secretary, facilitated the editorial process and arranged the final design and production.

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Further Information

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