

Annual Report 2010

IEA Bioenergy



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



Dr Arthur Wellinger (left) the new Technical Coordinator with Dr Adam Brown, who has moved to the Renewable Energy Division at IEA Headquarters in Paris.

To: IEA Headquarters, Paris

IEA BIOENERGY ANNUAL REPORT 2010

Under the IEA Framework for International Energy Technology Cooperation the Executive Committee of each Implementing Agreement must produce an Annual report for IEA Headquarters.

This document contains the report of the IEA Bioenergy Executive Committee for 2010. This year, we have presented a special feature 'Algal Biofuels Status and Prospects' prepared by Task 39.

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

Josef Spitzer
Chairman

John Tustin
Secretary

Algal Biofuels Status and Prospects	04
International Energy Agency	40
Introducing IEA Bioenergy	41
Progress Reports	
1. The Executive Committee	43
2. Progress in 2010 in the Tasks	53
Task 29: Socio-economic Drivers in Implementing Bioenergy Projects	53
Task 32: Biomass Combustion and Co-firing	56
Task 33: Thermal Gasification of Biomass	60
Task 34: Pyrolysis of Biomass	66
Task 36: Integrating Energy Recovery into Solid Waste Management	68
Task 37: Energy from Biogas	73
Task 38: Greenhouse Gas Balances of Biomass and Bioenergy Systems	76
Task 39: Commercialising Liquid Biofuels from Biomass	80
Task 40: Sustainable International Bioenergy Trade – Securing Supply and Demand	85
Task 41: Bioenergy Systems Analysis	91
Task 42: Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass	93
Task 43: Biomass Feedstocks for Energy Markets	98
Appendix 1: Task Participation in 2010	102
Appendix 2: Budget in 2010: Summary Tables	103
Appendix 3: Contracting Parties	105
Appendix 4: List of Reports and Publications	106
Appendix 5: Key Participants in Each Task	122
Appendix 6: Contact List: Operating Agents and Task Leaders	131
Appendix 7: Contact List: ExCo Members and Alternate Members	136
Appendix 8: Some Useful Addresses	141

Editor: John Tustin, IEA Bioenergy Secretary, Rotorua, New Zealand.

Design and layout: John Tustin; and Devcich Design, Tauranga, New Zealand.

Preparation of feature article: Jana Hanover, John Benemann, Jim McMillan and Jack Sadler

Preparation of text and tables: Danielle Rickard, Rotorua, New Zealand.

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

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

Algal Biofuels Status and Prospects

This feature article provides an overview of algal biofuels production. It was prepared by Jana Hanova¹, John Benemann², Jim McMillan³, and Jack Saddler⁴.

Summary of Findings

- Algal biofuels and the associated processing technologies have numerous intriguing and unique characteristics that merit further research, development, and demonstration investments.
- Microalgal oil-based biofuels are presently at the 'proof of concept' or pre-commercial stages of development, despite some overly enthusiastic projections on the cost-effectiveness and imminent production volumes of algal-based biofuels.
- There are multiple potential algae production techniques but some routes are more plausible than others. Studies consistently find that photobioreactor costs will greatly exceed those of raceway pond algae production facilities.
- Aside from the currently high algal oil production and upgrading costs, the most significant limiting factors affecting algal biofuels are those imposed by the need for climatically favourable locations with suitable land, water, and CO₂ resources.
- Meaningful estimates of the potential sustainable production volumes of algal biofuels worldwide are difficult to develop at present. However, algal biofuels are unlikely to be able to displace a large fraction of current petroleum fossil fuel usage.

Introduction

The bioenergy and biofuels industry has experienced rapid growth over the past few years. The use of liquid biofuels is growing in all regions of the populated world, with total world production in 2008 estimated to be roughly 90 gigalitres per year and growing. This represents about 3.5% of fossil transportation fuels use on a volumetric basis and somewhat less on an energy basis (Energy Information Agency, 2010)⁵. For example, 4% of the EU's transportation fuels are now biofuels, and between 2008 and 2009 biofuel use grew by 19% - although growth has slowed in the last year due to supply and sustainability issues (EurObserver, 2010).

¹IEA Bioenergy Task 39 Coordinator, UBC, Vancouver, BC, Canada.

²Benemann Associates, Walnut Creek, CA, USA.

³IEA Bioenergy Task 39 Co-leader, NREL, Golden, CO, USA.

⁴IEA Bioenergy Task 39 Co-leader, UBC, Vancouver, BC, Canada.

⁵World annual production of petroleum is 4900 gigalitres, with just over half being used for transportation.

Government policies are particularly influential in shaping the liquid transportation biofuels industry. For example, in OECD countries, key biofuels drivers include market share mandates and subsidies (UN FAO, 2010). Biofuels often receive subsidies due to their environmental, energy security or socio-economic attributes. However, despite highly publicised policy support for renewable alternatives, the International Energy Agency (IEA) reports that global annual government subsidies for fossil fuels reached US\$557 bn/yr in 2008 – dwarfing the relatively modest US\$43 bn/year in government support for renewables (IEA, OPEC, OECD, World Bank Joint Report, 2010).

Within this framework, algal biofuels have been suggested as possibly playing an increasing role in future alternative energy/transportation fuel scenarios because of their apparently inexpensive and basic requirements of sunlight, CO₂ and low grade water. However, there continues to be considerable debate about the technical and engineering challenges that have yet to be resolved, the overall economics of any of the various algal biofuel options and the overall sustainability of any of the proposed processes. This review hopes to provide a brief background on this topic while summarising the findings coming out of the IEA Bioenergy Algal Biofuels workshop and the recently published report commissioned by IEA Bioenergy Task 39 on the technical and economic prospects of commercialising algal biofuels.

Algal biofuels can be regarded as a promising route to the production of future liquid transportation fuels as a typical process will exhibit several attractive features, including:

- No need to compete for access to arable land.
- Processes likely to exhibit good productivity levels when compared to most conventional (land-based) biomass feedstocks.
- Production of high grade oils that can be converted to petroleum fuel substitutes (i.e. diesel and aviation fuel).
- Algae can be grown on lower grade water (i.e. seawater, brackish waters and wastewaters).
- Likely production of higher value co-products.

As summarised in Figure 1, the overall concept for producing biofuels from oil-containing algal strains will involve similar process steps to those used for other biofuels. Typically, the algae will be cultivated in open ponds or closed photobioreactors (PBRs) to achieve a high oil content, harvested, extracted and then converted into a suitable biofuel. The raw algal oil can then be either converted to biodiesel (monoalkylester), green diesel, jet fuel or other diesel type fuels. Usually the process wastewater and growth nutrients are recycled as much as possible, depending on the nature of the process, and the extracted residual algal cell mass can be sold as animal feed or used to produce additional energy or chemical products.



Figure 1. Simplified schematic diagram of major steps involved in producing algal-derived liquid biofuels.

Like all other conventional and alternative energy sources, algal-based biofuels also have strengths as well as limitations and trade-offs. One significant strength is that the production of algal biofuels has been demonstrated to be technically feasible in countries such as Australia, but at a scale currently used to produce higher value 'nutraceuticals'. However, the algal biofuels industry itself is still at an early, pre-commercial stage of development and most economic analyses have indicated that algal biofuels will remain economically challenging to produce at a commercial scale (USDOE, 2010). As this report will try to describe in more detail, every part of the value chain requires additional investment and significant RD&D advances before the 'algal biofuels' industry can realise its full potential. While the production of algal biofuels is technically feasible, achieving the high levels of algal biomass productivity and oil content required to make biofuel production economically attractive will take some time. For example, as is being currently demonstrated at various locations around the world, the scale-up of algal-based biofuels technologies to pilot and larger demonstration facilities requires significant scientific, engineering, logistical, and economic hurdles (USDOE, 2010).

This review discusses the issues and challenges to be resolved before large volume, low cost algal biofuels can be economically realised.

Historical Background

Algal-based biofuels were first discussed in the 1950s during the pioneering algal mass culture project that cultivated *Chlorella* using prototype PBRs on a MIT rooftop (Burlingame, 1953). The early experimental work and development of conceptual engineering processes to produce methane from algae was initially carried out at the University of California, Berkeley (Oswald and Golueke, 1960). The oil/petroleum supply crisis of the 1970s led to the first concerted effort to develop algal biofuels technology (Benemann *et al.*, 1980) and this initial research foray was followed by a larger R&D programme launched by the US Department of Energy in 1980 which focused on the development of microalgal oil. This 'Aquatic Species Program' (ASP) operated until 1996 when, because of the continued low price of oil, the algal biofuel R&D programme was wound down.

It should be recognised that, during these pioneering times, the ASP supported dozens of projects that resulted in significant advances being made in the science and engineering of algal biofuels production. A detailed 'close out' report that summarised the impact of the programme made several recommendations for any future development of algal biofuel production (Sheehan *et al.*, 1998). These included:

- A focus on basic biology and the tools of plant genetic engineering to maximise photosynthetic efficiency.
- The development of selected native strains for specific sites and for process optimisation and improvements.
- Policies which recognised, initially, that microalgae-derived biofuels cannot compete with cheap petroleum; (i.e. initial production may require policies such as carbon taxes or other incentives).

- Consideration of a strategic approach such as facilitating near term technology deployment, i.e. by combining algal-based biofuels production with wastewater treatment.

These recommendations remain highly applicable today.

The Potential of Algal Biofuels

Current biofuels such as seed oil-based biodiesel and sugar- and starch-based bioethanol are used primarily to offset petroleum-derived transportation fuels. However, these existing biofuels also have their limitations. For example, some traditional biofuel feedstocks compete for food/feed uses in certain regions of the world (UN FAO, 2008). Some biofuels, such as ethanol and biodiesel, have lower energy densities compared to the petroleum-based fuels that they currently displace or are co-blended with (Table 1). Vegetable oils (triglycerides), the main source for biodiesel, can be converted in specially equipped refineries to high energy-density fuels, including aviation fuels. However, from a refiner’s perspective, the ideal feedstock would have a lower oxygen content and be amenable to processing using proven commercial petroleum refining operations such as thermal or catalytic cracking, catalytic hydrocracking and hydrotreating, and catalytic structural isomerisation (USDOE, 2010). With a sufficiently low oxygen content, the feedstock would be considered to be interchangeable with petroleum and could be used for the production of traditional hydrocarbon fuels without disruptive changes in processes or infrastructure (USDOE, 2010).

Table 1. Energy density of fuels (Lower Heating Values - LHVs).

Fuel	Energy Density (MJ/Litre)
Ethanol	21.1
Gasoline	34.2
Biodiesel	33.0
Diesel	37.3
FT Synfuel	33.6
Jet A/Jet A-1	34.9

Source: Bioenergy Feedstock Information Network 2010, Hemighaus, 2010.

The production of high-quality energy-dense transportation fuels from algae has already been shown to be technically possible at a demonstration/small commercial scale (USDOE, 2010). However, continued RD&D efforts need to address the substantial inefficiencies and high costs which currently restrict algal biofuels from becoming an economically competitive alternative to conventional fuels and other biofuels.

Algal oil-derived biofuels offer the potential to produce substantial amounts of energy dense liquid fuels, such as required for jet aircraft, without directly competing with food/feed oil seed crops. Microalgae are currently the only known biofuel feedstock option potentially capable of directly producing significant amounts of high grade fuels such as

aviation fuel. One of the main drivers in the development of microalgal diesel fuels is the higher photosynthetic efficiency of microalgae when compared to conventional land based crops (Table 2), hence, the potentially higher productivities per unit area that have been claimed (Darzins *et al.*, 2010). A few microalgae species (e.g. *Botryococcus braunii*) naturally produce large amounts of hydrocarbons. Other engineered strains have also been shown to produce several potential new biofuel molecules, with some genetically modified organisms able to excrete fatty acids and hydrocarbons. Algae are also the only known plausible biofuel production system that can be grown in the sea and brackish water.

Table 2. Potential oil yields.

Crops	Oil yield (litres/ha/yr)
Soybean	450
Camelina	560
Sunflower	955
Jatropha	1,890
Oil palm	5,940
Algae – Demonstrated	3,800 ⁶
Algae – Potential	50,800 ⁷

Source: Darzins *et al.*, 2010.

Despite these positive attributes, there are still several, major technical hurdles to overcome before algal biofuels can demonstrate their potential to deliver on the promise of high-density sustainable fuels. Like vegetable oils, algal oils typically have a substantial oxygen content which not only reduces their energy content but also causes stability and corrosion complications.

Nevertheless, the promise of algal biofuels is not based solely on the prospect of meeting particular biofuel specifications or very high productivities. Rather, it is their potential for developing an entirely new, and possibly significant, source of biofuels that can help move human society towards a sustainable energy future. It is well recognised that biofuels, individually or even in aggregate, cannot replace even current demands, let alone projected growth, for liquid transportation fuels. Thus all possible biofuel resource options must be explored and, if warranted, developed.

Sustainability of Algal Biofuels

Worldwide, while many countries look for an alternative to fossil fuels for economic and energy security reasons, support for biofuels is also being driven by the promise of biofuels being both environmentally and socially sustainable. While sustainability

⁶Demonstrated at Roswell, USA. The following parameters are used: productivity at 10 g/m²/day, 15% lipid content, 330 days of operation, 70% of land dedicated to ponds.

⁷Estimated yields (Darzins *et al.* 2010). The following parameters are used: productivity at 50 g/m²/day, 40% lipid content, 330 days of operation, 70% of land dedicated to ponds.

criteria and assessment guidelines are still under development, the generally accepted principles of sustainability include:

- The GHG balance of the biofuel production chain must be substantially, not just marginally, positive.
- Biomass production must not occur at the expense of existing carbon sinks (in vegetation and soils) and this must be accounted for in GHG balances (e.g. Life Cycle Analysis, LCA).
- Biomass production should not compromise the food supply and existing local business activities (i.e. other local bioenergy supplies, medicines, building materials, higher value uses of land, etc).
- Biomass production should have a neutral or net positive impact on biodiversity.
- Soil quality must be retained or improved.
- Ground water resources must not be depleted and water quality should be maintained or improved.
- Air quality must be maintained or improved.
- Production and processing of biomass should contribute to local prosperity and benefit the social well-being of the local population and employees.

Proponents of algal biofuels claim that algal biofuels production systems are environmentally superior to terrestrial biofuels production systems (Chisti, 2007) because of their projected higher productivity levels. One of the main attractions is that algal processes can utilise non-arable land and water resources that are not used in crop production (e.g. sea, brackish and waste waters). In the absence of an algal biofuels industry any sustainability analysis must be based on assumptions, including the proposed productivity (metric tonnes of dry algal biomass per hectare per year, usually extrapolated from grams per square metre per day data) through to the projected oil content of the algae (which can range from about 10% to over 50% of dry weight, if all oils, not just triglycerides, are counted).

As has been shown in other biofuel sustainability studies, even seemingly small changes in these types of assumptions can lead to quite different conclusions. For example, if there was a need to double the mixing velocities in algal cultivation PBRs or open ponds to achieve good production, this could increase the power required for mixing by eight-fold. This type of 'minor' change could potentially tip the energy balance of the overall process from energy producing to energy consuming. Thus, it is not surprising that many recent analyses (Lardon *et al.*, 2009, Campbell *et al.*, 2009, Clarens *et al.*, 2010; Stephenson *et al.*, 2010) come to remarkably different conclusions, as the authors have each used different assumptions. For example, Stephenson *et al.* (2010), noted that a major uncertainty in the economics of operating PBRs is the mixing energy required. This parameter has not been documented in any great detail and it is recognised that it will vary with the type of algae and PBR used. Thus, it has been difficult to do any credible LCA analyses as these studies should be based on the actual engineering/energy used and the exact configuration of a particular process and then developed in enough detail to allow mass and energy balance calculations. As will be described later in the report, this type of information has been difficult to obtain.

Algal Biofuels Production Processes

In the absence of many commercial-scale or even demonstration-scale algal biofuel plants, conceptual system designs and LCA scenarios have been developed by extrapolating projections based on current commercial, 'nutraceutical' algal cultivation. These future engineering designs and biological processes are based on the quantitative goals of current R&D efforts, which should significantly increase algal biomass productivities. The basic concept for an algal biofuel production process was first formulated, experimentally studied, and analysed in the 1950s by Oswald and Golueke (1960). Their basic design evolved through several refinements, including the production of both algal oil and methane (Benemann and Oswald, 1996). This pioneering work has largely been the basis for many of the subsequent process analyses that have been carried out (Darzins *et al.*, 2010; Lundquist *et al.*, 2010).

An overall process schematic, showing inputs and outputs, is described in Figure 2. It should be noted that several scenarios were based on coal-fired power plants providing flue-gas CO₂, though many other sources of CO₂ can also be used.

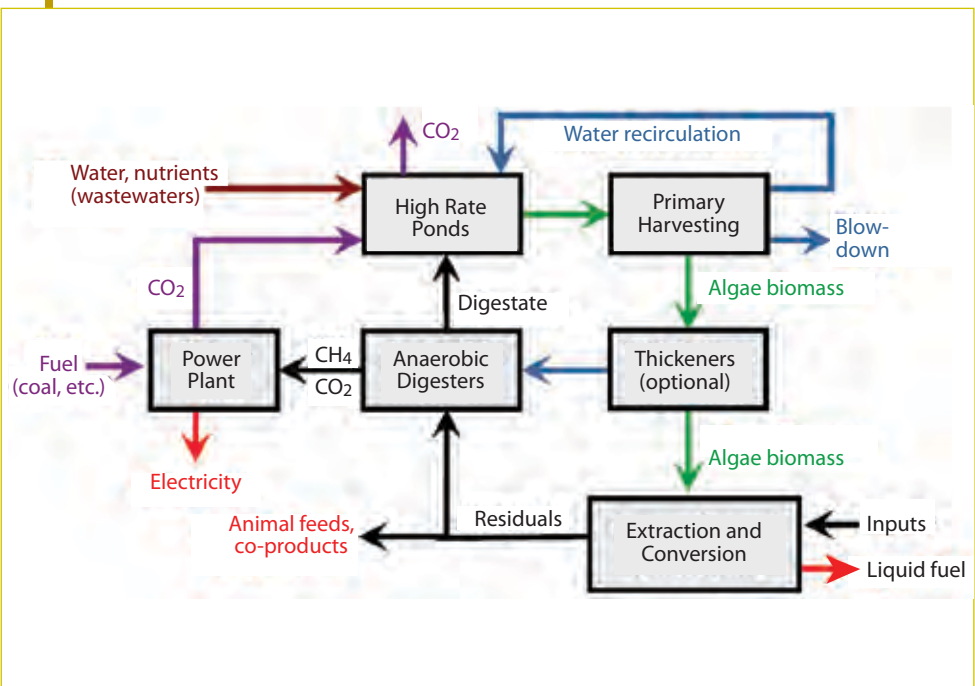


Figure 2: Generalised schematic of algae biofuels production (based on Oswald and Golueke, 1960, as further developed to include oil in addition to methane production (Benemann and Oswald, 1996, Lundquist *et al.*, 2010)). This is a flexible process in inputs (e.g. wastewater or agricultural fertilisers, etc.) and outputs (oil and methane, or oil and animal feeds, or methane, etc). The same general schematic is applicable to PBRs, but the quoted studies refer only to raceway ponds. Note: for alternative proposed processes using genetically modified algae, see text.

Some of these preliminary engineering and economic feasibility analyses projected favourable LCAs for net greenhouse gas emissions during algal biofuels production (Campbell *et al.*, 2009). However, as indicated earlier, these analyses were largely based on many untested assumptions. These include non-problematic large increases in both the size of the individual ponds and the scale of production (particularly in the case of photobioreactors), achieving and sustaining much higher productivities, both for algal biomass and algal oil, as well as the ability to cultivate microalgae in the face of potential invasions by wild strains, grazers, infectious fungi, lytic bacteria, viruses, etc., (particularly in the case of open ponds). The assumption that low-cost harvesting technology will be available is also frequently made. Although encouraging progress has been made in the area of algae mass culture in open raceway ponds, the actual commercial experience on which the basic process is founded is quite limited. With regard to scale and costs and, most importantly, the number of microalgae species currently being cultivated at appreciable scale, there are only 4-10 plants operating globally, even including experimental raceway ponds of above 100 m² which typically only operate for part of a year.

Thus any claims of the superior productivity of algal production systems when compared to terrestrial crops have to be considered in terms of the location of either system. Even assuming that a very high productivity of 100 mt/ha/yr with a 40% oil content can be achieved in the future, comparisons based solely on productivity will likely ignore one or another key parameter, such as capital and operating costs, water or energy demands, etc. For example, algae cultivation should be able to achieve higher productivities and release less nutrient runoff and would therefore result in better land use and lower eutrophication potential than terrestrial crops. However, some LCA analyses claim that terrestrial crops require lower energy use and have lower greenhouse gas (GHG) emissions and water use than algal cultivation.

Most algal LCA analyses or comparisons are based on process assumptions that are not derived from operational experience. Thus, any conclusions must be considered tentative, at best. One fundamental issue is whether any fossil CO₂ should be used in microalgae biofuels production, as by definition these would not be sustainable. These types of concerns have resulted in the European Commission disallowing fossil CO₂ to be used as the feedstock for the Seventh Framework Program (FP7) 10 ha algal cultivation pilot plants (Maniatis, 2010). However, the FP7 call for proposals did include both closed photobioreactors and open ponds as potential production systems. Funding for FP7 projects were awarded to consortia representing both approaches.

It should also be noted that algal biofuel technologies face significant challenges in resolving 'sustainability' issues in the following areas:

- Reducing the use of external energy inputs, fossil and renewable, required to operate the processes.
- The generally much higher fertiliser use by algae (when compared to land based crops) and the need to recycle or recover nutrients from the feed or co-products.
- Photobioreactors generally have a higher GHG footprint than ponds due to materials and energy use.

- If drying the harvested algal biomass is required, only solar drying or waste heat would be practical. Wet algae biomass processing is preferred but is more challenging.
- Algae, like other biofuels, generally have higher land use and eutrophication impacts than do other energy sources.
- Raceway ponds generally show a significantly better overall environmental performance than do photobioreactors, but there are still many R&D challenges in developing the technology for biofuels production.

Despite these significant challenges and by making reasonable (though optimistic) assumptions about progress through continued RD&D efforts and through obvious benefits such as their cultivation on non-arable land and saline water and/or wastewater resources not competing with agriculture, it should be possible to produce algal biofuels in a sustainable manner.

More recently, alternative processes other than the 'traditional' process described in Figure 1 for microalgae biofuels production have been suggested. These alternative schemes propose using genetically modified algae (GMA) to continuously produce and excrete biofuels, such as ethanol, fatty acids, hydrocarbons, butanol, etc. In these approaches the algae would divert all photosynthesis to biofuels production after an initial growth period. One difficulty with this concept is that competing and/or contaminating bacterial degradation of these types of excreted products would be problematic and unavoidable, even in relatively contained PBR systems. An alternative approach, extracting the oil from the algae with solvents without damaging the cells, has also been suggested. This would allow their recycling to the growth system for more oil production.

Environmental performance of any of these processes is likely to vary as the technology progresses along the experience curve. It will also be heavily influenced by regional and local conditions. Technologies must also include favourable social outcomes and include all sustainability criteria beyond the obvious energy balance and GHG emissions. Other key parameters will include water quantity and quality, land use, consumption of phosphates and other mined fertilisers.

Algal Cultivation

Current Production Levels

Commercial microalgae cultivation has been developing for fifty years, primarily for the production of human nutritional supplements (Becker, 2004). Algae have also been used for wastewater treatment, primarily due to their ability to provide the dissolved oxygen required by bacteria to break down organics in the wastes. Algae also have the ability to accumulate heavy metals and metabolise toxic compounds. Thus, microalgae are often used as tertiary water filtration systems (Oswald, 1988). Other smaller-scale commercial applications of microalgae include the production of feeds for aquaculture facilities.

Currently, most commercial microalgae production systems use open ponds (Benemann, 2008) or shallow raceways where the water is circulated, typically by paddlewheel devices (Spolaore *et al.*, 2006). Most recent R&D work has focused on photobioreactors, or closed tubular chambers, that may provide better process control and higher biomass concentrations, while reducing evaporation and CO₂ losses (Janssen *et al.*, 2003; Wijffles and Barbosa, 2010).

The commercial (>1 ha) production of algal biomass is currently limited to four species, *Spirulina* (*Arthrospira platensis*), *Chlorella vulgaris*, *Dunaliella salina*, and *Haematococcus pluvialis*, with a current total worldwide annual production of ~10,000 tonnes of algal biomass/year, of which ~99% is produced in open ponds. Currently, closed photobioreactor production systems are commercially used by only two plants, one in Germany (in a greenhouse) and one in Israel (in the open air), both using tubular designs. Presently there are no meaningful amounts of microalgal biofuels produced commercially using ponds or photobioreactors (Darzins *et al.*, 2010). In an alternative, fermentation approach, some companies produce algal biomass and fuels using facilities where the algae are grown on sugars, in the dark, in closed vessels. This type of process is currently used commercially to produce several thousand tonnes of algal oils used mainly in infant nutrition. These same producers are also developing a market for specialty animal feeds, with one company recently producing several thousand gallons of biodiesel.

Algae Types and Cultivation Pathways

Microalgae: Microalgae are small free-living photosynthetic micro-organisms that typically grow as very dilute (<1g/L) cultures in suspension. They can be found in a variety of aquatic environments, including fresh water, brackish, marine and even hypersaline waters (Falkowski and Raven, 2007; Darzins *et al.*, 2010). Microalgae also have a very low standing biomass (<100g/m²) and essentially require daily harvesting from large volumes of liquid. For microalgae to be grown at high productivity levels they require climatic conditions with a long cultivation season (as defined by temperature and insolation), nutrients, and a source of CO₂ (from power plant flue gases, biogas or ethanol plants, etc., see discussion in Section 'Requirements of Algae Productivity').

Key summary points about microalgae are:

- While microalgae make up only 0.2% of global standing biomass, they are claimed to account for approximately 50% of the total global fixed organic carbon generated through photosynthesis (Field *et al.*, 1998).
- They grow rapidly and can achieve a higher solar conversion efficiency than can most terrestrial plants.
- They must be harvested batch-wise or continuously year round, for as long as insolation and temperature allow, ensuring good productivity, profitability and a net energy yielding operation.
- Production can be located on non-productive, non-arable land, using water not suited for crops.
- Microalgae require an enriched source of CO₂ that must be piped and transferred into the ponds.

It is recognised that, as microalgae do not need to generate the elaborate support and reproductive structures found in macroalgae and most terrestrial plants, they can convert more of the solar energy they capture into algal biomass (Darzins *et al.*, 2010). Microalgae cultures typically convert 1-2% of the total solar incident radiation into biomass, but peak solar conversion efficiencies can be as high as 3-4% and theoretical efficiencies close to 10% have been claimed (Benemann *et al.*, 1980; Weyer *et al.*, 2010). By comparison, terrestrial crops have generally lower photosynthetic conversion efficiencies, although sugar cane, perhaps the most productive of all terrestrial crops, has a photosynthetic efficiency similar to those of microalgae (Odum, 1971). It is primarily because of this potential for high productivity that microalgae have become a target for scientific and technology biofuels development.

Macroalgae (Seaweeds): Macroalgae, generally referred to as seaweeds, are harvested both wild (~1 million t) and cultivated (~15 million t) (UNFAO, 2008), at scales of about a thousand times larger than current commercial microalgae production and at about one tenth the cost of commercial microalgae production. Macroalgae typically require sites near shore for their cultivation. In comparison to microalgae, seaweeds are currently not widely regarded as having the potential to be a viable source of future liquid transportation fuels. This is perhaps partly due to the disappointing experience with large-scale open ocean cultivation for biofuels that occurred in the Marine Biomass Project carried out in the USA in the late 1970s-early 1980s (Roesjadi *et al.*, 2008). However, within the EU, Japan, and Korea there are an increasing number of projects that have been initiated to investigate seaweeds for their suitability for methane production (by anaerobic digestion) and ethanol production (by saccharification and fermentation) (see the EU Regional Development Fund 'Biomara' project) (Darzins *et al.*, 2010).

Commercial macroalgae farms are typically located in protected near-shore coastal locations, with seed cultures often grown in greenhouses, where they are reared to plantlet size and then transplanted to coastal farms to grow to harvestable size. Macroalgae can also be cultivated on land in open ponds, including raceway type ponds (though the latter have not caught on beyond a couple of commercial farms). The interest now is in open ocean seaweed farming, a topic first investigated in the 'Marine Biomass Project in the USA' (Roesjadi *et al.*, 2008).

The remainder of this article discusses only microalgae.

Algal Production Systems

Commercial algal production uses three major types of production facilities which include open ponds; PBR cultivation systems; and fermentation tanks. Two companies using the fermentation approach to producing algal bio-oils are operating in the USA (Martek and Solazyme) as are several companies in the Far East which use *Chlorella* grown on sugars as the substrate. About 10,000 tonnes per year of algal biomass are produced commercially by both ponds and fermenters, but only a small amount is produced in photobioreactors (<100 tonnes). Just over half of the algae produced in ponds use the raceway pond system. However, *Chlorella* production in the Far East uses mainly circular ponds, and commercial algae production in Australia for beta-carotene production uses about 1000 hectares of large unmixed ponds (Darzins *et al.*, 2010).

It is recognised that both pond and closed photobioreactor systems are likely to experience significant cost reductions as they are scaled-up and developed for lower cost products than nutraceuticals. However, as noted earlier, PBRs are usually over ten times more expensive to build and to operate than are open systems (see section '*NREL Updated Techno-economic Analysis*'). As might be anticipated, both systems have their advantages, disadvantages and challenges (as summarised in Table 3). However, such a simple comparison warrants further discussion. Some comparative measures contradict each other. For example, with the PBR case, the advantage that 'water loss can be managed' is balanced by the challenge that 'larger water inputs may be required to maintain temperature'. In this particular instance, if cooling can be provided by some means other than by evaporative cooling, then PBRs would indeed have reduced water consumption. Unfortunately, no alternative processes are being used at this time. This means that all PBRs need to be either immersed in deep ponds (e.g. the Solix Biofuels system), which may evaporate somewhat less water than shallow raceway ponds, or alternatively, cooled by water sprays, which may evaporate much more water than do ponds. On balance water use is possibly comparable for both PBRs and open ponds.

For most other factors the two approaches do not show significant differences. For example, algae grown in ponds or PBRs would generally require the same amount of nutrients and there are no *a priori* reasons why nutrients cannot be recycled efficiently in ponds. It is generally recognised that while PBRs are typically more expensive to build and operate than are the land and operating costs of open systems, PBRs should be able to achieve higher cell densities than ponds. This higher cell density should facilitate harvesting, although this advantage will vary depending on the design of the PBRs (e.g. depth of culture) and algal species under cultivation. Culture contamination should also be reduced in PBRs, although it cannot be eliminated. Those PBRs that do experience contamination have proven to be a challenge to clean, with growth on vessel walls and biofouling causing major problems for several designs. Vertical PBRs should have a significant productivity advantage over ponds in terms of productivity per land area, of about 50%. However, vertical PBRs usually require at least 3 m² of PBRs/m² land to achieve these higher productivities. Thus, per m² of PBR surface, their productivity is only half of those obtained with ponds.

Table 3. Advantages and challenges of open pond and closed photobioreactor algae cultivation systems.

	Advantages	Challenges
Open Ponds	<p>Used commercially for many years but at a relatively small-scale for biofuels production</p> <p>Lower capital costs than PBRs</p> <p>Evaporative cooling to avoid high temperatures</p> <p>Pond surface outgases O₂, thus build-up is manageable.</p>	<p>Larger land footprint than PBRs</p> <p>Subject to contamination from wild strains and algae grazers</p> <p>Cannot control temperature, day/night seasonal variations</p> <p>Lead to solutions with lower biomass concentrations</p> <p>Evaporative water losses</p> <p>Require more nutrients</p>
Photobioreactors (PBRs)	<p>Allow single species culture</p> <p>Water loss can be managed</p> <p>Reduced land area used if oriented vertically</p> <p>Can be more controlled</p> <p>Allow easier, more accurate provision of nutrients</p> <p>Superior long-term cultures</p> <p>Higher cell density, need less water handling, harvesting</p>	<p>High capital and operating costs</p> <p>Commercial systems have proved problematic: many scalability problems, in addition to high costs</p> <p>Frequent, cleaning needed due to biofilm build-up</p> <p>Larger mixing energy and water inputs to maintain temperature</p> <p>High levels of O₂ inhibition</p>

Modified from: Darzins *et al.*, 2010, USDOE, 2010, Chisti, 2007.

In summary, any comparisons of algal production processes must be based on capital and operating costs as well as energy and material balances. It should also be noted that additional work such as the definition of critical sustainability factors needs to be done before any meaningful comparative analyses can be carried out.

Requirements of Algae Productivity

The multiple factors that affect the efficiency of algal production systems are explored in this section with much of the information taken from the IEA Bioenergy Task 39 report by Darzins *et al.* (2010). Algae are known to have significantly higher productivities and hence oil yields per unit area than do most terrestrial feedstocks (Chisti, 2007). However, for this to occur, algal biofuel plants must be situated at locations where there is a desirable production environment and key components such as light, nutrients, temperature, etc., can be cheaply and readily met. This is described in more detail below.

The environment or climate in which the algae are cultivated will be a key component of any successful biofuel production strategy. As with all land-based crops, the ambient diurnal and seasonal temperature range will influence the effective growing season for any pond-based algal production system. While temperature is a major factor which influences the rate of photosynthesis in all plants (Davidson, 1991), algae suspended in water should be less sensitive to air temperature fluctuations than terrestrial plants. This is because water has a higher specific heat and its temperature is determined by a multitude of factors including solar heating, evaporative cooling, culture depth, wind, humidity, etc. (Darzins *et al.*, 2010). However, for open ponds, climatic conditions, principally seasonal and diurnal temperatures, will have a significant impact on the number of months during which effective algal production can occur. For example, if the water temperature in the cultivation systems falls outside that of the optimal growth range, cells will cease to replicate and production will cease or slow down. In extreme cases, if algal oil production rates are particularly low, pond operations will no longer be profitable or energy positive⁸.

Due to the greenhouse effect and a generally lower thermal mass, temperatures will be higher and somewhat more directly controllable in PBRs than they are in open ponds. However, PBRs generally require higher capital investments (e.g. covers, containers, etc) and energy, (e.g. pumping power) and these higher capital and operating costs continue to be a major limitation of PBR-based biofuel production systems. The heat requirement for a given system is a major concern, since the best algae growth rates are obtained in a 25-30°C range, depending on the specific strain that is used (Mehlitz, 2009). Strategies to reduce these costs (such as recycling the residual algal biomass back to the growth section after oil extraction to provide supplemental nutrients or heat), are currently being pursued. These types of improvements should, in turn, increase the environmental benefits of algal biofuel production. It should be noted that ambient temperature is strongly linked to productivity and thus the economic viability of any of these approaches.

Generally speaking, a growing season which is long enough for effective production in open ponds should be achievable in regions where the average monthly temperatures exceed 15°C (Figure 3). However, the growing season is also dependent on diurnal temperature ranges, as regions with low night time temperatures will not allow the ponds to warm up fast enough for maximum daytime productivity. Temperature effects on algal biofuel productivity are an ongoing area of research.

⁸By definition, an algal facility must be net energy positive for algal biofuel production to make sense.

Degrees Celsius

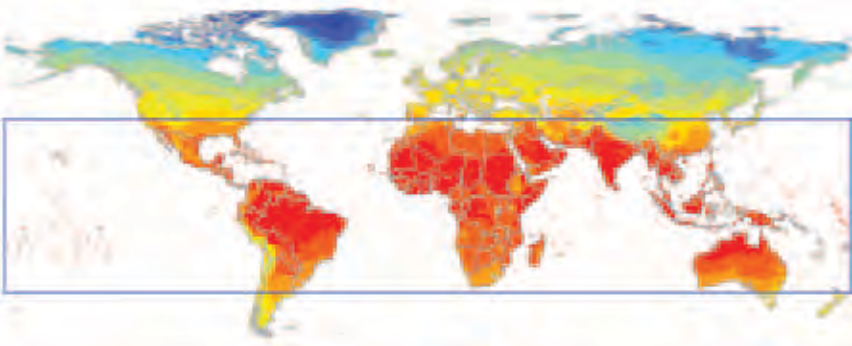
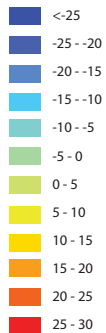


Figure 3: Global climate average annual temperature in °C (from Van Harlem and Oonk, 2006, original in IPCC, 2001). Regions with 15°C are considered most suitable for microalgae production.

Light Saturation, Photo-inhibition, Self-shading and Overcoming these Limitations:

While the amount of sunlight available to the algae is an essential factor, so that high productivity levels can be achieved, it is known that algae exposed to high sunlight intensities absorb more light than they can use for photosynthesis. This phenomenon of 'light saturation' occurs at relatively low levels (i.e. when about one-tenth, typically 5-15%, of normal sunlight occurs in sunny locations such as Australia) (Barbosa, 2003). Despite more sunlight being available, after this point photosynthetic rates do not further increase.

While the light absorbing pigments⁹ of the photosynthetic apparatus continue to absorb most of the intercepted photons, they cannot use these 'extra' photons, resulting in 85-95% of the captured photons being lost or wasted (mostly as heat). By integrating the light absorption coefficient (e.g. photon capture) of such cultures with the light saturation curve, it is possible to compute the relative efficiency of photosynthesis under full sunlight intensities. This is typically 20-30% of the maximum measured at low light intensities (below saturation). This is a major challenge for microalgal photosynthesis and, to a lesser extent, for higher crop plants as well. (Crop plants tend to receive diluted light due to their vertical growth, similar to vertical PBRs, and they can also modulate their pigment content. Thus traditional crop photosynthesis can sometimes be more efficient than can be achieved with microalgal cultivation).

It has been shown that the so-called 'light harvesting' or 'antenna' chlorophylls and other pigments capture more photons at high daylight levels than the photosynthetic apparatus can process. These excess photons which are absorbed by the pigments and not used in photosynthesis will degrade as heat and fluorescence. This results in a process termed photo-inhibition as it generates reactive oxygen species that

⁹Chlorophyll in green algae, phycobiliproteins in cyanobacteria, fucoxanthin in diatoms – the pigments that give the characteristic colors to green, blue-green and brown microalgae.

damage the photosynthetic apparatus. Photo-inhibition is exacerbated by the high levels of dissolved O_2 that are typically found in algal mass cultures and this, combined with the lack of CO_2 , can lead to the so-called photo-oxidative death of the cultures. Light saturation and photo-inhibition are caused by the same fundamental fact of photosynthesis – that the photosynthetic apparatus in individual algal cells has too many light absorbing pigments to work efficiently at high light intensities. Thus, most of the photons that are captured are not productively utilised. However, in most commercial situations the majority of the algal cells experience low light intensities most of the time as they are part of a dense algal culture where individual cells are shaded by the cells between them and the light source. This 'self-shading' is due to the high pigment content, e.g. large antenna size, of the cells. This conundrum is highlighted as it describes the fundamental challenge of microalgae mass cultures where the individual cells try to maximize their own advantage by having a large antenna size. However, this individual advantage can reduce the productivity of the overall culture.

Light saturation and a potential solution to this problem were recognised more than half a century ago by Kok (1953), who proposed that very rapid mixing (the 'flashing light effect') could overcome the light saturation effect. This pioneering approach led to the extensive studies currently aimed at increasing the productivities of algal mass cultures. However, most of these approaches, which will be described later, are currently too energy consuming to be practical. One potential way to overcome the light saturation effect is to orient photobioreactors vertically, or to distribute light deeper into the cultures by means of optical fibres. Again, the cost of these types of approaches appears prohibitive for even high value nutraceuticals, let alone biofuels.

An alternative approach (Benemann, 1990; Benemann and Oswald, 1996) was to develop algal strains with a reduced pigment content using the tools of traditional and molecular genetics. This was the basis of much of the research carried out at Mitsubishi Heavy Industries and at the University of California at Berkeley (Nakajima and Uedo, 1997; Neidhardt *et al.*, 1997; Melis *et al.*, 1999; Benemann *et al.*, 1980). Other groups have built on this earlier work in the hope that they will eventually develop algal strains that will exhibit higher productivities when grown in commercial facilities (Mussgnug *et al.*, 2010; Melis, 2009; Huesemann, 2009).

CO₂ Resources and Availability: It is recognised that the rates of unassisted atmospheric CO_2 diffusion into algal cultures are generally insufficient to sustain high algal growth, at least not without the significant energy inputs required for mixing or bubbling gas through commercial cultures. It has been shown that the natural CO_2 concentration in air is too low to sustain optimal algal growth and high oil productivities (Mehlitz, 2009). One solution to this problem is to use higher concentration of CO_2 sources such as flue gases from coal-fired power plants. However, there are significant cost and logistical challenges with using CO_2 from these sources. These are summarised below.

As there is a need for high CO_2 concentrations, not all stationary CO_2 sources can be used for algal biofuels production. For example, only emission sources where the CO_2

The use of CO₂ from Coal-fired Power Plants (CPP) to cultivate algae

- Even a small coal-fired power plant will need thousands of hectares of algae ponds.
- Flue gas transport will be limited by capital costs and power requirements.
- There will be CO₂ losses during transfer into and outgassing from the ponds before the algae growth is established.
- CO₂ supply must be designed for highest summer production, which may be several-fold higher than average productivity.
- Day-night and seasonal productivity disparities will reduce CO₂ use by ~75% compared to peak summer.
- Capture of CO₂ is not GHG abatement per se that can come only from using the biofuels.
- Biofuels grown on coal power plant flue gases are not sustainable (by definition).
- With losses, scale and other limitations, the maximum plausible net capture of CO₂ from coal power plants will only be ~10%.
- The 10% of CO₂ absorbed by algae is released when the biofuel is combusted, as for other biofuels, but this type of biofuel had a fossil carbon basis.
- Coal-fired powered plants need to reduce emissions by 90%, and need to permanently capture and sequester fossil carbon. Microalgae cannot solve this fundamental problem of CPPs.

is in excess of about 10% of the total waste gas, such as occurs at most coal-fired power plants and industrial facilities, can be used. Many large stationary sources, such as most natural gas-fired power plants, have waste gases whose CO₂ concentrations are less than 10% (in some cases, substantially less).

It should be noted that the area required to cultivate the algae necessary to capture a small amount of the CO₂ emitted by a small coal-fired power plant is significant. Even when the maximum plausible projected algal solar energy conversion efficiencies are assumed, the scale of the open ponds required to capture a small power plant's CO₂ output is in the many thousands, even tens of thousands, of hectares. To complicate things further, as algae do not grow at night and only poorly in winter in temperate climates, these large land areas would, at best, consume about 25% of the plant's CO₂ output. Once the unavoidable losses from transfer, slow cultivation, etc., are considered, about 10% (on a net basis) of the available CO₂ possibly could be converted into biofuels.

Coal-fired power plants and other industrial sources with high CO₂ concentrations are potential candidates for carbon capture and storage (CCS) projects. Similarly, these concentrated CO₂ sources could be used as a feedstock for algal biofuel production. Natural gas treatment plants and ammonia production facilities that are already separating CO₂ and in operation today (Rubin, 2005) could also provide another

potential feedstock. As noted in the text box, algal fixation of CO₂ is not CCS, but rather CO₂ re-use, although the beneficial effects on GHG abatement should be similar.

Possible non-fossil CO₂ sources for algae production include:

- municipal sewage (waste water) treatment plants;
- animal and agricultural waste and processing;
- municipal solid waste processes;
- ethanol and other agricultural processing plants; and
- biomass power plants, pulp and paper mills (if close to tropical locations).

In terms of finding a CO₂ source from a non-fossil feedstock, municipal waste water treatment is a particularly promising, although quite limited, near-term option, as the C, N, P, and other nutrients are usually present at concentrations that are near optimum for algal cultivation. Algal ponds with a primary role of sewage treatment already exist and combining this type of process with biofuel production might be the best near-term option (Lundquist *et al.*, 2010).

Other Nutrient Requirements: As noted above, algae require nitrogen, phosphorous, magnesium, manganese, iron, sulphur, and many other trace elements to grow effectively (Lobban and Harrison, 1994) while diatoms also require silicon for construction of their cell walls (Sheehan *et al.*, 1998). As also noted earlier, the likely lowest cost source for nutrients would be through waste recycling and even flue gas from power plants could provide some N in the form of NO_x (but only a small fraction of that required by the algae). Algae can also be cultivated using conventional agricultural fertilisers, but to ensure sustainability and to reduce costs they must be either recycled with high efficiency in the process or recovered in animal feeds or similar co-products (Benemann, 2003). The nutrients must be provided in high enough amounts to allow good growth, but at a low enough concentration to ensure significant costs are not incurred. However, increased lipid (oils) content in the algal biomass is typically obtained when algal cultures are limited in their access to nutrients, most notably N (or Si in diatoms). The dilemma is that these types of nutrient limitations also reduce the efficiency of overall photosynthesis, so that only the oil content is increased, but not the overall 'oil productivity'. A current top research and development priority is to try and couple good algal growth with good oil production, as in most cases studied so far these optimums are mutually exclusive.

Water and Land Requirements: A major benefit of using algal feedstocks for biofuel production is that algae can use water resources not suitable for agriculture, including seawater, brackish surface and ground water from aquifers, wastewaters, and water associated with oil and natural gas wells and coal production. If seawater is used, coastal locations are required, although inland regions with saline ground water resources are also potential sites. Waste water, municipal sewage and animal liquid wastes are other potential water and nutrient sources.

As noted earlier, large-scale algae production using raceway ponds will require large areas of flat land, (with a 2% slope or less, due to the increased costs of pond construction and

water lifting). Another likely requirement is the need for soils that are high in clay, as percolation (water leakage) has to be minimal and plastic liners would be an expensive addition to the open pond approach to biofuels production.

Biosynthetic Rates: Algae require adequate temperature, light, CO₂ and simple inorganic nutrients to sustain their cellular growth. It is recognised that the rates of biosynthesis of cellular components are finely tuned and controlled in cellular metabolism, partly to avoid the inefficiencies of a single enzyme becoming limiting. For example, Rubisco, the enzyme that fixes CO₂, has a very low turnover number (catalytic activity) and is present at high concentrations in algal cells (as it is in plant leaves). However, this is not an indication that it is actually a bottleneck in cellular metabolism, even though it requires a great deal of investment by the cell to produce such large amounts of this single enzyme. Although some groups have set themselves the goal of 'improving' Rubisco, this is a challenging undertaking as this enzyme has already had many million years of evolution to make it as efficient as it is today. Of potentially greater significance is the goal of improving the biosynthetic rates by better understanding the fundamental mechanisms of photosynthesis, such as the need for the antenna size discussed earlier.

Siting of Commercial-scale Facilities: Environmental considerations, specifically the temperature limits to algae cultivation for effective biofuel production, have yet to be fully resolved. A priority for the future development of algal biofuels should be the identification of climatically favourable locations where suitable land and water sources are available in close proximity to suitable CO₂ sources. Several optimistic claims that microalgae biofuels can provide much, or even most of the world's current transportation fuels, are not based on any actual or realistic analysis of the availability of sites where microalgae biofuels could physically be produced.

Sustained Algal Biomass and Oil Production

Potential algal biomass yields (i.e. metric tonnes of dry weight biomass produced per hectare per year) can, in theory, be significantly higher for algae than has been achieved so far with land-based crops (USD OE, 2010), particularly if the light saturation effect can be overcome. While several reports and presentations have projected yields of 100 mt/ha/yr, or an average of 30 g/m²/day over an 11 month growing season, with a cell containing 30% oil (triglyceride), these types of productivities still remain to be achieved experimentally, at a reasonable scale and over a full year of cultivation (IEA Bioenergy, 2010). As pointed out earlier, there are also major practical problems in maintaining active algal cultures under the constant threat of biotic invasions by herbivore grazers and many other contaminating micro-organisms. Similarly, projections that have been based on theoretical solar energy conversions have proven to be far from the levels achieved through practical experience. Some overly enthusiastic yield projections have even placed algal productivities beyond theoretical photosynthetic limits (IEA Bioenergy, 2010).

As mentioned above, there is some disagreement as to what can be considered a reasonable projection for current and future algal biofuel yields. For example, when using *Spirulina* grown in Israel, Richmond *et al.*, (1990) reported rather low productivities, with sustained productivities of 13–18 g/m²/day and a maximum daily productivity of 27 g/m²/day. Based on these types of productivities, overall cultivation in subtropical climates should result in an average productivity of about 20 g/m²/day. In fact, these types of productivities have been reported (Ben Amotz, 2008) after a year round cultivation of about ten species using small (a few hundred square metre) raceway ponds fed with coal power plant flue gas. A 25% total lipid (not just triglyceride) content was also reported to be obtained with some strains.

Although not yet demonstrated at a large-scale, algal growth levels of 20 g/m²/day appear to be a reasonable objective for a near-term demonstration at a scale of >1 ha (Richmond *et al.*, 1990). In the longer-term, assuming that the antenna size reduction approach works as anticipated, it may be possible to obtain at least a 50% oil content (USDOE, 2010) and even a doubling of productivity levels, at least for reasonably ideal (but not yet clearly defined) climatic and environmental conditions.

However, it is not likely that this issue of commercial yield and productivity will be resolved in the next few years, as data from commercial algal biofuels ventures are proprietary. Even some recently initiated government funded projects at the demonstration level will probably be limited in their release of information initially, due to potential commercial implications. Future economic analysis of algal biomass production must use realistic productivity projections, recognising that the currently low yields and oil content will increase to some extent. However there will continue to be technical challenges, such as co-optimising growth and oil production. There will also be geographical and physical challenges as the first commercial plants will probably need to be associated with a wastewater treatment facility, plus there will be a need for the co-production of higher value co-products such as nutraceuticals.

In a laboratory environment, numerous algal strains have been shown to produce more than 50% of their biomass as lipid. Much of this bio-oil is triacylglycerides (TAGs) which is the anticipated starting material for biodiesel fuels. As mentioned earlier, the lipid content of the algae is typically inversely proportional to its growth rate, increasing when growth is inhibited by lack of nutrients (especially nitrogen or silicon) or light, e.g. when a culture reaches stationary phase (Borowitzka, 1988; Darzins *et al.*, 2010). This is a fundamental problem and it remains to be demonstrated that algal oil can be produced at high growth productivities (e.g. at high solar conversion efficiency). Although the research focus to date has been on factors that might increase oil biosynthesis, perhaps the major limitation is the decline in photosynthesis efficiency. In summary, oil biosynthesis must be coupled to high, sustained rates of photosynthesis. That this is possible is demonstrated by the green alga *Botryococcus braunii* which produces large amounts (up to about 50% dry weight) of hydrocarbons constitutively during normal growth (Benemann, 2009). The disadvantage of this algal species is that it grows slowly, which might be anticipated from an organism that invests so much of its photosynthate into producing such a high energy hydrocarbon product. Similar metabolic pathways must, and could, be explored and developed in other microalgae.

Harvesting

Harvesting methods of algal biomass depend on the species under cultivation, cell density and often on the culture conditions used (Lardon *et al.*, 2007). While many terrestrial feedstocks can be readily removed from their environment at total solids greater than 40%, microalgae and cyanobacteria are usually cultivated as single cells suspended in water at concentrations below 1% solids (USDOE, 2010). Harvesting of the algal biomass, both the primary and secondary concentration, requires concentrating the algal cells by about a 100 to a 1000-fold. This will mean going from a few hundred mg/L in ponds and perhaps a few g/L in PBRs, to a more concentrated wet paste of 5% to 20% solids (dry organic biomass) from which the oil can be recovered. The technical challenge is significant when we considered that algae are microscopic particles suspended at near-neutral density in water (Benemann, 2003) and that initial harvesting and further concentration will require the removal about 1,000 to 10,000 tonnes of water (1-10 m³ water) for every tonne of dry algal biomass produced. Numerous potential harvesting methods have been investigated over the years, with Benemann and Oswald (1996) suggesting the following strategies:

- Flocculation with or without flocculant aids, followed by dissolved air flotation or gravity sedimentation.
- Flocculation without flocculants (bioflocculation), followed by gravity sedimentation.
- Centrifugal dewatering (used for e.g. *Chlorella* harvesting in Japan and Taiwan).
- Membrane filtration using new membrane technologies that may be applicable to microalgae.
- Screening (applicable only to filamentous algae, such as *Spirulina*).

Harvesting technologies with projected costs low enough to be applicable to microalgal biofuels production have not yet been demonstrated at a commercial scale, with the possible exception of the screening processes used to recover *Spirulina*. Thus, this crucial harvesting step requires significant advancements if algal biofuels are to reach commercialisation. The field currently lacks well-defined and demonstrated industrial-scale methods for effectively extracting and separating the oils and lipids from the algae (USDOE, 2010). It is clear that an effective harvesting process must also be developed as part of ongoing algae strain development and cultivation scale-up efforts.

Oil Extraction

It is also apparent that quite different oil recovery processes will have to be employed for microalgae than have been used for traditional terrestrial feedstocks such as sunflowers and rape seed/canola. Algal oils, which are also referred to as lipids (all cell constituents extracted by non-polar solvents, not just triglycerides), are stored as intracellular droplets within the algal cell as well as being found in

the cell membranes. Another important consideration in algal strains is the composition and structure of the cell itself, as a thick algal cell wall often complicates the extraction process (USD0E, 2010). This issue is discussed in more detail below.

A major issue in oil extraction is whether to dry the algal biomass prior to extraction or to extract the oil from the wet paste. As the desired percentage of dry biomass increases, energy costs climb steeply (USD0E, 2010). Drying is very energy intensive and either solar or waste heat drying would need to be used to avoid a negative energy balance. However, even these options still require significant capital and operating investments. Other options, such as solvent extraction (typically using hexane), require drying the feedstock prior to extraction (Mulbury *et al.*, 2009). A limited number of alternative solvents have been evaluated for large-scale extraction of algal biomass. However, little effort has so far been invested in determining the process economics or material and energy balances of these solvent-based processes (Nagle and Lemke, 1990). It has also been suggested that a variation of the solvent-based process could involve *in situ* transesterification, during which bound lipids are released as methyl esters (Ehimena *et al.*, 2010).

A process that seems attractive, but is currently cost-prohibitive for biofuel production, is to apply supercritical CO₂ to extract the algal oils. Supercritical CO₂ has been used on a large-scale for a variety of processes such as removing caffeine from coffee, separating high-value oils from plants and, in the laboratory, to transesterify lipids into biodiesel from domestic sewage sludge (Dufreche *et al.*, 2007). Supercritical CO₂ has both liquid and gas properties, allowing the fluid to penetrate the biomass and act as an organic solvent, without the challenges and expense of separating the organic solvent from the final product. When assessed at a smaller scale, Couto *et al.* (2010) demonstrated that this process worked for oil extraction from algae.

In earlier work Benemann and Oswald (1996) proposed extracting the algal oil from the wet paste (obtained by gravity thickening) by first breaking the cells and then emulsifying the mixture with heated oil, followed by centrifugal dewatering in a three phase centrifuge to separate oil, water, and residual biomass. A fraction of the oil is recycled in the process, with the remainder collected for biofuel production. Although this is still a conceptual process, similar processes are used in the petroleum industry to recover oil from water-oil emulsions and also in the corn ethanol industry, to recover corn oil from water-oil mixtures. This process does not require drying of the biomass. It is likely that these types of wet extraction processes will be a high priority for future development.

Other recovery methods include mechanically separating the oils through ultrasonic treatments or homogenisation (rapid pressure drops) to disrupt the cell wall, thereby improving oil recovery (Darzins *et al.*, 2010). Those processes that hope to use sonication and centrifugation will need further investigation to determine if they are economic and energy effective solutions.

Regardless of the method used, these types of lipid extraction processes are unlikely to generate a feedstock that will be clean enough to be converted directly to fuel. Thus,

further purification and fractionation will be required. Complications are also likely to arise from differences in the overall lipid content (i.e. relative levels of TAGs, phospholipids, and glycolipids) that will occur with changes in algal species or even in key growth conditions such as temperature (Darzins *et al.*, 2010).

Once the algal oil is recovered, downstream processing to biodiesel or green diesel is relatively well understood. This process step is discussed below.

Fuel Production Technologies

Historically, the most concerted R&D effort in the overall microalgal biofuels area has focused on the transesterification step where the algal oils (lipids) are converted to biodiesel (alcohol esters). Although algal oil transesterification processes are based on similar methods developed for the conversion of terrestrial plant-based oils to biofuels, the problems that arise from the compositional complexities of algal oils must be resolved before they can be applied effectively (USD OE, 2010). The algal derived lipids can also be hydroprocessed or hydrocracked to produce renewable diesel (also known as 'green diesel' or 'drop in fuels'). Although much of the algal biofuel production work has focused on the production of lipids, that will, hopefully, comprise 30-50% of cell mass, the remaining biomass, made up of approximately equal parts of carbohydrates and proteins, can also be converted to useful products such as other biofuels and feeds. These processes are discussed in more detail below.

Transesterification

Transesterification is the principal method of converting vegetable oils into biodiesel, during which relatively viscous TAGs are reacted with methanol in the presence of a catalyst (e.g. KOH) to produce fatty acid methyl esters (FAME) which resemble petroleum-based diesel fuel, along with a glycerol co-product (Darzins *et al.*, 2010). High conversion efficiencies are achieved in this reversible reaction by either adding an excess of methanol or removing glycerol as it is formed and both strategies have been used for commercial processes (van Gerpen *et al.*, 2004). Transesterification is a well known and relatively low cost process.

Although chemical processes generally result in a high conversion of triacylglycerols to their corresponding esters, they do also have drawbacks, as:

- they involve energy-intensive processes;
- there are difficulties with removing glycerol and alkaline catalysts from the product; and
- complications arise from treatment of alkaline wastewater (USD OE, 2010).

Although enzymatic methods are becoming increasingly attractive, they have not yet been used at a large-scale, mainly due to the relatively high price of lipase enzymes coupled with their relatively short operational life (primarily caused by the negative effects of excessive methanol and co-product glycerol). It has been reported that all

of the factors listed above must be addressed before a commercially viable chemical or biochemical conversion process of algal bio-oils can be realised (USDOE, 2010).

Hydroprocessing

In this process step, the algal oil is reacted with hydrogen with the aid of a catalyst and is subsequently isomerised to yield a mixture of alkanes. The mixture can be fractionated to produce synthetic kerosene, jet fuel and hydrogenation-derived renewable diesel (HDRD) or green diesel. Renewable diesel is compatible with the infrastructure of existing petroleum processing plants and the products are generally miscible (blendable) with petroleum products. Green diesel has essentially the same performance specifications as the petroleum-based analogue (USDOE, 2010). The glycerol component can be converted to propane which can then be liquefied to LPG or used to provide process heat. Vegetable oils and waste animal fats are currently being processed in a limited number of petroleum refineries to make renewable diesel, for example, an HDRD ConocoPhillips plant at the Whitegate refinery in Cork, Ireland, can produce up to ~ 160 000 L/day of HDRD, primarily using soybean and palm oils as the feedstocks. Among several other examples, Neste Oil has a large plant starting up in Singapore and UOP is working with Eni to demonstrate this technology in Sicily (Darzins *et al.*, 2010).

Pyrolysis

Pyrolysis involves the thermal decomposition of biomass which occurs in the absence of oxygen. Depending on the conditions used it can yield a variety of products including pyrolysis oil (also called bio-oil), synthesis gas (H₂-CO) tars and charcoal. Lower process temperature and longer vapour residence times favour the production of charcoal, higher temperatures and longer residence times increase the biomass conversion to gas, and moderate temperatures and short vapour residence times are optimum for liquid bio-oil production (IEA Bioenergy Task 34¹⁰). At higher pressures, it is possible to pyrolyse wet algal biomass, avoiding the need for drying, to recover the N in the process water, which could overcome a major drawback of conventional pyrolysis processes. Although synthetic diesel fuel cannot be produced directly by pyrolysis of algae, pyrolysis oil, also called bio-oil, can be produced and upgraded by hydrotreating and hydrocracking into a suitable feedstock for generating standard diesel fuel (USDOE, 2010). However, pyrolysis oil is itself a very high oxygen-containing liquid that requires further upgrading via hydroprocessing before it can be used as an effective transportation fuel.

Gasification – microalgae, macroalgae

Gasification of biomass produces synthesis gas which can be converted into liquid fuel such as alkenes (by Fischer-Tropsch Synthesis - FTS), mixed alcohols (through chemical catalysis), or ethanol (by microbial conversions) (USDOE, 2010). As was described previously for pyrolysis, gasification of the algal paste is the more economically attractive option. However this requires higher pressures, which increases costs, but it has the additional advantage of recovering nitrogen and other fertilisers in the water phase.

The various processes and end products that can be derived from the different algal biomass to biofuels conversion routes as well as the production of hydrogen, methane

¹⁰IEA Bioenergy Task 34 focuses on pyrolysis of biomass – for more information please go to www.pyne.co.uk.

and ethanol or the conversion of macroalgae to biofuels are outlined in Figure 4. While it is recognised that the conversion of algal biomass to biofuels still requires ongoing R&D support, questions have also been raised about what might constitute the minimum economic scale of the types of conversion processes described in Figure 4. It is likely that one open pond would be much larger than the optimum scale for effective algal production with the likely scenario involving the clustering of several smaller production systems feeding into the one larger conversion unit.

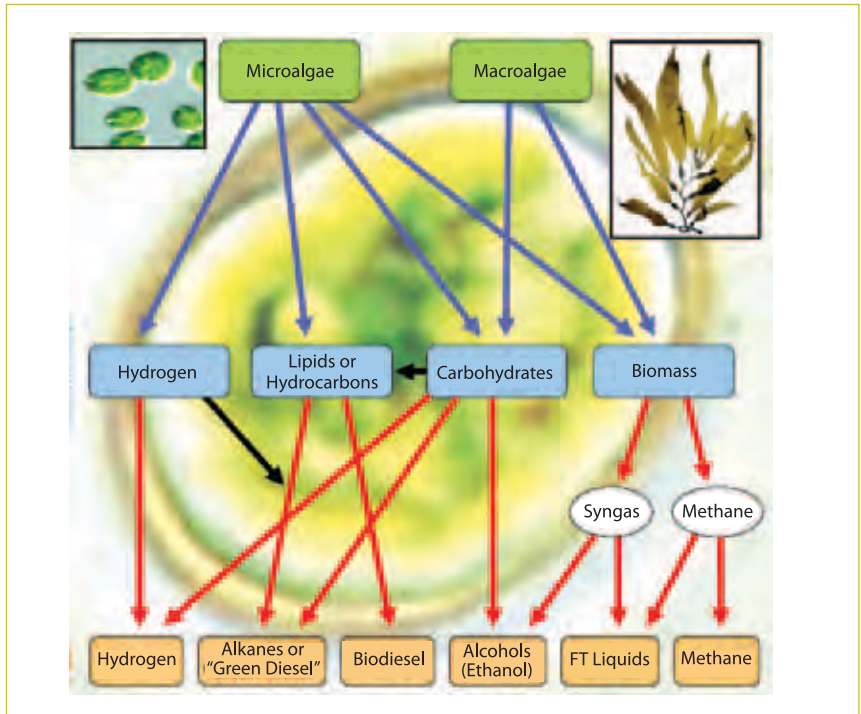


Figure 4: Algal bioenergy conversion routes (Source: Darzins, 2009).

Economics of Algae Biofuel Production

With the possible exception of Brazil-based sugar cane ethanol, algal biofuels, like other current biofuels, can be considered as 'low value, high volume' transportation fuels that are currently economically challenging to produce. As discussed in previous sections of this report, algae are currently grown primarily for relatively 'high value, low volume' nutraceuticals and aquaculture/animal feed products. To evolve from the production of relatively high value nutraceuticals to lower value biofuels it is recognised that the costs of production have to be reduced by over ten-fold, based on the current lowest cost commercial production of algae. For example, *Spirulina* grown in raceway ponds has plant gate production costs in the USA estimated at close to US\$10/kg dry weight. For biofuels, production costs of about US\$0.5/kg oil would be required (based on the current price of soybean oil), to be competitive.

Based on the energy content of the lipids and the likely oil content of the algal biomass, the difference between current production costs and those required for biofuels is nearly 50-fold. How to achieve these levels of cost reductions is the central issue discussed in the section below.

Co-Products

One way to improve the financial attractiveness of algal biofuels is to integrate their production with higher value co-products. For example the residual biomass left after oil extraction could be used for animal feed, analogous to the co-production of distiller dried grain solubles (DDGS) with corn ethanol fermentation/production. However, this option should consider both the high cost of drying DDGS (second only to distillation) and the relatively low value that DDGS normally commands (typically ~US\$100/tonne). It should also be noted that ethanol plants had to develop markets for DDGS, otherwise this material would have become a waste disposal problem.

However, in the case of microalgae, the residual biomass can be anaerobically digested to produce biogas, which can be used to generate electricity, while the digester effluent can also be recycled to the production ponds to recover key nutrients such as N, P, and also C. If higher value animal feeds could be produced, it is more likely that the biomass would be used for animal feed, as the residual algal oil associated with the biomass would have higher value as a feed than as a feedstock for anaerobic fuel production. Thus, it is suggested that algal-based biofuels production should initially focus on an integrated process in which oil is co-produced with biogas or animal feed production while encouraging digester residue recycling.

Another option often advanced is that it may be possible to co-produce algal biofuels with thickening agents (agar, carageenan), colouring agents (astaxanthin, lutein) and nutraceuticals (β -carotene, omega-3 fatty acids). However, virtually all of these markets would be saturated by one or two large-scale algal biofuels production plants. For example, the Cognis plant in Australia produces over 80% of the world's natural β -carotene from a total of ca. 1000 ha of extensive ponds, producing only about 30-40 tonnes of beta-carotene per year and less than 1,000 mt of microalgae biomass. A proposed 100 ML biofuels facility, producing a projected 40,000 litres/ha, would require 2500 ha of ponds, and produce over 250,000 metric tonnes of biomass. Other proposed co-products from microalgae also have markets that are much too small to support such large production volumes. Although several algae biofuel companies are already moving towards the production of high value products, they are quickly becoming nutraceutical rather than biofuels companies.

Even waste water treatment is not generally a suitable co-product for microalgae biofuels, as these types of facilities would primarily have a waste treatment focus, with biofuels providing a minor co-product. However, waste waters can be used to inexpensively provide water, nutrients and even a substantial fraction of the carbon required for algal biofuels production, even though waste water treatment credits would probably be minor (Lundquist *et al.*, 2010).

Techno-economic Analyses

Similar to the many uncertainties about the technical status of algal biofuels production, there are numerous unknowns surrounding the projected economics of commercial-scale biofuel production. Two recent cost estimates - an updated techno-economic analysis by NREL, and an analysis of large open pond systems in Australia are summarised and compared below.

NREL Updated Techno-economic Analysis: The algae-to-lipids cost analysis discussed below is based on a prior assessment by Benemann and Oswald (1996). The algal biofuels facility is envisioned as based on a plant with open raceway ponds; a hot oil extraction process; and hydrotreating processing to obtain green diesel or transesterification to form FAME biodiesel (Figure 5). The details of the techno-economic model used are described in the recent Task 39 report (Darzins *et al.*, 2010)

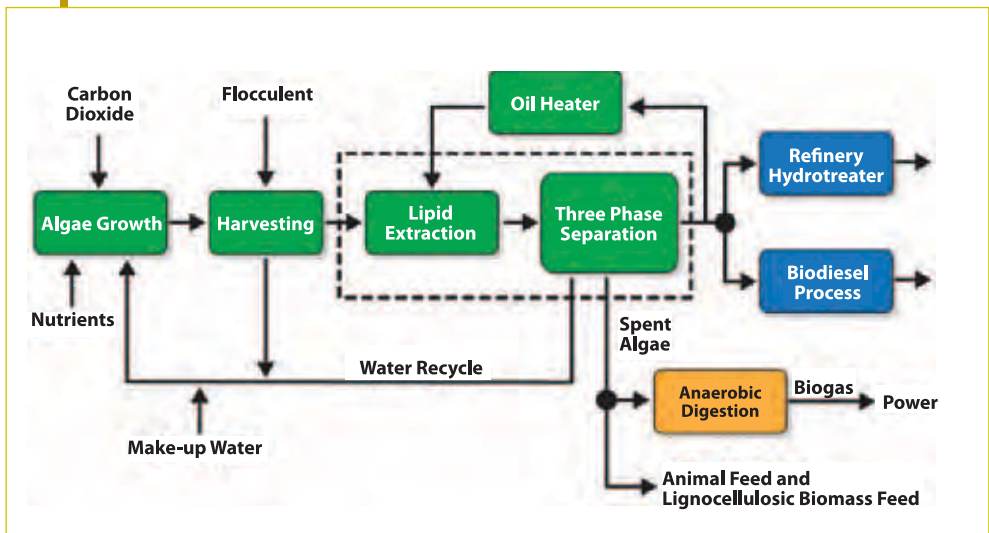


Figure 5: Algae lipid production process.

Three scenarios were evaluated with two cases based on data from the work at the Roswell, New Mexico ponds carried out by Weissman *et al.* (1989 and 1988) as part of the Aquatic Species Program, assuming an average annual productivity of only 10 g/m²/day and oil content of 10 and 40%. The third scenario assumed a much more climatically and environmentally favourable site as well as major biological breakthroughs in cultivation of algae strains with high lipid productivity, achieving 50 g/m²/day with a 45% lipid (oil) content. The estimated costs (capital + operating + land) for facilities producing 47 ML/yr of algal lipids for each scenario (producing 38 ML/yr of biodiesel) are outlined in Figure 6.

A similar economic analysis was also carried out for photobioreactors (PBRs) using the same three scenarios. It was found that the PBRs generally had a greatly reduced light path, of a few centimetres, compared to about 20 cm for ponds (i.e. their depth). This proportionally increased the algal biomass concentration and reduced harvesting

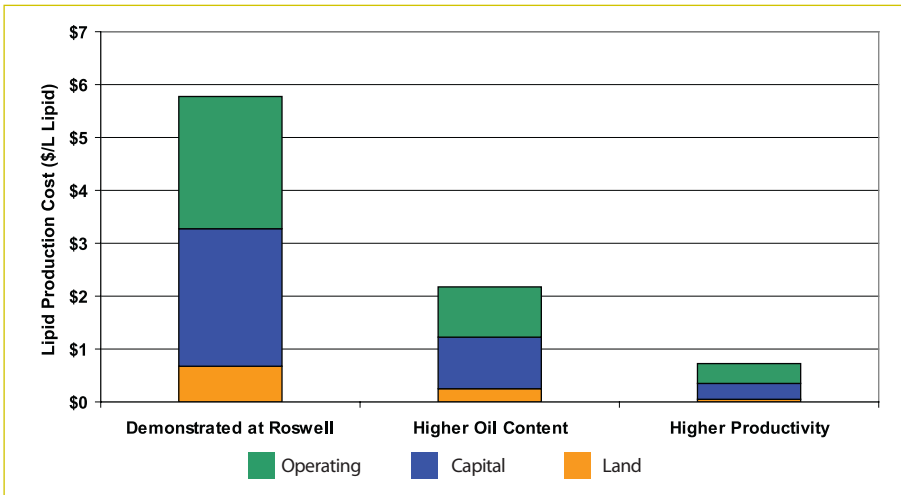


Figure 6: Cost to produce 46.9 ML/yr of algal derived lipids for three different algae growth scenarios. 'Demonstrated at Roswell' is for 10 g/m²/day, 20 cm deep ponds and 15% lipids; 'Higher Oil Content' is same as prior but 45% lipids; and 'Higher Productivity' is for 50 g/m²/day and 45% lipids.

costs. However, water use by the PBRs is higher when compared to open ponds, as the PBRs require evaporative cooling (no other process is currently available). A reasonable approximation for closed PBR capital costs is US\$1 million/hectare (ha) (US\$400,000/acre) (Huntley and Redalje, 2007) which results in an overall cost of algal oil of about ten-fold higher than has been estimated for open ponds. Reducing the capital cost of the PBRs by half only reduces the final cost of the algal oil by half, which is still about five-fold higher than can be achieved with open ponds.

This analysis by Darzins *et al.* (2010) supports prior work indicating projected PBR costs greatly exceeding those of raceway ponds. For PBRs to be competitive with ponds, they need to have costs of less than US\$100,000/hectare (US\$40,000/acre).

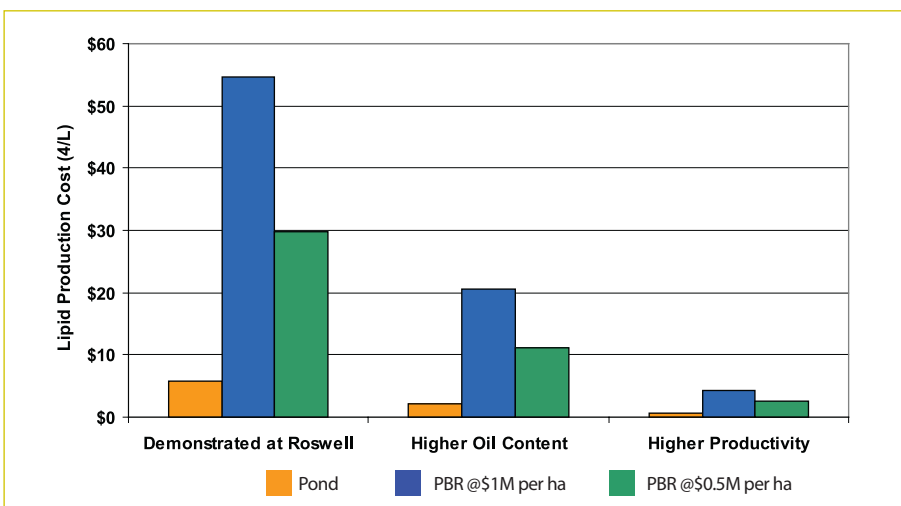


Figure 7: Comparison of raceway ponds and two different photobioreactor costs.

It should be noted that these economic analyses did not factor in several cultivation challenges, including competition by contaminants such as grazers and pathogens, which would arguably reduce productivities and raise costs. These issues are particularly acute in the operation of raceway ponds, although PBRs are not immune to these types of contaminations. These results support prior studies (e.g. Benemann and Oswald, 1996) which suggested that higher algae productivities and lipid content could yield algal biodiesel production costs which would be comparable to other biodiesel sources, although higher than current petroleum diesel costs.

Large-scale Open Ponds – Australia: In the second techno-economic analysis described by Darzins *et al.* (2010), a dynamic material balance and economic model was developed to further explore production cost sensitivities. This allowed various parameters to be modelled while examining several production scenarios. A hypothetical production system of 100 ML/year was modelled with a generic algae species grown in large raceway ponds in Karratha, Western Australia. This site was chosen as it met all of the requirements of, potentially, very large-scale algae production, including proximity to a CO₂ emitter, flat land with clay soils, seawater and a dry tropical climate allowing operation on about 340 days per year. The effect of the biomass productivity and lipid content on algal biodiesel production costs are outlined in Figure 8. When an oil content of 30% and a productivity of 20 g/m²/d were assumed, biodiesel production costs were estimated to be US\$2.13/l while at 60 g/m²/d and 60% oil (e.g. a six-fold increase in oil output per land area), costs would be US\$0.88/l. The higher productivities are near the theoretical maximum and thus are presented only to indicate the maximum effect of these parameters on the overall process economics. It should also be noted that these ponds are clay lined. Costs increase to US\$3.51/l and US\$1.10/l, respectively, with plastic pond liners, as may be required for some sites.

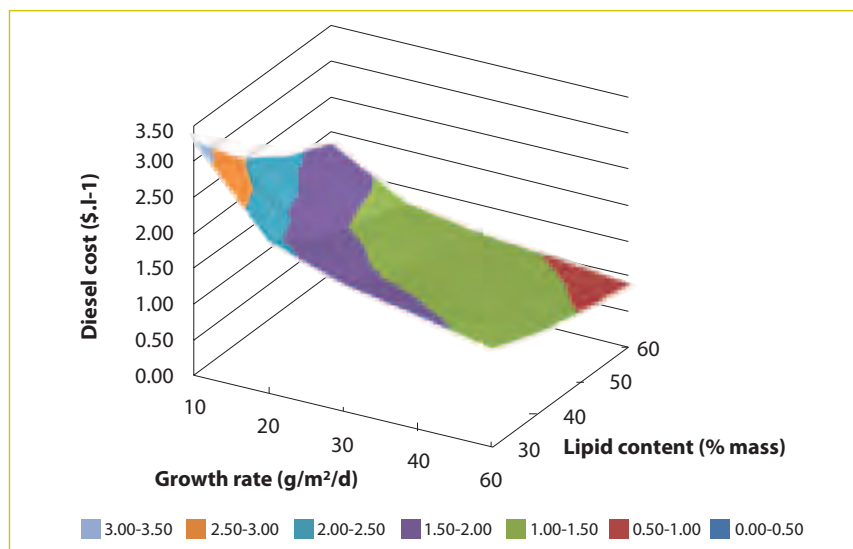


Figure 8: Effect of growth rate and lipid content of algal diesel costs in clay-lined ponds in Australia (Darzins, *et al.*, 2010).

This analysis also shows that carbon costs and the value of co-products have a significant impact on biofuel production economics. If in the above analysis an additional US\$100 t/CO₂ credit is assumed and it is also assumed that the residual algal cake is sold as an animal feed at US\$300/t dry basis (US\$600/t protein content), the biodiesel costs decrease by about 25%, with an after tax IRR of about 20% (Darzins *et al.*, 2010).

In summary, both of the techno-economic analyses concluded that, at current or near-term productivities and lipid content levels, algal biofuel production costs are estimated to be considerably higher than are petroleum, diesel and other traditional land-based biofuel options such as rape seed and palm oil. However, if algal strains that maintain very high productivities and a high oil content can be developed, algal biofuels might become competitive with other bio or fossil-based transportation fuels.

Contribution of Algal Biofuels to Future Liquid Transportation Fuel Markets

When Florentinus *et al.* (2008) tried to calculate the maximum, theoretical, unconstrained production potential of all biofuels they suggested that land-based microalgae biofuels might have the potential to produce several hundred EJ/yr with macroalgae grown in open oceans contributing over 6,000 EJ/yr. However, it should be noted that he also estimated that all terrestrial biomass would contribute about 1500 EJ/yr. Other proponents of algal biofuels make equally ambitious claims about the extent to which algal biofuels can contribute to the world's liquid transportation fuel needs. For example, in an often quoted publication, Chisti (2007) claimed that 50% of the USA transportation fuel needs could be produced on 2 million ha of land if the algal biomass oil content was 70%. This suggests an output of about 150,000 litres/ha/yr of algal oil, greatly in excess of even the most optimistic forecasts (Weyer *et al.*, 2010). There are serious concerns when exaggerated, highly speculative projections like this call into question the credibility of the entire field. A more realistic, achievable projection of land use, where near-term technology can result in sustainable growth rates (e.g. without assuming major breakthroughs such as the cultivation of genetically modified algal strains with reduced antenna size) indicates that a productivity of 20 g/m²/day of algal biomass (dry basis) containing 25% of its weight as oil would require using closer to 20 million ha, once unproductive land (berms, roads, etc.) is included. Ironically, palm oil, to which Chisti (2007) and others often compare algae biofuels, has fewer site limitations as it can be grown on a variety of terrain, typically requires no irrigation water and extracts its CO₂ from the atmosphere. However, palm oil has its own sustainability challenges and palm trees require wet, warm, tropical locations and cannot be grown in deserts or on seawater.

As with any biofuel process, algal biofuel production still requires that realistic assessments of land availability and suitability (e.g. in climatically favourable regions where sufficient water, CO₂ and sunlight are available) are carried out, as well as assessments of any potential environmental impacts. It is still too early to determine what the world-wide resource potential of sustainable algal biofuels production might be.

However, optimistic assessments would likely conclude that, just like other biofuel options such as cellulosic ethanol or biomass-to-liquids, microalgae will replace at most only a part of current fossil-based fuels such as diesel, kerosene and gasoline/petrol.

As noted earlier, algal routes provide the only plausible technology where seawater can be used to produce both biofuels and co-products such as animal feeds. Although, with ongoing R&D support, multiple technology breakthroughs and cost reductions along the entire algal biofuels value chain can be anticipated over time, a 1% algal biofuel contribution to the total current world liquid fuel supply, assuming a productivity of 50,000 litres oil/ha/year, would still require about one million hectares of algal production ponds.

It is likely that at least a few million hectares of suitable land (e.g. with suitable climate, water and CO₂ sources) could be available globally. However, even assuming that the technology is developed as projected by some advocates, the first large scale plants (e.g. ~1,000 hectares or larger) will not be fully operational before 2015-2020. To reach the required productivity levels, strain development will need to rely on genetically modified algae and the development of these strains will likely take a decade when regulatory approval, scale up, etc., are considered. Assuming success in these first commercial ventures and accelerated rates of adoption beyond 2020, construction of 1 million hectares of algae production systems by 2030 might be feasible.

This is within the established time frame of technology adoption that has already been experienced with so called 1st generation or conventional ethanol in Brazil and the USA, and assumes that by about 2020, previous algae biofuels production has been profitable enough to encourage further investment.

Conclusions and Recommended RD&D

This review is largely based on the IEA Bioenergy algal biofuels workshop (IEA Bioenergy, 2010) and the recent report by Darzins *et al.* (2010). It has tried to summarise the state of algae-to-fuels technologies and the economic challenges that must be resolved before algal biofuels can be successfully produced at a commercial scale. The creation of a vibrant algal biofuels industry will require continued and significant long-term industry and government RD&D support. This will be needed to establish algal biofuels production processes that have the potential to meaningfully contribute to future global liquid transportation fuel needs. Research, development and demonstration breakthroughs and advances will be required along all stages of the value chain, from basic science to process engineering, including bench through pilot-scale process development and larger scale demonstrations.

In addition to ongoing RD&D efforts, further techno-economic models and Life Cycle Assessments will also be needed to provide further insights to ensure that successful

algae biofuel commercialisation can be achieved. Key focal points include:

- Biological productivity as a key to reduce costs regardless of whatever process is used.
- Access and review of detailed economic models to indicate overall technological uncertainties.
- As with other biofuel options, sustainability will be a key determining factor in the future development and deployment of algal biofuels.

The perceived potential of algal biofuels to deliver high-density sustainable biofuels has understandably mobilised increased government support for algal routes to biofuels. This enthusiasm has resulted in a dramatic increase in the number of start-up companies, increased coverage of this topic in the popular press, heightened attention from both oil and energy companies and from potential customers such as airline companies.

However, although algal biofuels have the potential to displace a significant portion of high-density liquid transportation fuels, considerable caution is advised in terms of the time it will take to develop the technology from its current knowledge base and scale. It is also worth noting that, notwithstanding the over-enthusiastic projections put forward by some promoters, the eventual volume of algal biofuels that might be produced in the next 25 years is not likely to be as large as the volumes of biofuels from processes based on higher plants, (i.e. alcohols, alkanes, FAMES and pyrolysis oils from annual crops, trees and their residues), due to the constraints of siting algal production systems where CO₂ is available, the need for flat land, adequate water resources, a favourable climate, etc. However, algae do have definite advantages as they can be grown on marginal land, use saline waters or waste waters, etc. These types of issues are of increasing importance when the 'sustainability' of biofuel production is considered. Similarly, as the biorefinery concept is increasingly developed, microalgae based biofuel systems have shown they have the potential for co-production of products such as nutraceuticals or animal feed.

As has been described in the more extensive Task 39 commissioned report (Darzins *et al.*, 2010), none of the technologies currently advocated for algal biofuel production, from the cultivation of specific strains or species through to the harvesting and extraction of the oil, have been operating continuously at a demonstration level in an integrated fashion using conditions resembling realistic operational settings. Thus it has been difficult to develop good economic projections with any confidence. The extrapolations that have been used to estimate the economic potential of algal biofuels have generally been based on bench-scale observations, limited outdoor production data and rather limited engineering designs, assumptions and productivity and economic projections. However, although the economic feasibility and resource potential of algal biofuels is somewhat speculative, it appears that algal biofuels have considerable potential. In time, they could prove to be a significant contributor to our global goal of finding a more sustainable, carbon friendly way of providing an alternative, renewable, and sustainable transportation fuel. To achieve this goal it is important that all aspects of algal biofuel development, from fundamental research through to offsetting the financial risks of building the first commercial algal biofuels plants, receive continued and significant government support, so that the full potential of algal biofuels can be realised.

Acknowledgements

It is generally acknowledged that biodiesel production from microalgal oil was first extensively studied at the US Department of Energy's Aquatic Species Program, which ran from the late 1970's until 1996. This programme was coordinated by the National Renewable Energy Laboratory (NREL), formerly known as the Solar Energy Research Institute, SERI, based in Golden, Colorado.

In 2009 the IEA Bioenergy Executive Committee held a workshop 'Algae – The Future of Bioenergy?' in Liege, Belgium. This workshop featured eight invited speakers who discussed algal feedstocks and state-of-the-art technology options. The speakers were Al Darzins, Pierpaolo Cazzola, Michele Stanley, Sten Bjork, John Benemann, Peter van Dorpel, Rene Wijffels, and Marc van Aken. Their presentations are available at <http://www.ieabioenergy.com/DocSet.aspx?id=6436&ret=dss>). Prior to this workshop Task 39 had commissioned a study of 'the status and prospects for algal biofuels'. The final draft of this report titled 'Current Status and Potential for Algal Biofuels Production,' was completed in August of 2010 and is now available at www.task39.org. The information summarised in this featured article was largely drawn from these two sources.

Task 39 would particularly acknowledge the invaluable contributions of NREL's Al Darzins and Philip Pienkos, as well as Les Edye from BioIndustry Partners/ Queensland University of Technology who authored the 2010 report on which much of this article is based. Don O'Connor of (S&T)² is also gratefully acknowledged for his work in editing the 2010 report.

For more information please refer to:

Darzins, A., Philip, P. and Edye, L. 2010. Current Status and Potential for Algal Biofuels Production. A report to IEA Bioenergy Task 39. T39-T2. Report available at www.task39.org

IEA Bioenergy. 2010. Algae – The Future of Bioenergy? Summary and Conclusions from the IEA Bioenergy ExCo64 workshop. IEA Bioenergy: ExCo:2010:02.

Note: The presentations from the ExCo workshop above are available at www.ieabioenergy.com/DocSet.aspx?id=6436&ret=dss

References

- Barbosa, M.J.** 2003. Microalgal photobioreactors: scale-up and optimization. Thesis; ISBN 9058088987 Wageningen University. Netherlands.
- Burlew, J.S. (Ed.)**, 1953. Algal Culture: from Laboratory to Pilot Plant. Carnegie Inst. Wash.
- Becker, W.** 2004. Microalgae in human and animal nutrition. Richmond A (ed.) Handbook of microalgal culture. Blackwell, Oxford. pp. 312-351.
- Ben Amotz, A.** 2008. Bio-fuel and CO₂ capture by algae. Presentation. June 24, 2008, 11th ICAP Galway, Ireland.
- Benemann, J.R.** 2009. What's the potential market for algae for advanced biofuels? Presentation at World Biofuels Markets with the Algal Biomass Organization. Brussels, Belgium.
- Benemann, J.R.** 2008. Algae – The future for bioenergy? Presentation at IEA Bioenergy ExCo 64. Liege, Belgium.
- Benemann, J.R.** 2003. Biofixation of CO₂ and greenhouse gas abatement with microalgae – technology roadmap. Final report. USDOE, NREL Subcontract 7010000926.
- Benemann, J.R.** 1990. The future of microalgal biotechnology. Cresswell RC, Rees TAV, Shah N (eds.) Algal biotechnology, Longman, London, pp. 317–337.
- Benemann, J.R. and Oswald, W.J.** 1996. Systems and economic analysis of microalgae ponds for conversion of CO₂ to biomass. Final Report to US Dept of Energy NETL.
- Benemann, J.R. Koopman, B.L., Weissman, J.C., Eisenberg, D.E. and Goebel, R.P.** 1980. Algae biomass: Production and use. Shelef G and Soeder CJ (eds.) Elsevier North Holland Press, Amsterdam, 457-496.
- Bioenergy Feedstock Network Information Network.** 2009. Bioenergy Conversion Factors. Oak Ridge National Labs. http://bioenergy.ornl.gov/papers/misc/energy_conv.html
- Borowitzka, M.A.** 1988. Fats, oil, and hydrocarbons. Micro-algal Biotechnology. Borowitzka MA and Borowitzka LJ (eds.) Cambridge, United Kingdom: Cambridge University Press, pp.257-287.
- Campbell, W., Naucier, T. and Ruijs, J.** 2009. Carbon capture & storage: Assessing the Economics. McKinsey Climate Change Initiative. <http://www.mckinsey.com/client-service/ccsi>
- Chisti, Y.** 2007. Biodiesel from microalgae. Biotechnology Advances. (25); pp. 294-306. doi:10.1016/j.biotechadv.2007.02.001.
- Clarens, A.F., Resurreccion, E.P., White, M.A. and Colosi, L.M.** 2010. Environmental life cycle comparison of algae to other bioenergy feedstocks. Environ. Sci. Technol., 44 (5), pp 1813–1819. DOI: 10.1021/es902838n.
- Couto, R. M., Simões, P. C., Reis, A., Da Silva, T. L., Martins, V. H., Sánchez-Vicente, Y.** 2010. Supercritical fluid extraction of lipids from the heterotrophic microalga *Cryptocodinium cohnii*. Eng. Life Sci. (10); 158-164.
- Darzins, A.** 2009. The promises and challenges of algal-derived biofuels. Presentation at the IEA Bioenergy Algal Biofuels Workshop in Liege, Belgium, October 1, 2009.
- Darzins, A., Pienkos, P. and Edye, L.** 2010. Current status and potential for algal biofuels production. A Report to IEA Bioenergy Task 39. Report T39-T2. www.task39.org
- Davidson, I.R.** 1991. Environmental effects on algal photosynthesis: temperature. Journal of Phycology. Vol 27 (1), pp. 2–8. DOI: 10.1111/j.0022-3646.1991.00002.x.
- Dufreche, S., Liang, K., Hernandez, R., Toghiani, H., French, T., Mondala, A. and Sparks, D.** 2007. In-situ transesterification of biodiesel from sewage sludge. Mississippi State University, Dave C. Swalm School of Chemical Engineering, Mississippi State, MS, USA.
- Ehimena, E.A., Sun, Z.F. and Carringtona, C.G.** 2010. Variables affecting the in situ transesterification of microalgal lipids. Fuel 89 (2010) 677–684. doi:10.1016/j.fuel.2009.10.011.
- EurObserver**, 2010. Biofuels barometer. July 2010. www.eurobserv-er.org/pdf/baro198
- Energy Information Agency.** 2010. Worldwide Production of Biofuels in 2008. US Department of Energy. <http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=1>.
- Falkowski, P.G. and Raven, J.A.** 2007. Aquatic photosynthesis. 2nd edn. Princeton University Press, Princeton, NJ.

- Field, C.B., Behrenfeld, M.J., Randerson, J.T. and Falkowski, P. 1998. Primary production of the Biosphere: Integrating Terrestrial and Oceanic Components. *Science* 281 (5374): 237–240. doi:10.1126/science.281.5374.237. PMID 9657713.
- Florentinus, A., Hamelinck, C., de Lint, S. and van Iersel, S. 2008. Worldwide potential of aquatic biomass. Utrecht, Ecosys.
- Hemighaus, G., Boval, T., Bosley, C., Organ, R., Ling, J., Brouette, R., Thompson, T., Lunch, J. and Jones, J. 2010. Alternative Jet Fuels. Chevron Corporation. Alternative Jet Fuels, Addendum 1 to Aviation Fuels Technical Review (FTR-3/A1), pp16. http://www.chevronglobalaviation.com/docs/5719_Aviation_Addendum_webpdf.pdf
- Huesemann, M.H. and Benemann, J.R. 2009. Biofuels from microalgae: Review of products, processes, and potential, with special focus on *Dunaliella* sp. Science Publishers, New Hampshire.
- Huntley, M. and Redalje, D. 2007. CO₂ Mitigation and renewable oil from photosynthetic microbes: A new appraisal. *Mitigation and Adaptation Strategies for Global Climate Change*. (12:4); pp. 573–608.
- IEA Bioenergy. 2010. 'Algae – The Future of Bioenergy?' Summary and Conclusions from the IEA Bioenergy ExCo64 workshop. IEA Bioenergy:ExCo:2010:02.
- IEA Bioenergy Task 34. 2010. <http://www.pyne.co.uk>
- IEA. 2010. Analysis of the scope of energy subsidies and suggestions for the G-20 initiative. IEA, OPEC, OECD, World Bank Joint Report. Prepared 16 June 2010 for submission to the G-20 Summit Meeting Toronto (Canada), 26–27 June 2010.
- IPCC. 2001 Third Assessment Report, climate change, 2001. IPCC data distribution centre, Global mean temperature data set by month at 0.5 degree for 1981–1990 from <http://ipcc-ddc.cru.uea.ac.uk>
- Janssen, M., Tramper, J., Mur, L.R. and Wijffels, R.H. 2003. Enclosed outdoor photobioreactors: light regime, photosynthetic efficiency, scale-up and future prospects. *Journal of Biotechnology and Bioengineering*. (81); pp. 193–210.
- Kok, B. 1953. Experiments on photosynthesis by *Chlorella* in flashing light. In: J.S. Burlew, Editor; *Algal Cultures: From Laboratory to Pilot Plant*, The Carnegie Institution, Washington. pn. 600.
- Lardon, L., Helias, A., Sialve, B., Steyer, J.P. and Bernard, O. 2009. Life-cycle assessment of biodiesel production from microalgae. *Environ. Sci. Technol.*, 2009, 43 (17), pp 6475–6481 DOI: 10.1021/es900705j.
- Lobban, C.S. and Harrison, P.J. 1994. Seaweed ecology and physiology. Press Syndicate of the University of Cambridge, Cambridge, UK.
- Lundquist, T., Woertz, I., Quinn, N. and Benemann, J.R. 2010. A Realistic Technology and Engineering Assessment of Algae Biofuel Production. Energy Biosciences Institute, University of California, Berkeley, California.
- Maniatis, K. 2010. European Union policy measures and support for the promotion of next generation and advanced biofuels. Presentation, World Biofuels Markets, Amsterdam, March 15–17 2010. http://www.worldbiofuelsmarkets.com/downloads/presentations/Algae_15th/kyriakos_maniatis.pdf
- Mehlitz, T.H. 2009. Temperature influence and heat management requirements of microalgae cultivation in photobioreactors. Masters Thesis. GRIN Verlag. Druck und Bindung: Books on Demand GmbH ISBN 987-3-640-38225-5.
- Melis, A., Neidhardt, J. and Benemann, J.R. 1999. *Dunaliella salina* (Chlorophyta) with small chlorophyll antenna sizes exhibit higher photosynthetic productivities and photon use efficiencies than normally pigmented cells. *J Appl Phycol* 10, pp. 515–525.
- Melis, A. 2009. Solar energy conversion efficiencies in photosynthesis: Minimizing the chlorophyll antennae to maximize efficiency. *Plant Science* 177 (2009) 272–280. doi:10.1016/j.plantsci.2009.06.005.
- Mulbry, W.W., Ingram, S.K., Buyer, J.S. and Luthria, D.L. 2009. Extraction of fatty acids from dried freshwater algae using accelerated solvent extraction. *Journal of the American Oil Chemists' Society*. 86:909–915.
- Mussnug, J., Klassen, V., Schuler A., and Kruse, O. 2010. Microalgae as substrates for fermentative biogas production in a combined biorefinery concept. *J. of Biotechnology* 150(1): 51–56. doi:10.1016/j.jbiotec.2010.07.030.
- Nagle, N. and Lemke, P. 1990. Production of methyl ester fuel from microalgae. *Applied Biochemistry and Biotechnology*. Vol 24–25:1, 355–361. DOI: 10.1007/BF02920259.

- Nakajima, Y. and Ueda, R. 1997. Improvement of photosynthesis in dense microalgal suspension by reduction of light harvesting pigments. *J. Appl. Phycol.* 9: 503–510.
- Neidhardt, J., Benemann, J.R., Baroli, I. and Melis, A. 1997. Maximizing photosynthetic productivity and light utilization in microalgae by minimizing the light-harvesting chlorophyll antenna size of the photosystems. *Photosynthesis Res* 56, pp. 175–184.
- Odum, E.P. 1971. Trends Expected in Stressed Ecosystems. *BioScience* Vol. 35, No. 7, (Jul. - Aug., 1985), pp. 419-422. Published by: University of California Press on behalf of the American Institute of Biological Sciences <http://www.jstor.org/stable/1310021>
- Oswald, W.J. 1988. Micro-algae and waste-water treatment. In Borowitzka MA, Borowitzka LJ (eds), *Micro-algal Biotechnology*. Cambridge U.P., Cambridge, 305-328.
- Oswald, W.J. and Golueke, C.G. 1960. Biological transformation of solar energy. *Advances in Applied Microbiology*. (2); pp. 223-262.
- Richmond, A., Lichtenberg, E., Stahl, B. and Vonshak, A. 1990. Quantitative assessment of the major limitations on productivity of *spirulina platensis* in open raceways. *Journal of Applied Phycology* 2: 195-206.
- Roesjadi, G., Copping, A.E., Huesemann, M.H., Forster, J. and Benemann, J.R. 2008. Techno-economic feasibility analysis of offshore seaweed farming for bioenergy and biobased products. Battelle Pacific Northwest Division Report Number PNWD-3931.
- Rubin, E., Meyer, L. and de Coninck, H. 2005. Technical summary. Metz B, Davidson O, de Coninck, H, Loos M, and Meyer L, (Eds). *Carbon Dioxide Capture and Storage*. Cambridge University Press, UK.
- Sheehan, J., Dunahay, T., Benemann, J.R. and Roessler, P.G. 1998. A look back at the US Department of Energy's Aquatic Species Program—Biodiesel from algae. US Department of Energy, Office of Fuels Development. NREL/TP-580-24190. Golden, CO: National Renewable Energy Laboratory. pp. 294.
- Spolaore, P., Joannis-Cassan, C., Duran, E. and Isambert, A. 2006. Commercial applications of microalgae. *Journal of Bioscience and Bioengineering*. (101); pp. 87-96.
- Stephenson, A.L., Kazamia, E., Dennis, J.S., Howe, C.J., Scott, S.A. and Smith, A.G. 2010. Life-cycle assessment of potential algal biodiesel production in the United Kingdom: A Comparison of raceways and air-lift tubular bioreactors. *Energy Fuels*, 2010, 24 (7), pp 4062–4077. DOI: 10.1021/ef1003123.
- UN FAO. 2008. The State of Food and Agriculture 2008; Biofuels: Prospects, risks and opportunities. <http://www.fao.org/docrep/011/i0100e/i0100e00.htm>
- US DOE. 2010. National Algal Biofuels Technology Roadmap. Fishman D, Majumdar R, Morello J, Pate R, Yang J (eds). US Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program.
- van Gerpen *et al.* 2004. UN Food and Agriculture Organization. <http://www.fao.org/bioenergy/47280/en/>
- van Harlem, T. and Onk, H. 2006. Micro-algae Bio-fixation Processes: Applications and Potential Contributions to Greenhouse Gas Mitigation Options, Report for the International Network on Bio-fixation of CO₂ and Greenhouse Gas Abatement with Micro-algae operated under the International Agency Greenhouse Gas R&D Programme.
- Weissman, J.C. and Tillett, D.T. 1989. Design and operation of an outdoor microalgae test facility. Aquatic Species Program, Annual Report. Bollmeier WS, Sprague S (eds.) Solar Energy Research Institute Golden Colorado, SERI/SP-231-3579, pp. 41-57.
- Weissman, J.C., Goebel, R.P. and Benemann, J.R. 1988. Photobioreactor design: comparison of open ponds and tubular reactors. *Biotech Bioeng* 31, pp. 336–344.
- Weyer, K.M., Bush, D.R., Darzins, A. and Willson, B.B. 2010. Theoretical Maximum Algal Oil Production. *BioEnergy Research*. 3:204-213. <http://www.springerlink.com/content/778667h6747540t5/fulltext.pdf>
- Wijffles, R.H. and Barbosa, M.J. 2010. Perspective: An outlook on microalgal biofuels. *Science* 13 August 2010: Vol. 329. no. 5993, pp. 796 – 799 DOI: 10.1126/science.1189003.

International Energy Agency

The International Energy Agency (IEA) is an intergovernmental organisation which acts as energy policy advisor to 28 Member Countries in their effort to ensure reliable, affordable, and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. Energy security remains a key priority, but has expanded beyond concerns about oil supplies to include natural gas and electricity. The Agency's mandate has also broadened to incorporate the 'Three E's' of balanced energy policy making: energy security, economic development, and environmental protection. Current work focuses on diversification of energy sources, renewable energy, climate change policies, market reform, energy efficiency, development and deployment of clean energy technologies, energy technology collaboration and outreach to the rest of the world, especially major producers and consumers of energy like China, India, Russia and the OPEC countries.

With a staff of around 250, mainly energy experts and statisticians from its Member Countries, the IEA conducts a broad programme of energy research, data compilation, publication, and public dissemination of the latest energy policy analysis and recommendations on good practices.

Objectives

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-Member Countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

Organisation

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

Members

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

Introducing IEA Bioenergy

Welcome to this Annual Report for 2010 from IEA Bioenergy!

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

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

The IEA Implementing Agreement on Bioenergy, which is the 'umbrella Agreement' under which the collaboration takes place, was originally signed in 1978 as IEA Forestry Energy. A handful of countries took part in the collaboration from the beginning. In 1986 it broadened its scope to become IEA Bioenergy and to include non-forestry bioenergy in the scope of the work. The number of participating countries has increased during the years as a result of the steadily increasing interest in bioenergy worldwide. By the end of 2010, 24 parties participated in IEA Bioenergy: Australia, Austria, Belgium, Brazil, Canada, Croatia, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Republic of Korea, the Netherlands, New Zealand, Norway, South Africa, Sweden, Switzerland, Turkey, the United Kingdom, the USA, and the European Commission.

IEA Bioenergy is now 33 years old and is a well established collaborative Agreement. All OECD countries with significant national bioenergy programmes are now participating in IEA Bioenergy, with very few exceptions. The IEA Governing Board has decided that the Implementing Agreements may be open to non-Member Countries, i.e. for countries that are not Members of the OECD. For IEA Bioenergy, this has resulted in a number of enquiries from potential participants, and as a consequence new Members are expected. Three non-Member Countries currently participate in IEA Bioenergy – Brazil, Croatia, and South Africa.

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

There were 12 ongoing Tasks during 2010:

- Task 29: Socio-economic Drivers in Implementing Bioenergy Projects
- 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: Greenhouse Gas Balances of Biomass and Bioenergy Systems
- Task 39: Commercialising Liquid Biofuels from Biomass
- Task 40: Sustainable International Bioenergy Trade – Securing Supply and Demand
- Task 41, Project 3: Fuel and Technology Alternatives for Buses
- Task 42: Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass
- Task 43: Biomass Feedstocks for Energy Markets

Members of IEA Bioenergy are invited to participate in all of the Tasks, but each Member is free to limit its participation to those Tasks which have a programme of special interest. The Task participation during 2010 is shown in Appendix 1.

A progress report for IEA Bioenergy for the year 2010 is given in Sections 1 and 2 of this Annual Report.



The study tour group at Drax Power Station, Yorkshire, UK.

Progress Report

1. THE EXECUTIVE COMMITTEE

Introduction and Meetings

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

A survey of Members on the format for ExCo meetings produced an excellent response (91%). The conclusions were that 'Day 1' should be a full day workshop; 'Day 2' should be the business meeting and if necessary continued on the first half of 'Day 3'. 'Day 3' should include a study tour which, depending on the plan for the business meeting, would be either a half day or a full day. The Chairman and the host ExCo Member should work together to decide the strategy for each ExCo meeting.

The 65th ExCo meeting took place in Nara City, Japan on 12-14 May. There were 37 participants. The 66th ExCo meeting was held in York, UK on 12-14 October, with 52 participants. Representatives from IEA Headquarters attended ExCo66.

At the ExCo66 meeting, Birger Kerckow from Germany was elected Chairman and Paul Grabowski from USA was elected Vice Chairman for 2011.

The ExCo Secretariat is based in Rotorua, New Zealand under the Secretary, John Tustin. The fund administration for the ExCo Secretariat Fund and Task funds is consolidated with the Secretariat, along with production of ExCo publications, the newsletter, and maintenance of the website. By decision at ExCo63, John Tustin will provide the Secretariat and Fund Administration service for the period to 31 December 2012. The contact details for the ExCo can be found in Appendix 7 and for the Secretariat on the back cover of this report.

The work in the ExCo, with some of the achievements and issues during 2010, is described below.

Implementing Agreement

Extension of the Implementing Agreement to 31 December 2014 was approved by the IEA Committee on Energy, Research and Technology (CERT) at its meeting in November 2009, following a review by the REWP. The Chairman made a presentation at both committee meetings to achieve this outcome. Subsequently, in order to implement the CERT's recommendations at its meeting of 3-4 March 2010, the ExCo unanimously agreed to extend the current term of the Implementing Agreement to 28 February 2015.

New Participants/Contracting Parties

Turkey formally joined the Agreement on 4 March 2010. The Contracting Party is the Tubitak Marmara Research Center Energy Institute, Mr Ufuk Kayahan is the ExCo Member and Mr Fehmi Akgün is the Alternate Member. Turkey participates in Tasks 32, 33, 37 and 42.

Korea formally joined the Agreement on 7 May 2010. The Contracting Party is the Ministry of Knowledge Economy. Mr Soosung Hwang is the ExCo Member and Mr Soon-Chul Park is the Alternate Member. Korea participates in Task 39.

There is a new Contracting Party for South Africa – the South African National Energy Research Institute (SANERI). This change was effective from 26 July 2010.

Enquiries from potential Member Countries continued to be strong in 2010, including interest from Chile and Poland.

For a complete list of the Contracting Parties to IEA Bioenergy please see Appendix 3.

Supervision of Ongoing Tasks, Review and Evaluation

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

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

Approval of Task and Secretariat Budgets

The budgets for 2010 approved by the Executive Committee for the ExCo Secretariat Fund and for the Tasks are shown in Appendix 2. Total funds invoiced in 2010 were US\$2,169,659; comprising US\$285,800 of ExCo funds and US\$1,883,859 of Task funds.

Appendix 2 also shows the financial contributions made by each Member Country and the contributions to each Task. Very substantial 'in-kind' contributions are also a feature of the IEA Bioenergy collaboration but these are not shown because they are more difficult to recognise in financial terms.

Fund Administration

The International Energy Agency, Bioenergy Trust Account, at the National Bank of New Zealand is functioning smoothly. In 2010 this account was accessed electronically by Ms Jeanette Allen at the New Zealand School of Forestry, University of Canterbury on behalf of the Secretariat. The account is an interest bearing account denominated in US dollars. Details for making payments are:

Arrange an International Telegraphic Transfer/Swift Money Transfer (MT103) to:

Beneficiary Bank: The ANZ National Bank Ltd

Beneficiary Bank Address: 215-229 Lambton Quay, Wellington, New Zealand

Swift/BIC Address: ANZBNZ22

Beneficiary: Bioenergy Research Services Ltd, for and on behalf of IEA Bioenergy

Beneficiary Account Number: IEABRS-USD00

Quoting: Invoice Number

Correspondent Bank: JPMorgan Chase Bank, New York, NY, USA. Swift code: CHASUS33

The currency for the whole of IEA Bioenergy is US dollars. The main issues faced in fund administration are slow payments from some Member Countries and fluctuations in exchange rates. As at 31 December 2010, there were US\$78,900 of Member Country contributions outstanding.

KPMG is retained as an independent auditor for the ExCo Secretariat Fund until 31 December 2012. The audited accounts for the ExCo Secretariat Fund for 2009 were approved at ExCo65. The Tasks also produce audited accounts. These are prepared according to guidelines specified by the ExCo. The accounts for the Tasks for 2009 were approved at ExCo65 and ExCo66, except for Task 30. The accounts for this Task were approved by a written procedure which came into force on 23 December 2010.

The audited accounts for the ExCo Secretariat Fund for the period ended 31 December 2010 have been prepared and these will be presented for approval at ExCo67.

Task Administration and Development

Task Participation

Participation in the Tasks has continued to increase. In 2010 there were 125 participations in 12 Tasks. Please see Appendix 1 for a summary of Task participation in 2010.

Annex Documents

Annex documents for the Tasks in the new triennium were finalised and approved at ExCo65. In order to retain a flexible mechanism for project work, the ExCo had already approved the prolongation of Task 41 'Bioenergy Systems Analysis' to 31 December 2012.

Strategic Planning and Strategic Initiatives

Strategic Plan

The fourth Strategic Plan for IEA Bioenergy for the period 2010-2016 was printed and distributed in November 2009. Like the third plan it underpins a stronger emphasis on market deployment of technologies and systems for sustainable energy production from biomass. Further work is now being initiated to link the 'objectives' of the Strategic Plan with 'actions and performance indicators'. The goal is to provide guidelines for monitoring progress with the plan and thereby strengthen the transparency of the work undertaken by IEA Bioenergy.

Technical Coordinator

Adam Brown, the Technical Coordinator (TC) for more than three years, resigned to take up a position in the Renewable Energy Division at IEA Headquarters. Part of his new role will be to lead and coordinate IEA's activities on bioenergy and to ensure good liaison with the Implementing Agreements. At ExCo65 the Chairman made a presentation and thanked Adam for his energy and professionalism in developing the TC role. Given the success of the TC position it was decided to replace him immediately. A call for applications and an evaluation process led to Dr Arthur Wellinger being appointed the new TC from 1 May 2010.

Since taking up the position Arthur has been very busy. His main focus has been on organising and running the ExCo workshops, organising a joint ExCo/Task Leader strategic seminar, visiting IEA Headquarters and participating in the 'biofuel roadmap' workshop, establishing contact with GBEP and working with the Tasks on new initiatives and key publications.

Strategic Fund/Strategic Outputs

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

policy-relevant outputs of IEA Bioenergy. Initially the funds were distributed to the Tasks but it was decided that from 1 January 2008 these funds would be held by the Secretariat and distributed to the Tasks (or external contractors) for ExCo approved projects as they were undertaken. This allows uncommitted funds to be monitored more easily and implementation of the 'strategic' component of the work programme is facilitated. Current commitments funded from this source are as follows:

The Pellet Handbook: the production and thermal utilisation of biomass pellets: This comprehensive handbook has now been printed and distributed. An excellent publication has resulted. It was co-funded by the ExCo (through Task 32 with input from Tasks 29 and 40) and the Austrian organisations Landesenergieverein Steiermark and BIOS Bioenergysysteme GmbH. The handbook was edited by Ingwald Obernberger and Gerold Thek. Copies are available from Earthscan (www.earthscan.co.uk).

Bioenergy, Land Use Change and Climate Change Mitigation: This project is co-financed by the Swedish Energy Agency and IEA Bioenergy. It is led by Goran Berndes, the Leader of Task 43. The focus is on the climate benefit of bioenergy and how this can be affected by the possible direct and indirect emissions from converting land to bioenergy use. The deliverables will be one report written for the scientific community and one report for policy makers. The report for policy makers and policy advisors was approved by the ExCo on 30 November 2010 and was printed in January 2011. Copies are available for downloading from the IEA Bioenergy website.

Life Cycle Analysis Paper: A paper 'Life Cycle Analysis of Biomass Fuels, Power, Heat, and Products as Compared to their Petroleum Counterparts and Other Renewables' is being produced by Task 38. Production was delayed so that significant new material could be incorporated. A recent draft was reviewed by an ExCo subgroup which identified the need for further improvements in the content. A Consultant Editor has been engaged to work with the existing team. This is expected to accelerate progress with this very topical deliverable.

Better Use of Biomass for Energy: This was a joint project with the RETD Implementing Agreement. IEA Bioenergy contributed 'in-kind' support of expert information, in particular the publication 'Bioenergy – a Sustainable and Reliable Energy Source', and co-financing. The project produced a position paper for a side event at COP15 in Copenhagen in 2009. Since then, a more detailed background report has been produced and circulated. The Implementing Agreements now have a joint view of the role bioenergy can play. This completes a successful joint initiative. Electronic copies of these reports are available on the IEA Bioenergy website.

Two other strategic initiatives were as follows:

Collaboration with AMF: A proposal from the AMF Implementing Agreement for co-financing of a joint project 'fuel and technology alternatives for buses' was accepted.

Finland, Germany, and the European Commission agreed to participate through IEA Bioenergy Task 41, Project 3. This project, initiated by VTT in Finland, is also a joint Annex with the Hybrid and Electric Vehicles Implementing Agreement. It aims to assess the overall efficiency, emissions, and costs (direct and indirect) for several fuel and drivetrain technology options for buses. Most of the testing of various fuel alternatives has already been carried out except for hybrid buses, where approximately one third of the testing has been completed. The project involves a combination of desk studies and measurements on various types of buses. It is divided into two main parts, fuel pathway analysis (well-to-tank) and vehicle (tank-to-wheel) performance. The final report from the project is on target for completion in October 2011.

Collaboration with GBEP: The ExCo has been exploring how to achieve closer ties with the Global Bioenergy Partnership (GBEP). An ExCo subgroup recommended that this could be best achieved through joint results-oriented activities. The following ideas for cooperation were presented to GBEP by the Chairman:

- linking websites;
- exchanging newsletter material;
- considering the development of joint workshops or study tours;
- cooperation between the GBEP GHG Methodologies Taskforce and Task 38;
- cooperation between GBEP's Sustainability Taskforce and Tasks 38, 39, 40, and 43; and
- cooperation between GBEP's Technical Working Group and IEA Bioenergy.

The GBEP Taskforce on GHG Methodologies was established in October 2007 under the joint leadership of the USA and the UN Foundation to develop a common methodological framework for the use of policy makers and stakeholders when assessing GHG emissions associated with bioenergy and to make GHG lifecycle analyses more transparent. The GBEP Taskforce on Sustainability was established in June 2008 under the leadership of the UK. It is working to develop a set of relevant, practical, science-based, criteria and indicators as well as examples of best practice regarding the sustainability of bioenergy. There is considerable scope for IEA Bioenergy to contribute to the work of these Taskforces through the relevant Tasks. The ExCo is very supportive that the Leaders of these Tasks increase their involvement with GBEP. They would also like the Technical Coordinator to be more fully involved.

Although IEA Bioenergy proposed a MoU, GBEP preferred an exchange of letters and this is now in place.

ExCo Workshops

At ExCo53 it was decided to create time for strategic topics at ExCo meetings and to use the first day of each meeting for a technical workshop on a topic of high priority. Two very successful workshops on 'Developing Sustainable Trade in Bioenergy' (ExCo65) and 'Thermal Pre-treatment of Biomass for Large-scale Applications' (ExCo66) were held in 2010. The presentations, summaries by the rapporteurs, and

papers based on the presentations are available on the IEA Bioenergy website. A summary and conclusions publication is also produced for each workshop and this is also available on the website. The complete list is as follows:

- Liquid Biofuels from Black Liquor Gasification – IEA Bioenergy:ExCo:2007:03.
- Co-utilisation of Biomass with Fossil Fuels – IEA Bioenergy:ExCo:2006:02.
- Integrated Waste Management and Utilisation of the Products – IEA Bioenergy:ExCo:2009:02.
- Availability of Biomass Resources, Certification/Sustainability Criteria and Land-use and Bioenergy in the Kyoto and post-Kyoto Framework – IEA Bioenergy:ExCo:2008:02.
- The Biorefinery Concept.
- Innovation in the Field of Bioenergy Business Development – IEA Bioenergy:ExCo:2008:03.
- Biofuels for Transport – Part of a Sustainable Future? – IEA Bioenergy:ExCo:2008:04.
- Bioenergy - The Impact of Indirect Land Use Change (ILUC) – IEA Bioenergy:ExCo:2009:04.
- Algae – The Future for Bioenergy? – IEA Bioenergy:ExCo:2010:02.
- Developing Sustainable Trade in Bioenergy (*In preparation*).
- Thermal Pre-treatment of Biomass for Large-scale Applications (*In preparation*).

Seminars, Workshops, and Conference Sessions

A large number of seminars, workshops, and conference sessions are arranged every year by individual Tasks within IEA Bioenergy. This is a very effective way to exchange information between the participants and to transfer information to stakeholders. These meetings are described in the progress reports from the Tasks later in this Annual Report. The papers presented at some of these meetings are listed in Appendix 4. Workshops are also arranged by the Executive Committee.

Some examples of such outreach by the Tasks include the following:

- Task 29 organised a joint International Conference with the Energy Farm in Hadeland, Norway in June. The theme of the conference was 'Shaping bioenergy strategies for the future - how to increase regional impact on national policies and plans?'. There were 60 participants. A key feature was the mix of delegates which included mayors, senior government representatives, and key local businesses – all of whom can influence local actions and initiatives.
- Task 32 organised an expert workshop on 'Combustion of Challenging Biomass Fuels' at the European Bioenergy Conference in Lyon in May. The attendance comprised 75 delegates representing a wide range of stakeholders. Overall, there were more than 1500 delegates from 72 countries at the conference.
- Task 39 provided several key speakers for sessions at the Bioenergy Australia Conference 2010 in Sydney in December. The Task also provided lead papers for two plenary sessions (Professor Jack Saddler and Dr Jim MacMillan). There were over 320 participants from 16 countries at the conference.

- Task 40 supported the 'Biomass Power and Trade' Conference organised by the Singapore Centre for Management Technology, in Rotterdam in March. The conference provided opportunities for biofuels and biomass industry stakeholders to network with other industry suppliers and technology providers, as well as utility executives, researchers, policy makers, investors, and project developers. The Task contributed a number of speakers on 'biomass trade' with a focus on countries that participate in the Task. There were 160 participants from 30 countries.
- Task 43 organised a joint international workshop with the Long-Term Soil Productivity Study collaborators in Kamloops, Canada in June. The theme for this workshop was 'Sustainability across the supply chain of land-based biomass'. Seventy-five participants from 13 countries attended 12 technical sessions, a poster session, and two field tours.

Collaboration with FAO

The collaboration with FAO under the MoU signed in 2000 has continued. Both the Executive Committee and FAO are committed to capitalising on the opportunities provided through this initiative. Mr Miguel Trossero, Senior Forestry Officer was the long standing contact for the Agreement until his recent retirement. At ExCo64, his last ExCo meeting, he noted that although the overall results of the collaboration had been pleasing there was scope for increased activity in the areas of political awareness, sustainability, and bioenergy market opportunities in developing countries. Mr Maxim Lobovikov from the Forest Economics, Policy and Products Division, is the new FAO contact.

A major collaborative project between Task 31: Biomass Production for Energy from Sustainable Forestry and the FAO Forest Energy Programme was completed in 2010. This involved the preparation and publication of a book 'Criteria and indicators for sustainable woodfuels'. The book explores the concept of sustainability and tools for its assessment as applied to woodfuels, existing criteria and indicator schemes for sustainable woodfuel, and the environmental, economic, social, and cultural impacts, as well as the legal and institutional framework of woodfuel production in developing and developed countries. It also proposes a global set of principles, criteria, and indicators for sustainable woodfuels and discusses their practical implementation. This project generated a number of related papers and presentations to important international audiences, including the XIIIth World Forestry Congress in Buenos Aires in October where it received much attention. To access the book please visit: www.fao.org/docrep/012/i1673e/i1673e00.pdf

Promotion and Communication

The ExCo has continued to show lively interest in communication of IEA Bioenergy activities and information. There is a wide range of promotional material available through the Secretariat. This includes Annual Reports, technical brochures, copies of IEA Bioenergy News, the current Strategic Plan, strategic papers, and workshop proceedings.

The IEA Bioenergy website underpins this publishing activity.

The 2009 Annual Report with the special colour section on 'Bioenergy – a Sustainable Reliable Energy Source: Executive Summary', was very well received. Only a few copies of the Annual Report from the original print run of 1500 remain with substantially increased distribution in electronic format.

The newsletter 'IEA Bioenergy News' remains popular. Two issues were published in 2010. The first issue featured bioenergy in Japan and the second issue featured bioenergy in the United Kingdom as special themes. A free subscription is offered to all interested and there is a wide distribution outside of the normal IEA Bioenergy network. The newsletter is distributed in June and December each year which follows the pattern of ExCo meetings. It is produced in electronic format so potential subscribers should ensure that the Secretary has their email address. IEA Bioenergy News is also available from the IEA Bioenergy website.

Eight contributions under the banner of 'IEA Bioenergy Update' were provided to the journal Biomass and Bioenergy in 2010. These covered news from the Executive Committee and Technology Reports from the Tasks. This initiative provides excellent access to bioenergy researchers as the journal finds a place in major libraries worldwide.

OECD Case Study

IEA Bioenergy was selected as the case study for an OECD project on 'Multilateral Governance of Science, Technology, and Innovation for Global Challenges'. The project was undertaken by the Committee on Science and Technology Policy. The Secretary prepared a comprehensive response to the project plus nine supporting documents. The report from the project was completed in November and is available on the IEA Bioenergy website.

Interaction with IEA Headquarters

There is continuing contact between the IEA Bioenergy Secretariat, and IEA Headquarters in Paris and active participation by ExCo representatives in relevant meetings. The Chairman, Technical Coordinator, Secretary, and key Task Leaders have worked closely with Headquarters staff at both administrative and technical levels. Some specific examples include; the new Technical Coordinator made two visits to IEA Headquarters. The first was to meet key personnel involved with bioenergy and the second was to participate in the workshop 'Sustainable feedstock supply for bioenergy and biofuels'. Andre Faaij, the Leader of Task 40 also made a presentation at this workshop. Jack Saddler, the Leader of Task 39 attended the 'Biofuels Roadmap' workshop in April. Also the Chairman presented at the seminar 'Communication ... Impact ... Growth' held in September.

Takatsune Ito and Adam Brown attended ExCo66 in York. This participation by Headquarters is appreciated by the Members of the ExCo and helps to strengthen linkages between the Implementing Agreement and relevant Headquarters initiatives.

Status Reports were prepared by the Secretary and forwarded to the Desk Officer and the REWP following ExCo65 and ExCo66. Information was also sent to Nils-Olof Nylund, Vice Chairman of the End Use Working Party (EUWP) for the Transport sector to assist the report he prepares for the autumn meeting of the EUWP. This forms part of the exchange of information between Implementing Agreements and the Working Party.

IEA Bioenergy Website

There are around 3,000 'bona fide' visitors to the website each month. The most popular areas of the website are the Library, Workshops, and the Media Centre. On an annual basis there are approximately 30,000 downloads. The most popular items downloaded recently have been: the 2009 Annual Report; the ExCo64 Workshop 'Algae – the future; for bioenergy?'; and the Main Report: 'Bioenergy – a sustainable and reliable energy source' and its Executive Summary. There were a further 2,985 downloads of the ExCo64 Workshop presentations.

Colleagues Recognised

Kyriakos Maniatis was awarded the Johannes Linneborn Prize for achievements in biomass development at the 18th European Biomass Conference held in Lyon. The award was recognition of his leadership in promoting biomass as a sustainable energy source within the European Union and worldwide. He manages the bioenergy 'demonstration component' of the European Commission Framework Programmes and is responsible for all technical issues related to 1st and 2nd generation biofuels. He has also been responsible for the demonstration component of the biofuels and poly-generation sectors in the Commission's 7th Framework Programme. He initiated the CEN standardisation work for solid biomass fuels, solid recovered fuels, bioethanol, biodiesel, and biomethane and led the EU team to the tripartite work on International Compatible Biofuels Standards with USA and Brazil.

Göran Berndes, Leader of Task 43, was awarded the Nordic Council of Ministers' Bioenergy prize by the Swedish Minister of the environment, at the Swedish Energy Convention in Stockholm. The prize is for an outstanding contribution to the promotion, use, or production of bioenergy. It recognised Goran's research into large-scale bioenergy development and land use, and his focus on how biomass can be used to reduce the energy system's carbon footprint. The adjudication committee said 'Berndes has shown an extensive international commitment, both as a researcher and an adviser. In all contexts he has worked to show how the Nordic model of large-scale cost-effective bioenergy can be reconciled with the highest aspirations of both environmental and socio-economic objectives'.

2. PROGRESS IN 2010 IN THE TASKS

Task 29: Socio-economic Drivers in Implementing Bioenergy Projects

Overview of the Task

The objectives of Task 29 are to:

- achieve a better understanding of the social and economic drivers and impacts of establishing bioenergy fuel supply chains and markets at the local, regional, national and international level;
- synthesise and transfer to stakeholders critical knowledge and new information;
- improve the assessment of the above mentioned impacts of biomass production and utilisation in order to increase the uptake of bioenergy; and
- provide guidance to policy makers.

These objectives will be met through encompassing the results and findings obtained previously in the Task and also through the international state-of-the-art socio-economic evaluation of bioenergy programmes and projects. Activities will be expanded to include developing countries through the FAO and similar organisations. This will include the sharing of research results, stimulation of new research directions in national, regional, and local programmes, and technology transfer from researchers to resource managers, planners, and industry.

Participating countries: Canada, Croatia, Germany, Norway, and the United Kingdom

Task Leader: Dr Keith Richards, TV Energy Ltd, United Kingdom

Associate Task Leader: Dr Julije Domac, North-West Croatia Regional Energy Agency, Croatia

Operating Agent: Mr Kieran Power, Department of Energy and Climate Change (DECC), United Kingdom

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

For further details on Task 29, please refer to Appendices 2-6 inclusive; the Task website: www.task29.net, the biomass and bioenergy educational website: www.aboutbioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Task Meetings and Workshops

The Task organised two international events in 2010 alongside Task meetings. The first was a conference titled 'Local and regional influences on national bioenergy strategies and policies', on 17-19 June in Hadeland, Norway together with The Energy Farm. The conference was supported by the Norwegian University of Life Sciences, CENBIO and the Norwegian Research Council. It was attended by a number of Norwegian mayors and municipality leaders who presented their practical experiences in implementing local and regional based bioenergy projects. Their detailed case studies added to Task participants understanding of the genesis of such projects and the interplay with local drivers, be they social, economic, or environmental (or a mixture of these in most cases). Linkages between local, regional, and national bioenergy strategies and policies were explored in detail and the importance of clear communication was emphasised. Conference proceedings were prepared by the Energy Farm, in the form of a CD with PowerPoint presentations.

The second event was an international workshop titled 'Socio-economic drivers in implementing bioenergy projects: actions together' on 4-6 October in Ogulin, Croatia. This workshop included local authorities, international organisations, NGOs and experts from participating countries as well as invited guest participants from Slovenia, Austria and Macedonia who shared their knowledge and experiences on cooperation projects and programmes. Conference proceedings were prepared by the North-West Croatia Regional Energy Agency in the form of a CD with PowerPoint presentations.

Both meetings were attended by all participating countries. A list of the presentations made is provided in Appendix 4. The conference proceedings are also available on the Task website.

Work Programme

The first half of 2010 was dedicated to detailed planning of the three year programme. Germany, a new participant was updated on past activities and introduced to the current programme which was jointly reviewed with the other participants.

A collection of 14 case studies illustrating the opportunities for biomass use in both urban and rural communities, best practice procedures, and socio-economic drivers was completed by Task experts. These are available from the Task website and each case study will be made available on the educational website. The Task will prepare an illustrative brochure intended for a wider audience with a summary overview of each case study (including a short description, key findings, and further information). At the same time, a detailed scientific paper is under development. This paper will be published in a recognised scientific journal.

Another important deliverable completed was a Task poster, important for the visibility of the Task and targeted at local and regional events in partner countries. This was jointly created, published, and distributed to the Task participants.

The Task also prepared detailed plans for event-based meetings (conferences/workshops) over the three year programme. A UK Task event in 2011 will focus on how fuel poverty can be alleviated by making better use of bioenergy – particularly wood fuel. Housing Associations are being investigated as target organisations to take part in this meeting and to be beneficiaries of the resulting activity. So far five organisations in the South East of England have been identified as interested with two meetings being held. Sovereign Housing and the Maidenhead Housing Association wish to participate and are embarking on an examination of the role of bioenergy within their housing stock as a lead into the 2011 conference. They will case study their involvement in local schemes and seek to compare and contrast this with similar activities in partner countries. Two urban Local Authorities (Reading and Oxford) that retain large housing stock will also participate and are looking to host the event.

Website

The Task website (www.task29.net) is periodically updated. It is a key tool for dissemination. All publications, including workshop proceedings and meeting minutes, Task brochures and posters, Task reports and papers, can be downloaded in PDF format. Several video files, explaining various socio-economic issues related to bioenergy, are available for downloading or online viewing. The visual identity of the website was recently redeveloped and additional material (including presentations from Task workshops, separate articles from Task proceedings, and completed case studies) has been made available for downloading.

Collaboration with Other Tasks/Networking

The Task has collaborated on the production of a Pellet Handbook (Task 32) and was also an active participant in the multi-Task meeting in York, UK. Cooperation continues with the FAO and promising links have been established with FEDARENE (European Federation of Regional Energy and Environment Agencies) and some ongoing projects financed under the Intelligent Energy Europe Programme (e.g. IEE Wood Heat Supply and others).

Deliverables

Deliverables in 2010 included workshop presentations at the two international conferences organised by the Task, papers published in international journals, papers presented at other international events, the two progress reports and an annual audit report to the Executive Committee, along with the biomass and bioenergy educational website.

TASK 32: Biomass Combustion and Co-firing

Overview of the Task

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

Of all the thermochemical conversion technologies available for biomass, combustion can be regarded as the most widely applied option, with a global market share exceeding 90%. Commercial availability is high and there is a multitude of options for integration with existing infrastructure on both large and small-scale levels. Nevertheless, there are still a number of challenges for further market introduction, the importance of which varies over time. Priority issues tackled by the Task through different activities in this triennium are

- Aerosol emissions from residential solid fuel appliances
- Use of non-woody biomass types and ash-related problems
- Pre-treatment, storage, handling and sustainability of biomass resources
- New CHP concepts for small-scale applications
- Increasing co-firing percentages
- Utilisation of ash
- Database on biomass co-firing experiences

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

While most of the above actions are of a technical character, Task 32 also addresses non-technical issues on fuel logistics and contracting, environmental constraints and legislation, public acceptance and financial incentives. An overview of relevant policies is included in the Handbook of Biomass Combustion and Co-firing. In addition, the Task produced a number of reports on harnessing the co-firing potential in both existing and new coal-fired power plants.

Participating countries: Austria, Canada, Denmark, Finland, Germany, Ireland, Italy, the Netherlands, Norway, Sweden, Switzerland, Turkey, and the United Kingdom.

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

Sub-Task Leader for Co-firing: Ing Edward Pfeiffer, KEMA, the Netherlands

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

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

For further details on Task 32, please refer to Appendices 2-6 inclusive; the Task website www.ieabioenergytask32.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

In 2010, the Task organised two internal meetings, two workshops and a field trip. The first meeting was held in Lyon, France and the second in Copenhagen, Denmark. These internal meetings were used to monitor progress in different Task activities, reflect on Task-initiated workshops, share recent developments on application of biomass combustion in Member Countries and plan for the next triennium. An important milestone in 2010 was the completion of the 'Handbook of Pellet Production and Utilisation'.

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

The Task meeting held in May, in conjunction with the European Biomass Conference was mainly used to discuss the approach for the planned activities in this new triennium, to finalise the work on the pellet handbook and to exchange country reports. An expert workshop was also organised on 'Combustion of Challenging Biomass Fuels'.

The second Task meeting took place in October in Copenhagen. The meeting was used to discuss progress in the various Task projects initiated and to hold a field trip to the recently commissioned power plant of Amagerværket in Copenhagen, owned by Vattenfall. This 73 MW_e/250 MW_{th} plant is designed to operate 100% on pulverised biomass. In conjunction with this second meeting, a joint workshop was organised with Task 33 to present a technology status overview of various concepts for small-scale power production from solid biomass. This workshop attracted approximately 80 participants.

The reports of Task meetings and workshops can be downloaded from the Task website.

Work Programme

The work programme in the current triennium is structured as follows:

Aerosol Emissions from Residential Solid Fuel Appliances

A co-funded study is being carried out to evaluate and report on the cost effectiveness of new particle removal technologies. This work is planned to be finalised in mid-2011. Preparations have been made for an expert workshop on the formation mechanisms, reduction measures, and health impact of aerosols from biomass combustion. This will take place in January 2011, in conjunction with the Central European Biomass Conference in Graz, Austria.

The technical and environmental performance of domestic woodstoves is still increasing – driven by the European 'Energy using Product Directive, Lot 15'. At a workshop to be held in October 2011 in Ireland, manufacturers of residential solid fuel appliances will discuss with the Task participants the following topics:

- the effects of furnace design on combustion quality and emissions;
- small-scale dust removal systems; and
- the effectiveness of policy measures to promote clean small-scale combustion devices.

Use of Non-woody Biomass Types and Ash-related Problems

A workshop was organised in conjunction with the European Biomass Conference in May in Lyon, France. The theme was the resource base of alternative fuels for small-scale and industrial combustion, and the consequences of using challenging fuels for furnace design, boiler material selection, boiler operation, and emissions.

One of the problematic 'biomass-containing' fuel types is Solid Recovered Fuel. Several thermochemical options are being proposed to process this material (such as pyrolysis, gasification, dedicated combustion, co-firing) however in practice there are hardly any real initiatives in place, let alone a commercial breakthrough. A workshop will be organised with Task 36, and possibly other Tasks, in Ireland late in 2011, to explore and compare the different conversion routes available for Solid Recovered Fuel. The results will be made available through a joint publication.

Pre-treatment, Storage, Handling and Sustainability of Biomass Resources

A co-funded study will be initiated in 2011 to evaluate the technical characteristics of torrefied pellets, the flexibility of the process in terms of technical specifications of input and output, and the suitability of burning torrefied pellets in conventional small-scale combustion devices.

In a number of recent instances, biomass storages have unexpectedly caught fire. The mechanisms behind heating up of large storages are not yet well understood. The Task has agreed to coordinate a multi-disciplinary study with input of other Tasks to evaluate the

safety issues associated with large-scale handling and storage of biomass. The work will culminate with a review report.

A joint workshop will be organised with Task 40 at the Central European Biomass Conference in Graz, Austria in January 2011 on biomass torrefaction. The workshop will focus on the torrefaction technology status, as well as financial and logistical aspects.

New CHP Concepts for Small-scale Applications

An expert workshop was organised in October on the current status of various small-scale CHP technologies, providing information on operational performance, financial aspects and reliability.

Increasing Co-firing Percentages

A workshop will be organised early in 2012 on high percentage co-firing in coal-fired power plants. The aim is to share initial experiences amongst plant operators, illustrating the importance of fuel flexibility and how to address various technical and non-technical issues to establish high percentage co-firing systems. It has been agreed that this workshop will be jointly organised with the IEA Clean Coal Centre and VGB Powertech (the European Association of power plant owners).

Utilisation of Ash

Production of a paper is being coordinated by KEMA with contributions from other Task participants. It will show how the combustion process and biomass characteristics influence the quality of the various ashes produced, how the ashes are currently utilised, and what can be done to improve ash utilisation. The paper will be published early in 2011 and should facilitate improvement of national policies on ash utilisation.

Database on Biomass Co-firing Experiences

The existing web-database on biomass co-firing experiences is continuously updated with the latest information available worldwide. During the triennium this database will be made interactive and extended to include dedicated combustion.

Website

The Task website (www.ieabioenergytask32.com) attracts a continuously growing number of visitors (currently about 10,000 visitors every month) and is one of the key tools for information dissemination. Main products that are being downloaded from the website are publications and meeting reports, the database on experience with biomass co-firing in different power plants, and the databases on the composition of biomass and ash from actual combustion plants. The website is updated on a regular basis. In 2010, several electronic newsletters have been produced and distributed to provide information on developments related to the work of the Task and biomass combustion and co-firing in general. Task participants and ExCo Members can obtain access to a secured section of the website which includes internal reports and work in progress.

Collaboration with Other Tasks/Networking

The Task collaborates directly with industry and through industrial networks such as VGB Powertech. Within the IEA family, interaction is also solicited with other Tasks or other Implementing Agreements such as the IEA Clean Coal Centre and IEA Fluid Bed Conversion. Market relevance is also enhanced by the active involvement of ExCo Members in the selection of Task participants, based on their national programmes.

Effective coordination is achieved through joint events, and the exchange of meeting minutes and reports. Current examples are a joint workshop on CHP with Task 33 and the production of the pellet handbook, with Tasks 29, 31 and 40. In 2011 several joint workshops and studies with groups inside and outside of IEA Bioenergy are planned.

Deliverables

The following milestones were achieved in 2010. Organising and minuting of two Task meetings. Organising and reporting of workshops on 'Combustion of Challenging Biomass Fuels' and 'State-of-the-art technologies for small biomass co-generation'; publication of the Handbook of Pellet Production and Utilisation; updating of the international overview of initiatives for biomass co-firing; and maintenance of the Task website. The Task also produced progress reports and audited accounts for the ExCo.

TASK 33: Thermal Gasification of Biomass

Overview of the Task

The objectives of the Task are to monitor, review and exchange information on biomass gasification research, development, and demonstration; and to promote 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.

Participating countries: Austria, Denmark, Finland, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Switzerland, Turkey and USA. Sweden will join the Task from 1 January 2011.

Task Leader: Dr Richard Bain, NREL, USA

Operating Agent: Mr Paul Grabowski, Office of Biomass Programme, US Department of Energy, USA

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

For further details on Task 33, please refer to Appendices 2-6 inclusive; the Task website www.ieatask33.org and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work:Tasks'.

Progress in R&D

Task Meetings and Workshops

The first Task meeting for the triennium was held from 1-3 June in Helsinki, Finland. The Task meeting was held on the first day, and a workshop 'Second generation biofuels' on the second day. Day three was a visit to the VTT research laboratories and gasification and pyrolysis facilities in Espoo near Helsinki.

The second Task meeting was held from 5-7 October in Denmark. The Task meeting was held on the first day and took place in Skive. On the second day Task representatives visited the gasification plants in Skive, Harboøre and Hadsund. On the third day a workshop 'State-of-the-art technologies for small biomass co-generation' was organised together with Task 32 in Copenhagen. After the workshop the participants visited the Stirling.dk gasification/Stirling engine demonstration facility.

Work Scope, Approach and Industrial Involvement

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

The Task monitors the current status of the critical unit operations and unit processes that constitute biomass gasification (BMG) process, and identifies hurdles to advance further development, operational reliability, and reducing the capital cost of BMG systems. The Task meetings provide a forum to discuss the technological advances and issues critical to scale-up, system integration, and commercial implementation of BMG 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 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 are also invited as and when the need arises to seek information and cooperation in order to address basic and support research needs.

Work Programme/Sub-task Studies

The current work programme includes the following elements:

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

Details are:

Meeting	Associated Workshop	Dates and Location
1st Task meeting	WS1 'Second generation biofuels'	1-3 June 2010 Helsinki, Finland
2nd Task meeting	WS2 'State-of-the-art technologies for small biomass co-generation'	5-7 October 2010 Skive/Copenhagen, Denmark

- Survey the current global biomass and waste gasification RD&D programmes, commercial operations and market opportunities for BMG, and identify the technical and non-technical barriers to commercialisation of the technology. Use the survey results to prepare and update Country Reports for information dissemination.
- Conduct joint studies, conferences, and workshops with related Tasks, Annexes, and other international activities to address issues of common interest to advance BMG systems.
- Identify research and technology development needs based on the results from the work described above as a part of the workshop reports.
- Publish results of the work programme on the Task website (www.ieaTask33.org) for information dissemination. Maintain the website with Task updates.

Observations from WS1: Second Generation Biofuels

ECN reported on Bioenergy Carbon Capture and Storage (BECCS). This research is a multidisciplinary collaboration between different units. It offers opportunities for net atmospheric CO₂ reduction from CCS combined with production of 2nd generation biofuels: BioSNG, FT-diesel, and bioethanol from lignocellulose. ECN also reported on Biosyngas systems. Five systems were compared looking at efficiency, syngas price, technology status, and CO₂ reduction potential.

Andritz Carbona presented its portfolio for biomass gasification: biomass preparation and handling, belt and drum dryers, CFB gasifier atm, BFB gasifier low and high pressure, gasifier gas cleanup and combustion. Cooperation with the Gas Technology Institute, Chicago was mentioned.

Vienna University of Technology reported on the CHP plant in Güssing, including producer gas composition and use for biofuels production. Also covered was the OptiBtL gas, ERA Net project. The aim of the project is reforming of hydrocarbons to increase overall conversion of biomass to FT products. The second attractive project on mixed alcohols was also presented. The aim of this project is to obtain fundamental know-how in the synthesis of mixed alcohols. A project on the conversion of mixed alcohols to hydrocarbons is planned.

Information about liquid biofuels in Finland was reported by VTT. Neste Oil produces biofuels by hydrogenation of vegetable oils and animal fats. The first plant has been in operation since 2007; the second one since 2009. There are large plants under construction in Singapore and Rotterdam. The combined production capacity in Finland adds up to almost 10% of road transport fuels consumption in Finland.

NREL made a presentation on 'Techno-economics of the production of mixed alcohols from lignocellulosic biomass via high temperature entrained flow gasification'. DOE has the target to produce cost-competitive ethanol via thermochemical conversion by 2012. The key points were:

- at a pilot-scale, from lignocellulosic biomass;
- research targets primarily in the areas of syngas cleanup and alcohol synthesis;
- main cost drivers in this process: gasifier capital cost, air separation cost, feed preparation (grinding) cost; and
- the main advantage is getting relatively clean syngas with minimal downstream processing compared to lower temperature gasification.

The techno-economics of biofuel processes for synthetic natural gas (SNG) production was reported by PSI. The key points were:

- Energy and/or heat integration of SNG plants is much easier than for liquid biofuels value chains.
- Scale for biomass-to-SNG plant is probably determined by biomass supply chain.
- Analysis has shown that gasification technology is the most distinctive and critical choice that dominates the entire biomass-to-SNG process design.
- The developed model of EPFL suggests that pressurised, steam/oxygen gasification outperforms all other thermal gasification at ambient pressure with respect to efficiency and investment cost.
- A 1 MW SNG PDU has successfully been commissioned. There is strong evidence that fluidised bed methanation technology is quite robust towards bulk gas composition for SNG production.

Results of simulation studies for BTL were presented by TUBITAK. The aim was to compare the different technologies with respect to performance of a CTL/BTL process; to compare the different operational parameters with respect to performance of a CTL/BTL process; and to determine the mass and energy balance of the whole system with its subsystems, for a pilot-scale CTL/BTL plant at the Marmara Research Centre.

Observations from WS2: State-of-the-art Technologies for Small Biomass Co-generation

The second workshop was held together with Task 32. The Bioenergy 2020+ group reported on 'Next generation pellets combustion with thermoelectric power generation'. The advantages of the process are: direct energy conversion, no moving parts, and no working fluids (maintenance-free durability and noise-free operation). The process is targeted for micro-scale CHP based on biomass. The idea is to integrate a thermo-electrical generator (TEG) into a biomass furnace. Industrial available TEGs from cooling technology are Bismuth Telluride. The efficiency is 5-6%, and they may be used up to 250°C. Still under development are materials and technologies for higher temperatures. Prototypes TEG 250 and 400 were introduced.

Weiss A/S reported on its two-stage biomass gasification pilot-plant. In the two-stage gasification process, the pyrolysis and the gasification process are separated into two different zones. In between the pyrolysis and the gasification zones, the volatiles from pyrolysis are partially oxidised, decomposing most of the tars into gas. To enable high energy efficiency, the thermal energy in the gasification gas and the exhaust gas is being used for drying, air preheating and for pyrolysis. The two stage gasification process has successfully demonstrated that the process offers low tar content in gas (<5 mg/Nm³); stable unmanned operation; high cold gas efficiency (>95%); and low environmental impact (clean condensate, high carbon conversion). The process verification and documentation has been performed at small-scale. To manufacture economically attractive plants the process is now being scaled-up. The two-stage gasification process is being modified to separate the drying from the pyrolysis unit. The drying agent is steam and, produced steam from the dryer is led to the pyrolysis-gasification reactor to reduce soot production and increase char reactivity.

Turboden SRL reported on Organic Rankine Cycle (ORC) technologies for biomass plants. There are a whole range of ORC applications, including timber drying in saw mills; sawdust drying in wood pellets factories; and district heating networks, etc.

Pyroforce Technology reported on its down-draft gasification with a gas engine. They have been involved for 15 years with R&D concerning biomass gasification. Five gasification plants have been built and are successfully operating: Emmen, Spiez, Güssing, Stans I and Stans II.

The status of the Babcock & Wilcox Vølund gasifier facility at Harboøre was presented.

The main data on this facility are:

- Updraft gasifier (Dr Gratzke)
- Feed: wood chips (moisture 35-55%)
- 3.5 MW_{th} /1 MW_e
- Commissioned in 1996
- CH capability added in 2000

- Originally designed for district heating
- Gasifier operated for more than 120,000 hours
- Gasifier engine operated for more than 80,000 hours
- Present power production more than 500 MWh/month

The Andritz-Carbona gasifier CHP plant at Skive, Denmark was introduced. It is an air-blown bubbling fluidised bed gasifier with 20 MW_{th}, and 6 MW_e. Wood pellets are used as a feedstock – 40,000 t/year. Bed material has been changed from dolomite to olivine. The construction of the plant was started in 2005. Investment is DK 248 million (33.3 million Euro). The write-off period is about 20 years. Annual sale of district heating is 120,000 MWh and electricity 22,000 MW.

Vienna University of Technology reported on indirect gasifier commercialisation in Austria and Germany; and Dong Energy reported on scale-up of the LTCFB gasifier. Siemens presented an overview of Siemens steam turbines, and IDA reported on perspectives for data collected through the Danish follow-up program for biomass CHP.

Website

The Task website (www.ieatask33.org) is the most important tool for dissemination of results. Descriptions of the Task including the contact data of national experts are given. Minutes of the Task meetings and the results of workshops can be downloaded as PDF files. In addition, the Country Reports of participating countries are available, along with descriptions of work being undertaken in the area of gasification. In this triennium a Google-map based database of implementations of gasification plants will be incorporated.

Collaboration with Other Tasks/Networking

The workshop 'State-of-the-art technologies for small biomass co-generation' was organised as a joint effort in cooperation with Task 32 and IDA.

Deliverables

The Task deliverables included planning and conducting two semi-annual Task meetings focused on the workshops selected by the Task participants, involving academic and industrial experts; the preparation and distribution of workshop reports; updating and publishing Country Reports; conducting joint studies, conferences, and workshops with related Tasks, Annexes, and other international activities to address mutually beneficial issues; and preparation of periodic progress, financial, technology, and annual reports as required by the ExCo.

TASK 34: Pyrolysis of Biomass

Overview of the Task

The objective of the Task is to improve the rate of implementation and success of fast pyrolysis of biomass for fuels and chemicals (where this complements the energetic considerations) by contributing to the resolution of critical technical areas and disseminating relevant information particularly to industry and policy makers. The scope of the Task is to monitor, review, and contribute to the resolution of issues that will permit more successful and more rapid implementation of biomass pyrolysis technology, including identification of opportunities to provide a substantial contribution to bioenergy. This will be achieved by a programme of work, which addresses the following priority topics: norms and standards; analysis – methods comparison and developments; and country updates and state-of-the-art reviews.

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 by-product. The Task focus is on fast pyrolysis to maximise liquid product. The technology review may focus on the thermal conversion and applications steps, but implementation requires the complete process to be considered. Process components as well as the total process are therefore included in the scope of the Task, which covers optimisation, alternatives, economics, and market assessment.

The work of the Task addresses the concerns and expectations of the following stakeholders: pyrolysis technology developers; bio-oil applications developers; equipment manufacturers; bio-oil users; chemical producers; utilities providers; policy makers; decision makers; investors; planners, and researchers.

Industry is actively encouraged to be involved as Task participants, as contributors to workshops or seminars, as consultants, or as technical reviewers of Task outputs to ensure that the orientation and activities of the Task match or meet their requirements.

Participating countries: Finland, Germany, Canada, United Kingdom and USA.

Task Leader: Dr Douglas Elliott, Battelle-Pacific Northwest, USA

Operating Agent: Mr Paul Grabowski, Department of Energy, USA

The Task Leader directs and manages the work. A National Team Leader from each country is responsible for coordinating the national participation in the Task. For further details on Task 34, please refer to Appendices 2-6 inclusive; the Task website www.pyne.co.uk and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Task Meetings

Task meetings were held in June in Finland (subsequent to its postponement from April when the Icelandic volcano erupted and disrupted air travel) and in October in the UK. The first meeting was held on 29-30 June in Espoo. It included a two day agenda of country reports, discussions of progress in norms and standards, website and newsletter developments, round robin planning and a tour of the VTT pyrolysis laboratories. Technical presentations were made on the European effort to assess the use of bio-oil in smoke flavourings and on the regulation of bio-oil transport. To address the 'Analysis' topic area, a number of analytical methods were assessed and the need for round robin validation will be determined. Also, the need for a new MSDS for fast pyrolysis bio-oil was assessed. This includes further processing of original EU Biotox-data. On July 1 the Task members also participated in a seminar organised by VTT on developments in biomass liquefaction since the original IEA Bioenergy Tasks on biomass liquefaction (BLTF and DBL) in the 1980s.

The second meeting was held on 16-17 October in Stratford-upon-Avon, UK. The agenda included country reports and a proposed publication of that information, and norms and standards developments. Most of the group also toured the biomass pyrolysis laboratories of Professor Tony Bridgwater at Aston University in nearby Birmingham. The most important outcome of the meeting was the final organisation of a round robin analysis of bio-oil samples for viscosity and thermal aging. An additional outcome of the meeting was the decision to undertake a symposium on Bio-oil Upgrading to Transportation Fuels, tentatively scheduled for October 2011.

Work Programme and Progress in 2010

The work typically consists of Task meetings, workshops, and Task projects, in addition to the 'usual' Task management and ExCo support actions. Among the work efforts were the following:

- Revision and updating of the website was completed to reflect the new Task participants. Input to the revisions was provided by all the participants.
- Similarly, two issues of an electronic newsletter were published and have been posted on the website.
- The standard development effort in USA and Canada continued forward. The Solids Determination Method for the Burner Fuel Standard for fast pyrolysis bio-oil was approved by ASTM as a stand-alone method D7579-09. Further work on standards will now proceed in Europe. A new CAS number was proposed and approved for Fast Pyrolysis Bio-oil as #RN1207435-39-9.
- A carryover project from the previous Task activities was publication of the results of the lignin pyrolysis round robin. A draft report was submitted for journal publication in 2009 and following review and revision was published in 2010 in the Journal of Analytical and Applied Pyrolysis.

- Planning was completed for a round robin to be undertaken in 2011. The round robin will include two bio-oil samples distributed to 21 laboratories in the five participating countries. The expected analyses are viscosity and thermal stability (change in viscosity following 24 hour ageing at 80°C).

Newsletter

The Task newsletter continues the tradition of the PyNe newsletter and is an important vehicle for dissemination of relevant information. It is circulated to participants via the Task 34 website in electronic format. Issue 27 was published in June 2010 and Issue 28 was published in December 2010.

Website/Dissemination

The Task 34 website is an important mechanism for information and technology transfer. It is revised and updated under a contract with Aston University.

Collaboration with Other Tasks

The priority topics in the Task work programme can be formulated to provide projects that can be shared with other IEA Bioenergy Tasks. As an example, there is opportunity for a joint assessment of a fast pyrolysis-based biorefinery. In particular, the Netherlands has expressed interest in a collaboration to facilitate pyrolysis-based biorefineries. This collaboration would be with Task 42, which is lead by the Netherlands. A Task 42 participant is undertaking an assessment of a pyrolysis-based biorefinery, based on lignin feedstocks.

Deliverables

Deliverables for 2010 were: reporting to the ExCo (Annual Report, progress reports, and audited accounts); continuation and updating of the Task website; two issues of the Task newsletter; organisation and minuting of two Task meetings; and organisation of the round robin.

TASK 36: Integrating Energy Recovery from Solid Waste Management

Overview of the Task

The waste and energy sector worldwide is currently undergoing a period of intense legislative and institutional change. The prime aim of Task 36 is to keep abreast of both technical and policy developments and to exchange information and dissemination on how energy integrates into these developments. This means that the sharing of good practice

and/or new technology and techniques is also a major goal, so a further objective of the Task is to maintain a network of participating countries as a forum for information exchange and dissemination. To achieve these goals the Task participants have chosen a number of key Topic Areas for inclusion in the work programme.

Many countries have different approaches to waste treatment and disposal, but common themes are concern about the increasing quantities of waste needing to be treated and disposed and the impact of landfilling mixed wastes on the environment. For some countries decreasing available landfill void space adds to this pressure. Consequently policy makers are examining alternatives to landfill, including reduction and recycling of waste, followed by recovery of value from waste. Within the EU the Waste Framework Directive sets out a waste hierarchy that ranks priorities in waste management, puts forward conditions for determining whether or not processing changes waste to a product and sets out the requirements for classifying the incineration of waste as energy recovery (specifically related to the efficiency of energy recovery). A major driver for decision makers is the Landfill Directive, which sets targets for the diversion of biodegradable waste from landfill. This has led to increased interest in recycling and treatment of waste, followed by recovery of energy from the residual waste stream. Elsewhere, notably in North America and Australia, countries continue to rely on landfill, but even here there are increasing pressures to reduce waste production and to recycle or recover where possible. Globally these policy pressures have led to a proliferation of research work on waste management, including policy development, environmental systems analysis, technology development and economic drivers. Whilst this has assisted in the development of more sophisticated waste management systems in many cases it has also delayed deployment of energy recovery systems (specifically for residual wastes) in particular due to confused policy making, public awareness (and opposition) and uncertainty over environmental performance and technology performance.

Against this background policy makers require guidance and information on all of these aspects if waste and resource management systems that are environmentally and economically sustainable are to be developed. Task 36 provides a unique opportunity to draw together information on how systems, policies and technologies are being applied in different countries to provide guidance for policy makers on key issues. It has already provided a guide to waste management systems in participating countries, which includes an overview of energy recovery options using combustion systems. It now aims to examine key work streams of relevance to the deployment of residual waste technologies, specifically to integrating energy recovery into such management systems.

Participating countries: Canada, France, Germany, Italy, Norway, Sweden and the United Kingdom

Task Leader: Dr Pat Howes, AEA Energy&Environment, United Kingdom

Operating Agent: Mr Kieran Power, Department of Energy and Climate Change, United Kingdom

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

For further details on Task 36, please refer to Appendices 2-6 inclusive, the Task website www.ieabioenergytask36.org and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

The Task held two meetings in 2010. The first took place on 26-28 May in Trondheim, Norway. This meeting included a seminar on energy from waste technologies applied in Norway and a report from the EC-funded NextGenBioWaste project, which reviews innovative demonstrations of the next generation of biomass and waste combustion plants for energy recovery. There was a site visit to the local district heating plant, the supply of which is dominated by the 70 MW energy from waste plant.

The second Task meeting took place in Rome on 17-19 November. This meeting included a seminar on developments in energy from waste in Italy. The meeting was hosted by GSE, who presented on renewable energy in Italy. Further presentations were made by researchers working on the measurement of the biogenic content of waste, which is important in waste qualification for renewable energy incentives. There was also a site visit to Marangoni Tyres factory where waste tyres are incinerated in a rotary kiln and the energy used to generate electricity. The meeting was attended by an Observer from the UK Environmental Services Association.

Work Programme

The goal of the Task is to produce a series of Topic Reports, each covering a subject that is important to the deployment of energy from waste. viz.

Topic 1: Policy support (Measurement of the biogenic content of waste and heat support)

Topic 2: Integration of processes for optimising resource recovery

Topic 3: Emerging small-scale energy recovery from waste

Topic 4: Life cycle assessment of waste management and recovery options

Topic 5: Management of residues from energy recovery

Progress on each Topic is summarised below.

Topic 1: Policy Support

This Topic will examine key issues that are important to policy at present and which are important to the development of 'green certification' of EfW:

- How to optimise (incentivise) the use of heat from EfW plants. This work will summarise the work being done in Sweden, the Netherlands, Germany and Denmark on the incentivisation of heat.

- How to measure the biogenic content of waste – this will draw from work undertaken by RSE spa and from the work of the CEN committee on this subject. A programme of work has been drawn up to include:
 - o A review of models currently available to model the biogenic content of waste
 - o The project just being started by the Swedish MSW organisation to determine $^{14}\text{C}/^{12}\text{C}$ in MSW samples.
 - o Work being done in Italy, the Netherlands, and Denmark on this subject.
 - o A critical review of data around 'representative sampling'.

The programme of work for this Topic has been defined and data gathering has commenced.

Topic 2: Integration of Processes for Optimising Resource Recovery

This Topic is examining proposed 'refinery-like' configurations for the processing of waste and recovery of energy in one integrated system. Three potential waste refinery configurations have been agreed for study. The first of these is modelled on systems that are available now; the second on systems that could be available in the near future; and the third of systems that might be offered further down the line. These 'waste refinery plants' will be referred to as 'Integrated Advanced Waste Refineries (IAWARE)'. The future configurations include advanced conversion technologies where feasible.

A preliminary paper setting out the proposed configuration for further study has been presented to the Task and the information gathering phase has commenced.

Topic 3: Emerging Small-scale Energy Recovery from Waste

This Topic will examine the potential for plants <50,000 t/y. It will include:

- Why small plants might need to be developed (e.g. rural areas or policy for small plants).
- Why it is difficult to develop plants that are small, cheap and efficient (or why it is more expensive, less efficient or higher risk to develop small plants).
- Technical versus policy issues e.g. how local policy may result in the need for local solutions which contradict the need to deal with technical issues.

Topic 4: Life Cycle Assessment of Waste Management and Recovery Options

This Topic will provide an environmental impact assessment of the options being examined for IAWARE in Topic 2. It will use Life Cycle Assessments (LCA) of different waste management systems completed in the Task over the past three years as a baseline for the impact assessment, in order to provide a comparative analysis for the IAWARE systems. A work plan has been submitted showing that this work will lag that of Topic 2 by six months. It includes collaboration with Task 37 for data input to the impact assessment.

Topic 5: Management of Residues from Energy Recovery

This Topic will examine the management of residues from energy recovery. It will cover:

- All types of combustion plants.

- Waste incineration, co-treatment of biomass, SRF, pyrolysis.
- Thermal energy recovery only (not biological treatment). Biological residues could be covered through liaison with Task 37.
- Comparisons of different technologies for use and the tests for use of fly ash.
- Provision of an overview of procedures, technologies and standards in all countries (including Danish standards).
- Comments on long-term impacts of use and how each country currently monitors these impacts.

The programme of work for this Topic has been defined and data gathering has commenced.

Website

The website (www.ieabioenergytask36.org) is the key tool used for dissemination of information from the Task. It provides access to the latest publications produced by the Task, including a recent report aimed at providing information on energy from waste to decision makers. The website also provides access to past reports, articles, case studies and presentations at workshops run by the Task. In addition, it provides a 'members only' forum, to allow rapid access to the latest drafts of documents and to information on Task meetings. In 2010 the visitor numbers were around 6,000 per week, with an average of four downloads per day. Visits have been steadily increasing over the past few years and peaked in 2010, coinciding with the release of the 2007-2009 End of Task Report that was specifically aimed at informing policy makers. The website is currently being upgraded to improve the information on visitor numbers.

Collaboration with Other Tasks

Collaboration with other Tasks has been proposed as follows: a joint workshop with Task 32 to be held in Ireland in late 2011; collaboration with Task 37 to gather data for Topics 2, 4 and 5; and proposed collaboration on the multi-Task 'health and safety' report.

Deliverables

The deliverables for the Task in 2010 included a final report for the previous triennium – this is now available on the Task website. The report has been well received, with a number of comments on how useful it is. Presentations from the workshops in Rome and Trondheim are also available on the Task website. The Task also prepared two progress reports and an annual audit report for the Executive Committee.

TASK 37: Energy from Biogas

Overview of the Task

The objectives of the Task are to review and exchange information and promote best practices concerning all steps of the anaerobic digestion (AD) of biomass residues and energy crops to produce clean biogas for utilisation as a clean renewable fuel, either directly or after up-grading to biomethane, and to recover digestate (compost) for use as an organic fertiliser. The scope of the work covers biogas on farm-scale, for waste water and sewage treatment as well as for the treatment of the biodegradable fraction of municipal waste (biowaste).

The scope of the work focuses on adoption of appropriate waste management practices, promotion of the commercialisation of biogas installations, improvement of the quality of the products, assuring high levels of health and safety and improving environmental standards. Through the work of the Task, communication between RD&D programmes, relevant industrial sectors and governmental bodies is encouraged and stimulated. Continuous education at all levels as well as targeted information for decision makers and plant operators are important topics.

To achieve the objectives, the Task maintains strong relationships with the governments of Member Countries, R&D institutions and industry. Partners in the work are plant and equipment providers, existing and future operators and potential clients interested in the products of anaerobic digestion, i.e., fertiliser (digestate) and biogas up-graded to biomethane.

Participating countries: Austria, Brazil, Canada, Denmark, Finland, France, Germany, Ireland, the Netherlands, Norway, Sweden, Switzerland, Turkey, United Kingdom, and the European Commission

Task Leader: Dr David Baxter, European Commission, Petten, the Netherlands

Operating Agent: Dr Kyriakos Maniatis, European Commission, Brussels, Belgium

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

For further details on Task 37, please refer to Appendices 2-6 inclusive; the Task website www.iea-biogas.net and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Task Meetings and Workshops/Seminars

Two Task meetings were held in 2010. The first meeting took place on 26-28 May in Copenhagen, Denmark. On 27 May, a small technical seminar 'Digestate and biogas utilisation - practices and perspectives' with local Danish speakers and the Task representative from Canada, was organised together with the University of Southern Denmark. This seminar was led by the National Team Leader from Denmark, Teodorita Al Seadi. The presentations, as well as the country contributions given during the business meeting, are available on the Task website. During the last day of the meeting a study tour was made to the Snerting eco-digestion facility in Western Zealand (Sjælland) where a well-established system of nutrient recycling back to the farmers supplying animal slurries to the plant was shown.

The second meeting took place on 3-5 November in Den Bosch, the Netherlands. The second day of the meeting was a policy workshop dealing with 'Biogas in the Netherlands: current situation and future perspectives'. The workshop was organised in collaboration with the Dutch province of Noord Brabant, at the centre of a major food-producing region in the country, and NL Agency. More than 150 mainly local participants attended, including people from industry, farming associations and local and national politicians. The presentations are available on the Task website, along with country reports made during the business meeting. On the last day a study tour was made to the Sterksel pig research unit of the University of Wageningen where work focussed on small-scale biogas production was described. A demonstration project is about to start on mono-digestion of pig slurry at Sterksel at a scale that should be capable of economic operation on small-to-medium scale animal rearing farms.

Planning of Future Task Meetings and Workshops

Task meetings in 2011 will be held in Turkey (13-15 April) and Ireland (14-16 September). There will be a workshop connected to the meeting in Ireland.

Work Programme

In 2010 the work programme consisted of the following Topics:

- Closure of 2007-2009 work programme Topics
- Drafting of new technical brochures/reports
- Collaboration with other Tasks
- Reports to ExCo65 and ExCo66, including input to the ExCo Member/Task Leader Seminar 'Strategic Priorities for IEA Bioenergy'
- New 'biogas handbook'
- Website: updating; maintenance; proceedings, country reports, etc.
- Planning of future Task meetings and workshops

The progress made on Task Topics is summarised below.

Closure of 2007-2009 Work Programme Topics

The brochure on 'Utilisation of digestate from biogas plants as biofertiliser', authored by Lukehurst, Frost and Al Seadi, was completed and published. This item was the last remaining deliverable from the 2007-2009 work programme.

New Technical Brochures/Reports

- Extension of the energy crop brochure to include additional feedstocks: A new draft was discussed at the November Task meeting and recommendations were made for final amendments.
- Feedstock pre-treatment: The first draft of the report will be available for distribution by the end of February 2011.
- Digestion process optimisation: The first draft report will be ready for discussion at the next Task meeting in April 2011.
- Economics of small-scale biogas production: Data collection from most Task participants by the lead author to be completed by January 2011. This will be followed by a review of the scope of the report at the next Task meeting.
- Updating the biogas upgrading list and identification of 'Success Stories': Upgrading the plant list will be completed by January 2011, followed by identification of 'success stories' in this fast developing technology area. The drafting of the texts for publication on the website will be completed as soon as possible.
- Review of gas quality requirements for natural gas pipeline injection: A review of gas quality standards from Member Countries will be completed by the end March 2011, followed by a decision on how to proceed with the available information.
- Digestate processing and quality control: The first draft of a new technical brochure was completed and distributed to Task members in December.
- Review of emissions from biogas installations: Collection of available data to be completed by the end of January 2011. Formulation of the scope of the Task report will be up for discussion with Task members. Studies on emissions from biogas installations are far from complete, so there will need to be a decision on how any resulting report will be published.

Biogas Handbook

Agreement has been reached with the publisher for a major new 'biogas handbook' authored in large part by members of the Task and edited by the Task.

Website

The website (www.iea-biogas.net) is updated with news and meeting dates on a monthly basis. The Country Reports as well as the Task publications and proceedings of the workshops were made available along with important publications from the participating countries. The website was completely rebuilt with modern software at the end of 2010.

Collaboration with Other Tasks

The Task contributed to the proposal for an ExCo-funded study of 'health and safety aspects of biomass feedstock treatment and handling'. There are ongoing discussions with Task 36 on joint work on anaerobic digestion of biowaste to start in 2011. The Task participated in the 18th European Biomass Conference in Lyon. Close cooperation with the EU project Biogasmax as well as with the European Biogas Association (EBA) has been maintained.

Deliverables

The deliverables for the Task included: minutes of the Task meetings, progress reports to ExCo65 and ExCo66, input to the ExCo Member/Task Leader Seminar on Strategic Priorities for IEA Bioenergy, Country Reports, workshops/seminars with publication of the presentations, and updating of the website.

TASK 38: Greenhouse Gas Balances of Biomass and Bioenergy Systems

Overview of the Task

The objective of the Task is to integrate and analyse information on greenhouse gases, bioenergy, and land use, thereby covering all components that constitute a biomass or bioenergy system. It focuses on the application of methodologies to greenhouse gas mitigation projects and programmes.

Participating countries: Australia, Austria, Belgium, Brazil, Finland, Germany, the Netherlands, Sweden, and USA

Task Leader: Mr Neil Bird, Joanneum Research, Austria

Co-Task Leader: Dr Annette Cowie, University of New England, NSW, Australia

Operating Agent: Dr Josef Spitzer, Joanneum Research, Austria

The Task Leader directs and manages the work programme. The Task Leader is assisted by Susanne Woess-Gallasch (Joanneum Research) and Annette Cowie (University of New England). A National Team Leader from each country is responsible for coordinating the national participation in the Task.

For further details on Task 38, please refer to Appendices 2-6 inclusive, the Task 38 website www.ieabioenergy-task38.org and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work:Tasks'.

Task Meetings and Workshops

In 2010, the Task organised one international workshop and one expert meeting.

In cooperation with the 'Centre Wallon de Recherches Agronomiques' (CRAW) and Joanneum Research, the Task organised an international conference on 'Greenhouse gas emissions from bioenergy systems: impacts of timing, issues of responsibility' on 8-9 March in Brussels, Belgium. There were 47 participants representing many organisations from all over the world. The programme, presentations and a workshop summary are available on the Task website at: <http://ieabioenergy-task38.org/workshops/brussels2010>. The conference was followed by an excursion to the bioethanol plant 'Biowanze' in Wanze and the pellet-fired thermal power plant 'Les Awirs' near Liège. The annual Task meeting took place in Brussels directly following the workshop and excursion on 11-12 March.

A Task and Graz Group expert meeting with some invited external experts was organised on 4-5 October in Graz, Austria. The topic of this meeting was 'Timing of emissions from wood-based bioenergy – solutions'. The object of the meeting was to discuss the topic on the basis of some presentations and to start drafting short papers from discussions in the meeting. The expert meeting was attended by 20 participants. They were made up of Task 38 members (or representatives), with representation from Task 40 and non-Task members.

The Task Leader participated in the 18th European Biomass Conference on 3-7 May in Lyon, France, and gave a presentation on 'Emissions from bioenergy: Improved accounting options and new policy needs'. This paper also appears in the proceedings of the conference. In addition, the Task Leader participated in the IEA Bioenergy ExCo66 meeting in October in York.

The Co-Task Leader was invited to present to, and participate in, a workshop hosted by the Joint Research Centre of the EC on 7-8 October in Ispra, Italy to discuss the issue of including time in life cycle assessment.

The Co-Task Leader also summarised the current work of the Task at the Bioenergy Australia 2010 conference, held on 8-10 December in Sydney, Australia, in a presentation titled 'Bioenergy: carbon neutral or climate neutral?'

The Task is working with Tasks 40 and 43 to plan a joint meeting in Campinas, Brazil in September 2011. The meeting will focus on land use issues associated with bioenergy.

Work Programme

In 2010 the Task worked on:

- organisation of the Task 38 international workshop in Brussels;
- participation in the 18th European Biomass Conference in Lyon;
- organisation of the Task 38 expert meeting in Graz;
- participation in the ExCo66 in York, UK;
- participation in the JRC Meeting, Ispra, Italy;
- the planning and continuation of sub-projects such as case studies;
- a contribution to the report for the ExCo on Bioenergy, Land Use Change and Climate Change Mitigation;
- ongoing work on the Strategic Paper for the ExCo on 'Lifecycle Analysis of Biomass Fuels, Power, Heat, and Products as compared to their Petroleum-Based Counterparts and Other Renewables';
- preparing of a Special Issue of Biomass and Bioenergy with papers from the Task workshops held in 2009 and 2010;
- a paper on linking different emission trading systems (ETS);
- a discussion text on emissions from forest-derived bioenergy; and
- maintenance of the website.

Case Studies

Final amendments to case studies commenced in the 2004-2006 period were made.

Specifically:

- Austria: Dedicated energy crops for biogas production in Austria. The case study has been translated from German to English and the CO₂ emissions from direct land use change have been calculated. The report is finalised and a brochure will be available in early 2011.
- Australia: GHG benefits of using biochar as a soil amendment. The case study will be finalised in early 2011.

Further work on case studies for the period 2007-2009 includes:

- Austria: GHG and energy balance of a wood to bioethanol biorefinery concept in Austria.
- Finland and Sweden: GHG and energy balance for systems producing biofuels (DME and Fischer-Tropsch) from pulp and paper mill residues, black liquor and other biomass sources (harvest residues and peat).
- Germany: Harvested wood products (HWP) model for estimating the carbon storage potential in Germany (Demonstrating IPCC Tier 3 method, and applying the three proposed approaches (+ hybrid approach) to HWP estimation).
- Germany: Environmental assessment of liquid biofuels from woody biomass. Comparison of Fischer-Tropsch diesel to CHO renewable energy N-process based on short rotation coppice, post-consumer wood and industrial roundwood.

Work is continuing on these case studies, and they are expected to be finalised in the current work programme.

Currently there is a call for new case studies. Decisions on these will be made at the next Task business meeting, scheduled for March 2011.

Strategic Paper for the ExCo

A new draft of the paper 'Lifecycle Analysis of Biomass Fuels, Power, Heat, and Products as Compared to their Petroleum-Based Counterparts and Other Renewables' was submitted at ExCo65. At ExCo66, there was a decision to employ a managing editor, Tat Smith, to supervise the finalisation of the strategic paper.

Task 38 Special Issue of Biomass and Bioenergy

Task 38 is currently preparing a special issue of Biomass and Bioenergy on 'Land use impacts of bioenergy: selected papers from the IEA Bioenergy Task 38 meetings in Helsinki, 2009 and Brussels, 2010'. All papers have now been delivered to the Journal Editor.

Paper on Linking Different ETS

The paper on 'The Influence of Linked Emission Trading Systems on the Bioenergy Market' was finalised in December. This paper analyses the incentives which emissions trading schemes created for the use of biomass. Furthermore, it assesses the effects on biomass use that occur when emissions trading schemes are linked.

Discussion Text on Emissions Through Forest-derived Bioenergy

The Task worked on a discussion text with the title 'Reduction of carbon emissions through forest-derived bioenergy substituting for fossil energy'.

Website/Communication

The Task website and the internal FTP site are continually updated. The presentations from the Brussels workshop and new Task papers and publications are available for downloading. In addition, publications and announcements are distributed through the 'climate change' mailing list and at national levels through NTLs.

Collaboration with Other Tasks/Networking

The Task collaborates widely with other Tasks and also external organisations as detailed above. Task 38 provided essential input to the report 'Bioenergy and Land Use Change'. This project is led by Göran Berndes, Leader of Task 43.

Through numerous EU-funded projects outside of the Task, Neil Bird has developed networks with palm oil researchers and industry through the CIFOR – BioSusT project.

Annette Cowie has completed a paper on monitoring and assessment of sustainable land management for the UNCCD, commenting on the interactions between the UNCCD and UNFCCC in relation to land used for bioenergy. She is also involved in the Biochar Researchers Network and International Biochar Initiative, contributing to development

of approaches for ensuring sustainability of biochar, based on approaches developed for bioenergy. Annette is developing a joint case study proposal with Task 43 (Brendan George, Australian NTL for Task 43) on optimising land use in NSW.

Neil Bird and Annette Cowie continue to be involved with the GBEP developments. For example, they provided detailed comment on the proposed 'Common methodological framework for GHG life cycle analysis of bioenergy' and engaged in follow-up discussions with GBEP.

Kim Pingoud participated as a lead author of the Bioenergy Chapter of the forthcoming IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. The report will be accepted by the IPCC in May 2011.

Deliverables

Apart from the wide range of deliverables mentioned above, the Task also produced progress reports and audited accounts for the ExCo. Other outputs were minutes of the Task meeting and updating of the website. Please see Appendix 4 for more details.

TASK 39: Commercialising Liquid Biofuels from Biomass

Overview of the Task

Task 39 remains focussed on primarily supporting the commercialisation of liquid biofuels from biomass, with a primary focus on 1st and 2nd generation technologies, but with a mandate that includes 'next-generation' fuels (including, for example, algal and 'drop-in' biofuels). Through coordinated policy and technical networks, the Task assists participants in their efforts to develop and deploy biofuels, including ethanol from lignocellulosics, Fischer-Tropsch fuels, and biomass-to-liquid (BTL) or biosyngas (biodiesel made from synthesis gas). It also continues to identify opportunities for comparative technical assessment and support for policy development. The success of the Task has been, in large part, a direct result of providing a forum for these types of integrated discussions. The Task objectives are to:

- Catalyse cooperative research and development projects to help participants:
 - develop and commercialise improved, cost-effective bio-based processes for the generation of 2nd generation biofuels, including converting lignocellulosic biomass to ethanol;
 - work with other Tasks to develop and commercialise improved, cost-effective thermochemical-based processes, such as the Fischer-Tropsch process, for converting syngas to synthetic biodiesel and other 2nd generation biofuels; and
 - understand advancements in 'next-generation' 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 participants encourage commercialisation of liquid biofuels as a replacement for fossil-based biofuels, by continuing the deployment of 1st generation biofuels and supporting development of 2nd generation biofuels and (potentially) next-generation biofuels.
- Provide information dissemination, outreach to stakeholders, and coordinate with related groups both within IEA Bioenergy and externally.

The Task structure allows participants to deal with biofuels in a comprehensive manner.

Participating countries: Australia, Austria, Brazil, Canada, Denmark, Finland, Germany, Japan, Korea, the Netherlands, New Zealand, Norway, South Africa, Sweden, United Kingdom, and USA

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

Associate Task Leader: Dr Jim McMillan, NREL, USA

Operating Agent: Mr Ed Hogan, Natural Resources Canada, Canada

The Task leadership is shared between the University of British Columbia (Canada) as represented by Jack Saddler, and the National Renewable Energy Laboratory (USA) as represented by Jim McMillan. Both Task Leaders are engaged in all aspects of the Task's operations. Sub-task Leaders for Technology and Commercialisation include Tony Sidwell, Michael Persson, Guido Zacchi, Tuula Makinen, and Axel Munack. Sub-task Leaders for Policy, Markets and Implementation include Manfred Wörgetter, Tony Sidwell, and Warren Mabee. The Task is coordinated by Jana Hanova (UBC), who acts as Editor of the Task Newsletter and Webmaster. Dina Bacovsky (Austria) manages the demonstration plant database. Axel Munack has been acting as the liaison person with the Advanced Motor Fuels Implementing Agreement. A National Team Leader for each country is responsible for coordinating the national participation in the Task.

For further details on Task 39, please refer to Appendices 2-6 inclusive; the Task website www.task39.org and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

The Task was very active in 2010. The first planning session for the new triennium, was held on 19-21 January in Cambridge, UK. The Task was grateful to Tony Sidwell and his colleagues at British Sugar for hosting and making arrangements for the business meeting and subsequent technical tour. The meeting re-emphasised that the participants value the primary role that the Task network plays in, not only bridging the gap between

the European Union and USA, but also in incorporating issues from the other Member Countries active in the liquid biofuels area, such as Brazil, Canada, New Zealand, Korea, Japan and South Africa. It was recognised that with USA and Brazil being major players in the biofuels area, the input from American and Brazilian colleagues (including Jim McMillan, Tom Foust, Paul Grabowski, and Viviana Coelho from Petrobras, Brazil) has been invaluable to the Task.

Some of the participants in the Task held an informal business meeting within the 'Biotechnology for Fuels and Chemicals Symposium' on 19-22 April in Clearwater, Florida. Due to the Icelandic volcanic eruption and accompanying ash cloud, numerous country representatives from Europe and Asia were unable to attend, so the Task held a smaller more targeted, yet still productive meeting.

The third business meeting was held in December and attracted approximately 20 participants. The business meeting was followed by Bioenergy Australia 2010 – an annual bioenergy conference. The conference featured virtually all of the Task representatives in a special session titled 'Recent progress in the liquid biofuels area'.

Work Programme

The work programme for the Task included the following elements:

Providing Information on Policy, Regulatory, and Infrastructure Issues

The overall objective is to provide governments and policy makers with improved information that will help them identify and eliminate non-technical barriers to liquid biofuels deployment.

The Task continues to compile country-specific information on biofuels including fuels usage, regulatory changes, major changes in biofuels policies, and similar items. The purpose of this effort is to maintain the Task's role as a central source of relevant information on biofuels. The first meeting in Cambridge, UK was considered successful because it allowed country representatives to provide updates on developments in their respective regions.

An informal report from the Florida meeting, as well as more formal notes from a well-attended business meeting in Sydney, have been posted in the 'members only' section of the Task website. The Task participants were also invited to share their expertise with the Bioenergy Australia 2010 Conference and held a special session to showcase recent progress.

Technical Aspects of Lignocellulosic Biomass-to-Ethanol Processes

The Task provides an information exchange network for participants who are conducting research and development activities in the area of lignocellulosic biomass-to-ethanol.

The working group in this area is focused on the technical and economic issues related to this technology option. The Task has undertaken an update of a 2nd generation biofuels facility database that provides up-to-date information on over 66 companies which includes biochemical, thermochemical, and hybrid conversion approaches to producing biofuels.

Major Reports

Three major reports were completed and are summarised below:

Current Status and Potential for Algal Biofuels Production: The Task commissioned a report on algal-based biofuel technologies which was authored by Al Darzins and Phil Pienkos (NREL, USA) and Les Edey (Australia). The NREL component of the draft report was circulated to the Task at the Cambridge meeting, while Les Edey subsequently worked on the report. A penultimate draft of the report was circulated to all of the country representatives and the authors then incorporated further feedback into the draft. The final report 'Current Status and Potential for Algal Biofuels Production' was released to the Task participants for three months after which the report was made available to the public. Due to the considerable interest in the algal biofuels area, the Task will commission a LCA analysis of algal biofuels to help guide Member Countries in their exploration of this area.

Throughout the production of the Task 39 report, drafts were sent to colleagues at AMF, to ensure they were informed of progress. It had been suggested that the Task 39's report focus primarily on the technical and economic issues associated with the production of algal-derived biofuels while the AMF report focus on engine-related issues with regard to using these types of biofuels. It is hoped that a joint executive summary can be produced once AMF have completed their algal biofuels report.

Overall, the algal biofuels report indicated that, although these fuels have considerable potential, significant technical and economic challenges will have to be resolved before they can be fully commercialised. The Task has an ongoing activity in the area and colleagues at NREL have agreed to update the report in the latter half of 2012.

Status of 2nd Generation Biofuel Demonstration Facilities: Currently, significant efforts have been invested in the production of biofuels from lignocellulosic raw material. While few production facilities are operational, many are planned or are currently under construction. This report attempts to answer questions such as: which companies are involved?; where are production facilities currently under construction?; and which technologies will be applied? In order to answer these questions, the Task collected data on pilot and demonstration projects of 2nd generation facilities and compiled an up-to-date database of these plants. The plant descriptions reflect the current status of projects for which the authors have received data from the project owners. Updating of the database and contacting new companies is ongoing. Interest in the database is considerable. This is an ongoing project for the current triennium.

Major Environmental Criteria of Biofuel Sustainability: This report (Phase I) embodies projects that will progressively analyse 'sustainability-related' information as it becomes available. This high level, more comprehensive report was meant to establish a 'base framework' for sustainability analysis, using four primary sustainability indicators. The report includes three key sections: Introduction; Trends in biofuel sustainability criteria; and Policy recommendations. Phase II will use the four indicators to assess the sustainability of bioethanol and biodiesel (and other biofuels) in various geographies using regional feedstocks. The overall sustainability of biofuels remains an issue of considerable debate. This overview report describes the general areas that are being discussed.

Newsletter

The Task published three newsletters in 2010. These provided information about the Task activities and international events related to biofuels. The newsletter continues to be sent to more than 1,000 individuals worldwide.

Website

The Task continues to build on its already considerable international community in the liquid biofuels area through the newly redesigned website and the newsletter. In 2010 the Task undertook a rebranding effort to update the look and feel of the group's website and to facilitate communication and information dissemination. The new website was launched in September (www.Task39.org). New information is added on a regular basis. The website is heavily cited and generates many enquires that are handled daily by the Task coordinators and webmaster.

Collaboration with Other Tasks/Networking

The Task has ongoing interactions with the other Tasks, IEAHQ and with external groups such as FAO, USDOE, the Global Bioenergy Partnership, and others. The Task continued discussions with Task 42 on biorefining and hopes to set up a multi-Task meeting in Brazil in 2011.

The Task continues to liaise with other Implementing Agreements, especially the Advanced Motor Fuels Implementing Agreement (AMF) with Axel Munack acting as the liaison person and attending meetings of the AMF as an observer on behalf of Task 39. More recently Dina Bacovsky has taken on a role with the AMF Implementing Agreement as their overall coordinator, providing even better linkages between the two Implementing Agreements.

Deliverables

The deliverables for the Task in 2010 included: two progress reports and audited accounts, as required by the ExCo; development and maintenance of the website; plus three newsletters and three technical reports on issues relating to biofuel implementation, deployment, and sustainability. The full library of Task reports, country specific reports, etc, are available through the Task website (www.Task39.org). These are detailed in Appendix 4.

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

Overview of the Task

In the first decade of the 21st century, a strong increase in the trade of both solid and liquid biofuels has been observed, until the recent economic crisis. Since 2008, the combination of the economic crisis, lower fossil fuel prices, disappointing outcomes from the Copenhagen Climate Conference and other factors have seriously hampered trade in these products. However, in the longer term, it is expected that there will again be a strongly growing demand for biomass and biofuels, so there is increasing need to develop biomass resources and exploit biomass production potentials in a sustainable way and to understand what this means in different settings. In some markets, prices of biomass resources and fuels are already rising, causing indirect effects on raw material prices, for example in the forest and food industries (e.g. sugar). Biomass markets are still immature and vulnerable, and this is particularly true for the demand side of the market. Many biomass markets, e.g. solid biofuels, rely on policy support and incentives.

It is important to develop both supply and demand for biomass, and energy carriers derived from biomass, in a balanced way and to avoid distortions and instability that can threaten investments in biomass production, infrastructure and conversion capacity. Understanding how this is best organised and managed needs further investigation. International biomass markets have been mapped by the Task, but the analyses, statistics, and modelling exercises undertaken so far still have limitations

The core objective of the Task remains 'to support the development of a sustainable, international, bioenergy market, recognising the diversity in resources, and biomass applications'.

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

Participating countries and institutions: Austria, Belgium, Brazil, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Norway, Sweden, United Kingdom, and USA. Canada will rejoin the Task from 1 January 2011.

Task Leader (Scientific): Prof. Dr André Faaij, Copernicus Institute, Utrecht University, the Netherlands, assisted by Dr Martin Junginger, Copernicus Institute, Utrecht University, the Netherlands

Task Leader (Administrative): Mr Peter-Paul Schouwenberg, RWE Essent, the Netherlands

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

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

For further details on Task 40, please refer to Appendices 2-6 inclusive; the Task website www.bioenergytrade.org and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

During 2010, the Task contributed significantly to two international workshops.

On 11-12 March, with support from the Task, CMT organised a 'biomass power and trade' conference in Rotterdam, the Netherlands. It provided opportunities for biofuels and biomass industry stakeholders to network with other industry suppliers and technology providers, as well as utility executives, researchers, policy makers, investors, and project developers. The Task contributed a large number of speakers on the biomass trade situation in various Member Countries, sustainability certification, torrefaction developments, and several other topics.

On 21 October, the Task organised a joint workshop with EUBIONETIII, with support from GSE and ETA Florence, in Rome. The aims of this workshop were:

- To provide an overview of experiences regarding sustainability certification, including the current status of legislation in the EU and elsewhere.
- To provide specific case studies of ongoing sustainable, international supply chains – both for solid and liquid biomass.
- To discuss opportunities for the development of sustainable, international bioenergy supply chains and identify the policy barriers to be overcome.

The workshop gave a good overview of the activities of governments, market parties, and NGOs regarding the implementation of sustainability certification schemes and the efforts to assure sustainable biomass production, trade, and use. Case studies from Belgium, Brazil, the UK, and Mozambique showed a lot of activity is currently ongoing regarding the certification of especially liquid, but to some extent also solid biofuels. Valuable experience has been gained from systems such as the RTFO and the Laborelec label, proving that sustainability certification is feasible in practice, with acceptable costs. Yet, as the RTFO experience shows, it remains a challenge for producers, traders and end-users to source sufficient sustainably produced liquid biofuels.

An important issue pointed out by the participants is the large variety of different certification systems, which may confuse market actors and cause additional market barriers. However, within the EU, there is a trend towards harmonisation, thanks to the mandatory EU sustainability criteria for liquid biofuels. It remains somewhat unclear exactly how the certification for the RED will take place, and to what extent the imported biofuels will be able to meet the criteria. Regarding the question of voluntary or mandatory sustainability criteria for solid biomass, the decision by the EC is still pending until the end of 2011. Many large European end-users favour mandatory criteria. Finally, there is an ongoing discussion concerning direct and indirect land use change – all participants present recognised the importance of iLUC, but opinions varied in terms if, and how, it should be included in biofuel certification schemes. Several methodological approaches exist to quantify the effect of iLUC caused by biofuel production, yet the principal question remains whether such an approach should really focus on overall sustainable land use by agriculture and forestry rather than just on bioenergy crops.

The programmes, presentations, and summaries are available on the Task website.

Both events were preceded by a two day internal meeting of the Task participants.

Future Meetings and Workshops

The first meeting of the Task in 2011 will be in January in Graz, Austria, preceding a joint Task 32 and Task 40 workshop on 28 January, as a side-event of the Central European Biomass Conference. The topic of the workshop is 'Development of torrefaction technologies and impacts on global bioenergy use and international bioenergy trade'. Torrefaction is an interesting pre-treatment technology for biomass before pelletisation and/or combustion. It is a thermochemical process for the upgrading of biomass that is usually run at temperatures ranging from 200°C to more than 300°C without oxygen and at ambient pressure. This workshop will give a comprehensive overview of the fundamentals of torrefaction, including the advantages and challenges of producing torrefied biomass. Ongoing R&D activities will be highlighted, along with demonstration plants under construction or in operation, and the latest state-of-science in torrefaction. The implications of commercially available torrefaction technology for international bioenergy trade will also be discussed.

The Task 40 is supporting the conference 'Biomass Trade and Power Americas' organised by CMT, on 23-25 February in Atlanta, USA. The theme of the conference is 'Pushing forward biomass utilisation and international trade'. Five Task members will be speaking.

A third major Task event scheduled for 19-21 September is a joint Task 38 and 43 workshop on 'direct and indirect land use change and bioenergy'. The event will take in Campinas, Brazil, and will include a one day field trip. The exact scope and format of the workshop is still being developed.

The meetings in Graz and Campinas will be linked to Task meetings. In addition, the Task plans to have a meeting in Denmark in June 2011 to discuss the development of several deliverables and to prepare for the workshop in Brazil.

Work Programme and Outputs

As outlined in the 2010-2012 work programme, the Task has four key objectives. A fifth objective is dissemination of the results of 1 to 4 below:

1. *Biomass supplies*: To deliver refined insights of the availability, potential production, and supply of biomass resources at regional, national, and global levels. This explicitly includes a range of biomass residue streams, land use, and competition for land in various markets worldwide, including developing regions.
2. *Sustainability and certification*: To determine how the sustainability of biomass supplies, use and trade can be secured optimally and efficiently, especially from a market perspective, with specific attention on the impacts of certification on international biomass and biofuels trade.
3. *Trade, market and demand dynamics*: To map and provide an integral overview of biomass markets and trade at a global level, as well as for specific regions. Identify and map new markets and products, improve the understanding on how biomass trade and markets respond to fluctuating fossil energy prices, developments on global markets for food and forestry products, emission trading, and the policies of different countries.
4. *Transport, logistics, and trade*: To provide insights of international biomass supply lines and logistic requirements (including new producing regions, i.e. developing countries and Eastern Europe) and how these can be optimised over time. This includes increasing the understanding of how costs of biomass production, pre-treatment and transport can be reduced. Such work includes advanced forecasting exercises on the required logistic capacity to facilitate increased biomass use and trade.

During the Task meetings in Rotterdam and Rome, a number of studies and deliverables were formulated based on participant preferences and available budget as follows:

Development of a Tool to Model European Biomass Trade

Currently, no model exists that can capture ongoing biomass energy trade flows. However, data availability for both current and future supply and demand of biomass in Europe is available. Thus an effort will be made to devise a modelling tool to describe ongoing and possible future trade flows. The aims of this work are:

1. To get a comprehensive overview of expected biomass production and demand for the EU-27 Member States, and the resulting biomass deficits/surpluses which may be covered by international bioenergy trade. This will be largely based on the recently published NREAPS, and the data contained in the Green-X model.

2. To develop an Excel/GIS-based modelling tool linked to the Green-X model to simulate biomass trade flows in the EU-27 up to 2020/2030 (based on the projected demand and supply from Phase 1 above).

The work will be led by Martin Junginger and Andre Faaij at Utrecht University, with large contributions from TU Vienna, and minor contributions from VITO and LUT. First results are expected in early-2011, the first modelling results are expected by mid-2011. This deliverable has clear relevance for Objectives 1, 3 and especially 4.

An Updated Wood Pellet Study with an Additional Wood Chip Trade Analysis

Historically, the 'wood pellet trade overview' study by the Task has been one of the most downloaded documents. However, it is now outdated. In addition, wood chips are increasingly traded for energy purposes, but very little is known regarding trade routes, volumes and possible barriers for this new commodity. Therefore, the Task has decided to carry out an update of the wood pellet study, in conjunction with an analysis of the wood chip markets (including an analysis of current trade routes: what is driving these markets? whether phytosanitary measures are an issue?). This work will be led by Maurizio Cocchi (wood pellets) and Didier Marchal (wood chips), with input from almost all Task participants. The results should be available by mid-2011. This study covers the Objectives 1, 3 and 4.

Country Overviews

Previously, Task participants have produced Country Reports describing the ongoing market and trade developments in their country. These have covered the types and volumes of biomass traded, prices, and current drivers and barriers. In 2011 the Task participants will each prepare another comprehensive Country Report.

Torrefaction Overview

As a minor deliverable, a short study will be made covering the current status of torrefaction, including a literature review, activities overview in Member Countries, and a summary of the main issues. Depending on the outcome, the Task may decide to further develop this topic (e.g. an assessment of how commercially-available torrefaction technology will impact on international trade flows).

Other Tentative Topics

Depending on the available budget and participant interests, other topics to be covered in the remainder of the triennium may include:

- A study on optimising logistic fuel supply chains.
- A study assessing to what extent certification/accreditation requirements affect international bioenergy trade.
- A handbook on biomass trade, in which the accumulated experiences of the Task could be collated.
- A study on 'business models that work'.
- An analysis of sustainability through the entire supply chain.

Workshops

In addition to the written deliverables, the workshops are linked to the Task work programme as follows:

- The workshop on the impact of sustainability certification on trade in Rome is at the heart of Objective 4, and the main summary and presentations are key outputs for this deliverable.
- The workshop on torrefaction clearly relates to Objectives 3 and 4, as it focuses on the impact of torrefaction on biomass logistics, which biomass feedstocks may become available due to torrefaction, and which markets may open up for torrefied biomass.
- The conference in Rotterdam and the conference in Atlanta clearly link to Objective 3 (development of solid biomass markets in USA, EU and other regions).
- The joint workshop in Brazil will have a large sustainability aspect (Objective 2), covering both the sustainable production related to land use change and the possibilities (and limitations) of certification to assess and control unwanted land use change.

Website

The Task website is a key tool for dissemination of information. In 2010, visitor numbers varied between 4500-7700 per month, on average slightly less than in 2009. This is probably because the Task had a record number of five events in 2009, compared with two in 2010, triggering large amounts of visitors before the event (to view the programmes) and afterwards (to download presentations). However, the amount of monthly downloaded data has increased compared to 2009. As in previous years, each month, at least 10 documents are downloaded over one hundred times. All Task deliverables (e.g., country reports, market studies, etc.) and presentations given at the Task workshops are available for downloading.

Collaboration with Other Tasks/Networking

As described above events were organised jointly with EUBIONETIII and CMT. At these events, the work of the Task was disseminated via presentations. The Task's work was also presented to a large number of other audiences during 2010, such as the BioPower Generation Conference in Amsterdam in March, the Biomass Pellets Trade Asia Conference in Jakarta in September, and the Sustainable Biomass for European Energy Conference in November in Brussels. The Task aims to continue this outreach and collaboration in the coming triennium. Collaborations with Tasks 32, 38 and 43 are planned for 2011.

Deliverables

Deliverables in 2010 included two workshops, various types of reports, several market studies, contributions to the wood pellet handbook, two newsletters (circulation of 1200), an updated leaflet, minutes from two Task meetings, two progress reports and audited accounts to the ExCo; plus over 10 presentations at various international workshops and conferences. These are detailed in Appendix 4.

TASK 41: Bioenergy Systems Analysis

Overview of the Task

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

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

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

For further details on Task 41, please refer to Appendices 2-6 inclusive; and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Work Programme

The work programme is comprised of a series of Projects. Each Project has its own budget, work description, timeframe, and deliverables and is approved by the participants. The focus is on the needs of the participants by way of Project outputs. Three projects have been initiated to date and Projects 1 and 2 have been completed. Details are:

Project 1: Bioenergy – Competition and Synergies

Participating Countries: Germany, Sweden, United Kingdom, USA and the European Commission

Project Leader: Mr Sven-Olov Ericson, Ministry for Sustainable Development, Sweden

Operating Agent: Dr Björn Telenius, Ministry of Enterprise, Energy and Communications, Sweden

Status: Completed in December 2008

Project 2: Analysis and identification of gaps in fundamental research for the production of second generation liquid transportation biofuels

Participating Countries: Finland, the Netherlands, Sweden, United Kingdom, USA and the European Commission

Project Leader: Dr Michael Ladisch, Purdue University, USA

Operating Agent: Mr Paul Grabowski, US Department of Energy, USA

Status: Completed in July 2008

Project 3: Joint project with the Advanced Motor Fuels Implementing Agreement, Annex XXXVII 'Fuel and Technology Alternatives for Buses: Overall energy efficiency and emission performance'

Participating Countries: Finland, Germany and the European Commission

Project Leader: Professor Kai Sipilä, VTT, Finland

Operating Agent: Professor Kai Sipilä, VTT, Finland

Status: The project commenced in January 2009 and is expected to be completed in late 2011.

The objective of this high profile Task is to bring together IEA expertise to access overall energy efficiency, emissions, and costs, both direct and indirect costs, of various technology options for buses. City buses are amongst the most coherent vehicle fleets. Procurement of bus services is often handled by municipalities or state in a centralised manner. The impact of city buses on urban air quality is huge, and fuel efficiency is crucial for operational costs. Biofuels will have a major role in the test programme.

The project is of interest to seven Implementing Agreements, including IEA Bioenergy, all of which have transport-related activities. The participants from IEA Bioenergy are co-financing the project at the level of €75,000. The total budget is €1,075,000. A final report is planned for October 2011.

Deliverables

The deliverables may consist of progress reports and financial accounts to the ExCo, and a final report on each project – see details in Appendix 4.

TASK 42: Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass

Overview of the Task

The aim of the Task is to initiate and actively promote information exchange on all aspects of the biorefinery concept. The information exchange (and cross fertilisation) will include biomass feedstocks, conversion and fractionation technologies, integration of processes and the use of side-streams, products, energy efficiency, economic aspects, environmental performance, social acceptance, and sustainability issues (impact on food production, water use and quality, changes in land use, access to resources, biodiversity, and the net balance of greenhouse gases). The work of the Task should minimise fragmentation in this multi-disciplinary field by providing a platform for stakeholders. It will also result in cross-thematic synergies, identification of gaps and overlaps, and definition of priority research needs and infrastructure. The following activities have been identified and agreed by the participants:

- Prepare a common definition of biorefineries, including a clear and widely accepted classification system.
- Gain better insights into the processing potential of existing biorefineries in the participating countries.
- Assess biorefinery-related RD&D programmes in participating countries to help national governments define their national biorefinery policy, goals, and related programmes.
- Prove the advantages of biorefinery concepts over more conventional single product processes by assessing and comparing their financial, economic, ecological, and societal characteristics.
- Bring together key stakeholders normally operating in different market sectors (e.g. agriculture, forestry, transportation fuels, chemicals, energy, etc.) in multi-disciplinary partnerships to discuss common biorefinery-related topics, to foster necessary RD&D trajectories, and accelerate the deployment of developed technologies.
- Identify the most promising added-value chemicals, e.g. functionalised chemicals and platform chemicals (building blocks), to be co-produced with energy to optimise overall process economics and minimise the overall environmental impact.
- Co-operate with ongoing national and international activities and programmes, e.g. other Tasks, Implementing Agreements, and EU Technology Platforms.
- Disseminate knowledge, including teaching material to make students familiar with the integral concept-thinking of biorefineries.

The Task commenced in January 2007.

Participating countries: Australia, Austria, Canada, Denmark, European Commission, France, Germany, Ireland, Italy, the Netherlands, Turkey, United Kingdom, and USA

Task Leader: Dr Ing. René van Ree, Wageningen University and Research Centre (WUR), the Netherlands

Assistant Task Leader: Dr Ed de Jong, Avantium Technologies BV, the Netherlands
Operating Agent: Ir Kees Kwant, NL Agency, the Netherlands

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

For further details on Task 42, please refer to Appendices 2-6 inclusive; the Task website www.IEA-Bioenergy.Task42-Biorefineries.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

The Task organised two meetings in 2010. The 7th Task meeting on 3-4 March in Lille, and the 8th Task meeting on 4-6 October in Chicago. Both meetings were in conjunction with national workshops in which industrial stakeholders met with the Task participants to discuss biorefinery-related topics and undertake study tours to operating biorefinery facilities.

The Lille event started with a meeting organised by Ademe in which some major French stakeholders (IAR, Sofiproteol, ACDV, OECD, Ademe) presented their activities within the biorefinery framework. In the afternoon the participants visited the Roquette facilities in Lestrem, a main production site of corn starch, wheat starch, sugars, and polyols. On the second day there was an internal Task meeting, which discussed progress in the Task activities. In the afternoon the Austrian team organised a thermochemical biorefinery session with speakers from the Vienna University of Technology, Lund University, and the German Biomass Research Centre.

The Chicago event started with a meeting organised by DOE in which a selection of their current biorefinery projects with a focus on thermochemical conversion were presented. On the second day there was an internal Task meeting, which discussed progress in the Task activities. On the third day the participants visited both the UOP Riverside McCook Facility and the GTI Energy and Environmental Technology Campus in Des Plaines. At the UOP site there were about 100 pilot facilities, including the Ecofiningtm jet fuel process. At the GTI site, the group saw the 'wood to green gasoline using Carbona gasification' and the 'TopsoeTigas' processes operating.

The Task also organised a full day Biorefinery Training Course in Amsterdam on 13 September 2010. This was in conjunction with EC FP6 IP Biosynergy and EC FP7 SSA Bioref-Integ. The course was attended by about 50 participants from industry, institutes, universities, and government.

All presentations given at the Task meetings and the Biorefinery Training Course can be found on the Task website.

Work Programme

The work programme of the Task is based on a prioritisation of activities agreed upon by the participating countries, and is as follows:

- Development of a classification system and complexity index on biorefineries.
- Identification of the most promising bio-based products to be co-produced with bioenergy.
- Assessment of the current status and development potential of both energy and product-driven biorefineries based on a 'full sustainable value chain' approach.
- Preparation of a guidance document on sustainability assessment for biorefineries.
- Preparation of a strategic biorefinery paper.
- Preparation of Country Reports on current processing potential and mapping of existing biorefinery pilot, demonstration and commercial plants, and of major RTD projects.
- Organisation of bi-annual Task meetings, including excursions to operating facilities (internal knowledge dissemination).
- Organisation of industrial stakeholder workshops and setting up a Task website (external knowledge dissemination).
- Setting up and organising a Biorefinery Training Course/Summer School.

The progress achieved is described below.

Classification System and Complexity-index for Biorefineries

This work has been comprehensively reported in the feature article of the 2008 Annual Report and also under Task 42 in the 2009 Annual Report. In 2010 the classification system for the energy-driven biorefineries was finalised, and a start made with the product-driven biorefineries. The pros and cons of developing a Biorefinery Complexity Index were discussed. In 2011 a decision will be made on whether to develop a Biorefinery Complexity Index. This activity is co-ordinated by Joanneum Research (Austria). The schedule for final delivery is early 2011.

Bio-based Products to be Co-produced with Bioenergy

The Task is currently preparing a report, identifying the most promising bio-based products, i.e. food, feed, added-value materials (e.g. fibre-based) and chemicals (functionalised chemicals and platform chemicals) to be co-produced with bioenergy, to maximise overall process economics and environmental benefits. The report will focus on material outputs alone and intends to update DOE's 2004 report on Bioproducts. It will take stock of all available studies in different countries and condense them into a single document. The report is not an independent study – more a dissemination activity. The target audiences are industry and policy makers. Preparation of the report is co-ordinated by NNFFC (UK). The schedule for delivery is mid-2011.

Current Status and Development Potential of Both Energy and Product-driven Biorefineries Based on a Full Sustainable Value Chain Approach

The Task is currently assessing the status and development potential of both energy-driven biorefineries (including biofuels) and product-driven biorefineries. These assessments will be based on a 'full value chain' approach, covering raw materials issues (crops, residues, algae),

conversion processes, and final product applications in an integrated approach. In 2010 a start has been made with the set-up of a gross-list of promising advanced biofuel-driven value chains. In 2011 this gross-list will be used to select about 10 advanced biofuel value chains for further assessment. One of the selection criteria is that the value chains to be considered should be of interest to the participating countries, i.e. pilot, demonstration, or commercial initiatives which can deliver market-sound data input for the chain assessment study. This activity is co-ordinated by Joanneum Research (Austria). The schedule for delivery is mid-2011.

Guidance Document on Sustainability Assessment for Biorefineries

This activity will commence in 2011. Because 'sustainability assessment' is also an important activity in other Tasks (for example Tasks 29, 38, and 39) a joint meeting will be organised to discuss the methodology to be developed. At ExCo66 in York, it was decided to set up a Taskforce on this subject. From the Task's point-of-view, the co-production of both, human food, animal feed, and/or bio-based chemicals/materials with bioenergy/biofuels, should be an integral part of the assessment methodology. Canada will lead this initiative.

Strategic Biorefinery Paper

This paper is scheduled to be produced in 2012. The proposed title is 'Adding Value to the Sustainable Utilisation of Biomass on a Global Scale - Biorefining'. All relevant Task results produced in the last six years will be integrated showing the technical, economic, ecological, and social advantages of co-production of bioenergy and bio-based products for sustainable biomass use in a future bio-based economy. The Task will invite representatives from other Tasks to contribute to this paper. Wageningen University and Research Centre (the Netherlands) will lead this initiative.

Country Reports on Current Processing Potential and Mapping of Existing Biorefinery Plants and Major RTD-projects

Within the Task a detailed summary report was prepared, based on the individual Country Reports provided by the National Team Leaders. The reports provided an overview of the biomass, bioenergy and biorefinery situation, and activities in the participating countries. The reports included current biomass use for both energy (power, heat, CHP, fuels) and non-energy (food, feed, materials, chemicals) purposes, biorefinery-related policy goals and funding programmes, operating commercial biorefineries, biorefinery demonstration and pilot plants, major RTD projects, and stakeholders (industry, universities, institutes, GOs, and NGOs). This activity is co-ordinated by the University of Copenhagen (Denmark). The schedule for delivery is late 2010.

Biorefinery Training Course/Summer School

Together with the EC FP6 IP BIOSYNERGY, the Task prepared a Biorefinery Course. This half day course was provided to about 50 participants at the RRB5 Conference in Genth, Belgium on 12 June 2009. The Task also organised a full day Biorefinery Training Course in Amsterdam, on 13 September, in conjunction with the EC FP6 IP Biosynergy and the EC FP7 SSA Bioref-Integ. This course was attended by about 50 participants from industry,

government, universities, and institutes. In 2011, the training course will be upgraded to a four day Biorefinery Summer Course in co-operation with EC FP7 IP BIOCORE. It will be hosted by INRA in France in 2011, and by WUR in the Netherlands in 2012.

Multi-disciplinary Partnerships

In 2007 it was decided that the National Team Leaders would be responsible for the creation of 'stakeholder forums' at national level. For example, in the Netherlands, WUR is doing this by organising a variety of biorefinery-related activities within the framework of the National (Dutch) Platform on Biorefineries. International knowledge exchange between the Task and these stakeholder forums will take place frequently, for example by inviting them to Task-related workshops, and will be reported to the other participants at Task meetings.

Task Website

A new Task website was set up in 2010 (www.IEA-Bioenergy.Task42-Biorefineries.com). It is used for both information management using a password protected extranet-site and a public area for knowledge dissemination. The website contains information on the progress of the Task activities, biorefinery news, biorefinery events, contacts for National Team Leaders, country-specific stakeholders, publications, and a database on country specific commercial facilities, demonstration and pilot plants, and major RTD projects.

Collaboration with Other Tasks/Networking

In 2010 co-operation was established with ongoing international activities, e.g. other Tasks, European-based Technology Platforms, Specific Support Actions, and Integrated Projects. This co-operation will be enhanced in 2011 by organising joint events, e.g. workshops and meeting regularly with ongoing EU-initiatives. In 2010 the following activities took place:

- Preparation of the 'biorefinery' part of updated SRA of the EC Technology Platform Biofuels.
- Presentation of the Task at a variety of national and international workshops and conferences.
- Presentation of the Task at a variety of EC Biorefinery RTD project meetings (Biosynergy, Bioref-Integ, Starcolibri, Biscore).
- Presentation of the Task at the Biorefinery Training Course in Amsterdam.

In 2011 and beyond, the following collaborative actions are planned:

- A joint EC FP7/Task event on running major biorefinery RTD projects, in Brussels, Belgium, 7 February 2011.
- Co-operation with Task 34 on pyrolysis-related biorefining.
- Presentation at the World Biofuels Conference, Rotterdam, the Netherlands, 22-24 March 2011.
- Presentation at the EC FP7 Starcolibri Meeting, Budapest, 12-13 April 2011.
- Presentation at the RRB7, Brugge, Belgium, 8-10 June 2011.

- Joint Conference with Task 39 on 'Developing advanced biofuels in a biorefinery concept' in early 2012.
- Joining a taskforce on sustainability that will be organised by the Task Coordinator.

Deliverables

Deliverables in 2010 included organising and minuting of two Task meetings and workshops; reporting to the ExCo (two progress reports, audited accounts, and a contribution to the Annual Report); setting up and maintenance of the Task website; preparation of a classification system for energy-driven biorefineries; Country Reports on biorefinery mapping; and a one day biorefinery training course.

TASK 43: Biomass Feedstocks for Energy Markets

Overview of the Task

Work in the current triennium is based on the premise that in many countries biomass demand for energy will enter a period of rapid expansion as a way to ensure sustainable and secure energy sources. Feedstocks from many land uses and cropping systems (e.g. agriculture, forestry, dedicated energy crops) can become a plausible energy source if production systems are economically and environmentally attractive. New science, tools, and technology must be developed to support this era of rapid expansion. Such developments will ensure that suitable production systems are established and can be relied on to help achieve the energy policy targets in many countries.

The objective of the Task is to promote sound bioenergy development that is driven by well-informed decisions in business, governments, and elsewhere. This will be achieved by providing relevant actors with timely and topical analyses, syntheses, and conclusions on all matters relating to biomass feedstock, including biomass markets and the socio-economic and environmental consequences of feedstock production.

The work programme has a global scope and includes commercial, near-commercial and promising production systems in agriculture and forestry. The primary focus is on land use and bioenergy feedstock production systems. The Task will be concerned with issues related to the linking of sustainable biomass feedstocks to energy markets, explicitly considering environmental and socio-economic aspects.

Participating countries: Australia, Canada, Denmark, European Commission, Finland, Germany, Ireland, Italy, the Netherlands, New Zealand, Norway, Sweden, United Kingdom, and the USA

Task Leader: Associate Professor Göran Berndes, Chalmers University of Technology, Sweden

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

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

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

The Task Leader directs and manages the work programme assisted by an international team. A National Team Leader (NTL) from each country is responsible for coordinating the national participation in the Task. During 2010, the Task capacity was further increased through the NTLs engaging support persons within their country. The aim was that all participating countries should have a national team consisting of participants actively supporting the NTL at the national level as well as being engaged in Task activities at the international level.

For further details on Task 43, please refer to Appendices 2-6 inclusive; the Task website www.ieabioenergytask43.org and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings

The Task was involved with several specific events in 2010, starting with the kick-off meeting in Göteborg, Sweden, where the NTLs met for the first time to plan for the 2010-12 triennium. The NTLs have been engaged in sub-Task working group meetings in connection with Task events, and have been involved in relevant activities at the national level. The NTLs also achieve substantial outreach as part of their role.

An international workshop titled 'Sustainability across the supply chain of land-based biomass' was organised by the Task and the Long-Term Soil Productivity Study collaborators on 1-4 June, in Kamloops, Canada,. Seventy-five participants from 13 countries attended the 12 technical sessions, including four plenary sessions, a poster session, and two field tours. This provided workshop participants opportunities to share experiences, findings, and directions on the environmental, economic, and social sustainability of a secure biomass supply for bioenergy. Refereed papers stemming from the workshop presentations will be submitted to the new Journal of Forest Energy, being launched at METLA by Finnish NTLs Asikainen, Röser, and colleagues, and in collaboration with the Task participants.

The Task organised an international workshop 'Spotlight on Bioenergy and Water' on 5-6 July in Paris in collaboration with UNEP and the Oeko Institute. It brought together about 40 bioenergy and water experts from different regions of the world to discuss areas of critical importance, exchange experiences on ways to address potential risks, and identify further research needs. A state-of-the-art report, involving about 20 authors, is being produced for publication in January 2011. In addition, a special issue of the scientific journal *Biofuels, Bioproducts and Biorefining* will be published in 2011.

Work Programme

The work programme for the current triennium is planned to provide answers, from different perspectives, to the following questions:

- How can the Task further develop and implement feedstock production systems to provide attractive solutions for energy security, climate change, and sustainable development?
- How can policy- and market-based instruments effectively promote sustainable development, and how can science-based sustainability criteria and standards be formulated to take into account the vast regional variation in conditions for production of different feedstocks?
- What are the costs and gains associated with productivity, competitiveness, and environmental performance of feedstock supply systems and how do they impact deployment and market penetration of the systems?
- What are the motivations, opportunities, and capabilities for producers in agriculture and forestry to change from conventional production systems and deploy or integrate sustainable bioenergy production systems in response to new demands? What are necessary and sufficient conditions for financial investment in developing feedstock production systems?

A number of Focus Topics have been established as a basis for Task activities:

- Bioenergy and land use change
- Integration of food and fibre production with cost effective biomass supply for energy
- Sustainability of bioenergy feedstock supply systems
- Bioenergy and environmental services
- Certification systems to ensure sustainable bioenergy systems

Systematic knowledge transfer is achieved through the website, reports and briefs, a compendium, international collaboration, and IEA networks to educate and inform the bioenergy sector. In addition to contributing to the Journal of Forest Energy mentioned above, the Task has taken steps to establish strong channels for its outreach: including a role as Associate Editor (bioenergy) for the Wiley journal WIREs: Energy and Environment and cooperation with the journal Biofuels, Bioproducts and Biorefining in instances where this journal can offer suitable channels such as the planned special issue on 'bioenergy and water'.

Website

The Task website (www.ieabioenergytask43.org) designed with the objective of obtaining a wider Task exposure, is updated regularly. The website informs about Task 43 and presents the outcomes of Task activities. It also provides web links to the previous Tasks 30 and 31.

Collaboration with Other Tasks/Networking

Besides the collaboration associated with the two workshops presented above, the Task collaborated with Task 38 in the production of the strategic publication 'Bioenergy Land Use Change and Climate Change Mitigation' and was represented at the Task 38 workshop in Graz. Tasks 38, 40, and 43 have also worked together in planning for the international workshop in Brazil in September 2011.

Deliverables

Deliverables for 2010 included reporting to the ExCo (two progress reports, audited accounts, and a contribution to the Annual Report). Also the organisation and minuting of two Task meetings, and updating of the Task website. Please see Appendix 4 for more details including technical reports produced in 2010.

IEA BIOENERGY TASK PARTICIPATION IN 2010

TASK	AUS	AUT	BEL	BRA	CAN	CRO	DEN	FIN	FRA	GER	IRE	ITL	JAP	KOR	NEL	NZE	NOR	SA	SWE	SWI	TUR	UK	USA	EC	Total
29: Socio-econ					•				•								•					⊗			5
32: Combustion		•		•		•		•	•	•	•	•			⊗		•		•	•	•	•			13
33: Gasification		•				•		•	•			•	•		•	•	•			•	•	⊗	⊗		12
34: Pyrolysis					•			•	•	•					•							•	⊗		5
36: MSW									•	•		•					•		•			⊗			7
37: Biogas		•		•	•			•	•	•	•				•		•		•	•	•	•	⊗		15
38: GHG	•	⊗	•	•				•		•					•				•				•		9
39: Biofuels	•	•		•				•	•	•			•	•	•	•	•	•	•	•		•	•		16
40: Trade		•	•	•				•	•	•		•	•		⊗		•		•	•		•	•		13
41 (3): AMF								⊗	P3	P3													P3		3
42: Biorefineries	•	•		•					•	•	•	•			⊗						•	•	•	•	13
43: Feedstocks	•			•				•	•	•	•	•			•	•	•		⊗			•	•	•	14
Total	4	7	2	4	8	1	7	9	3	12	4	6	3	1	8	3	8	1	7	3	4	9	7	4	125

⊗ = Operating Agents

• = Participant

BUDGET IN 2010 – SUMMARY TABLES

Budget for 2010 by Member Country (US\$)

Contracting Party	ExCo Funds	Task Funds	Total
Australia	10,700	59,500	70,200
Austria	13,700	103,000	116,700
Belgium	8,700	31,500	40,200
Brazil	10,700	60,500	71,200
Canada	14,700	123,320	138,020
Croatia	7,700	14,000	21,700
Denmark	13,700	103,500	117,200
Finland	15,700	141,373	157,073
France	9,700	44,320	54,020
Germany	18,700	185,693	204,393
Ireland	10,700	59,000	69,700
Italy	12,700	89,820	102,520
Japan	9,700	44,500	54,200
Korea	7,700	15,000	22,700
Netherlands	14,700	118,000	132,700
New Zealand	9,700	42,500	52,200
Norway	14,700	117,820	132,520
South Africa	7,700	15,000	22,700
Sweden	13,700	105,820	119,520
Switzerland	9,700	41,500	51,200
Turkey	10,700	56,500	67,200
UK	15,700	140,320	156,020
USA	13,700	109,000	122,700
European Commission	10,700	62,373	73,073
Total	285,800	1,883,859	2,169,659

BUDGET IN 2010 – SUMMARY TABLES

Budget for 2010 by Task (US\$)

Task	Number of participants	Annual contribution per participant	Total Task funds
Task 29: Socio-economic Drivers in Implementing Bioenergy Projects	5	14,000	70,000
Task 32: Biomass Combustion and Co-firing	13	15,000	195,000
Task 33: Thermal Gasification of Biomass	12	12,500	150,000
Task 34: Pyrolysis of Biomass	5	20,000	100,000
Task 36: Integrating Energy Recovery into Solid Waste Management	7	15,320	107,240
Task 37: Energy from Biogas	15	14,000	210,000
Task 38: Greenhouse Gas Balances of Biomass and Bioenergy Systems	9	14,500	130,500
Task 39: Commercialising Liquid Biofuels from Biomass	16	15,000	240,000
Task 40: Sustainable International Bioenergy Trade - Securing Supply and Demand	13	17,000	221,000
Task 41(3): Joint Project with AMF IA	3	18,373	55,119
Task 42: Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass	13	15,000	195,000
Task 43: Biomass Feedstocks for Energy Markets	14	15,000	210,000
Total			1,883,859

CONTRACTING PARTIES

Rural Industries Research and Development Corporation (Australia)

The Republic of Austria

The Government of Belgium

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

Natural Resources Canada

The Energy Institute "Hrvoje Pozar" (Croatia)

The Ministry of Transport and Energy, Danish Energy Authority

Commission of the European Union

Tekes, Finnish Funding Agency for Technology and Innovation

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

Federal Ministry of Food, Agriculture and Consumer Protection (Germany)

The Sustainable Energy Authority of Ireland (SEAI)

Gestore dei Servizi Energetici – GSE (Italy)

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

Ministry of Knowledge Economy, the Republic of Korea

NL Agency (The Netherlands)

The New Zealand Forest Research Institute Limited

The Research Council of Norway

South African National Energy Research Institute (SANERI)

Swedish Energy Agency

The Swiss Federal Office of Energy

Tubitak Marmara Research Center Energy Institute (Turkey)

Department of Energy and Climate Change (United Kingdom)

The United States Department of Energy

LIST OF REPORTS AND PUBLICATIONS

The Executive Committee

Final Minutes of the ExCo65 meeting, Nara City, Japan, May 2010.

Final Minutes of the ExCo66 meeting, York, United Kingdom, October 2010.

IEA Bioenergy News Volume 22(1), June 2010.

IEA Bioenergy News Volume 22(2), December 2010.

IEA Bioenergy Update. Number 41. Biomass and Bioenergy. Volume 34, Issue 3, March 2010.

IEA Bioenergy Update. Number 42. Biomass and Bioenergy. Volume 35, Issue 1, January 2011.

IEA Bioenergy Update. Number 43. Biomass and Bioenergy. Volume 35, Issue 1, January 2011.

IEA Bioenergy Update. Number 44. Biomass and Bioenergy. Volume 35, Issue 1, January 2011.

IEA Bioenergy Update. Number 45. Biomass and Bioenergy. Volume 35, Issue 2, February 2011.

IEA Bioenergy Update. Number 46. Biomass and Bioenergy. Volume 35, Issue 2, February 2011.

IEA Bioenergy Update. Number 47. Biomass and Bioenergy. Volume 35, Issue 2, February 2011.

Anon. IEA Bioenergy Annual Report 2009. IEA Bioenergy ExCo:2010:01.

Anon. Algae – The future for bioenergy? Summary and conclusions from the IEA Bioenergy ExCo64 workshop. IEA Bioenergy ExCo:2010:02.

Anon. IEA Bioenergy ExCo65 workshop presentations 'Developing sustainable trade in bioenergy'. Nara City, Japan, May 2010.

Kwant, K. Overview of world bioenergy trade: IEA Bioenergy Task 40.

Kimura, S. Overview of market development in Asia.

Smith, D. Australian pellet export outlook.

Kojima, K. Wood pellet production.

Takemura, S. Ethanol trading flow in East and South-East Asia.

Wei, P.C. Palm oil as feedstock for biodiesel: production and exports from Malaysia.

Konishi, T. Sustainable biomass utilisation in East Asia.

Faaij, A. Scientific needs and market impacts of securing sustainability of bioenergy.

Anon. IEA Bioenergy ExCo66 workshop presentations 'Thermal pre-treatment of biomass for large-scale applications'. York, UK, October 2010.

Kiel, J. Overview of thermal pre-treatment processes for large-scale biomass applications.

Bridgwater, A. Biomass pyrolysis.

Rauch, R. Overview of full-scale gasification processes.

Gunnarsson, I. The GoBiGas project: efficient transfer of biomass to biofuels.

Sipilä, K. Bioenergy carriers: integrated pyrolysis and torrefaction concepts.

Weaver, M. The pyrolysis of biomass to give us biochar and using it as a soil improver.

Jungmeier, G. LCA of thermal processes: examples for gasification and pyrolysis to transportation biofuels, electricity, and heat.

Berndes, G., Bird, N. and Cowie, A. 2010. Bioenergy, land use change and climate change mitigation. IEA Bioenergy: ExCo:2010:03.

IEA RETD and IEA Bioenergy. 2010 Better use of biomass for energy. Joint position paper of IEA RETD and IEA Bioenergy. www.ieabioenergy.com/LibItem.aspx?id=6476

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

TASK 29

Minutes of the Task meeting in Hadeland, Norway, June 2010.

Minutes of the Task meeting in Ogulin, Croatia, October 2009.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Anon. Papers presented at the international conference 'Local and regional influence on the national bioenergy strategies and policies', Hadeland, Norway, June 2010.

Hjørnegård, S. The Norwegian bioenergy policies – present, schemes and regulations.

Richards, K. The position of bioenergy in the UK regional and national energy policies and energy planning.

Domac, J. The position of bioenergy in the regional and national energy policies and energy planning in Croatia.

White, B. The position of bioenergy in the regional and national energy policies and energy planning in Canada.

Elbe, S. The position of bioenergy in the German regional and national energy policies and energy planning.

Hohle, E. The position of bioenergy in the regional and national energy policies and energy planning in Norway.

Narud, O.G. A mayor in a typical bioenergy region's experience with promoting, building and using bioenergy as a local resource of energy.

Rinnan, O.M. A mayor in a typical bioenergy region's experience with promoting, building and using bioenergy as a local resource of energy.

Hauge, F. Bioenergy's role in energy planning for the future - according to an environmental organization.

Bjartnes, A. Drivers in implementing bioenergy worldwide.

Anon. Papers presented at the international workshop 'Socio-economic drivers in implementing bioenergy projects: actions together', Ogulin, Croatia, October 2010.

Elbe, S. Bioenergy regions: Approaches for regional value added, bioenergy networks, coping with conflicts, know-how transfer and process-continuation.

Richards, K. Making wood fuel a significant option in the SE England by 2020.

Hohle, E. Norwegian bioenergy regional cooperation on a regional, national and international basis - Methods, experiences and goals.

Offermann, R. Social networks to optimise biomass use - Monitoring of bioenergy production and use.

Loibnegger, T. Biomass trade centres - Securing the regional wood fuel supply in due consideration of social and eco-political aspects.

White, B. Government incentives to encourage regional bioenergy development: Two contrasting approaches.

Cvetkovic, J. Establishment of the educational centre for sustainable living in Karlovac.

Krajnc, B. Bio-management in municipality of Velenje.

Rajic, K. Biomass in action for Karlovac County.

Petrovski, S. Wood residues as source for heating and possibilities to shift from traditional way of heating with wood.

Robic, S. CEUBIOM project.

Staracic, T. Wood heat supply project.

Marjanovic, H. RoK FOR project.

Please also visit the Task website: www.task29.net

TASK 32

Minutes of the Task meeting in Lyon, France, May 2010.

Minutes of the Task meeting in Copenhagen, Denmark, October 2010.

IEA Bioenergy Task 32 Newsletter, Issue 1 September, 2010.

IEA Bioenergy Task 32 Newsletter, Issue 2 December, 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Koppejan, J. Biomass ash characteristics and behaviour in combustion systems, biomass and bioenergy, 2010.

Obernberger, I. and Thek, G. (Eds). The pellet handbook: the production and thermal utilisation of pellets. Earthscan Publications Limited. October 2010.

Pfeiffer, E. and Koppejan, J. (Eds.) Report from the workshop 'Options combustion of challenging biomass fuels', Lyon, France, May 2010.

Strömberg, B. The fuel handbook.

Alakangas, E. European standards for solid biofuels.

Baxter, D. Variations in biomass composition.

Brunner, T. Combustion characteristics of *Miscanthus*.

Bolhär-Nordenkamp, M. Operation experience from combustion of challenging biomass.

Kalf, R. First experiences with chicken litter fired BFB combustion plant at Moerdijk.

Livingston, B. Plant experience with the firing and co-firing of challenging biomass fuels.

Koppejan, J. Report from the workshop 'State-of-the-art technologies for small biomass co-generation', Copenhagen, Denmark, October 2010.

Koppejan, J. Why small-scale CHP and where is the market?

Moser, W. Next generation of pellet combustion with thermoelectric power generation.

Jagd, L. Gasfication in stirling engine applications.

Grøn, M. Staged gasification with gas engine, the Viking Gasifier.

Augustin, T. Steam engines.

Bini, R. State-of-the-art of ORC technology for biomass plants.

Gemperle, H. Downdraft gasification with gas engine.

Heeb, R. Updraft gasification with gas engine.

Rauch, R. Indirect gasifier.

Boisen, A. Upscaling the LTCFB (low temperature circulating fluid bed) gasifier.

Skjoldborg, B. The Skive plant (BFB gasification).

Schenk, R. Steam turbines.

Evald, A. and Christensen, H.F. Summary.

Please also visit the Task website: www.ieabioenergytask32.com

TASK 33

Minutes of the Task meeting in Helsinki, Finland, June 2010.

Minutes of the Task meeting in Skive/Copenhagen, Denmark, October 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Anon. Technical presentations from the Task workshop 'WS1: Second generation biofuels', Helsinki, Finland, June 2010.

Bain, R. Techno-economics of ethanol production.

Biollaz, S. Techno-economics of biofuels processes for substitute natural gas.

van der Drift, B. Biosyngas and BECCS.

Gül, S. Simulation studies for BTL.

Kurkela, E. FTL and other BTL.

Mäkinen, T. Liquid biofuels for transportation in Finland.

Rauch, T. Hydrogen and SNG.

Räsänen, T. NSE biofuels project activities.

Salo, K. Carbona pressurized gasification technology.

Anon. Technical presentations from Task workshop 'WS2: State-of-the-art technologies for small biomass co-generation', Skive/Copenhagen, Denmark, October 2010.

Augustin, T. Steam engines.

Bini, R. State-of-the-art of ORC technology.

Boisen, A. Upscaling the LTCFB gasifier.

Christiansen, H.F. Perspectives on data collected through the Danish follow-up program for biomass CHP.

Gemperle, H. Downdraft gasifier with gas engine.

Heeb, R. Updraft gasifier with gas engine.

Jagd, L. Gasification in Stirling Engine application.

Grøn, M. Staged gasification with gas engine, the Viking Gasifier.

Moser, W. Next generation of pellet combustion with thermoelectric power generation.

Rauch, R. Indirect gasifier.

Schenk, R. Steam turbines.

Skjoldborg, B. The Skive plant.

Please also visit the Task website: www.ieaTask33.org

TASK 34

Minutes of the Task meeting in Espoo, Finland, June 2010.

Minutes of the Task meeting in Stratford-upon-Avon, UK, October 2010.

Progress report for ExCo65, Nara City, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Task 34 Newsletter No. 27, June 2010.

Task 34 Newsletter No. 28, December 2010.

Nowakowski, D.J., Bridgwater, A.V., Elliott, D.C., Meier, D. and de Wild, P. 2010. Lignin fast pyrolysis: Results from an international collaboration. *Journal of Analytical and Applied Pyrolysis* 88, 53-72.

Please also visit the Task website: www.pyne.co.uk

TASK 36

Minutes of the Task meeting in Trondheim, Norway, May 2010.

Minutes of the Task meeting in Rome, Italy, November 2010.

Progress report for ExCo65, Nara City, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Anon. End-of-Task Report for 2007-2009: Integrating energy recovery into solid waste systems.

Anon. Presentations from the Task meeting, Rome, Italy, November 2010.

Guandalini, R. Determination of the biomass content of waste: the optimized mass balance method.

Caggiana, R. Energy recovery from municipal waste in Italy: state of the art and future perspectives.

Falcucci, N. Italian RES support mechanisms.

Martignon, G. Biomass content of H&NH wastes: a preliminary assessment based on waste composition and physico-chemical properties.

Toscano, G. The 14C method.

The publications are available from Pat Howes, please email: pat.howes@aeat.co.uk

TASK 37

Minutes from the Task meeting in Copenhagen, Denmark. May 2010.

Minutes from the Task meeting in Den Bosch, Netherlands. November 2010.

Progress report for ExCo65, Nara City, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Anon. Country reports of the Task Member Countries and the EC. May and November 2010. www.iea-biogas.net/publicationsreports.htm

Anon. Presentations from the joint Task and University of Southern Denmark seminar 'Digestate and biogas utilisation - practices and perspectives', Copenhagen, Denmark. May 2010.

Birkmose, T. Utilisation of digestate as fertiliser in Denmark.

Lukehurst, C. Digestate utilisation United Kingdom.

Crolla, A. Digestate utilisation in Canada (by video-link).

Jensen, T.K. Utilisation of the existing natural gas grid for distribution of biogas in Denmark.

Petersson, A. Overview of biogas up-grading.

Tafdrup, S. Using biogas for CHP and/or transportation purposes, in the long run.

Anon. Presentations from the Task workshop 'Biogas in the Netherlands: current situation and future perspectives', Den Bosch, Netherlands. November 2010.

Jacobs, L. Welcome and introduction: (Province Noord Brabant).

Baxter, D. IEA Bioenergy Task 37 and the contribution of biogas to a low-carbon society.

Eijkelberg, E. Overview from the Ministry of Economic Affairs.

Volk, G. Grid injection in Germany.

Mulieeneers, E. Manure and the environment in the Netherlands.

Huijbers, H. The ZLTO farmers view of biogas.

Al Seadi, T. Utilisation of digestate as fertiliser in Denmark.

van der Molen, A. Green gas.

Backx, A. Suiker Unie.

Petersson, A. Swedish biogas and biomethane experiences.

Beumers, P. Green gas working group.

Kluytmans, H. Green gas injection.

Braun, R., Weiland, P. and Wellinger, A. 2010. Biogas from energy crop digestion.

Lukehurst, C., Frost, P. and Al Seadi, T. 2010. Technical brochure 'Utilisation of digestate from biogas plants as biofertiliser'.

The publications are available on the Task website: www.iea-biogas.net

TASK 38

Minutes from the Task meeting in Brussels, Belgium, March 2010.

Minutes from the Task meeting in Graz, Austria, October 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Anon. Conference Report: Greenhouse gas emissions from bioenergy systems: impacts of timing, issues of responsibility. Summary. Brussels, Belgium, March 2010.

Anon. Presentations from the international conference 'Greenhouse gas emissions from bioenergy systems: impacts of timing, issues of responsibility', Brussels, Belgium, March 2010.

O'Hare, M. Keynote address: Adding when to the what, where, if and why of biofuels' indirect climate effects - and adding others to the list of usual suspects.

Cowie, A. Is bioenergy carbon neutral? An overview of the work of IEA Bioenergy Task 38 on GHG balances of biomass and bioenergy systems.

Popp, A. The net-benefit of bioenergy for climate change mitigation.

Fritsche, U. Better use of biomass for energy. IEA RETD/IEA Bioenergy Position Paper.

Persson, M. Preserving the world's tropical forests: A price on carbon may not do.

Fehrenbach, H. Global Bioenergy Partnership: Version zero of the methodological framework for GHG LCA of bioenergy.

Bowyer, C. The EU Renewable Energy Directive and its implementation, including addressing indirect land use change.

Hodson, P. Methodological issues on GHG emission calculations.

Ros, J. Intensification of agriculture for bioenergy: Impacts on GHG emissions and biodiversity.

Gorissen, L. Opportunities and complications in the transition towards a sustainable bio-based economy.

Verhoest, C. Sustainable biomass imports - Challenges for GHG LCA methodology implementation within an operational verification procedure.

Kirschbaum, M. Invited address: Reassessing optimal climate-change mitigation strategies through more explicit consideration of the role of time in impact assessments.

Bird, N. On the timing of greenhouse gas emissions.

Peters, G. CO₂ perturbation and associated global warming potentials following emissions from biofuel based on wood.

Sathre, R. Radiative forcing effects of forest fertilization and biomass substitution.

Klvørpris, J.H. Improved time accounting in the estimation of GHG emissions from indirect land use change.

Sterner, M. Future bioenergy and sustainable land use. The vision of the German Advisory Council on Global Change.

Bird, D.N., Cowie, A., Frieden, D., Gustavsson, L., Pena, N., Pingoud, K., Rueter, S., Sathre, R., Soimakallio, S., Tuerk, A., Woess-Gallasch, S. and Zanchi, S. Emissions from bioenergy: Improved accounting options and new policy needs. In Proceedings of the 18th European Biomass Conference and Exhibition, Lyon, May 2010.

Bird, D.N., Pena, N. and Zanchi, G. A review of existing methods for carbon accounting and implications for the assessment of emissions from bioenergy. In Proceedings of the 18th European Biomass Conference and Exhibition, Lyon, May 2010.

Bird, D.N., Zanchi, G. and Pena, N. Bioenergy and Forest Resources: What strategies provide energy and climate change mitigation. Presented at XXIII IUFRO World Congress. Seoul, Republic of Korea. August 23-28, 2010.

Bird, D.N., Zanchi, G. and Pena, N. Demand and supply of food energy from agriculture – How does bioenergy fit in? In Proceedings of the 7th International Biofuels Conference, New Delhi, India, 2010.

Türk A., Cowie A. and Leopold, A. The influence of emissions trading schemes on bioenergy use December 2010.

Woess-Gallasch, S. Bird, D.N., Enzinger P., Jungmeier G., Padinger R., Pena N. and Zanchi, G. Greenhouse gas benefits of a biogas plant in Austria. Task 38 Case Study Report. December 2010.

The publications are available on the Task website: www.ieabioenergy-task38.org

TASK 39

Minutes from the Task meeting in Cambridge, UK, January 2010.

Minutes from the Task meeting in Florida, USA, April 2010.

Minutes from the Task meeting in Sydney, Australia, December 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Hanova, J. (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 24, April 2010.

Hanova, J. (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 25, August 2010.

Hanova, J. (Ed.) IEA Bioenergy Task 39 Newsletter Vol. 26, December 2010.

Bacovsky, D., Dallos, M. and Wörgetter, M. 2010. Status of 2nd generation biofuel demonstration facilities. Task 39, Report T39-P1b.

Darzins, A., Pienkos, P. and Edye, L. 2010. Current status and potential of algal biofuels production. Task 39, Report T39-T2.

Ackom, E., Mabee, W. and Saddler, J. 2010. Backgrounder: major environmental criteria of biofuel sustainability. Task 39, Report T39-PR4.

The publications are available on the Task website: www.task39.org

TASK 40

Minutes from the Task meeting in Rotterdam, the Netherlands, March 2010.

Minutes from the Task meeting in Rome, Italy, October 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Junginger, M., Faaij, A. and Schouwenberg, P-P. (Eds.) Task 40 Newsletter - Issue 1 -2010, February 2010, p. 4.

Junginger, M., Faaij, A. and Schouwenberg, P-P. (Eds) Task 40 Newsletter - Issue 2 -2010, September 2010, p. 5.

Bradley, D. Canada report on bioenergy 2010. Climate Change Solutions. September 2010, p. 52.

Bradley, D., Hektor, B. and Schouwenberg, P. World biotrade equity fund study. April 2010, p.30.

Junginger, M. and Jonker, G. J. (Eds). Country report, the Netherlands, update 2009. Task 40/EUBIONETIII Universiteit Utrecht, Copernicus Institute, November 2010, p. 65.

Junginger, M., Faaij, A. and Schouwenberg, P-P. Task 40 Leaflet – Update October 2010. p. 2.

Junginger, M., Bradley, D., Dieseneriter, F., Faaij, A., Heinimö, J., Marchal, D., Tromborg, E. and Wild, M. Task 40 contribution to the wood pellet handbook (Editors Obernberger and Thek), September 2010, p. 547.

Junginger, M., van Dam, J., Zarrilli, S., Ali Mohamed, F., Marchal, D. and Faaij, A. Opportunities and barriers for international bioenergy trade. May 2010, p. 76.

Junginger, M. Biomass power and trade – conference summary. March 2010, p.3.

Manning, E. and Junginger, M. International trade of bioenergy commodities: experiences with certification and setting up sustainable supply chains. Workshop summary. p. 23.

van Dam, J., Junginger, M. and Faaij, A.P.C. 2010 From the global efforts on certification of bioenergy towards an integrated approach based on sustainable land use planning. Renewable and Sustainable Energy Reviews, Renewable and Sustainable Energy Reviews, 14(9), pp. 2445-2472, doi:10.1016/j.rser.2010.07.010.

van Dam, J. 2010. Update: initiatives, in the field of biomass and bioenergy certification. Background document from: van Dam, *et al.* (2010), from the global efforts on certification of bioenergy towards an integrated approach based on sustainable land use planning. April 2010, p. 330.

In addition, Task 40 participants provided numerous presentations on the work of Task 40 at international events. Presentations which addressed key themes of Task 40 and that were given in a variety of settings are:

Faaij, A. Future for the biobased economy, Seminar for FEDEPALMA/CENIPALMA, Bogota, Colombia, March 2010. (Keynote Speaker)

Faaij, A. Key drivers and prospects for the biobased economy; resources, sustainability, technology and markets. Presentation at EurAsiaBio – The Global Event for Biotechnology and Bioenergy, Moscow, Russia, April 2010. (Invited Speaker)

Faaij, A. Reconciling growing food demand and a bio-based economy. Presentation at 'Global feed and food congress', organised by IFIF, FAO and CONAFAB, Cancun, Mexico, April 2010. (Keynote/Plenary presentation)

Junginger, M. Barriers and opportunities for solid biomass trade in Europe, Presentation at the EUBIONETIII workshop 'International Biomass trade workshop', Verona, Italy, February 2010. In connection with Bioenergy Expo 2010.

Junginger, M. Biomass certification and implications for trade. Presentation at the 'Biomass Trade and Power' Conference, Rotterdam, the Netherlands, March 2010.

Junginger, M. Barriers and opportunities for bioenergy trade, Presentation at the 'BioPower Generation' Conference, Amsterdam, the Netherlands, March 2010. (Invited Speaker).

Junginger, M. Sustainability criteria for biomass trade: How to meet/comply with the certification? Presentation at the 'Biomass Pellets Trade Asia', Jakarta, Indonesia, September 2010. (Invited Speaker).

Junginger, M. Sustainable international bioenergy trade - IEA Bioenergy Task 40. Presentation at the workshop 'Nationaal Task 40 overleg', Utrecht, the Netherlands, 4 October 2010.

Junginger, M. Barriers and opportunities for bioenergy trade. 'Biomass and the role of standards' conference, Rotterdam, The Netherlands, October 2010. (Invited Speaker).

Junginger, M. Overview bioenergy sustainability certification systems and European stakeholder views, presentation at the workshop: International trade of bioenergy commodities: Experiences with certification and setting up sustainable supply chains, jointly organized by IEA Bioenergy Task 40 and EUBIONETIII Rome, Italy, 21 October 2010.

Junginger, M. Worldwide potential of biomass for energy, issues concerning mobilisation, trade flows and logistics. Presentation at the conference 'Sustainable Biomass for European Energy', Brussels, Belgium, November 2010. (Invited Speaker).

Schouwenberg, P. Sourcing of sustainable solid biomass for large-scale co-firing in NW Europe, presentation at the workshop: International trade of bioenergy commodities: Experiences with certification and setting up sustainable supply chains, jointly organised by Task 40 and EUBIONETIII Rome, Italy, October 2010.

van Dam, J. Private and public certification initiatives for sustainability. Aebiom European Bioenergy Conference, Brussels, July 2010. (Keynote Speaker)

In addition, presentations from Task 40 workshops and conference delegates are available to be downloaded from the Task website: www.bioenergytrade.org

TASK 41

Anon. Final report for Task 41, Project 1: 'Synergies and competition in bioenergy systems'. IEA Bioenergy: T41(1): 2008:01

Ericson, S-O. Summary and conclusions.

Nylander, B.N., and Nilssen, S. Part A: Identifying synergies and competition in forest-based bioenergy in selected countries.

Thrän, D., Seidenberger, T. and Zeddies, J. Part B: Agricultural sector.

Ladisch, M. (Lead Author). Gaps in the research of 2nd generation transportation biofuels – Final report from Task 41, Project 2. IEA Bioenergy: T41(2): 2008:01.

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

TASK 42

Minutes of the Task meeting, Lille, France, March 2010.

Minutes of the Task meeting, Chicago, USA, October 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Anon. Task 42 country reports.

Anon. Training course on biorefinery – presentations.

van Ree, R. Introduction to biorefinery course.

Sanders, J. General introduction biorefinery.

Jungmeier, M. Definition and classification.

Reith, J.H. Lignocellulosic feedstock biorefinery.

Mandel, M. Green biorefinery.

Barbosa, M. Marine biorefinery.

Jungmeier, M. Sustainability assessment.

These publications are available on the Task website www.IEA-Bioenergy.Task42-Biorefineries.com.

TASK 43

Minutes of the Task meeting, Göteborg, Sweden, 16-17 February 2010.

Minutes of the Task meeting, Kamloops, Canada, 1-2 June 2010.

Progress report for ExCo65, Nara, Japan, May 2010.

Progress report for ExCo66, York, UK, October 2010.

Berndes, G., Bird, N. and Cowie, A. 2010. Bioenergy, land use change and climate change mitigation. IEA Bioenergy: ExCo:2010:03.

FAO. 2010. Criteria and indicators for sustainable woodfuels. FAO Forestry Paper 160. (This report was produced in cooperation between FAO and Task 31, involving authors now working in Task 43).

Please also visit the Task 43 website: www.ieabioenergytask43.org and Journal of Forest Energy www.journal.forestenergy.org for access to more publications.

KEY PARTICIPANTS IN EACH TASK

TASK 29 – Socio-economic Drivers in Implementing Bioenergy Projects

- Operating Agent:** Kieran Power, Department of Energy and Climate Change (DECC), United Kingdom.
For contacts see Appendix 7.
- Task Leader:** Keith Richards, TV Energy Ltd, New Greenham Park, Newbury, UK.
For contacts see Appendix 6.
- Associate Task Leader:** Julije Domac, North-West Croatia Regional Energy Agency, Croatia.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Canada	Bill White	Natural Resources Canada, CFS
Croatia	Julije Domac	North-West Croatia Regional Energy Agency
Germany	Sebastian Elbe	SPRINT Consulting
Norway	Anders Lunnan	Norwegian Forest Research Institute
UK	Keith Richards	TV Energy Ltd

TASK 32 – Biomass Combustion and Co-firing

- Operating Agent:** Kees Kwant, NL Agency, the Netherlands.
For contacts see Appendix 7.
- Task Leader:** Jaap Koppejan, Procede Group BV, the Netherlands.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Austria	Ingwald Obernberger	Technical University of Graz
Canada	Sebnem Madrali	Department of Natural Resources
Denmark	Anders Evald	Force Technology
Finland	Jorma Jokiniemi	VTT Energy
Germany	Hans Hartmann	Technologie- und Fordersentrum
Ireland	John Finnan	Teagasc
Italy	Silvia Lattanzi	ENEP S.p.A.

The Netherlands	Sjaak van Loo Jaap Koppejan Edward Pfeiffer Kees Kwant	Procede Group BV Procede Group BV KEMA NL Agency
Norway	Øyvind Skreiberg	SINTEF
Sweden	Claes Tullin	Swedish National Testing and Research Institute
Switzerland	Thomas Nussbaumer	Verenum
Turkey	Hayati Olgun	Tubitak
UK	William Livingston	Doosan Babcock Energy Limited

TASK 33 – Thermal Gasification of Biomass

Operating Agent: Paul Grabowski, US Department of Energy, USA.
For contacts see Appendix 7.

Task Leader: Richard Bain, NREL, USA.
For contacts see Appendix 6.

The Task is organised with 'National Teams' in the participating countries. The contact person (National Team Leader) in each country is listed below. Also shown, where appropriate, are other participants within some of the Member Countries.

Country	National Team Leader	Institution
Austria	Reinhard Rauch	Vienna University of Technology
Denmark	Henrik F. Christiansen	Danish Energy Agency
Finland	Ilkka Hannula	VTT Energy
Germany	Thomas Kolb	Inst. Fur Tech.Chemie, FZK
Italy	Guiseppe Fiorenza	ENEA
Japan	Mayumi Morita	NEDO
The Netherlands	Bram van der Drift	ECN
New Zealand	Shusheng Pang	University of Canterbury
Norway	Rainer Backman	SINTEF
Switzerland	Martin Rügsegger	ETECA
Turkey	Serhat Gül	Tubitak MAM
USA	Richard Bain	NREL

TASK 34 — Pyrolysis of Biomass

Operating Agent: Paul Grabowski, US Department of Energy, USA.
For contacts see Appendix 7.

Task Leader: Doug Elliott, Battelle PNNL, USA.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Australia	Damon Honnery	Monash University
Finland	Anja Oasmaa	VTT (Technical Research Centre of Finland)
Germany	Dietrich Meier	vTI-Institute for Wood Technology and Biology
USA	Douglas Elliott	Battelle Pacific Northwest

TASK 36 — Integrating Energy Recovery into Solid Waste Management

Operating Agent: Kieran Power, Department of Energy and Climate Change (DECC), UK.
For contacts see Appendix 7.

Task Leader: Pat Howes, AEA Energy & Environment, UK.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Canada	René Pierre Allard	Natural Resources Canada
European Commission	David Baxter	JRC Petten
France	Elisabeth Poncelet	ADEME
Germany	Helmut Seifert	FZK, Karlsruhe
Italy	Giovanni Ciceri	ERSE
The Netherlands	Timo Gerlagh	NL Agency
Norway	Lars Sorum	SINTEF
Sweden	Evalena Blomqvist	SP Sweden
UK	Paul James	Ramboll

TASK 37 — Energy from Biogas

Operating Agent: Kyriakos Maniatis, European Commission, Belgium.
For contacts see Appendix 7.

Task Leader: David Baxter, EC JRC Petten, the Netherlands.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Austria	Rudolf Braun	IFAT; Dept of Environmental Biotechnology
Canada	Andrew Mc'Farlane	CETC-O, NRCan
Denmark	Jens Bo Holm-Nielsen	University of Southern Denmark
European Commission	David Baxter	JRC Petten
Finland	Jukka Rintala	University of Jyväskylä
France	Olivier Théobald	ADEME
Germany	Peter Weiland	FAL Braunschweig
The Netherlands	Mathieu Dumont	NL Agency
Sweden	Anneli Petersson	Swedish Gas Technology Centre
Switzerland	Arthur Wellinger	Nova Energie GmbH
UK	Clare Lukehurst	Probiogas UK

TASK 38 — Greenhouse Gas Balances of Biomass and Bioenergy Systems

Operating Agent: Josef Spitzer, Joanneum Research, Austria.
For contacts see Appendix 7.

Task Leader: Neil Bird, Joanneum Research, Austria.
For contacts see Appendix 6.

Co-Task Leader: Annette Cowie, University of New England, Australia,
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Australia	Annette Cowie	University of New England, Australia
Austria	Susanne Woess-Gallasch	Joanneum Research
Belgium	Florence Van Stappen	Walloon Agricultural Research Centre
Croatia	Ana Kojakovic	Energy Institute HrvojePozar

Finland	Kim Pingoud	VTT Technical Research Centre of Finland
	Sampo Soimakallio	VTT Technical Research Centre of Finland
Germany	Sebastian Rueter	Federal Research Institute for Rural Areas, Forestry and Fisheries
Sweden	Kenneth Möllersten	Swedish Energy Agency
	Leif Gustavsson	Mid Sweden University
USA	Mark Downing	Oak Ridge National Laboratory

TASK 39 – Commercialising Liquid Biofuels from Biomass

Operating Agent: Ed Hogan, Natural Resources Canada, Canada.
For contacts see Appendix 7.

Task Leader: Jack Saddler, University of British Columbia, Canada.
For contacts see Appendix 6.

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

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

Country	National Team Leader	Institution
Australia	Les Edge	Queensland University of Technology
Austria	Manfred Wörgetter	BTL Wieselburg
	Dina Bacovsky	Austrian Bioenergy Centre
Brazil	Viviana Coelho	Petrobras
	Paulo Barbosa	Petrobras
Canada	Jack Saddler	University of British Columbia
	Warren Mabee	Queen's University
Denmark	Michael Persson	Inbicon A/S
	Henning Jørgensen	University of Copenhagen
Finland	Tuula Makinen	VTT Biotechnology
	Niklas von Weymarn	VTT Biotechnology
Germany	Axel Munack	Johann Heinrich von Thünen Institute
	Jürgen Krahl	Coburg University of Applied Sciences
Japan	Tatsuo Hamamatsu	NEDO
	Shiro Saka	Kyoto University
The Netherlands	John Neeft	NL Agency
New Zealand	Ian Suckling	Scion
Norway	Gisle Johansen	Borregaard
	Karin Øyaas	PFI

South Africa	Emile van Zyl	University of Stellenbosch
	Bernard Prior	University of Stellenbosch
South Korea	Jin Suk Lee	Korean Institute of Energy Research
	Jun Suk Kim	Kyungki University
	Seonghan Park	Pusan National University
Sweden	Bärbel Hahn-Hägerdal	LTH/Lund University
	Alice Kempe	Swedish Energy Agency
	Guido Zacchi	LTH/Lund University
	Lisbeth Olsson	Chalmers
UK	Tony Sidwell	British Sugar
USA	Jim McMillan	NREL

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

Operating Agent: Kees Kwant, NL Agency, the Netherlands.
For contacts see Appendix 7.

**Task Leader:
(Scientific)** André Faaij, Copernicus Institute, Utrecht University,
the Netherlands
For contacts see Appendix 6.

**Task Leader:
(Administrative)** Peter-Paul Schouwenberg, RWE Essent, the Netherlands.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Austria	Lukas Kranzl	Vienna University of Technology
	Michael Wild	EBES AG
Belgium	Luc Pelkmans	VITO - Flemish Institute for Technological Research
	Didier Marchal	Walloon Forest Service, Service Public de Wallonie
Brazil	Arnaldo Walter	University of Campinas
Canada	Douglas Bradley	Climate Change Solutions
Denmark	Lars Nikolaisen	Danish Technological Institute
Finland	Tapio Ranta	Lappeenranta Technical University
	Jussi Heinimö	Lappeenranta Technical University

Germany	Uwe Fritsche Daniela Thrän	Oeko-Institut Deutsches Biomasse Forschungs Zentrum
	Michael Deutmeyer	CHOREN Biomass GmbH
Italy	Alessandro Berti Maurizio Cocchi	API Nova Energia ETA Florence
Japan	Shinichi Goto	National Institute of Advanced Industrial Science and Technology
	Yuji Iwasaki	NEDO
The Netherlands	André Faaij	Copernicus Institute, Utrecht University
	Peter-Paul Schouwenberg	RWE Essent
	Martin Junginger	Copernicus Institute, Utrecht University
Norway	Roar Grønhaug Erik Tromborg	Enova SF Norwegian University of Life Sciences
Sweden	Bo Hektor	Svebio
UK	Frank Rosillo-Calle Ben Goh	Imperial College E.On
USA	Richard Hess Richard Nelson	Idaho National Laboratory Kansas State University

TASK 41 — Bioenergy Systems Analysis

Project 3: Joint Project with AMF Annex XXXVII project 'Fuel and Technology Alternatives for Buses: Overall energy efficiency and emission performance

Operating Agent: Professor Kai Sipilä, VTT, Finland.
For contacts see Appendix 7.

Project Leader: Professor Kai Sipilä, VTT, Finland.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Finland	Kai Sipilä	VTT
Germany	Birger Kerckow	Fachagentur Nachwachsende Rohstoffe.V. (FNR)
European Commission	Kyriakos Maniatis	DG Energy and Transport

TASK 42 — Biorefineries: co-production of fuels, chemicals, power and materials from Biomass

- Operating Agent:** Kees Kwant, NL Agency, the Netherlands.
For contacts see Appendix 7.
- Task Leader:** René van Ree, Wageningen University and Research Centre (WUR), the Netherlands.
For contacts see Appendix 6.
- Assistant Task Leader:** Ed de Jong, Avantium Technologies B.V., the Netherlands.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Australia	Graeme Bullock	BioIndustry Partners Australasian Pulp and Paper Institute
	Gill Garnier	Australasian Pulp and Paper Institute
Austria	Gerfried Jungmeier	Joanneum Research
Canada	Kirsty Piguette	Alberta Agriculture and Rural Development
	Maria Wellisch	Natural Resources of Canada, CANMET Energy
Denmark	Henning Jorgensen	University of Copenhagen
European Commission	Maria Georgiadou	EC – DG Research
France	Jean-Christophe Pouet	Ademe
Germany	Thomas Willke	Johann Heinrich von Thunen-Institut
Ireland	Patrick Walsh	Galway – Mayo Institute of Technology
Italy	Isabella De Bari	ENEA
The Netherlands	René van Ree	Wageningen University and Research Centre
	Ed de Jong	Avantium Technologies B.V.
Turkey	Ozlem Atac	Tubitak Marmara Research Center
UK	Jeremy Tompkinson	NNFCC
USA	Melissa Klembara	DOE

TASK 43 — Biomass Feedstocks for Energy Markets

Operating Agent: Åsa Karlsson, Swedish Energy Agency, Sweden.
For contacts see Appendix 7.

Task Leader: Göran Berndes, Chalmers University of Technology, Sweden.
For contacts see Appendix 6.

Associate Task Leader: Tat Smith, University of Toronto, Canada
For contacts see Appendix 6.

Task Secretary: Sally Krigstin, University of Toronto, Canada.
For contacts see Appendix 6.

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

Country	National Team Leader	Institution
Australia	Brendan George	Tamworth Agricultural Institute
Canada	Jeff Karau	Natural Resources Canada
Denmark	Kjell Suadicani	University of Copenhagen
European Commission	Jean-Francois Dallemand	JRC, European Commission
Finland	Antti Asikainen	The Finnish Forest Research Institute
Germany	Jörg Schweinle	Johann Heinrich von Thünen-Institute (vTI)
Ireland	Kevin McDonnell	Biosystems Engineering, Bioresources Research Centre
Italy	Fabrizio Rossi	Agriconsulting S.p.A.
Netherlands	Jan van Esch	Ministry of Agriculture, Nature and Food Quality
New Zealand	Peter Hall	SCION
Norway	Simen Gjølsljø	Norwegian Forest and Landscape Institute
Sweden	Gustaf Egnell	Swedish University of Agricultural Sciences
UK	Ian Tubby	Forestry Commission England
USA	Marilyn Buford	USDA Forest Service

OPERATING AGENTS AND TASK LEADERS

Operating Agent Task 29: United Kingdom

(duration 1 January 2010-31 December 2012)

OA: Kieran Power

TL: Keith Richards

TV Energy Ltd

Liberty House, The Enterprise Centre

New Greenham Park

NEWBURY, RG19 6HS

UNITED KINGDOM

Phone: +44 1635 817 420

Fax: +44 1635 552 779

Email: keith.richards@tvenergy.org

Julije Domac (Associate Task Leader)

Managing Director

North-West Croatia Regional Energy Agency

Dužice 1

ZAGREB, 10000

CROATIA

Phone: +385 1 309 8315

Fax: +385 1 309 8316

Email: jdomac@regea.org

Operating Agent Task 32: The Netherlands

(duration 1 January 2010-31 December 2012)

OA: Kees Kwant

TL: Jaap Koppejan

Procede Biomass BV

PO Box 328

ENSCHDE. 7500 AH

THE NETHERLANDS

Phone: +31 53 7112 500/502

Fax: +31 53 7112 599

Email: jaapkoppejan@procede.nl

Operating Agent Task 33: USA

(duration 1 January 2010-31 December 2012)

OA: Paul Grabowski

TL: Richard Bain

NREL

National Renewable Energy Laboratory

1617 Cole Blvd.

Golden, CO 80401-3305

USA

Phone: +1 303 384 7765

Email: richard.bain@nrel.gov

Reinhard Rauch (Associate Task Leader)
Institute of Chemical Engineering
Vienna University of Technology
Getreidemarkt 9/166
A-1060 VIENNA
AUSTRIA

Phone: +43 1 58801 15954
Fax: +43 1 58801 15999
Email: rrauch@mail.zserv.tuwien.ac.at

Operating Agent Task 34: USA

(duration 1 January 2010-31 December 2012)

OA: Paul Grabowski
TL: Doug Elliott
Battelle PNNL
902 Battelle Boulevard
PO Box 999
RICHLAND
Washington 99352
USA

Phone: +1 509 375 2248
Fax: +1 509 372 4732
Email: dougc.elliott@pnl.gov

Operating Agent Task 36: United Kingdom

(duration 1 January 2010-31 December 2012)

OA: Kieran Power
TL: Pat Howes
AEA Technology
Gemini Building/ Cherwell Wing
Fermi Avenue
Harwell International Business Centre
DIDCOT, OX11 0QR
UNITED KINGDOM

Phone: +44 (0) 870 190 6151
Fax: +44 (0) 870 190 6327
Email: Pat_Howes@uk.aeat.com

Operating Agent Task 37: European Commission

(duration 1 January 2010-31 December 2012)

OA: Kyriakos Maniatis
TL: David Baxter
Clean Energies Unit
European Commission Joint Research Centre
Westerduinweg 3
1755 LE PETTEN
THE NETHERLANDS

Phone: +31-22456-5227
Fax: +31-22456-5626
Email: david.baxter@jrc.nl

Operating Agent Task 38: Austria*(duration 1 January 2010-31 December 2012)***OA:** Josef Spitzer**TL:** Neil Bird

Joanneum Research
 Elisabethstrasse 5
 GRAZ, A-8010
 AUSTRIA

Phone: +43 316 876 1423

Fax: +43 316 876 1423

Email: neil.bird@joanneum.at

Annette Cowie (Co-Task Leader)
 Agronomy and Soil Science (cage)
 Trevenna Rd
 University of New England
 Armidale NSW 2351
 AUSTRALIA

Phone: +61 2 6773 3924

Fax: +61 2 6773 3238

Email: annette.cowie@une.edu.au

Susanne Woess-Gallasch (Assistant to Task
 Leader)
 Joanneum Research
 Elisabethstrasse 5
 GRAZ, A- 8010
 AUSTRIA

Phone: +43 316 876 1330

Fax: +43 316 876 1320

Email: susanne.woess@joanneum.at

Operating Agent Task 39: Canada*(duration 1 January 2010-31 December 2012)***OA:** Ed Hogan**TL:** Jack Saddler

Department of Wood Science
 University of British Columbia
 4th Floor, Forest Sciences Center
 4041-2424 Main Mall
 VANCOUVER, BC V6T 1Z4
 CANADA

Phone: +1 604 822 9741

Fax: +1 604 822 9104

Email: saddler@ubc.ca

Jim McMillan (Associate Task Leader)
 NREL
 1617 Cole Boulevard
 Golden, CO 80401-3393
 USA

Phone: +1 (303) 384-6861

Fax: +1 (303) 384-6877

Email: jim_mcmillan@nrel.gov

Operating Agent Task 40: The Netherlands

(duration 1 January 2010-31 December 2012)

OA: Kees Kwant

TL: Andre Faaij (Scientific)
Sectie Natuurwetenschap en Samenleving /
Utrecht University
Wiskunde gebouw
Budapestlaan 6,
NL - 3584 CD Utrecht
THE NETHERLANDS

Phone: +31 30 253 7613

Fax: +31 30 253 7601

Email: a.p.c.faaij@uu.nl

Peter-Paul Schouwenberg (Administrative)
Senior Officer Regulatory Affairs-Corporate
Affairs
Essent
Willemsplein 4
5211 AK 's-Hertogenbosch
THE NETHERLANDS

Phone: +31 06 11513528 (mobile)

Email: Peter-Paul.Schouwenberg@
essent.nl

Martin Junginer (Assistant to Task Leaders)
Sectie Natuurwetenschap en Samenleving /
Utrecht University
Wiskunde gebouw
Budapestlaan 6,
NL - 3584 CD Utrecht
THE NETHERLANDS

Phone: +31 30 253 7613

Fax: +31 30 253 7601

Email: h.m.junginger@uu.nl

Operating Agent Task 41

(duration 1 January 2009-31 December 2012)

OA: The Secretary until a new project commences

Operating Agent Task 42: The Netherlands

(duration 1 January 2010-31 December 2012)

OA: Kees Kwant

TL: René van Ree
Programme Co-ordinator Biorefinery
Wageningen University and Research Centre
(WUR)
Agrotechnology and Food Sciences Group (AFSG)
P.O. Box 17
WAGENINGEN, 6700 AA
THE NETHERLANDS

Phone: +31 317 480 710

Fax: +31 317 475 347

Email: rene.vanree@wur.nl

Ed de Jong (Assistant Task Leader)
Avantium Technologies BV
Zekeringstraat 29
AMSTERDAM, 1014 BV
THE NETHERLANDS

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

Operating Agent Task 43: Sweden

(duration 1 January 2010-31 December 2012)

OA: Bjorn Telenius

TL: Göran Berndes

Department of Energy and Environment,
Physical Resource Theory
Chalmers University of Technology
GÖTEBORG, SE-412 96
SWEDEN

Phone: +46 31 772 3148
Fax: +46 31 772 3150
Email: goran.berndes@chalmers.se

Tat Smith (Associate Task Leader)

Department of Forest Science
Faculty of Forestry
University of Toronto
33 Willcocks Street
TORONTO, Ontario, M5S 3B3
CANADA

Phone: +1 416 978 5480
Fax: +1 416 971 3077
Email: tat.smith@utoronto.ca

EXCO MEMBERS AND ALTERNATES

	Member	Alternate Member
AUSTRALIA	<p>Dr Stephen Schuck Bioenergy Australia Manager c/o Stephen Schuck and Assoc. Pty Ltd 7 Grassmere Road Killara, SYDNEY, NSW 2071 Phone: +61 2 9416 9246 and 9416 7575 Fax: +61 2 9416 9246 Email: sschuck@bigpond.net.au</p>	<p>Mr Brendan George Tamworth Agricultural Institute Industry & Investment NSW 4 Marsden Park Rd, TAMWORTH, NSW 2340 Phone: +61 2 6763 1238 Fax: +61 2 6763 1222 Email: brendan.george@industry.nsw.gov.au</p>
AUSTRIA	<p>Dr Josef Spitzer Wastlergasse 2 GRAZ, A-8010 Phone: +43 699 1814 8673 Email: josef.spitzer@live.at</p>	<p>Ms Martina Ammer Federal Ministry for Transport, Innovation and Technology Department of Energy and Environmental Technologies Renngasse 5 WEIN, A1010 Phone: +43 1 71162 652923 Fax: +43 1 71162 652926 Email: martina.ammer@bmvit.gv.at</p>
BELGIUM	<p>Dr Yves Schenkel CRAW Rue de Liroux, 9 GEMBLOUX, B-5030 Phone: +32 8 162 7148 Fax: +32 8 161 5747 Email: schenkel@cra.wallonie.be</p>	<p>Mr Luc Pelkmans VITO - Flemish Institute for Technological Research Dpt. Transition Energy & Environment Boeretang 200 MOL, BE-2400 Phone: +32 14 33 58 30 Fax: +32 14 32 11 85 Email: luc.pelkmans@vito.be</p>
BRAZIL	<p>Mr Ricardo de Gusmão Dornelles Director, Department of Renewable Fuels Ministry of Mines and Energy Esplanada dos Ministérios, Bloco U, 9º Andar 70 065-900 – BRASÍLIA - DF Phone: +55 61 3319 5509 Fax: +55 61 3319 5626 Email: Rdornelles@mme.gov.br</p>	<p>Mr Hamilton Moss de Souza Director, Department of Energy Development Ministry of Mines and Energy Esplanada dos Ministérios, Bloco U, sala 530 70 065-900 – BRASÍLIA - DF Phone: +55 61 3319 5811 Fax: +55 61 3319 5874 Email: Hamilton.moss@mme.gov.br</p>
CANADA	<p>Mr Ed Hogan Manager, Thermochemical Conversion Industrial Innovation Group Bioenergy CETC – Ottawa Natural Resources Canada 580 Booth Street, OTTAWA, Ontario K1A 0E4 Phone: +1 613 996 6226 Fax: +1 613 996 9416 Email: ehogan@nrcan.gc.ca</p>	<p>Mr Jeff Karau Project Officer Forest Science Division Natural Resources Canada 580 Booth Street OTTAWA, Ontario K1A 0E4 Phone: +1 613 947 8997 Fax: +1 613 947 9035 E-mail: jkarau@nrcan-nrcan.gc.ca</p>

	Member	Alternate Member
CROATIA	<p>Dr Branka Jelavic Head Dept for Renewable Resources Energy Institute 'Hrvoje Pozar' Savska 163 P.B. 141 ZAGREB, 10001 Phone: +385 1 632 6117 Fax: +385 1 604 0599 Email: bjelavic@eihp.hr</p>	<p>Dr Julije Domac Managing Director North-West Croatia Regional Energy Agency Dužice 1 ZAGREB, 10000 Phone: +385 1 309 8315 Fax: +385 1 309 8316 Email: jdomac@regea.org</p>
DENMARK	<p>Mr Jan Bünger – Senior Adviser Energy R&D and Joint Implementation Danish Energy Authority Amaliegade 44 COPENHAGEN, DK-1256 Phone: + 45 33 927 589 Fax: + 45 33 114 743 Email: jbu@ens.dk</p>	<p>Mrs Bodil Harder Programme Manager Energy R&D Danish Energy Authority Ministry of Climate & Energy Amaliegade 44 COPENHAGEN, DK-1256 Phone: +45 33 926 797 Email: bha@ens.dk</p>
FINLAND	<p>Professor Kai Sipilä VTT PO Box 1000 Vuorimiehentie 3 ESPOO, FIN 02044 VTT Phone: +358 20 722 5440 Fax: +358 20 722 7048 Email: kai.sipila@vtt.fi</p>	<p>Mrs Marjatta Aarniala Tekes, Finnish Funding Agency for Technology and Innovation Energy and Environment Industries PO Box 69 Kyllikinportti 2, Lansipäsilä HELSINKI, FIN-00101 Phone: +358 10 605 5736 Fax: +358 10 605 5905 Email: marjatta.aarniala@tekes.fi</p>
FRANCE	<p>Mr Jean-Christophe Pouet Head of Bioresources Department (DBIO) ADEME 20 avenue du Grésillé BP 90406 49004 ANGERS Cedex 01 Phone: +33 02 4120 4327 Fax: +33 02 4120 4302 Email: jean-christophe.pouet@ademe.fr</p>	<p>Ms Alba Departe ADEME Bioresources Department (DBIO) 20 avenue du Grésillé BP 90406 49004 ANGERS Cedex 01 Phone: +33 2 4120 4326 Email: alba.departe@ademe.fr</p>
GERMANY	<p>Mr Birger Kerckow Fachagentur Nachwachsende Rohstoffe e.V. (FNR) Hofplatz 1 GÜLZOW, 18276 Phone: +49 3843 6930 125 Fax: +49 3843 6930 102 Email: B.Kerckow@fnr.de</p>	<p>To be announced</p>

	Member	Alternate Member
IRELAND	<p>Mr Pearse Buckley Project Manager – Bioenergy and CHP Sustainable Energy Authority of Ireland Wilton Park House Wilton Place DUBLIN 2 Phone: +353 1 808 2012 Fax: +353 1 808 2002 Email: pearse.buckley@seai.ie</p>	<p>Ms Katrina Polaski Head of Low Carbon Technologies Dept Sustainable Energy Authority of Ireland Wilton Park House Wilton Place DUBLIN 2 Phone: +353 1 808 2102 Fax: +353 1 808 2002 Email: Katrina.polaski@seai.ie</p>
ITALY	<p>Mr Gerardo Montanino Head of Operations Department Gestore dei Servizi Energetici – GSE S.p.A. Viale Maresciallo Pilsudski, 92 00197 ROME Phone: +39 06 8011 4469 Fax: +39 06 8011 2040 Email: gerardo.montanino@gse.it</p>	<p>Mr Vito Pignatelli ENEA Research Centre of Casaccia Via Anguillarese, 301 – 00123 – S.M. di Galeria, ROME Phone: +39 06 3048 4506 Fax: +39 06 3048 6514 Email: vito.pignatelli@casaccia.enea.it</p>
JAPAN	<p>Dr Tadashi Kohno Director of Biomass Group NEDO Muza Kawasaki Central Tower 18F 1310 Ohmiyacho, Saiwai-ku, Kawasaki, KANAGAWA 212-8554 Phone: +81 44 520 5271 Fax: +81 44 520 5275 Email: kohnotds@nedo.go.jp</p>	<p>To be announced</p>
KOREA	<p>Mr Soosung Hwang Director, New and Renewable Energy Division Ministry of Knowledge Economy 88 Gwanmoonro, GWACHEON-SI Gyeonggi-do 427-723 Phone: +82 2 2110 5401 Fax: +82 2 503 9498 Email: sshwang@mke.go.kr</p>	<p>Mr Soon-Chul Park Korea Institute of Energy Research Bioenergy Research Center 102 Gajeong-ro, DAEJEON Yuseong-gu 305-343 Phone: +82 42 860 3557 Fax: +82 42 860 3739 Email: bmscpark@kier.re.kr</p>
NETHERLANDS	<p>Ir Kees Kwant NL Agency NL Energy and Climate Change PO Box 8242, UTRECHT, 3503 RE Phone: +31 88 602 2458 Email: kees.kwant@agentschapnl.nl</p>	<p>Mr Wouter Schaaf Ministerie van Economische Zaken Directie Energie en Duurzaamheid Postbus 20101 DEN HAAG, 2500 EC Phone: +31 70 379 6663 Email: w.j.c.schaaf@minez.nl</p>

	Member	Alternate Member
NEW ZEALAND	<p>Dr Elspeth MacRae SCION Private Bag 3020 ROTORUA Phone: +64 7 343 5824 Fax: +64 7 343 5528 Email: elspeth.macrae@scionresearch.com</p>	<p>Dr Michael Jack Unit Leader Bioenergy SCION Private Bag 3020 ROTORUA Phone: +64 7 343 5601 Fax: +64 7 348 0952 Email: michael.jack@scionresearch.com</p>
NORWAY	<p>Dr Petter Nilsen The Research Council of Norway Division for Innovation Stensberggata 26, PO Box 2700, St Hanshaugen OSLO, N-0131 Phone: +47 98 0948 60 Email: pn@rcn.no</p>	<p>Mr Øyvind Leistad Enova SF Professor Brochsgt Gate 2 7030 TRONDHEIM Phone: +47 73 1904 61 Fax: +47 99 5180 08 Email: oyvind.leistad@enova.no</p>
SOUTH AFRICA	<p>Dr Thembakazi Mali SANERI (Pty) Ltd Senior Manager: Clean Energy Solutions PO Box 786141 Sandton, 2146 JOHANNESBURG Phone: +27 010 201 4782 Fax: +27 010 201 4932 Email: thembakazim@saneri.org.za</p>	<p>To be announced</p>
SWEDEN	<p>Dr Åsa Karlsson Swedish Energy Agency P.O. Box 310 ESKILSTUNA, SE-631 04 Phone: +46 16 544 2342 Fax: +46 16 544 2261 Email: asa.karlsson@energimyndigheten.se</p>	<p>Dr Björn Telenius Division for Energy Ministry of Enterprise, Energy and Communications Mäster Samuelsgatan 70 103 33 STOCKHOLM Phone: +46 8 405 4032 Fax: +46 8 543 56977 Email: bjorn.telenius@enterprise.ministry.se</p>
SWITZERLAND	<p>Dr Sandra Hermle Swiss Federal Office of Energy (SFOE) Energy Research, Biomass and Combustion BERN, CH - 3003 Phone: +41 31 325 8922 Fax: +41 31 323 2500 Email: sandra.hermle@bfe.admin.ch</p>	<p>Mr Bruno Guggisberg Swiss Federal Office of Energy Renewable Energies, Biomass BERN, CH - 3003 Phone: +41 31 322 5640 Fax: +41 31 323 2500 Email: bruno.guggisberg@bfe.admin.ch</p>

	Member	Alternate Member
TURKEY	<p>Mr Ufuk Kayahan Tubitak Marmara Research Center, Energy Institute P.K. 21 41470 Gebze KOCAELI Phone: +90 262 6772732 Fax: +90 262 642 3554 Email: Ufuk.Kayahan@mam.gov.tr</p>	<p>Mr Fehmi Akgün Deputy Director Tubitak Marmara Research Center, Energy Institute P.K. 21 41470 Gebze KOCAELI Phone: +90 262 677 2702 Fax: +90 262 642 3554 Email: Fehmi.Akgun@mam.gov.tr</p>
UNITED KINGDOM	<p>Mr Kieran Power Bioenergy and Renewable Materials Team Department of Energy and Climate Change 3 Whitehall Place LONDON, SW1A 2HH Phone: +44 300 068 6189 Email: kieran.power@decc.gsi.gov.uk</p>	<p>Dr Elizabeth McDonnell Bioenergy and Renewable Materials Team Department of Energy and Climate Change 3 Whitehall Place LONDON, SW1A 2HH Phone: +44 300 068 6187 Email: elizabeth.mcdonnell@decc.gsi.gov.uk</p>
USA	<p>Mr Paul Grabowski US Department of Energy Energy Efficiency and Renewable Energy Office of the Biomass Program, EE-2E 1000 Independence Ave., SW WASHINGTON, DC 20585-0121 Phone: +1 202 586 0478 Fax: +1 202 586 1640 Email: paul.grabowski@ee.doe.gov</p>	<p>Dr Don Stevens Senior Program Manager Pacific Northwest National Laboratory P.O. Box 999, MSIN P8-60 RICHLAND, WA 99352 Phone: +1 509 372 4603 Fax: +1 509 372 4732 Email: Don.Stevens@pnl.gov</p>
EUROPEAN COMMISSION	<p>Dr Kyriakos Maniatis DG Energy and Transport European Commission Rue de la Loi/Wetstraat 200 BRUSSELS, B-1049 BELGIUM Phone: +32 2 299 0293 Fax: +32 2 296 6261 Email: Kyriakos.Maniatis@ec.europa.eu</p>	<p>Dr David Baxter Clean Energies Unit European Commission Joint Research Centre Westerduinweg 3 1755 LE PETTEN THE NETHERLANDS Phone: +31 2 2456 5227 Fax: +31 2 2456 5626 Email: david.baxter@jrc.nl</p>
TECHNICAL COORDINATOR	<p>Dr Arthur Wellinger Nova Energie GmbH Châtelstrasse 21 AADORF, CH-8355 SWITZERLAND Phone: +41 52 365 4310 Fax: +41 52 365 4320 Email: arthur.wellinger@novaenergie.ch</p>	

SOME USEFUL ADDRESSES

ExCo Chairman 2011

Mr Birger Kerckow
 Fachagentur Nachwachsende Rohstoffe
 e.V. (FNR)
 Hofplatz 1
 GÜLZOW, 18276
 GERMANY

(Address etc., see below)
 Phone: +49 3843 6930 125
 Fax: +49 3843 6930 102
 Email: B.Kerckow@fnr.de

ExCo Vice Chairman 2011

Dr Paul Grabowski
 US Department of Energy
 Energy Efficiency and Renewable Energy
 Office of the Biomass Program, EE-2E
 1000 Independence Ave., SW
 WASHINGTON, DC 20585-0121
 USA

(Address etc., see below)
 Phone: +1 202 586 0478
 Fax: +1 202 586 1640
 Email: paul.grabowski@ee.doe.gov

IEA Liaison

Mr Takesune Ito
 Renewable Energy Analyst
 Implementing Agreement Desk Officer
 International Energy Agency
 9 Rue de la Fédération
 75739 PARIS Cedex 15
 FRANCE

(Address etc., see below)
 Phone: +33 1 40 57 65 62
 Fax: +33 1 40 57 66 09
 Email: takatsune.ito@iea.org

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

IEA Bioenergy

IEA BIOENERGY SECRETARIAT

Website:

www.ieabioenergy.com

Secretary:

John Tustin
PO Box 6256
Whakarewarewa
Rotorua
NEW ZEALAND
Phone: +64 7 348 2563
Fax: +64 7 348 7503
Email: jrtustin@xtra.co.nz

Technical Coordinator:

Arthur Wellinger
Nova Energie mbH
Châtelstrasse 21
Aadorf, CH-8355
SWITZERLAND
Phone: +41 52 365 4310
Fax: +41 52 365 4320
Email: arthur.wellinger@novaenergie.ch

Webmaster:

Heather McKenzie
Centralis Limited
102A Hillcrest Road
Raumati Beach
Paraparaumu 5032
NEW ZEALAND
Phone: +64 4 9021000
Email: webmaster@ieabioenergy.com