European Commission

Biomass supply and demand for a sustainable bioeconomy – exploring assumptions behind estimates

Report of the Workshop held on 23 February 2017

Research and Innovation

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European Commission
Directorate-General for Research and Innovation
Directorate F — Bioeconomy
Unit F.2 — Bio-based Products and Processing
Contact Gaia Fantechi
E-mail Gaia.Fantechi*@ec.europa.eu*
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

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EUROPEAN COMMISSION

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2017 Directorate-General for Research and Innovation

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FOREWORD from the Director for the Bioeconomy

DIRECTORATE-GENERAL for Research and Innovation – European Commission

The European Union, alongside a growing number of regions and countries around the globe, recognises the central role of the bioeconomy in tackling two of the world's most serious challenges: the growing demand for food, raw materials, energy and water resulting from a fast-growing human population; and anthropogenic climatic change.

Creating a successful bioeconomy means tapping into the potential of renewable biological resources. But the bioeconomy will only be successful if it is sustainable – the over exploitation of natural resources would undermine the very basis on which the bioeconomy is built and could even result in worsening climate change, environmental degradation and greater food insecurity.

A key prerequisite for defining a coherent bioeconomy policy is having joined-up knowledge on the current and future potential of renewable biological resources and on demand projections for their various uses i.e. food, energy, industrial raw materials. This knowledge is needed to strike the right balance in the bioeconomy equation: firstly to ensure food security and to safeguard environmental capital and ecosystem services; and secondly to maximise the resource efficient use of biomass, to deliver robust and verifiable greenhouse gas savings, and to allow for fair competition between the various uses.

Our current understanding of biomass potential and demand is imperfect and incomplete. This existing uncertainty impedes effective policy action and fosters ambivalence on the sustainability of the bioeconomy.

This report is a step towards filling this knowledge gap. I hope that it will help to make future research on biomass potential and demand more comprehensive, rigorous and influential in framing a coherent bioeconomy policy.

John Bell

Director for the Bioeconomy DIRECTORATE-GENERAL for Research & Innovation

INTRODUCTION

Estimates of future biomass potential can vary 20 fold from highest to lowest, reflecting the lack of harmonized methodologies and uncertainty about how to measure biomass sustainability. On the demand side, a reasonable amount is known about food/feed and bioenergy but much less about industrial and material uses of biomass – and there is definitely a need for more analyses that look at all three uses together and the interactions between them. 11 assumptions behind estimates". It took place in February 2017 and gathered 12 experts from various backgrounds with the aim to gain understanding on the main factors determining the variability of biomass potentials and demands, and to acquire references on the limits and potential of a sustainable bioeconomy both at EU level and globally.

The workshop helped to identify challenges ahead, as well as opportunities and actions for improving our knowledge on current and future availability and demand of biomass for a sustainable bioeconomy. It should be of interest to policy-makers, scientists, business people, environmental activists and other stakeholders.

The present report summarises the main "take home messages" from the workshop, and includes summaries of the presentations from the speakers with data on this fundamental subject.

PART 1: TAKE HOME MESSAGES

1. Considerable progress has been made to improve modelling and estimates of biomass potential and demand; however it remains very challenging to cover all sectors of the bioeconomy system in an integrated way

It is acknowledged that strong progress has been made in recent years to better assess the potential and limits of biomass production and demand. Researchers have developed more sophisticated and more robust models. In some cases this has gone hand-in-hand with the development of biomass sustainability schemes (e.g. for biofuels).

Models and estimates nevertheless often emphasise a particular type of biomass and/or one particular use. It is a major challenge to develop more integrated models capable of representing the complete bioeconomy system in a balanced way, including potential synergies and trade-offs between all different sources and uses of biomass. The work recently undertaken by the European Commission's Joint Research Centre under its mandate on biomass supply and demand is a positive step to address this. Cooperation and cross-referencing between organisations that develop models and estimates from different perspectives should in any case be encouraged.

2. The assumptions behind models and estimates should be made explicit, and policy-makers should read and understand them

Policy-makers should understand that there is no single correct figure on biomass potentials. The result of any modelling or estimate depends critically on the assumptions made, constraints imposed, and the trade-offs that are judged acceptable by the authors. If higher constraints are imposed, the figure for biomass potential will naturally be lower, at least in the short and medium term.

It is therefore important that studies on biomass potentials clearly and prominently state the assumptions on which they are based. It is equally important that policy-makers read and understand these assumptions.

3. A distinction should be made between 'predictable' and 'desirable' assumptions

Estimates of biomass potential and demand can be based on assumptions that are broadly-speaking 'predictable', in the sense that they follow trends according to existing practice and policies. Other estimates may more deliberately integrate assumptions that reflect desired outcomes, for example the restoration of biodiversity and the provision of healthy and balanced diets. Some estimates used in policy-making may be based on assumptions that are themselves not desirable, but such connections are not always explicitly acknowledged.

Policy-makers and researchers should be conscious of the difference between these two approaches, and ensure that due consideration is given to desired assumptions and policy outcomes.

4. Assumptions should be openly debated and rigorously tested

Models and estimates of biomass potential and demand will be enhanced by rigorous and inclusive debate about the assumptions on which they are based. The involvement of a wide group of experts from different fields and stakeholders representing different interests will improve the value and credibility of models and estimates. Lessons can also be learned from other agricultural initiatives e.g. those related to development, poverty alleviation and attempts to close yield gaps.

5. Harmonisation of sustainability criteria for biomass production and use at international level should go hand in hand with greater coherence and comparability of models and estimates.

The EU has introduced sustainability criteria for biofuels and partially for bioenergy. But there are no equivalent sustainability criteria for other sectors of the bioeconomy (food and feed, and material uses of biomass). In addition, there is no international consensus on what sustainability criteria should be applied, although the Organisation for Economic Cooperation and Development (OECD) has signalled the need to work towards such a consensus.

A higher degree of international convergence on sustainability criteria, and the availability and application of sustainability criteria for biomass production and uses beyond bioenergy, could be incited by collaborative work between researchers and scientists on a more solid and more complete set of assumptions on which to base estimates of biomass supply and demand. They would also enable better comparisons to be made between different models and estimates, and therefore improve the quality of scientific and policy debate.

6. Models and estimates should:

…take greater account of material uses of biomass, and better account for synergies and competition between material and energy uses

Some studies and experts have pointed to current inefficiencies in some circumstances in the allocation and use of biomass for energy and materials, in particular when biomass is used for energy before other high value and resource efficient (material) uses have been explored. There are also examples of a so-called 'cascading' use of biomass, where material uses are initially prioritised and energy recovery is applied only in the final stage of the product cycle. Some studies also suggest that demand for material uses may rise faster than demand for energy uses as there are no renewable alternatives to biomass for material uses unless renewable Carbon Capture and Use (rCCU) becomes available at commercial stage.

Models and estimates of biomass potential and demand should not only take greater account of material uses of biomass than has usually been the case to date, they should also explicitly address the question of possible synergies and competition between material and energy uses of biomass. They should consider the relative sustainability and other benefits of incentivising one or other of those uses. An additional point to consider is that markets and supply of biomass can vary significantly from one location to another, so what makes sense in one location may not make sense in another.

…consider the need to hold down biomass demand and promote more sustainable consumption

Biomass demand is growing in many different sectors. But this increase in demand may not always be compatible with desired outcomes such as reduction in greenhouse emissions from agriculture or better and balanced diets. There is a risk that some estimates concentrate on alternative ways of increasing the supply of biomass to match demand without adequately addressing options for restraining demand for biomass. Such options include policy measures to promote sustainable consumption.

…address circularity and the use of wastes and residues

As circularity takes on increasing political importance as an organising principle for our economy, work on biomass supply and demand must give more attention to the potential of bio-waste, such as urban bio-waste, food waste, agricultural residues, and other side-streams and co-products. A figure which illustrates the latter is that uneaten food occupies close to 30 percent of the world’s agricultural land area. Although a share of this feedstock is already used, the potential remains very substantial. At the same time, care is needed to ensure that the negative effects of overexploitation of wastes and residues are avoided. For example, excessive removal of agricultural residues could have negative impacts on biodiversity, soil fertility and erosion, and carbon loss, undermining climate goals.

…incorporate a broader range of social, economic and political issues

Models and projections of biomass supply and demand should consider a broader range of social, political and economic variables than has sometimes been the case to date. The costs of achieving any given projection should be quantified as far as possible.

For any given projection, a non-exhaustive list of additional variables to consider would include:

- The level of financial investment required

- The kind of policy support required

- The social and behavioural changes required (e.g. what diets and level of meat consumption?)

- The price effects on different goods and services, and the social and political acceptability of those effects

- Other developments and innovation that may impact biomass demand (e.g. the effect of developments in wind and solar energy on demand for bioenergy?)

- On which groups of people and countries/regions are biggest negative effects likely to fall (e.g. people in oil producing countries?). And which groups are likely to benefit most? Assumptions made at a high aggregate level (e.g. global) may hide large regional variations in impacts.

Analyses might also strive to identify positive synergies between policy goals (e.g. on food, energy and raw material security, climate, biodiversity), while building scenarios in which biomass supply and demand are in balance.

An important issue mentioned in relation to food systems but that should be extended to other sectors, is the need to find mechanisms to ‘internalise externalities' (i.e. ensure that their real costs and benefits are taken into account). For instance, a shift towards a more nutritious food system would result in downstream benefits by removing negative health externalities.

7. Further research is necessary to address bioenergy related questions and move beyond the current controversy on bioenergy development and its policy support

Policy support to bioenergy, which in the EU began twenty years ago with the adoption of the EU White Paper on Renewable Energy, and subsequent policy initiatives, has been a source of controversy in public opinion and in the scientific community.

The positions of experts remain quite far apart from each other. Some support a large expansion of bioenergy (e.g. 300 EJ bio-based economy by 2015 with a major bioenergy component) to meet the greenhouse gases (GHG) mitigation efforts set in Paris in COP21. Others advocate no bioenergy, but rather reforestation coupled with the use of other renewable sources (solar/wind) as a more efficient way to meet climate targets.

Disagreement persists on a number of questions, including: (1) Methodologies to calculate the mitigation potential of bioenergy, in particular the assumption of carbon neutrality (2) Impact of the large scale deployment of bioenergy on other biomass using sectors (3) Comparative efficiency of bioenergy vs. other renewable energies (4) Suitability of specific bioenergy feedstocks to contribute to short term decarbonisation needs (5) The time horizon over which it should be assumed that a policy should have an effect.

Further analysis and research is needed to address these questions and on that basis to define policies that ensure biomass is used as efficiently as possible across sectors and to deliver the highest climate and other benefits.

8. There is a broad agreement on the need to support research into a sustainable increase of agricultural productivity

According to estimates of the Food and Agriculture Organisation (FAO), the demand for agricultural products is expected to rise by 50% from 2013 to 2050. Meeting this demand requires an increase of agricultural production, which in the context of intensification of pressures on already scarce land and water resources, should come mainly (80% of the increase) from yield growth and not from land expansion. Yet, this is an assumption whose feasibility raises some doubts.

In this context, there is general agreement on the need to intensify research efforts into alternative solutions which bring together productivity increases while reducing environmental impact. Some ideas which come strongly are integrated landscape management and precision farming. The latter is a good example of technology leading to higher yields with less input. It illustrates the misconception that sustainability is linked with low yields.

Experts also consider the need to shift R&I and agriculture investments beyond the current focus on a few mono-culture crops. It is estimated that about 50-60% of agriculture research is funded by the private sector and supports only a few, mono-culture crops, and most publicly-funded research follows the same pattern.

In terms of the potential of aquatic systems, main R&I priorities relate to the search and domestication of new species, reduce the production costs and increase productivity.

9. The European Commission should continue to give a high priority to work on biomass supply and demand.

The European Commission should continue to work on this subject and contribute to international initiatives by raising concerns such as those discussed in the meeting today. Important international initiatives include the Intergovernmental Panel on Climate Change (IPCC), the Committee on World Food Security (FAO) and the OECD policy analysis on the Bioeconomy.

The upcoming IPCC special report on Climate Change and Land should place "land management" at the centre of the analysis and consider integrative approaches of land, avoiding sectorial focuses on e.g. food, feed, energy, etc. For the role of negative emissions technologies, it is important that the report assesses the impact of biomass with carbon capture on the availability of biomass for materials or other uses.

PART 2: SHORT SUMMARIES OF PRESENTATIONS FROM SPEAKERS

Presentation 1: Scenarios for global biomass supply and demand covering the various bioeconomy sectors (baseline & 2050)

Presentation: Michael Carus, Nova Institute

The presentation summarised the main conclusions of the study "Global bioeconomy in the conflict between biomass supply and demand1". It proposed scenarios which highlight how under different assumptions the supply and demand of biomass may develop for the year 2050. For about 100 parameters, which significantly determine future supply and demand, different sets of assumptions have been applied, and it has then been calculated what these imply for the supply (by biomass constituents) and demand (by sectors) for biomass in the year 2050 (Figure 1).

Under the low supply scenario[[1]], only the demand for food and feed would be covered but hardly any of the demand for materials and bioenergy and none of the demand for biofuels, based on a hierarchical order of uses which puts food and feed first, then materials, then bioenergy and then biofuels.

Under the business as usual (BAU) supply scenario[2] a BAU demand scenario of food, feed, materials and bioenergy could be covered and there would be even some room for an expansion of biofuel. The BAU demand of biomass for materials results in an increase from about 1.3 billion tons of dry matter (bln tdm) today to 2.4 bln tdm in 2050[3]. This assumes that the share of renewable raw materials in the chemical industry would increase from 10% today to 20% in 2050. The BAU demand of biomass for bioenergy, which amounts to 4.3 bln tdm (from 2 bln tdm today) [4], is based on a scenario of the International Energy Agency. An additional expansion of biofuel of up to 1 bln tdm of biomass would be possible under the BAU supply.

The BAU supply scenario could also cover a bio-based high demand scenario where the demand of the chemical and plastic industry increases from 10% today to 95%, but already the demand for bioenergy can only be half-covered, and no biomass would be left for biofuels.

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[1] http://bio-based.eu/publication-search/?wpv_post_search=nova-Paper+%237&wpv_filter_submit=

[1] Low supply scenario: 12.4 bln tdm, which represents 211 EJ, considering a CHV of 17 EJ/bln tdm.

[2] BAU supply scenario: 18.2 bln tdm, which represents 309 EJ, considering a CHV of 17 EJ/bln tdm.

[3] Considering a CHV of 17 EJ/bln tdm, the BAU demand of biomass for materials results in an increase from about 22 EJ today to 41 EJ in 2050.

[4] Considering a CHV of 17 EJ/bln tdm, the BAU demand of biomass for bioenergy, which amounts to 73EJ (from 34EJ today)

The “High demand – low pressure” scenario even goes one step further and assumes a massive development of solar and Carbon Capture and Use technologies. This scenario shows that it is possible to cover the highest demand of all scenarios with at the same time using less biomass than in the BAU scenario.

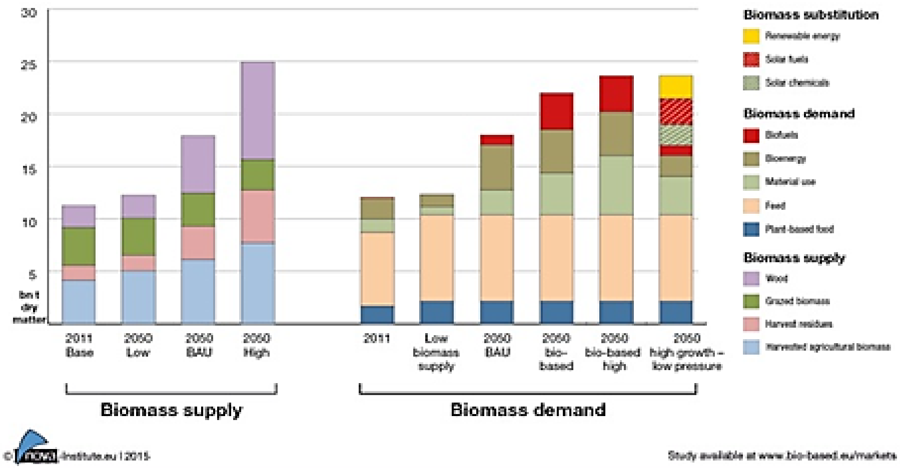

Figure 1. Comparison between global biomass supply and demand scenarios

Presentation 2: Projections of global food/feed production and demand (baseline and 2050)

Presentation: Lorenzo Bellu, FAO Agricultural Development Economics (ESA)

The main question is how to feed humanity in the future and especially reduction of hunger. Hunger is not a result of food/feed shortage but rather a question of limited purchasing power (poverty).

Based on assumptions of population grow and per capita income increase, the demand of agricultural products is expected to rise by 50% from 2013 to 2050 (Figure 2). A shift in demand is also expected towards fruits, vegetables, meats and dairy products. 80% of the increase of agricultural production should come from yield growth and not from land expansion. Is this feasible? By how much do you have to expand yield in order not to expand land? Will yield gaps be closed? Yields have expanded over the last 40 years, but their rate of growth is slowing (about 1% now). There is therefore a reasonable doubt that yield growth may not be enough to meet requirements. Reducing yield gaps is not just a technology issue – also social, economic, political factors.

Climate change has to be factored in the models. Until about 2030, climate change is expected to lead to both gains and losses in crop yields, beyond 2030, the negative impacts will become increasingly severe (Figure 3). Climate change impact on yields

- Agriculture accounts for 20% of the global GHG without taking into account energy use. Agriculture is improving in terms of efficiency, i.e. GHG emissions per unit of output are improving. Although absolute emissions from agriculture are reasonably stable, a reduction of emissions from agriculture will be needed to meet COP21 agreement.

- FAO is working on the report Food and Agriculture towards 2050-80 for which a number of scenarios will be developed. The overall sustainability scenario will consider less increase in yield but better distribution of food, i.e. social equity as ROUTE TO environmental sustainability not as barrier to environmental sustainability.

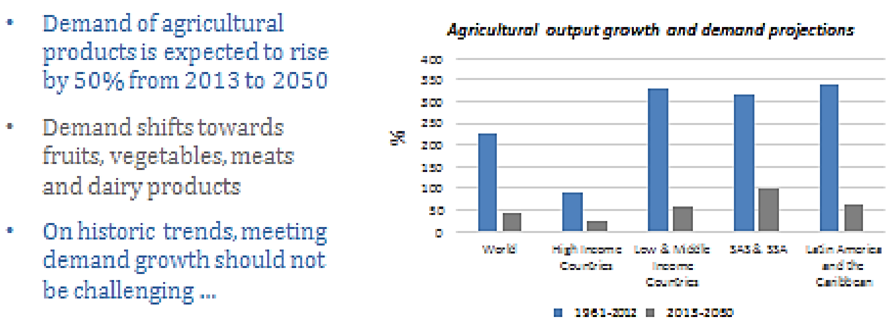

Figure 2. Agricultural output growth and demand projections

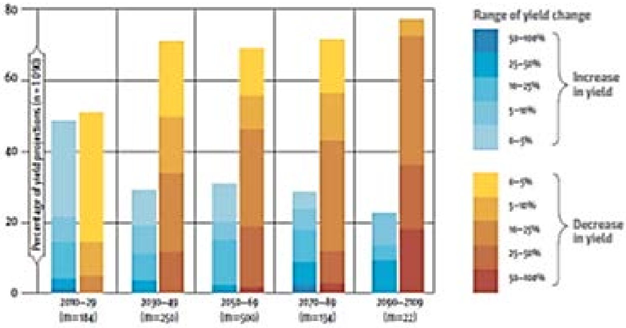

Figure 3. Climate change impacts on yields

Presentation 3: Biomass supply & demand for industrial applications: bioenergy & bio-based products (baseline and 2050)

Presentation: Andre Faaij, University of Groningen

The development of the bio-based economy for essential GHG mitigation effort will require ca.300 EJ post-2050. This may represent up to 40% of the GHG effort and includes a mix of advanced fuels, power, heat, materials and bioenergy with carbon capture and storage (bio-CCS). The ratio between biomass use as feedstock or for energy generation is set at 10/90 following broadly the same proportion as the current use of fossil resources.

Biomass potentials (technical, economic, sustainable) suffice to cover the previous demand, when combined with modernisation of agriculture and good land management. Residues are the first resource to be dispatched, readily available, followed by energy crops.

Key factors of improvement are intercropping, agro-forestry and multiple harvest, value chain efficiency, production on saline soils, yield improvements. On the latter, for instance, livestock footprint per unit of meat /milk may improve a factor 2 to 20 depending on the setting. Studies indicate that precision agriculture could even come with negative GHG emissions (less inputs and more carbon in the soil).

More attention should be paid to synergies between more resilient food production, more efficient use of natural resources and increased carbon stocks. Integrative approaches combining land demand for food, feed and energy crop production. Logical and efficient pathways are needed with a gradual development of (biomass) markets, infrastructure and technologies; intersectoral approaches.

Rural development boosted by the shift of fossil fuel expenditures into rural areas can amount several trillion of Euros per year.

Policy makers want a figure on biomass potentials, but this figure does not exist. It depends on the assumptions and constrains which are imposed. The higher constrains introduced, the lower it is the potential (Figure 4[2]). Policy

[2] Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E. A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N. H. Ravindranath, C. W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of
Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R.
Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J.
Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United
Kingdom and New York, NY, USA.

makers should therefore read the studies AND the assumptions they contain to be able to understand the results.

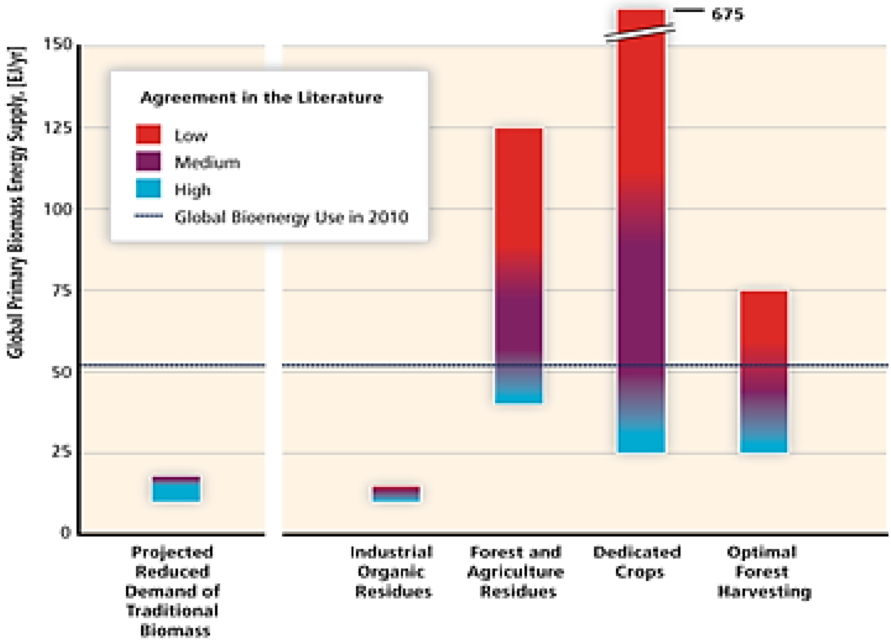

Figure 4. Bioenergy potentials 2050

Presentation 4: Strategies to increase supply

Presentation: Chris Malins, Cerulogy

It is likely that many (most?) assessments of biomass potential are unduly optimistic. On one hand energy crop yields assumed in studies may be higher than in the reality due to the following points: (1) yields are often lower at large scale than in small plots, commercial producers should expect yields at least 1/3 lower than average small trials (2) yields are lower on marginal land than on agricultural land, (3) Yields are lower under hard conditions (drought) vs. normal conditions.

On the other hand, yield projections may also be too hopeful when extrapolating yield growth of food crops, as energy crops may be systematically harder to improve: (1) Energy crops have limited response to fertilisers, (2) there is not always a possibility of GM (e.g. miscanthus is triploid), (3) perennials crops have longer breeding cycles (longer to improve selection), (4) there is no possibility of multiple harvests. In addition to yields, other corrections for 'implausible' scenarios relate to cost factor, residue retention and political stability (e.g. it is unlikely that lands in Sudan will be used for energy crops in 35 years).

A "Realistic" reassessment of biomass potentials for bioenergy resulted in estimates of (17-209 EJ yr-1) as compared to original estimates (0-1548) (Figure 5). It is important to note that the reassessment was done with some degree of optimism. Therefore in many plausible scenarios the potential could be lower than the reassessed one. It is also important to note that delivering the full reassessed potential would require enormous amounts of extensive land use change, with significant ecological implications that ought to be taken extremely seriously. With all this in mind, it becomes apparent that overly optimistic bioenergy policies risk driving unsustainable production or not being met.

For what relates residues and wastes, there is undoubtedly significant potential. However, residue collections rates should be managed properly as excessive removals could have negative impacts on biodiversity, soil fertility and erosion and carbon loss (undermining climate goals). In addition, many resources are already effectively utilised (e.g. palm fatty acid distillate, PFAD), therefore there are no environmental gains from using public money to redirect materials that are already well used. Developing the use of sustainably available residues/wastes may require targeted support

On the way forward to increase sustainable biomass supply it is acknowledged that current policies are very soft in terms of providing any "directionality" except to encourage operators to do what is easiest and cheapest. Thus, further guidance and efforts are needed to (1) maximise certainty in the RED II by deploying effective sustainability rules and guidance, (2) Develop an integrated view of biomass cropping which recognises co-benefits of perennials and more diverse landscapes (3) Support the development of residual biomass collection by sharing best practices, supporting the development of supply chains and guarantee added value for sustainably available wastes and residues over biomass crops, (4) keep on doing R&D.

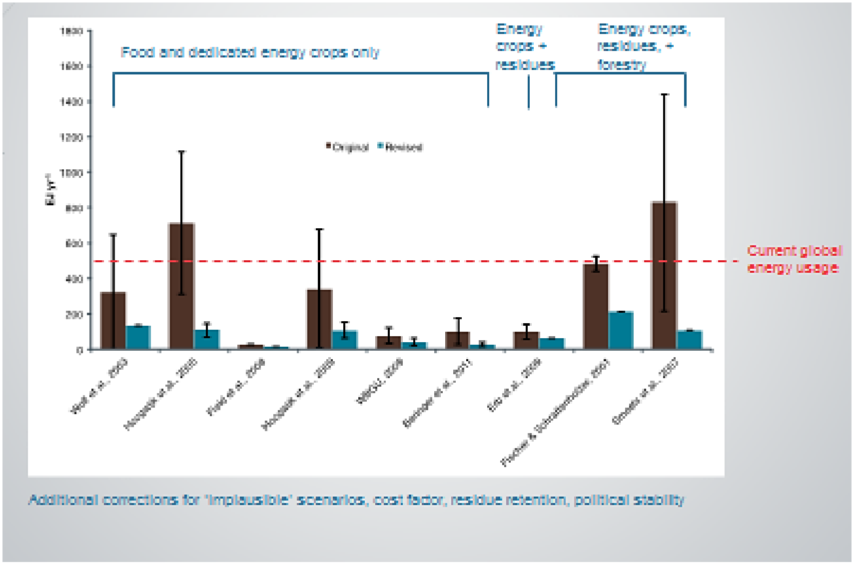

Figure 5. Re-assessment of biomass potentials

Presentation 5: Strategies to increase supply

Presentation: Liliana Rodolfi, University of Florence

Microalgae have huge advantages compared to traditional terrestrial biomass: (1) microalgae grow fast, they can double their number every few hours, (2) can have high oil (up to 15 t/ha year) and protein (up to 20 t/ha year) yields, (3) consume CO2, which can be supplied by emission sources, (4) can be grown in sea or brackish waters, (5) can be used for high protein feed and food production, (6) can be used to purify wastewaters, (7) can be used to obtain many other useful products (pigments, PUFA, vitamins..), (8) can be grown in deserts or marginal areas, (9) can be grown without pesticides and using fertilisers with 100% efficiency, (10) can attain much higher productivities than traditional crops. Advantages are obvious, but there are also limitations. For instance, algae grow fast, but they are very small and cultivation and harvesting are energy intensive processes. Algae can be grown in wastewaters, but this biomass is of very low value. Algae contain high amount of oil and chemicals, but extraction may be difficult.

Despite the large biodiversity of microalgae (>50,000 species, >million strains) only 10-20 species are commercialised. The commercial production represents about 20,000 tons per year, and the selling price ranges from 5€ per kilo up to 400-500 € per kilo and more (Figure 6). Outdoor microalgae cultivation is quite complex with numerous factors to monitor and optimise: mixing rate, irradiance, temperature, pH, oxygen accumulation, supply of CO2, nutrient availability, contamination by other organisms. The result is that photosynthesis efficiency outdoors is much lower than in laboratory conditions.

Macroalgae (seaweeds) features: (1) CO2 uptake from water/atmosphere (2) High biomass productivity (3) Large cultivation area available (4) Limited competition with food and other land uses (5) composition: carbohydrate up to 65%; protein 15%; minerals 20%. Major applications: Food, phycocolloids as thickeners/gelling agents, molecules for cosmetics, animal feed in aquaculture, fertilizers.

Most of the macroalgae production (around 80 to 90%) is in China (50%), Philippines, Indonesia and Japan. Europe mainly harvests wild seaweeds from the environment. The global market size is about 6 billion US$ per year, with an estimated production cost in the range of 50 – 400 € per ton of dry matter (Figure 7).

- The main challenges ahead for the expansion of the algae biomass production are the reduction of production costs and increase productivity. A key is the search and domestication of new species.

Product	Species	Status
Health food and feed supplements	*Arthrospira* *Chlorella* *Dunaliella* *Aphanizomenon* *Haematococcus*	Commercial (Raceway ponds, circular ponds, lagoons, PBR)
Pigments (carotenoids, phycobiliproteins)	*Dunaliella* *Arthrospira* *Haematococcus*	Commercial (as above)
ω 3 PUFA (DHA)	*Schyzochitrium* *Crypthecodiniun*	Commercial (10-100 m^3 fermenters)
Fluorescent diagnostics Labeled compounds (stable isotopes) Restriction enzymes	*Arthrospira* *Anabaena* *Anacystis*	Commercial (small PBR)
Aquaculture feeds	Various spp.	Commercial (cylinders, bags, tanks)
Polysaccharides		Research
Biofertilizers		Research
Bioactive molecules (biopesticides, probiotics, pharmaceuticals, biosensors,cosmetics)		Research
Bioremediation (xenobiotics, heavy metals)		Research
CO_2 biofixation		Research
Energy (biodiesel, H_2)		Research

Figure 6. World microalgae biomass production (2012) (from Benemann, Verdelho, Tredici, modified)

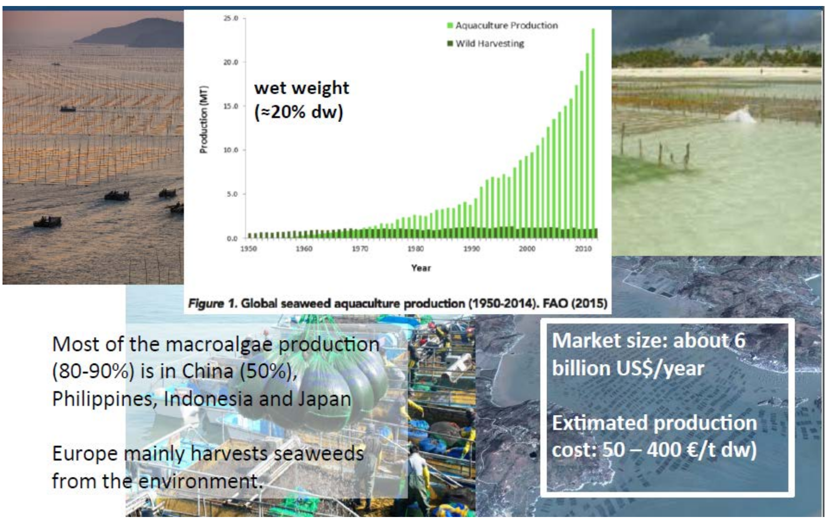

Figure 7. Macroalgae's production and market size

Presentation 6: Environmental limits

Presentation: Tim Searchinger, Princeton University

The assumption that biomass is a carbon-free source of energy is wrong. Both biomass and fossil fuel combustion emit carbon dioxide. Therefore the potential savings come from plant uptake. However, as plant growth and resulting biomass is nearly all used for food, timber and either sequestering or replenishing carbon storage, to provide benefits, bioenergy must use or result in additional plant growth (or use waste).

According to IPCC guidelines (IPCC 2000 Land Use Report, p. 355: Because "fossil fuel substitution is already 'rewarded'" by excluding emissions from the combustion of bioenergy, "to avoid underreporting . . . any changes in biomass stocks on lands . . . resulting from the production of biofuels would need to be included in the accounts." However, not all countries keep the carbon stock accounts.

A number of large bioenergy potential studies double count biomass and carbon such as recounts existing forest, forest re-growth, net terrestrial carbon sink, land counted for grazing. Forest regrowth on abandoned land is critical to lower net loss of forests and carbon. Wet savannahs are not potential low carbon sources of biofuels: Carbon payback ties for the use of dedicated perennial grasses for ethanol in wet savannah ranges from less than 10 years to more than 100.

Existing global plant harvests have transformed or substantially manipulated ~ 75% of all vegetated lands. Harvested area for 15 major crops has expanded by almost 100 million hectares in the last ten years. Yet the projections of global land use demands by 2050 without more bioenergy are the following: (1) 70% more crops, (2) 80-90% more forage for livestock, (3) 20-70% more wood, (4) > 120 million hectares of urban expansion by 2030[3]. Some estimates: >1 billion hectares agricultural expansion without biofuels[4].

Biomass is inefficient way of meeting any human demands that could be met in other ways. It requires massive quantities of land & water for modest quantities of energy. Photosynthesis has low energy efficiency in particular comparing with other technologies such as photovoltaic (PV). It has been calculated that on 73% of the world's land, the useable energy output of PV would exceed that of bioenergy by a ratio of more than 100 to 1. The average ratio would be 87 to 1 (Figure 8).

-Some models estimate could be available for bioenergy in the future without double-counting but only based on highly unlikely contingencies. For example, the GCAM model estimates hundreds of millions of hectares of present grazing land would be available for bioenergy in later decades, but only if the world imposes a large price on all terrestrial carbon that would have the effect of

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[3] Seto et al. PNAS 2012

[4] Bajzeji et al. Nature Climate Change 2014

taxing beef by something like 15$ per kilogram, leading to massive decline in beef. Unless and until governments globally do this, we should not assume this land is available.

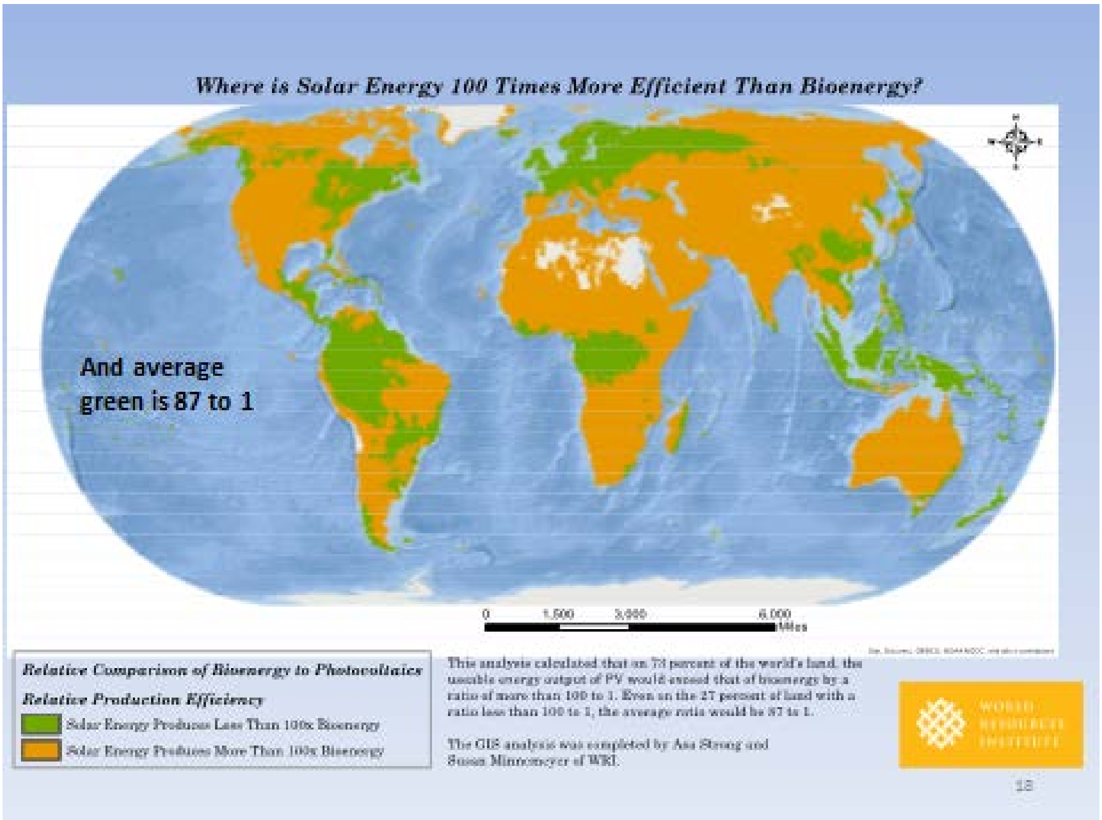

Figure 8. Comparison of energy efficiency between bioenergy and PV

Annex I. Agenda

DRAFT AGENDA

Workshop: "Biomass supply and demand for a sustainable bioeconomy – exploring assumptions behind estimates"

Brussels, 23 February 2017 (9.00 – 16.00)

DG Research and Innovation, Covent Garden 2, Place Rogier 16, B-1210 Brussels

Room COV2 5/183

9.00 – 9.15	Welcome and introduction Waldemar Kütt, European Commission James Philp, OECD Directorate for Science Technology and Innovation

Part I: Global biomass potential for a sustainable bioeconomy

9.15 – 9.55	Global bioeconomy: Biomass supply and demand (baseline & 2050) Scenarios for global biomass supply and demand covering the various bioeconomy sectors. - Presentation: Michael Carus, Nova Institute (15 min.) - Commentary: Raphael Slade, Imperial College (5 min.) - Discussion (20 min.)
9.55 – 10:35	Food/feed supply & demand (baseline & 2050) Projections of global food/feed production and demand, crop yields, diets, food waste, meat protein alternatives, etc - Presentation: Mr Lorenzo Bellu, FAO Agricultural Development Economics (ESA) (15 min.) - Commentary: Emile Frison, International Panel of Experts on Sustainable Food Systems (IPES-Food) (5 min.) - Discussion (20 min.)

10.35 – 11:00	Coffee

11.00-11:40	Biomass supply & demand for industrial applications: bioenergy & bio-based products (baseline and 2050) Projections for industrial applications. Traditional and innovative bio-based products, competition with other renewable energy sources, CO2 conversion to fuels and chemicals, etc - Presentation: Andre Faaij, University of Groningen (15 min) - Commentary: Nicklas Forsell, International Inst. for Applied Systems Analysis (5 min) - Discussion (20 min)
11.40 – 12:25	Strategies to increase supply Advances on plant breeding and agronomic practices, marginal lands, mobilisation of residues, alternative feedstocks such as aquatic, etc - Presentation. Chris Malins, Cerulogy (10 min.) - Presentation: Liliana Rodolfi, University of Florence, (10 min.) - Commentary: Mieke De Schoenmakere (EEA) (5 min.) - Discussion (20 min.)

12.30 – 13.30	Lunch

13:30-14:10	Environmental limits Land use change, biodiversity, water and soil quality, ecosystem services. - Presentation: Tim Searchinger, Princeton University (15 minutes)

	- Commentary: Pieter De Pous, European Environmental Bureau (5 minutes) - Discussion: (20 minutes)

Part II: A focus on Europe

14:10-14:45	EC study biomass supply and demand, boundary conditions and first results - Presentation: Andrea Camia, European Commission Joint Research Centre (15 minutes) - Discussion (20 minutes)

Part III: Final Discussion

14.45 – 15.45	Sustainable Bioeconomy – where do we focus? Moderators: Waldemar Kütt, European Commission James Philp, OECD Directorate for Science Technology and Innovation

Part IV: Conclusions

15.45 – 16.00	Conclusions

List of participants

First Name	Last Name	Organisation	Country
Jim	Philp	OECD	FR
Michael	Carus	Nova Institute	DE
Raphael	Slade	Imperial College Centre for Energy Policy & Technology	UK
Lorenzo G.	Bellu	FAO, Agricultural Development Economics Division	IT
Emile	Frison	International Panel of Experts on Sustainable Food Systems (IPES-Food)	BE
André	Faaij	University of Groningen, Energy and Environmental Studies	NL
Nicklas	Forsell	International Institute for Applied Systems Analysis (IIASA)	AT
Chris	Malins	Cerulogy	UK
Liliana	Rodolfi	University of Florence	IT
Mieke	De Schoenmakere	European Environmental Agency	DK
Tim	Searchinger	Princeton University	US
Pieter	DE POUS	European Environmental Bureau	NL
Andrea	Camia	EC DG JRC-Ispra	IT
Waldemar	Kütt	EC, DG RTD	BE
Tom	Dodd	EC, DG RTD	BE
Jüri	Rute	EC, DG RTD	BE
María	Fernández Gutiérrez	EC, DG RTD	BE

Annex II: Participants details

Lorenzo Giovanni Bellù is senior economist, leader of Global Perspectives Studies Team, at FAO. Key areas of expertise and work include: global and country-level development processes and related implications for food and agriculture. Socio-economic and environmental impact assessment of policies; policy impact analysis by means of Computable General Equilibrium (CGE) and other quantitative analysis tools. PhD in Economic Policy (Università Cattolica Milan, IT) with a thesis on "International Price shocks and development: a computable General Equilibrium Approach with applications to Burkina Faso". Graduated in Economics with a thesis on labour demand and wages in the wholesale and retail sector (Università Cattolica, Milan, IT).

Michael Carus is founder and managing director of the nova-Institute. He studied physics and mathematics at the University of Cologne. After Carus left university in 1983, he became a tele-education teacher at the University of Tübingen, for the topics of ecology, nuclear energy and radioactivity. He worked as science journalist and as scientist at the KATALYSE Environmental Institute with a focus on energy and ecology. He is recognized as one of the leading European experts, market researchers and policy advisers for bio- and CO2-based economy. Carus is main author and co-author of many fundamental reports and policy papers concerning the bio-based economy, markets and sustainability.

Pieter de Pous holds a master degree in forestry sciences from the University of Wageningen in the Netherlands. Since 2005 he has worked in the policy unit of the European Environmental Bureau, coordinating the organizations advocacy work in the areas of biodiversity, water, soil, bio-energy and agriculture policies. Since September 2010 he is the EEB's policy director. Managing a team of 13 policy officers, he leads the EEB's policy work with a focus on horizontal issues like environmental governance, trade and better regulation. He is also chairman of the board of ECOS, Vice Chair of Green Budget Europe, Member of the Board of Seas At Risk and the RISE Foundation.

Mieke De Schoenmakere works at the EEA in Copenhagen as project manager for circular economy. She graduated as Industrial Engineer and gained for several years, experience in the sector of organic fertilizers and in applied research on field grown vegetables. The sustainable management of waste and materials, resource efficiency and circular economy became the central themes afterwards, while for more than 10 years she has been working at governance level (OVAM and the Flemish ministry for environment), as policy advisor both on regional and EU matters. She has been head of the unit responsible for European and International waste and materials policies.

André Faaij is appointed as Academic Director Energy Academy Europe and Distinguished Professor *Energy System Analysis* at Groningen University.–His research covers, amongst others, bio-based economy, carbon capture and storage, renewable energy, alternative transport fuels, energy system & scenario analysis, technological learning and energy policies. He works as an advisor for governments, the EC, IEA, the UN system, GEF, OECD, WEF, WEC, the energy sector & industry, NGO's, etc. He published over 600 titles in scientific journals, reports, books and proceedings, qualifies as 'highly cited researcher' (top 1% of research field) by criteria of Thomson Reuters ISI Web of Science and is frequently lecturing across the globe.

Nicklas Forsell joined the Ecosystems Services and Management (ESM) Program in 2012 as a postdoctoral research scholar on a scholarship given by IIASA. His current research interests include the use of optimization models to analyse the links between forest, agricultural, and energy planning. His research focus on developing integrated assessments of national and global policies. He obtained his PhD in economics from the Swedish University of Agricultural Science (SLU) in collaboration with the French National Institute for Agricultural Research (INRA). Prior to joining IIASA, Dr. Forsell worked at MINES ParisTech, France, where he focused on long-term energy system analysis.

Emile Frison is a Belgian national with a career in international agricultural research for development. He worked in Africa for six years on agricultural research and development, in Nigeria and Mauritania. In 2003, he became Director General of Bioversity International and developed a strategy entitled "Diversity for Well-being" focusing on the contribution that agricultural biodiversity makes to the nutritional quality of diets and to the sustainability, resilience and productivity of smallholder agriculture. He is Chair, International Scientific Committee on Sustainable Food Systems of the Daniel and Nina Carasso Foundation. In 2015, he joined the International Panel of Experts on Sustainable Food Systems. He is author or co-author of over 175 scientific, technical and policy papers.

Chris Malins of Cerulogy is an independent consultant specialising in alternative fuels sustainability and policy. Chris' research interests include indirect land use change, advanced biofuel investment support, biomass availability, ecological impacts of palm oil, greenhouse gas intensity of fossil fuel extraction and aviation biofuels. He has served on expert advisory groups for organisations including the European Commission, International Civil Aviation Organisation, California Air Resources Board, UK Department for Transport, Roundtable on Sustainable Biomaterials and Alberta Department of Energy. Chris has lectured on alternative fuels for the Environmental Technologies masters course at Imperial College London. He holds a PhD in Applied Mathematics from Sheffield University.

Jim Philp is a microbiologist who has worked as a policy analyst since 2011 at the OECD, specialising in industrial biotechnology, synthetic biology and biomass sustainability. He was an academic for about sixteen years researching environmental and industrial biotechnology: bioremediation, biosensors, wastewater science and engineering. He became involved with various UK government initiatives in biotechnology, such as Biotechnology Means Business, and BioWise. He has authored over 300 articles. He was elected as a Fellow of the Royal Society of Chemistry in 2015, and a Fellow of the Institution of Chemical Engineers in 2016.

Liliana Rodolfi is researcher at the University of Florence (Department of Agrifood Production and Environmental Sciences) since 2010. Lecturer of “Forest Microbiology” at the University of Palermo and of “Microbiological Techniques”, “Industrial Microbiology” “Aquatic Biomasses”, “Tropical Agriculture Microbiology” and “Environmental and Applied Microbiology” at the University of Florence. PhD in 2001 in Food Biotechnology at the University of Florence with a thesis on “Nannochloropsis: biochemical characterization, mass cultivation and use in aquaculture”. Co-author of more than 30 scientific papers (journal articles and book chapters), two patents, numerous proceedings and invited lectures at international conferences on algae cultivation and applications.

Timothy D. Searchinger is a Research Scholar in the Woodrow Wilson School of Public and International Affairs at Princeton University. Although trained as a lawyer, his work today combines ecology and economics to analyse the challenge of how to feed a growing world population while reducing deforestation and greenhouse gas emissions from agriculture. He was the lead author of papers in *Science* in 2008 and 2009 offering the first calculations of the greenhouse gas emissions associated with land use change due to biofuels, and describing a broader error for bioenergy in the accounting rules for the Kyoto Protocol and many national laws.

Raphael Slade is a Senior Research Fellow at Imperial College London and Head of Science for the Intergovernmental Panel on Climate Change Working Group 3 Technical Support Unit. His research focusses on the economic, technological and policy aspects of producing energy and materials from biomass, the strategic responses to increasing natural resource scarcity, and the environmental implications of the transition to a low carbon energy future. He has over 10 years’ experience working in a multidisciplinary environment delivering high impact, policy relevant analysis.

Andrea Camia is Scientific Officer at the Joint Research Centre of the European Commission since 2004, adjunct professor at the University of Torino and University of Palermo from 1996 to 2003, PhD in Forest Sciences in 1995. Currently he leads the Bioeconomy Project in Directorate JRC.D - Sustainable Resources, encompassing the coordination of the JRC Biomass Study (under the mandate agreed by the EC Services on the provision of data and analysis on biomass flow, supply and demand by the JRC on a long-term basis) and the Bioeconomy Knowledge Centre.

Tom Dodd has worked in the Bioeconomy Directorate of the European Commission's Directorate-General for Research and Innovation since 2013. From 2004-2013 he was a member of the Corporate Social Responsibility (CSR) team in the Directorate-General for Enterprise and Industry. He started working for the European Commission in 1995, managing emergency humanitarian assistance to various African countries, and subsequently completed a four year posting in the Commission's Delegation in Nicaragua. He studied at the University of Edinburgh in Scotland and at the College of Europe in Bruges.

María Fernández joined the European Commission in 2002. She is a policy officer in the Unit "Bio-based products and processes" at Directorate General for Research and Innovation. In this role Ms. Fernandez contributes to the development of the European Bioeconomy with particular emphasis on the field of bio-based industries. María Fernández obtained her PhD in Chemical Engineering at the University of Oviedo, Spain and worked as a post-doctoral fellow at Chalmers University of Technology, Sweden. She worked in a number of research centres across Europe and published a number of research papers concerning emissions reduction during energy conversion.

Waldemar Kütt joined the Research Directorate General of the European Commission in 1997 after obtaining his ph.d. from the Technical University in Aachen (RWTH) in 1988 in solid state physics and semiconductor technology. He held various positions as senior expert, Deputy and Head of Cabinet in the Cabinet of Research Commissioners Potočnik and Geoghegan-Quinn. His main responsibilities included the €80billion new Framework Programme for Research and Innovation, Horizon 2020. From November 2014 to December 2016 he was Head of Unit of "Bio-based Products and Processing" in the Bioeconomy Directorate of DG Research and Innovation. Since January 2017, he is heading the strategy unit in the same directorate.

Jüri Rute joined the European Commission in 2006 as the desk officer in charge of Estonian rural development programmes. In 2015 he moved from DG Agriculture and Rural Development to DG Research and Innovation to deal with biomass issues as a policy officer of the Bioeconomy Directorate. Before moving to Brussels, Jüri Rute was Estonian state official in the fields of youth policy, regional and rural development.

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This report summarises the knowledge gathered during the workshop on "Biomass supply and demand for a sustainable bioeconomy – exploring assumptions behind estimates" that was organised by the European Commission (DG Research & Innovation, Unit F2 Bio-based Products and Processes) in February 2017. The workshop gathered 12 external experts from various backgrounds and offered an opportunity to meet and exchange ideas. The first part of the report includes the main "take home messages" from the workshop. Short summaries of the presentations are included in the second part. The agenda and a full list of participants can be found in annex.

This report reflects statements made by the experts during their presentations and discussion, but does not imply that all participants endorse all points.

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