IEA Bioenergy triannual conference 2021 - highlights

Online, 29 November – 9 December 2021

Conference Report

IEA Bioenergy 12 2021

Luc Pelkmans, Technical Coordinator, IEA Bioenergy

The IEA Roadmap 'Net Zero Emissions by 2050' recognises bioenergy as an important option, representing a substantial part of total energy supply in 2050, and playing a significant role to reach carbon neutrality of the global energy system, through the direct replacement of fossil fuels and/or to offset remaining emissions through the combined use of bioenergy with carbon capture and storage/utilisation. A growing role of biomass/biofuels would be needed in industry, transport as well as heat and power production.

The central theme of the 2021 IEA Bioenergy conference was '**The role of biomass in the transition towards a carbon neutral society**'. The conference sessions considered the latest developments and prospects of biomass/bioenergy in different sectors, as well as sustainable feedstock mobilisation and the role of biomass in a circular bioeconomy.

The conference was held online and spread over 2 weeks, between 29 November and 9 December 2021, with one or two sessions of 2 hours per day. Each day was dedicated to a central topic. Almost 1200 people participated in one or more of the conference sessions. They were from around 90 countries from all over the globe.

This report presents the general conclusions of the conference, as well as each session's highlights.

Key takeaways of the conference

Bioenergy's role in decarbonisation is substantial; BECCS is one of the critical options to achieve negative emissions

Reaching climate neutrality globally requires an unprecedented transformation of the energy system. A portfolio of options will be needed; there are no silver bullets and we do not have the luxury to dismiss good options. A strong boost will be needed for all relevant options, also for bioenergy. The role of bioenergy in net zero scenarios of IEA, IRENA, IPCC, … is substantial - up to 20% of total energy supply in 2050 at the global level, based on realistic sustainable biomass potentials.

Next to deep and rapid reductions of GHG emissions, CO_2 removal from the atmosphere (CDR) will be absolutely necessary to limit global warming. Bioenergy combined with stable geological storage of carbon (BECCS) is one of the critical CDR options.

Bioenergy should not be considered in isolation – it is part of a broader bioeconomy

Bioenergy should not be considered in isolation, but as part of a broader bioeconomy, which includes forestry, agriculture, the food industry, wood processing industries, biomaterials & biochemicals production, waste management and the energy sector. It is by definition cross-cutting and requires a holistic approach over different policy fields.

Good practices show multiple co-benefits (beyond energy and climate), for example, rural development, waste management, circular economy, soil improvement, or land restoration. Impacts on the different Sustainable Development Goals (SDGs) need to be considered; depending on the contextual conditions there can be synergies or trade-offs.

Increased efforts needed for sustainable biomass mobilisation; sustainability governance is key

Increased efforts for sustainable biomass mobilisation are needed. To de-risk investments there needs to be a clear understanding of what sustainable biomass means and how much biomass can be mobilised within sustainability constraints. Sustainability governance is a key requirement.

With the trend towards lower value/underutilised heterogeneous biomass resources on the one side, and higher value applications of biomass (advanced transport fuels, biobased chemicals) on the other side, there is a need to connect the local and dispersed biomass feedstock base with centralised processing at scale. Biohubs, providing storage and pre-treatment at the regional level, can be a tool to make such connections.

Transition is accelerating; priorities of biomass use will evolve

Company ambitions in terms of decarbonisation goals are growing fast, both in sectors which are relatively easy to transform (e.g., light industries, services), and in harder to abate sectors (e.g., aviation or heavy industries). Companies and sectors are taking concrete steps to manage the transition in practice. This requires major investments; companies are vulnerable during transition periods and need a stable policy framework.

There is a gradual shift of biofuels/biomass to difficult-to-electrify sectors (like aviation, marine transport, industry), although short term displacement of fossil fuels in current systems (e.g., in road transport, heat systems) remains important.

Reliable and coherent political framework conditions needed for the necessary scale-up

Reliable and coherent political framework conditions are of key importance to motivate investments and to scale up new technologies. The most important policy measures to support biomass applications are carbon pricing, support for RD&D to lower costs and obligations in specific markets.

Flexibility is one of the key characteristics of bioenergy; important synergies with hydrogen

In the near future the integration of energy vectors (power, heat, gas) will be essential to facilitate variable renewables such as solar or wind energy, where dispatchable renewable energy sources such as bioenergy gain importance for grid balancing and cover seasonal fluctuations (particularly for heat). Fossil gas replacement requires much more attention, with biomethane being one of the major options.

In an energy mix dominated by wind and solar, flexibility (short and long term) and Bio-CCUS are expected to be two of the more important characteristics of bioenergy. There are important potential interactions and synergies between bioenergy and green hydrogen deployment, for example to combine biogenic CO_2 (from biobased processes) with renewable hydrogen to produce e-fuels.

Session highlights

The table below shows an overview of the conference sessions. The highlights of each session are summarised in the coming chapters.

All information on the sessions (presentations, recordings, highlights, poll results) is also available on the session pages of the conference website https://www.ieabioenergyconference2021.org.

Sessions of the IEA Bioenergy triannual conference 2021

Date & timing (UTC)		Session
29 Nov 2021	2-4 pm	*Opening panel: Implications of COP26 for future bioenergy & bioeconomy*
30 Nov 2021	7-9 am	Setting up regional biohubs to enhance biomass mobilisation
	8-10 pm	Realising sustainable bioenergy pathways towards climate goals
1 Dec 2021	2-4 pm	Emerging biofuels markets and the importance of LCA and certification
	8-10 pm	The potential of drop-in biofuels to decarbonise aviation
2 Dec 2021	7-9 am	State of the art and innovation in Green Gas
	2-4 pm	Green Gas perspectives
3 Dec 2021	8-10 am	*Industry panel: Long term markets for biomass and biofuels*
6 Dec 2021	2-4 pm	Waste and residue valorisation in a circular economy
	8-10 pm	Industrial symbiosis and biorefineries in a circular economy
7 Dec 2021	7-9 am	Biomass and renewable heat
	2-4 pm	Bioenergy's contribution to low-carbon energy systems
9 Dec 2021	12-2 am	*Closing panel 1: How can biomass/bioenergy aid the transition towards carbon neutrality? - focus on East Asia/Oceania & North America*
	12-2 pm	*Closing panel 2: How can biomass/bioenergy aid the transition towards carbon neutrality? - focus on Europe, Africa, South-America & India*

OPENING PANEL: IMPLICATIONS OF COP26 FOR FUTURE BIOENERGY & BIOECONOMY

Monday 29 November 2021, 2-4 pm UTC

Moderators: Paul Bennett, Scion/IEA Bioenergy & Paolo Frankl, IEA

Speakers/panellists:

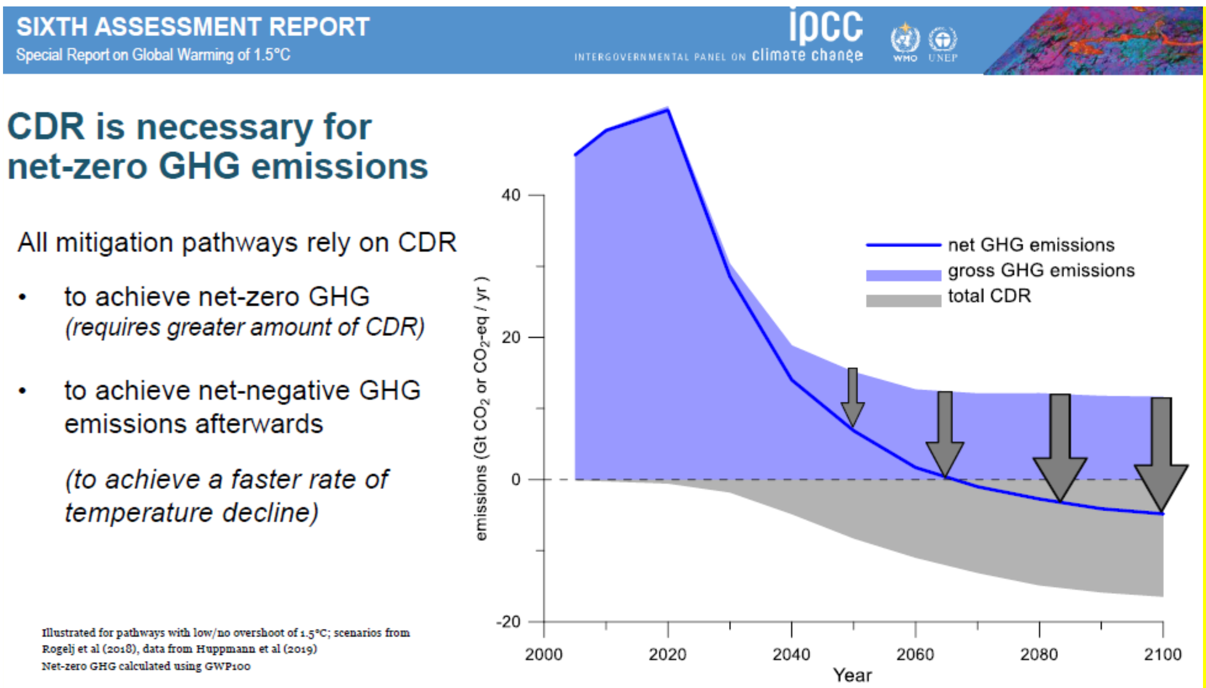
- Andy Reisinger, IPCC — Intergovernmental Panel on Climate Change
- Paolo Frankl, International Energy Agency (IEA)
- Maria Georgiadou, DG Research & Innovation, European Commission
- Dolf Gielen, International Renewable Energy Agency (IRENA)
- Jim Spaeth, U.S. Department of Energy
- Jossy Thomas, UN Industrial Development Organization (UNIDO)

Highlights of the session:

- A portfolio of options will be needed to limit climate change; there are no silver bullets and we **do not have the luxury to dismiss good options**.
- Considering the current country pledges (NDCs) it is unrealistic to expect that 1.5°C warming can be reached without overshoot. Actions and targets for 2030 and 2050 need to be considered as a start for sustained efforts. Every 0.1°C counts!
- Next to deep and rapid reductions of CO_2 emissions (through efficiency measures, replacing fossil fuels by renewables, …), **CO_2 removal from the atmosphere (CDR) will be absolutely necessary to limit global warming**. Bioenergy combined with stable geological storage of carbon (BECCS) is one of the critical CDR options.
- The **role of bioenergy in net zero scenarios is substantial** - up to 20% of total energy supply in 2050 at the global level, based on realistic sustainable biomass potentials. Deployment of

modern bioenergy in buildings (replacing traditional bioenergy), in industries and for transport biofuels can happen at the short-to-medium term but is not on track and **needs much more efforts** (which is also valid for most other decarbonisation options we need). Clear targets as well as supporting and de-risking the financing of first-of-a-kind commercial projects, e.g., through the European Innovation Fund, can give a push to deployment.

- We need to **act quickly to phase out 'traditional biomass'**, meaning inefficient burning of biomass, associated with high toxic emissions, mostly in developing countries. This will not be an easy task as it comes with **important social challenges**. Switching to bioethanol for clean cooking in developing countries can have many advantages. Relevant initiatives are setup by UNIDO, e.g., in Tanzania, to create favourable market conditions and promote private sector engagement.
- Bioenergy comes with its challenges, stemming from uncertain availability and/or sustainability of biomass feedstocks. A **joint understanding** is important on the availability of sustainable biomass feedstock and **how bioenergy pathways can be developed in a sustainable way**. Biomass supply is cross-sectoral and needs to be actively integrated in land, forest or waste management, and, next to trade-offs, it **can deliver important co-benefits**, e.g., in supporting rural employment and reducing land degradation.



Importance of carbon dioxide removal (CDR) technologies (indicative). From presentation Andy Reisinger

SESSION 2: SETTING UP REGIONAL BIOHUBS TO ENHANCE BIOMASS MOBILISATION

Tuesday 30 November 2021, 7-9 am UTC

Moderator: Mark Brown, University of the Sunshine Coast, Australia

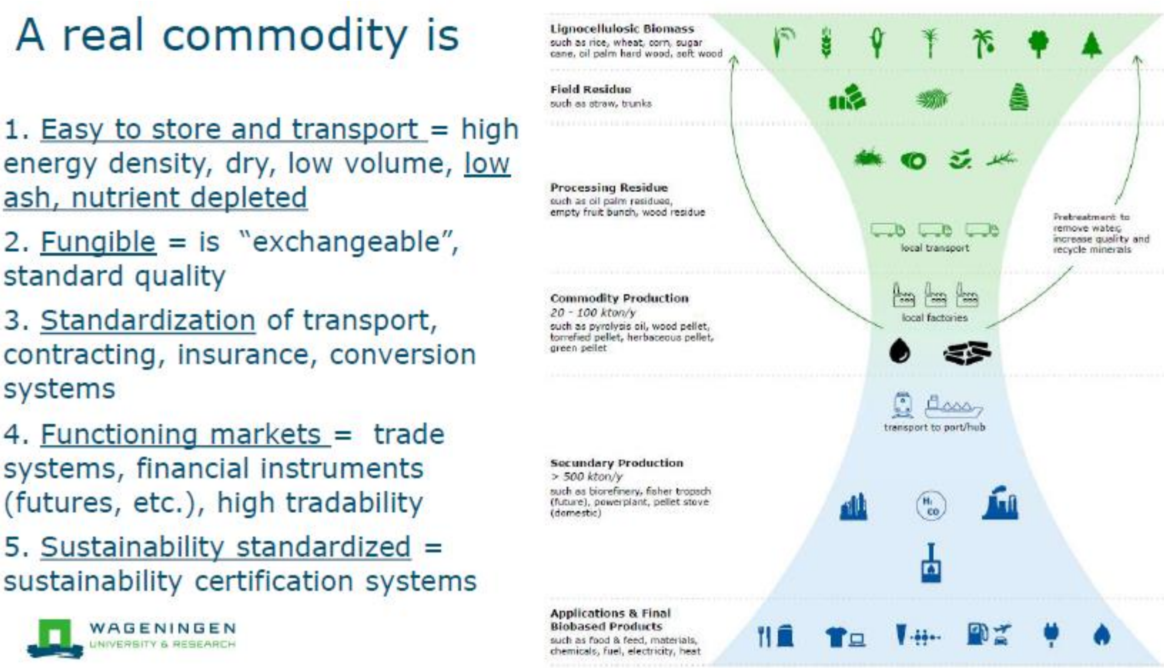
Speakers/panellists:

- Ric Hoefnagels, Utrecht University, the Netherlands
- Fabian Schipfer, Technical University Vienna, Austria
- Wolter Elbersen, Wageningen University & Research, the Netherlands
- Biljana Kulišić, Energy Institute Hrvoje Pozar (Croatia)
- Mohammad R. Ghaffariyan, University of the Sunshine Coast, Australia

Highlights of the session:

- The use of **low value/underutilised heterogeneous biomass resources** will be very important for future deployment of the bioeconomy (which includes bioenergy). Dedicated **mobilisation strategies** addressing multiple levels of governance will provide participatory and environmental benefits on top of broadening the sustainable feedstock base.
- With the trend towards higher value applications of biomass (advanced transport fuels, biobased chemicals), there is a need to connect local and dispersed biomass on the one side, with central processing at commercial scale on the other side. Such centralised conversion plants will not necessarily be located near the biomass, but preferably near logistic centres.
- Biohubs / regional biomass depots for lignocellulosic biomass are a way to **connect local biomass with markets**, providing intermediate storage as well as pre-treatment to tradable and standardised commodities. They can also facilitate the engagement of local stakeholders (e.g., in a cooperative structure).
- Business models preferably take a **cascading approach** (in time and product quality). Primary products (food, chemicals, biomaterials) will always come with a share of residues/by-products (from farmers, post-harvest facilities). Collecting and treating these residues at regional scale in biohubs adds value to these residues and allows for income diversification, thereby improving the overall business model.

- We need to **learn from examples**. IEA Bioenergy Task 43 provides a dashboard where biohub case studies come together, each with an indication of Strengths, Weaknesses, Opportunities and Threats. Available at: https://arcg.is/qLqaK



Connecting biomass resources and biobased markets. From presentation Wolter Elbersen

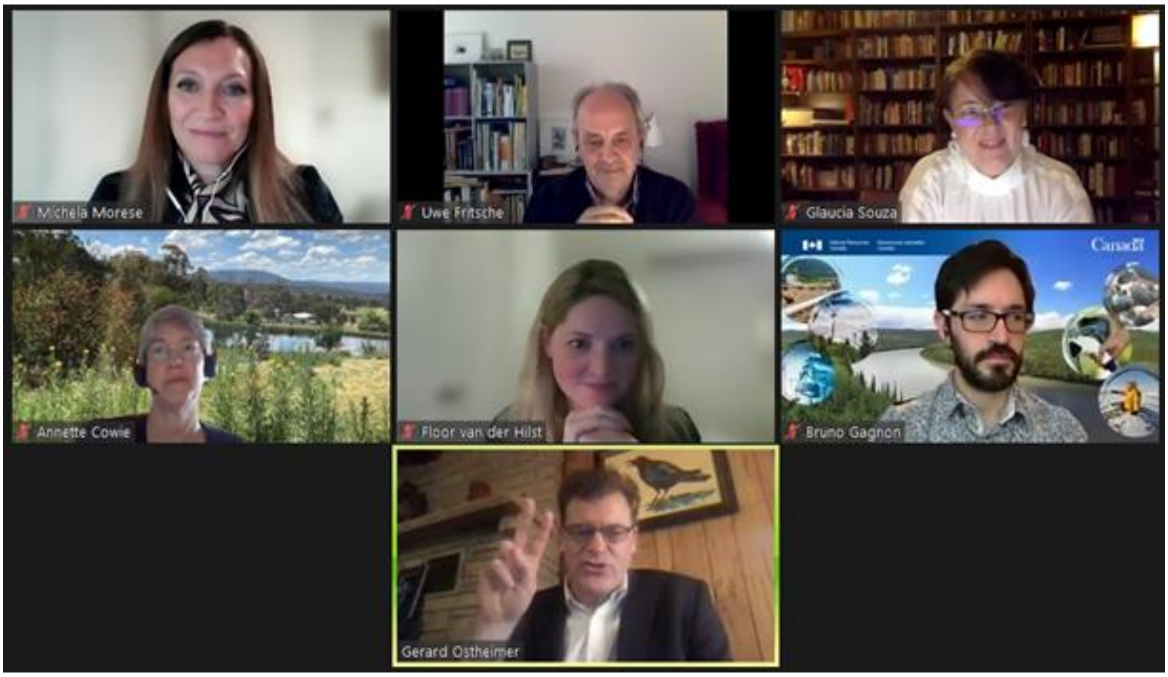
SESSION 3: REALISING SUSTAINABLE BIOENERGY PATHWAYS TOWARDS CLIMATE GOALS

Tuesday 30 November 2021, 8-10 pm UTC

Moderator: Glaucia Mendes Souza, University of São Paulo (Brazil)

Speakers/panellists:

- Bruno Gagnon, Natural Resources Canada
- Floor van der Hilst, Utrecht University, the Netherlands
- Annette Cowie, NSW Department of Primary Industries, Australia
- Gerard Ostheimer, Biofuture Workshop, (United States
- Michela Morese, Global Bioenergy Partnership (GBEP), Italy
- Uwe Fritsche, IINAS, Germany



Highlights of the session:

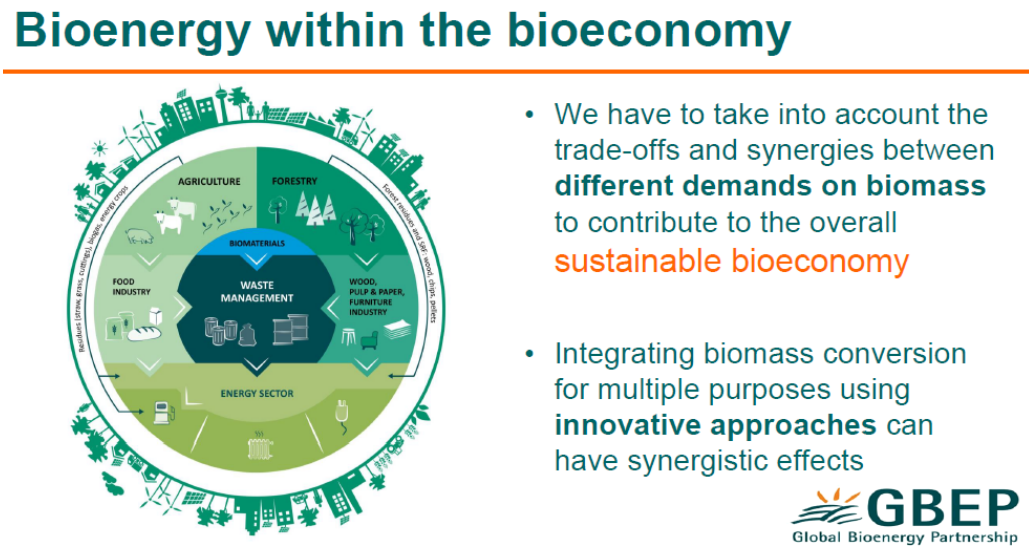
- Bioenergy should **not be considered in isolation, but as part of a broader bioeconomy**. It is by definition cross-cutting and requires a holistic approach over different policy fields. A risk is that this is perceived as complex by policy makers.
- **Sustainability governance** is a key requirement - it is critical that there is a thorough and transparent monitoring of evolutions in the field of the bioeconomy and its impacts to assist policy making.
- It is important to consider bioenergy/bioeconomy in relation to the Sustainable Development Goals (SDGs). Bioenergy **touches on several SDGs**, not only SDG7 (energy) or SDG13 (climate). For almost all SDGs both synergies and trade-offs can occur. Depending on the contextual conditions, it can turn out to be a synergy or a trade-off.

- **Good practices show multiple co-benefits**, going beyond energy and climate alone, e.g., in terms of soil quality and land restoration as well as rural development, while limiting potential negative effects. Most positive impacts are reached if biomass production systems are integrated into land and resource management systems in a way that complements, not competes with existing production systems, and involve close cooperation and partnerships amongst multiple stakeholders along the supply chain.

- Land use can be a critical issue, particularly if large blocks of land would be devoted to energy crops (as could be required if extreme amounts of carbon dioxide removal would be needed to compensate for delays in climate action). Nevertheless, there are many good examples of biomass production, e.g., on abandoned/marginal lands, through integrated production with food/feed crops (as intercrop, in riparian areas, as wind buffer, …), or through the use of agricultural residues.

- There is active debate on the climate impacts of using forest biomass for energy, with studies providing conflicting results. Often insufficiently recognised is that (commercial) forests are primarily managed for timber, with biomass being a co-product. There can be important analytical differences in studies/reports, e.g., in terms of system boundaries (*short vs medium timeframe; stand vs landscape level; bioenergy only vs different products coming from the forest*) and the assumed counterfactual (*in terms of land use and energy system if the specific biomass is not used for energy*). Only considering the smokestack or just considering the forest carbon ignores important parts of the system; we **need to look at the broader picture** (including the forest carbon storage and sink, the forest products, the bioenergy produced) **to understand the climate impact of how the forest is managed**.

- There are many uncertainties in terms of global/regional sustainable biomass availability, going from extremely cautious estimates to analyses taking into account extra mobilisation efforts, coming to a wide range of figures from less than 30 EJ to more than 100 EJ at the global level. This uncertainty also has a knock-on effect on the demand side. To **de-risk feedstock availability for investors**, the CEM Biofuture Platform Initiative is starting a new workstream on sustainability governance and biomass quantification for which it will engage different experts and stakeholders. IEA Bioenergy and GBEP will contribute to that.



Bioenergy is embedded in the bioeconomy. From presentation Michela Morese

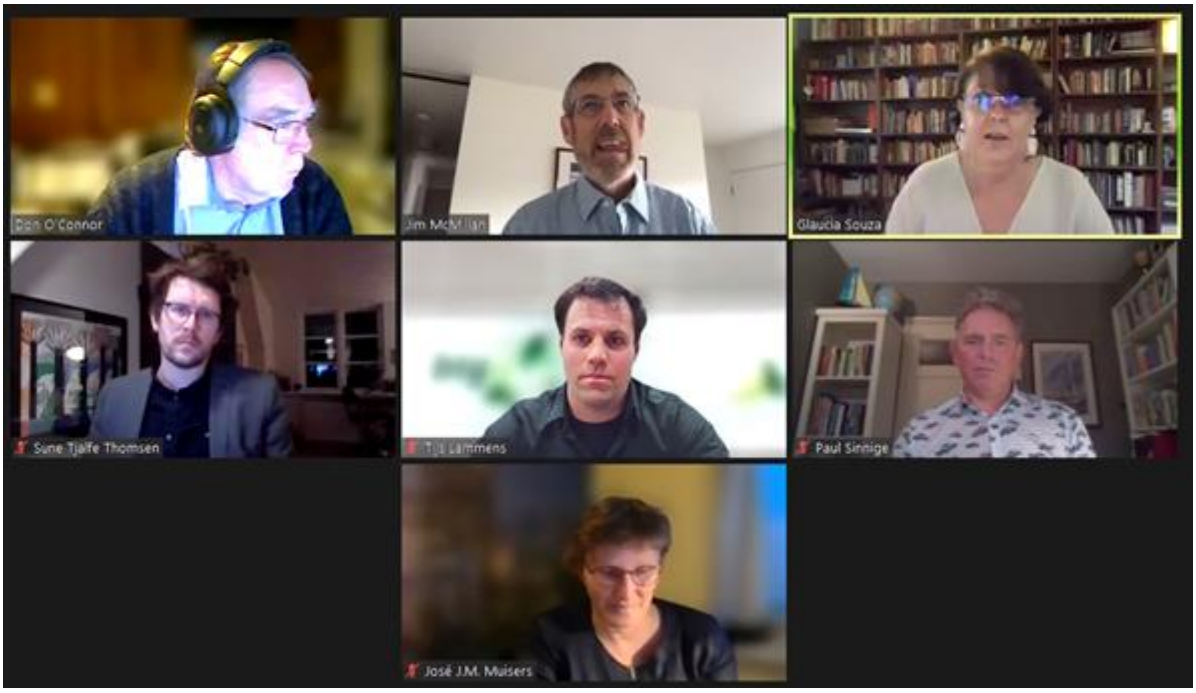
SESSION 4: EMERGING BIOFUELS MARKETS AND THE IMPORTANCE OF LCA AND CERTIFICATION

Wednesday 1 December 2021, 2-4 pm UTC

Moderator: Jim McMillan, National Renewable Energy Laboratory (NREL), United States

Speakers/panellists:

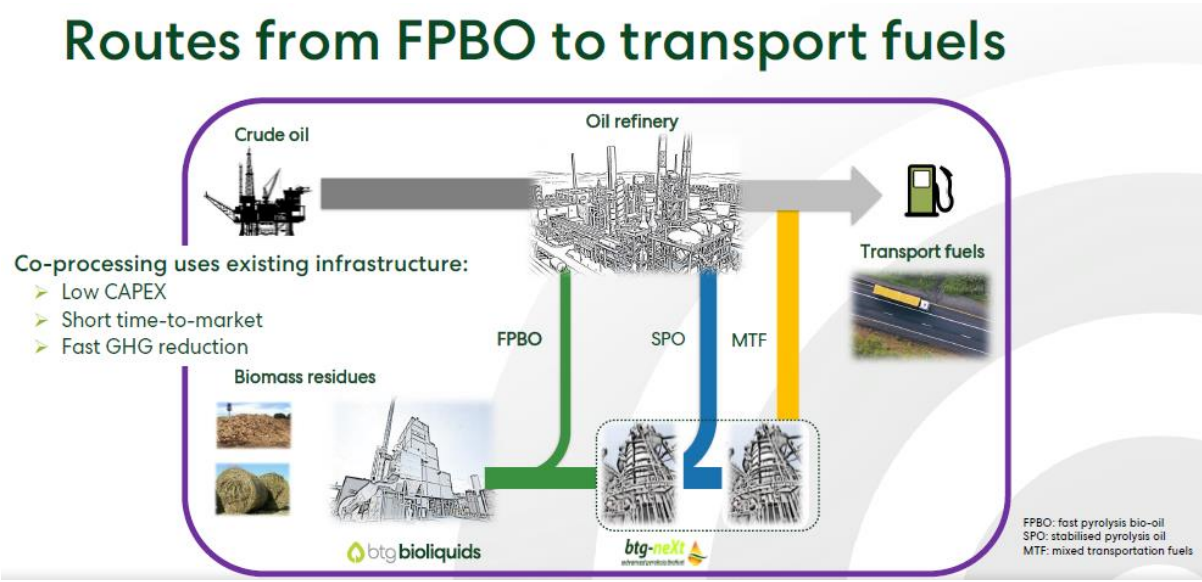
- Sune Tjalfe Thomsen, University of Copenhagen, Denmark
- Tijs Lammens, BTG Bioliquids, the Netherlands
- Glaucia Mendes Souza, University of São Paulo, Brazil
- José J.M. Muisers & Paul Sinnige, NL Enterprise Agency (RVO), the Netherlands
- Don O'Connor, S&T2 Consultants, Canada



Highlights of the session:

- **Biofuels are highly promising for the marine sector**, both for reducing its carbon footprint and for meeting more stringent sulphur regulations. While several actors show high ambitions, the main barriers for deployment are (1) uncertainty on sustainability requirements (what feedstock is acceptable?), (2) incompatibility with international marine fuel standards, and (3) lack of economic incentives and targeted policies. International policies targeting alternative fuel technologies more directly such as carbon taxation or renewable fuel mandates could significantly accelerate the transition from fossil to alternative fuels.
- Fast pyrolysis of biomass close to the feedstock source and transporting the bio-oil for more central processing is a promising concept. Co-processing biocrude/bio-oil in existing petroleum refineries can provide an efficient way to immediately reduce the carbon footprint of transport fuels that are brought to the market. With further phase-down of fossil fuels, dedicated refining of the bio-oil will be required.

- In several emerging economies in Latin America and Sub-Saharan Africa there are **many opportunities to expand land use** (including land restoration) for biomass production, without compromising food provision or high biodiverse/carbon stock areas. High yields are particularly possible in tropical and sub-tropical areas.
- Ethanol already represents the major fuel in the flex fuel car fleet in Brazil, both in pure (hydrous) form and in a 27% blend with gasoline. The current Brazilian Policy for Biofuels - RenovaBio rewards biofuels with low carbon intensity.
- With mandates **shifting from volume mandates to GHG emission reduction mandates** (e.g., in California, Brazil, Germany, Sweden, …) and putting a price on carbon, LCA becomes a critical tool. Nevertheless, LCA tools were not originally designed as compliance tools and results largely depend on the quality of the data used. Particularly for secondary data (not under the control of the producer, e.g., in terms of feedstocks) this is a challenge. There needs to be a continual effort to update these secondary data sets if we want credible LCAs.
- **Certification of feedstocks and biofuel pathways** can serve to monitor compliance for a policy framework, manage the Chain of Custody (CoC), and ensure good traceability and transfer of data. Data availability and correctness is key. A wide range of approved private certification schemes underlines the importance of a clear policy framework for those countries where certification plays a role in co-regulation. Different requirements from different countries/regions (also due to different scopes) have resulted in the development of specific modules under certification schemes, to be able to adapt to specific policy frameworks. Aligning requirements between different regions or at international level is highly recommended for good market operation.



Different routes to convert fast pyrolysis bio-oils (FPBO) to transport fuels. From presentation Tijs Lammens

SESSION 5: THE POTENTIAL OF DROP-IN BIOFUELS TO DECARBONISE AVIATION

Wednesday 1 December 2021, 8-10 pm UTC

Moderator: Jack Saddler, University of British Columbia (UBC), Canada

Speakers/panellists:

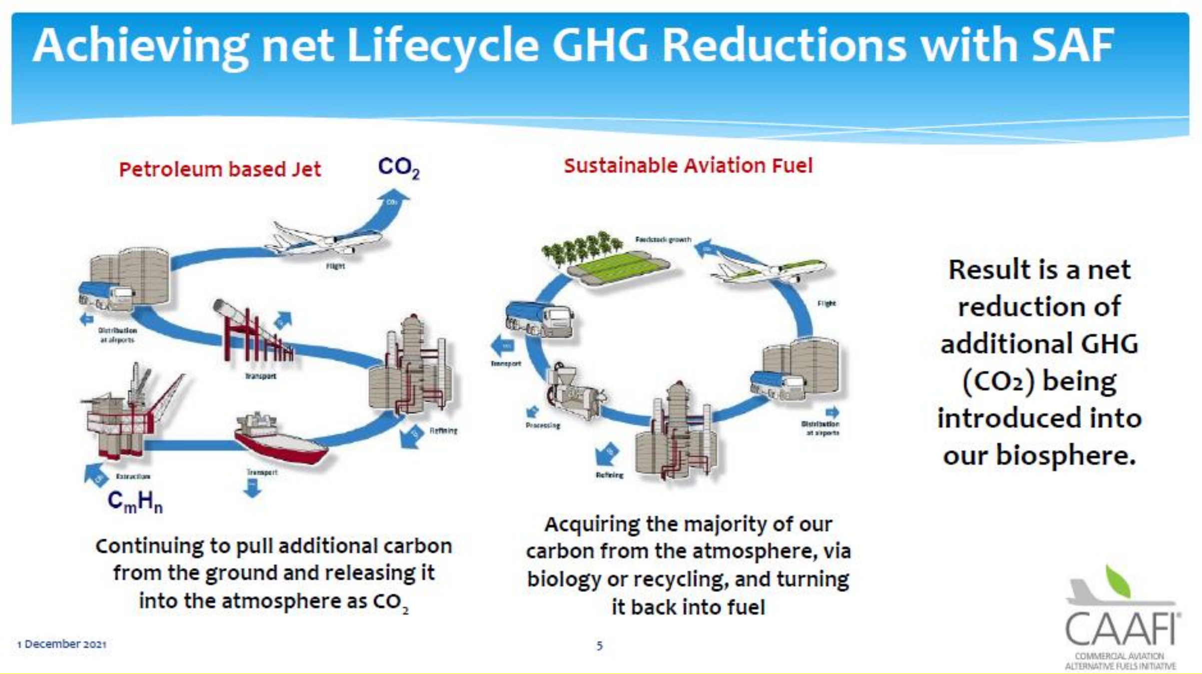
- Sean Newsum, Boeing, United States
- Steve Csonka, Commercial Aviation Alternative Fuels Initiative (CAAFI), United States
- Geoff Tauvette, Canadian Council for Sustainable Aviation Fuels (C-SAF), Canada
- Susan van Dyk, University of British Columbia (UBC), Canada

Highlights of the session:

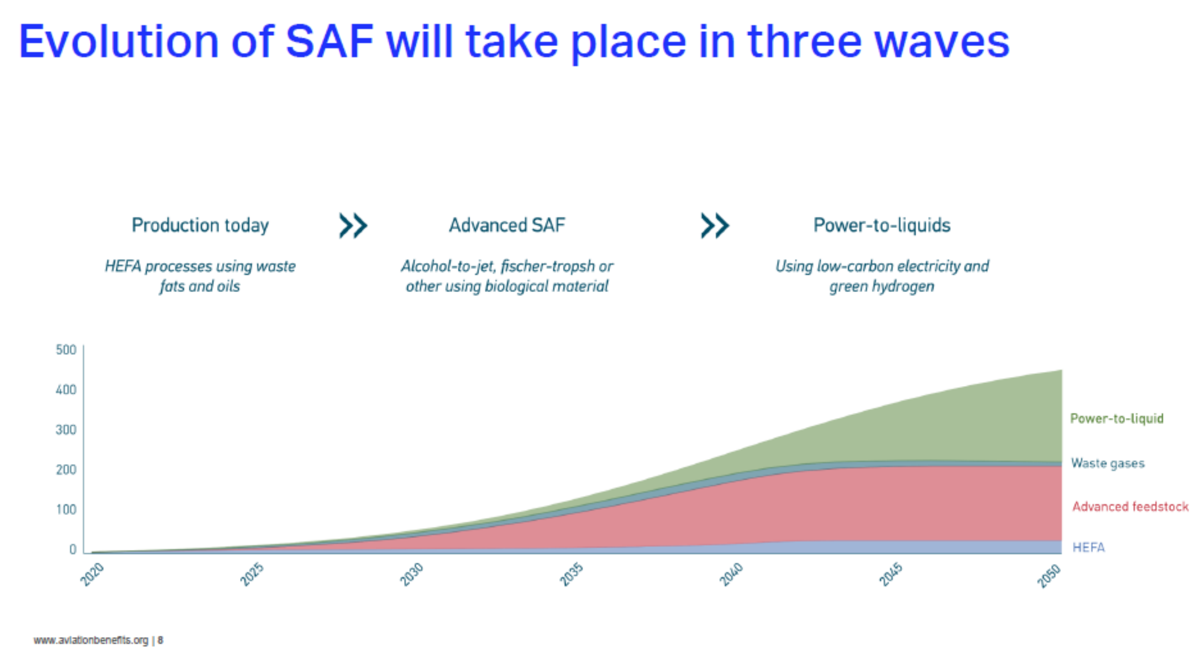
- In October 2021, the Air Transport Action Group (ATAG) announced its mission to achieve net zero carbon emissions by 2050 for global civil aviation operations (up from the earlier target to reduce GHG emissions by 50% by 2050). Next to efficiency improvements, **Sustainable Aviation Fuels (SAF) will be the immediate and primary focus to decarbonise aviation**. Medium and long-haul aviation requires hydrocarbon fuel, also in the longer term. Estimated required volumes of SAF range between 330 and 450 million tonnes per year by 2050.
- There are several SAF pathways: HEFA - produced from fats, oils, and greases - is fully commercial and will continue to be the biggest supplier of SAF for the next 10 years at least. Alcohol-to-jet and Fischer-Tropsch jetfuel could follow, as well as co-processed biocrude in refineries and fuels produced through pyrolysis/hydrothermal liquefaction technologies. In the longer term (2040+) power-to-liquid jetfuels are expected to play an increasing role, based on renewable electricity and captured CO_2.
- Most SAF are currently limited to 50% blending for technical reasons (particularly lack of aromatics). Nevertheless 100% SAF has already been demonstrated in some flights, and producers like Boeing commit that from 2030 new airplanes will be compatible with 100% SAF.
- The main challenge is achieving production at reasonable cost. SAF will always remain more expensive than fossil jetfuel, so its use **needs to be enabled by policies and sector commitments**. Policies could either provide incentives (see Californian LCFS), or impose mandates (see proposed ReFuelEU in Europe). Carbon pricing is also an important tool.

Voluntary actions, e.g., buyers' alliances, can also create demand in the short term to reduce the carbon footprint of these businesses. This can go through book and claim systems, with provisions to avoid double counting.

- A lot is moving in aviation markets and the announced intentions for SAF production would represent 3% of commercial jetfuel supply within 5 years. Commercial agreements are being pursued, fostered by policy and other unique approaches. Airline and fuel consortia are working together to build solutions for aviation fuel supply and logistics challenges, for example in Canada.



GHG difference between fossil jet fuels and SAF. From presentation Steve Csonka



Trajectory of SAF introduction. From presentation Robert Boyd, IATA @ Industry Panel

SESSION 6: STATE OF THE ART AND INNOVATION IN GREEN GAS

Thursday 2 December 2021, 7-9 am UTC

Moderator: Jerry Murphy, MaREI/University College Cork, Ireland

Speakers/panellists:

- Jan Liebetrau, Rytec, Germany
- Berend Vreugdenhil, TNO, the Netherlands
- Amy Philbrook, ATCO Group, Australia
- Ole Hvleplund, Nature Energy, Denmark

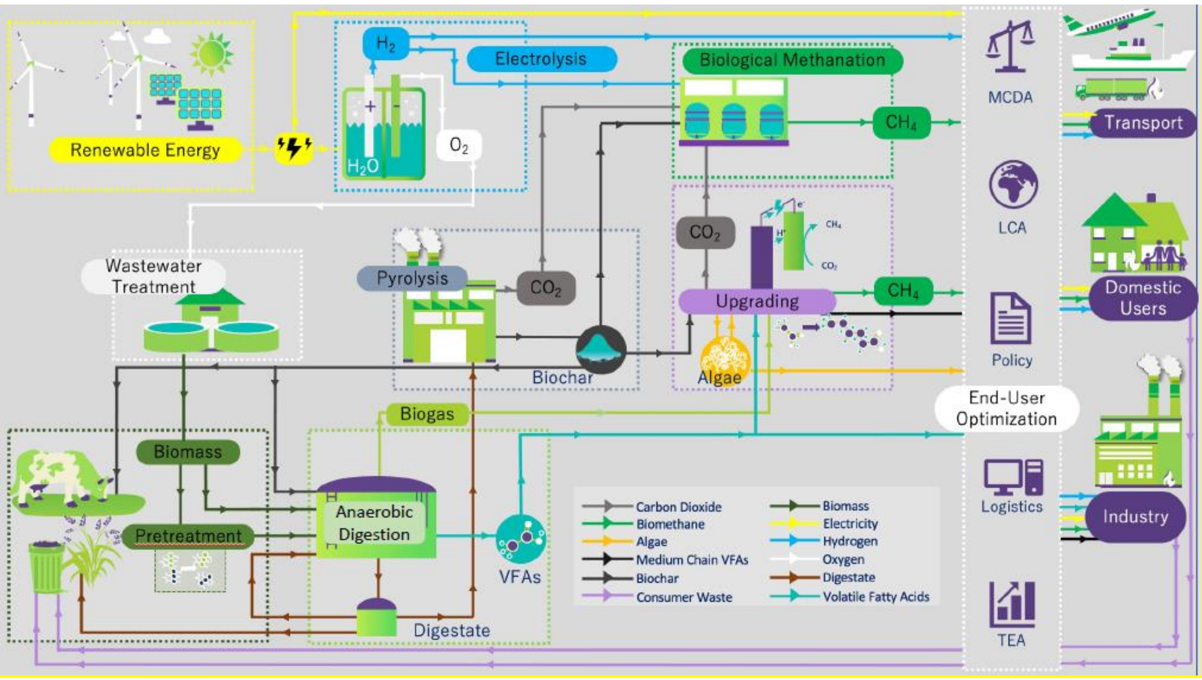
Highlights of the session:

- In the EU and US, up to twice as much energy is sourced from gas grids as electricity grids. **Fossil gas replacement requires much more attention.** Three green gas options are generally considered: (1) biomethane produced from anaerobic digestion (AD) or from gasification processes; (2) green hydrogen; (3) synthetic methane produced from hydrogen combined with CO_2.

- In the near future, the integration of energy vectors (power, heat, gas) will be essential to facilitate variable renewables such as solar or wind energy, where dispatchable renewable energy sources such as bioenergy gain importance for grid balancing and cover seasonal fluctuations (particularly for heat). Biogas plant operation itself can be controlled extensively and with this control comes high levels of flexibility (for power production or other uses). Nevertheless, **flexibility** comes with an extra cost as it results in reduced capacity utilisation and/or requires extra gas storage capacity; these **costs need to be balanced by financial benefits**.

- **Biogas is circular economy at its best**. It generally starts from organic wastes and/or farm wastes; the co-product of AD is a digestate that can go back to the field as efficient fertiliser. The biogas can be used for local heat/electricity demand, or it can be upgraded to biomethane which can be injected into the gas grid and used for different applications instead of fossil natural gas. When hydrogen is used in the upgrading process it can boost the methane production by up to 67% (from reaction of hydrogen with CO_2 from the biogas). Alternatively, the CO_2 can be separated and used for other industry applications. In Denmark, biomethane already represent 25% of the gas grid. Several large-scale biogas plants have been built, and they can be replicated in all parts of the world.

- Next to the anaerobic digestion pathways, biomethane can also be produced through gasification, followed by methane synthesis. This opens up a broader biomass resource base and could also be done in more central facilities. CO_2 from the process can be captured and sequestered, which can lead to negative emissions. Biochar co-products can also be sequestered in soils.
- **Hydrogen** currently receives a lot of attention, also in government support programmes. There are **different markets where it could be used**, for example chemical and refining industries (which already use fossil-based hydrogen), heavy industries, transport, power production, or to produce power-to-X fuels such as methane, methanol, or ammonia. At the moment it is unclear which markets will be the main driver for green hydrogen in the coming years/decades and it **will depend on the willingness to pay in these markets**. Replacing existing hydrogen uses by renewable hydrogen would be the least complex; the highest paying capacity currently seems to come from transport, although the implementation would be much more complex, requiring building hydrogen infrastructure / filling stations and investing in fuel cell vehicles.
- Australia has high prospects for producing renewable hydrogen as it has very windy and sunny areas and a lot of land available. First electrolyser plants are being supported and constructed at a scale of 10 MW. Hydrogen is mainly considered for export in the longer term but can also be used to decarbonise national gas networks. International export of hydrogen tends to shift to intermediates such as ammonia, methane or methanol.
- Overall, it was concluded that **different technologies are not competing but complementing**. There is still a large undersupply of green electricity for what it is expected to produce in future and enormous efforts will be needed in that area. **Taking care of waste products and valorising biogas and its co-products is an option that can make a difference today**.



Integration options of biogas and other renewable energies. From presentation Jerry Murphy

SESSION 7: GREEN GAS PERSPECTIVES

Thursday 2 December 2021, 2-4 pm UTC

Moderator: Uwe Fritsche, IINAS, Germany

Speakers/panellists:

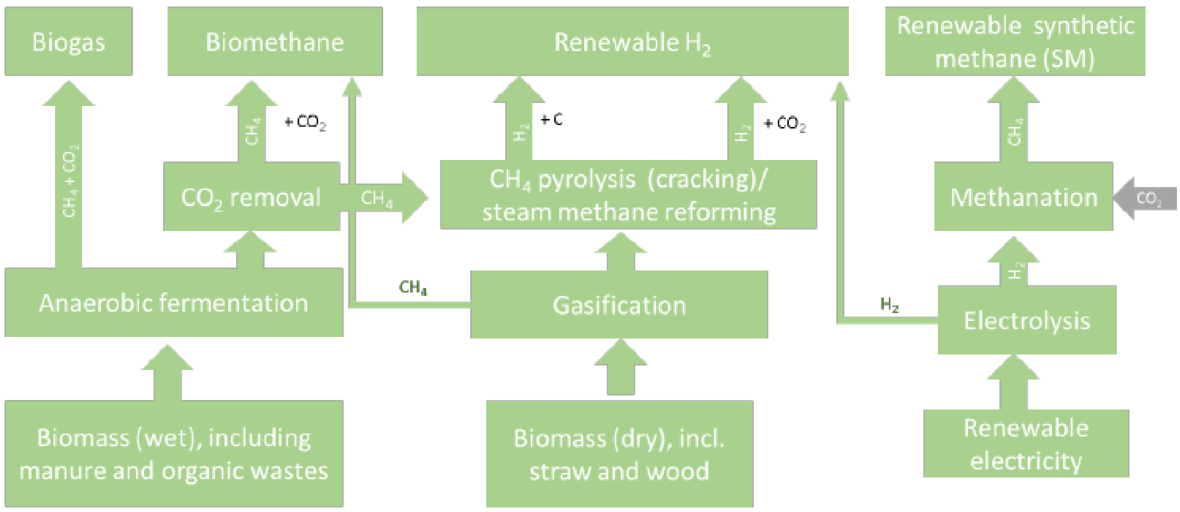
- David Chiaramonti, Polytechnic of Turin, Italy
- Michela Morese, Global Bioenergy Partnership (GBEP), Italy
- Renjie Dong, China Agricultural University (CAU), China
- Sam Lehr, RNG Coalition, United States
- Uwe Fritsche, IINAS, Germany

Highlights of the session:

- **Biomethane is fully compatible with the gas infrastructure** and is one of the major components to decarbonise the gas system.
- Biomethane (derived from manure, sludges, and organic waste) is **among the most sustainable options for transport** and can be implemented immediately in natural gas vehicles. The paying capacity in the transport sector is much higher than other applications of natural gas. In the US, Clean Fuel Standards in transport are the largest driver for upcoming biomethane/RNG demand.
- There are **multiple benefits in emerging economies** to use farm and livestock waste as well as household waste for biogas (e.g., reducing energy expenditure, less methane emissions, less indoor air pollution). The main challenge is the lack of knowledge (which may lead to poor management of anaerobic digestors) and the lack of capital (e.g., to buy generators to convert excess biogas into power and avoid flaring). This **requires capacity building and training** in rural areas, and international collaboration, for instance OECD countries to support low-income countries in this.
- The agreement at COP26 to reduce methane emissions by at least 30% by 2030 is extremely important for the biogas sector as it **can drastically avoid methane emissions from biowaste**.
- In China there are many small and medium-scale applications of biogas, mostly based on manure or household waste. **Anaerobic digestion with biogas production is one of the cheapest ways to**

treat manure or biogenic waste and should also be deployed at the medium scale. Considering the potential of animal manure and crop residues, China could replace 70% of its current natural gas consumption. Biogas can also serve as a buffer in the energy system, to support other low-carbon solutions. Biogas generation and the field application of digestates can contribute a lot to carbon neutralisation in terms of avoiding methane leaching, fossil fuel and chemical fertiliser substitution, and increased soil carbon sinks.

- Transforming the waste management sector deserves much more attention. For every biowaste there should be a reflection if biogas could first be derived as it captures the easily degradable fractions that would otherwise release CH_4 and CO_2 into the air. The harder to degrade fractions can end up in digestate, compost or biochar.
- In agricultural systems where biogas production is integrated, the carbon that is sequestered in the soil (through good management practice and feeding back the digestate and/or biochar to the soil) should also be recognised. An **effective carbon accounting logic** is needed, including for land carbon sinks.
- Promising future solutions that take decades to implement at scale may not distract us from implementing good solutions now (such as biogas) and start from low-hanging fruit. ‘Don’t let the perfect be the enemy of the good.’
- Communication is important. The difference between biogenic CO_2 (which is part of an atmospheric cycle) and fossil CO_2 (which is transferred to the atmosphere from the deep underground) is often still lost in the media and the general public. For biogas and biomethane, the time between biogenic C release to the atmosphere and reabsorption in plants is very short so that these renewable gases contribute to quick CO_2 reductions when replacing fossil fuels, or even negative C emissions when co-products (e.g., biochar from digestate) are sequestered in the soil.



Overview renewable gases. From presentation Uwe Fritsche

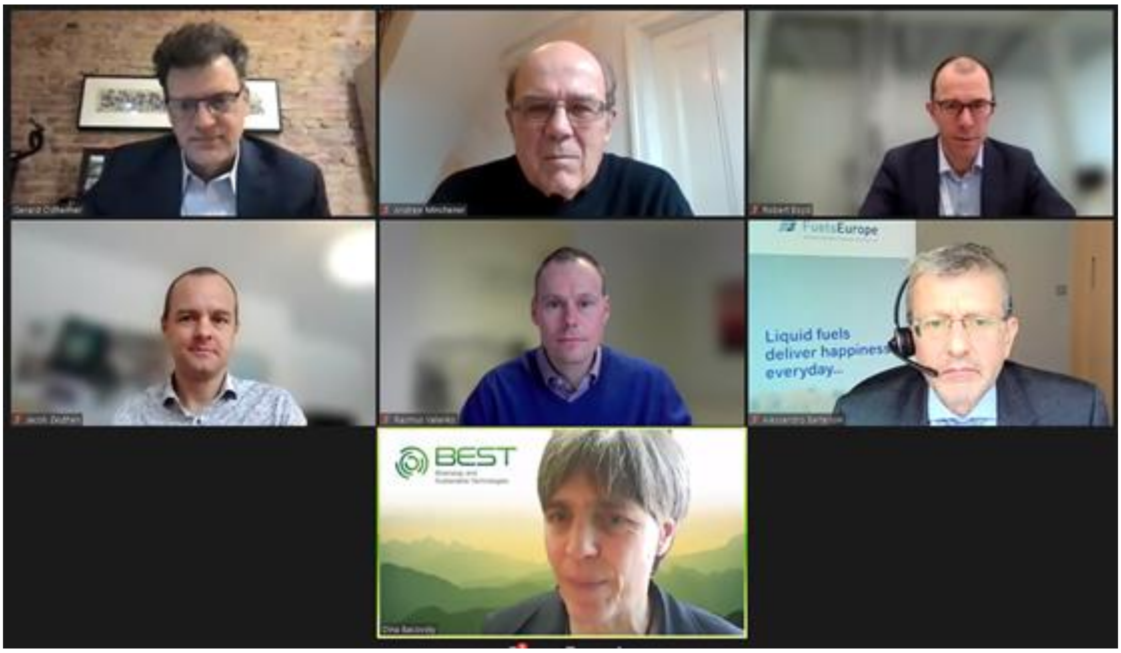
SESSION 8: INDUSTRY PANEL - LONG TERM MARKETS FOR BIOMASS AND BIOFUELS

Friday 3 December 2021, 8-10 am UTC

Moderators: Dina Bacovsky, BEST Bioenergy and Sustainable Technologies, Austria & Gerard Ostheimer, Biofuture Workshop, United States

Speakers/panellists:

- Gerard Ostheimer, Biofuture Workshop, United States
- Robert Boyd, International Air Transport Association (IATA)
- Jacob Zeuthen, Maersk, Denmark
- Rasmus Valanko, We Mean Business Coalition, Finland
- Alessandro Bartelloni, FuelsEurope, Belgium
- Andrew Minchener, International Centre for Sustainable Carbon (ICSC), United Kingdom



Highlights of the session:

- Company ambitions in terms of **decarbonisation goals are growing fast**, both in sectors which are relatively easy to transform (e.g., light industries, services), and in harder to abate sectors (e.g., aviation or heavy industries).
- It requires a lot of efforts to educate stakeholders/sectors and make them join in decarbonising, but once you´ve reached the tipping point it starts rolling. The We Mean Business Coalition currently counts over 3100 company commitments to net zero. The focus is currently moving from country roadmaps to how companies can handle the transition in practice.
- In times of transition companies need to invest heavily, which makes them vulnerable. During this transition it is **important to have a stable policy framework**, also protecting transitioning companies from carbon leakage, i.e., when businesses transfer production to other countries with laxer emission constraints.

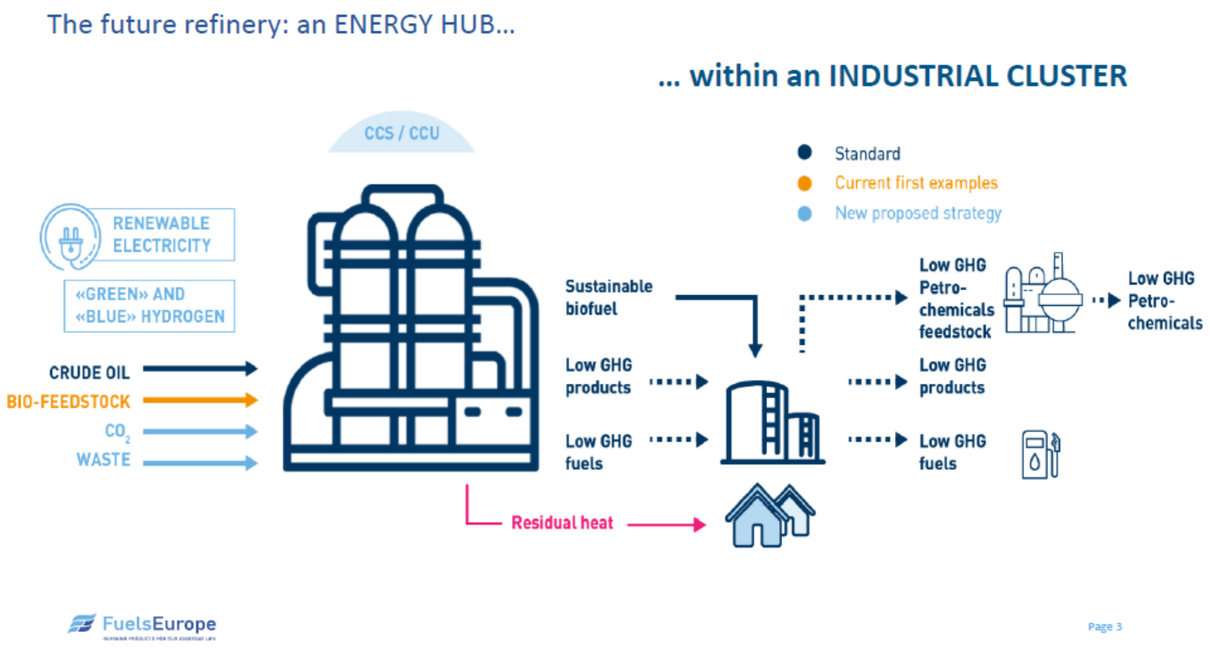
- It will be really hard to decarbonise the economy in practice and there is growing recognition that we need to look beyond 'simple' solutions like sun and wind, which can't solve everything. Bioenergy/biofuels can play an important role in the near term being largely compatible with current infrastructures. Nevertheless, it is commonly recognised that the **role of biomass will evolve in the coming decade**s, e.g., towards sectors that are difficult to electrify. We will also get better in producing and mobilising sustainable biomass feedstocks, so opportunities should not be downplayed.

- The aviation industry recently committed to achieve net zero carbon emissions by 2050. **Sustainable Aviation Fuels (SAF) will be the cornerstone of decarbonisation of the aviation sector**, estimated to provide 65% of the required emission reduction in the sector by 2050. The evolution of SAF is expected to take place in three waves: (1) from waste fats and oils today; to (2) advanced SAF based on other biological materials in the medium term, to (3) power-to-liquids by mid-century (once there is excess renewable power).

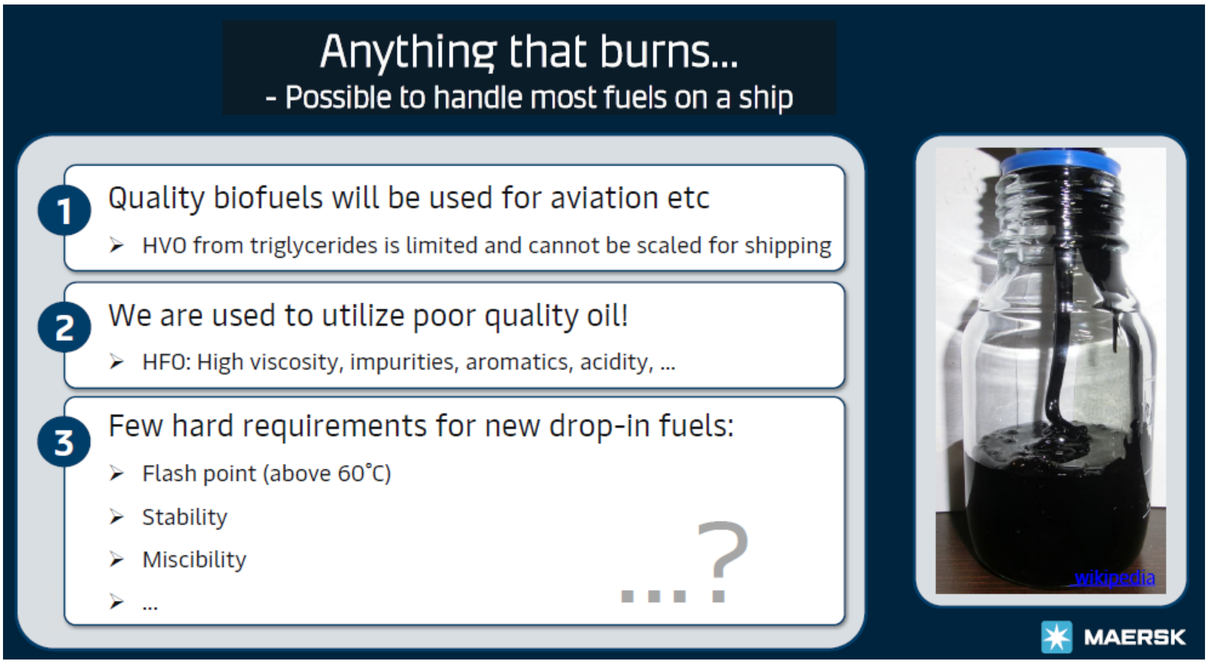
- Several players in the maritime shipping area are taking steps towards decarbonisation. The lifetime of ships is typically 20+ years so it is important to **consider the legacy fleet**. The current maritime fleet largely runs on heavy fuel oil – drop-in biofuels can play an important role there, and don't have to be high quality. Different new fuel options are explored in the sector, for example methanol, which requires investing in new ships. Moving to e-fuels is an option in the longer term, although this would require high availability of renewable hydrogen (*replacing the current fuel consumption of the Maersk fleet by e-fuels would require more than 6 times the current power consumption in Denmark*), as well as captured CO_2.

- The European refining sector also recognises the need to transform in the next decades and move away from fossil fuels. Overall fuel consumption in transport will progressively go down, particularly from 2030, and for the remaining fuels low-carbon liquid fuels (LCLF) will progressively replace fossil fuels. An important share of the LCLFs will come from biomass - recent analysis at European level has shown that there is sufficient sustainable biomass potential to cover that (taking into account competing uses). **Future refineries will be energy hubs where biomass, CO_2, waste, renewable electricity and hydrogen are transformed to low carbon products, chemicals and fuels**.

- Asia is a key player in the global energy debate, and still a lot of coal and gas facilities are being constructed. Co-firing of biomass can be considered as a medium-term measure to reduce GHG emissions in the energy sector, and CCS also has high potential once it takes off. In several Asian countries there are large issues with agricultural residues, particularly the practice to burn them in the field, creating significant health issues. **Using agricultural residues for energy production creates opportunities to diminish coal use, reduce air pollution and provide socio-economic opportunities in rural areas**.



Future refineries. From presentation Alessandro Bartelloni



Drop-in biofuels are important options for the marine sector, and they don't have to be high quality. From presentation Jacob Zeuthen

SESSION 9: WASTE AND RESIDUE VALORISATION IN A CIRCULAR ECONOMY

Monday 6 December 2021, 2-4 pm UTC

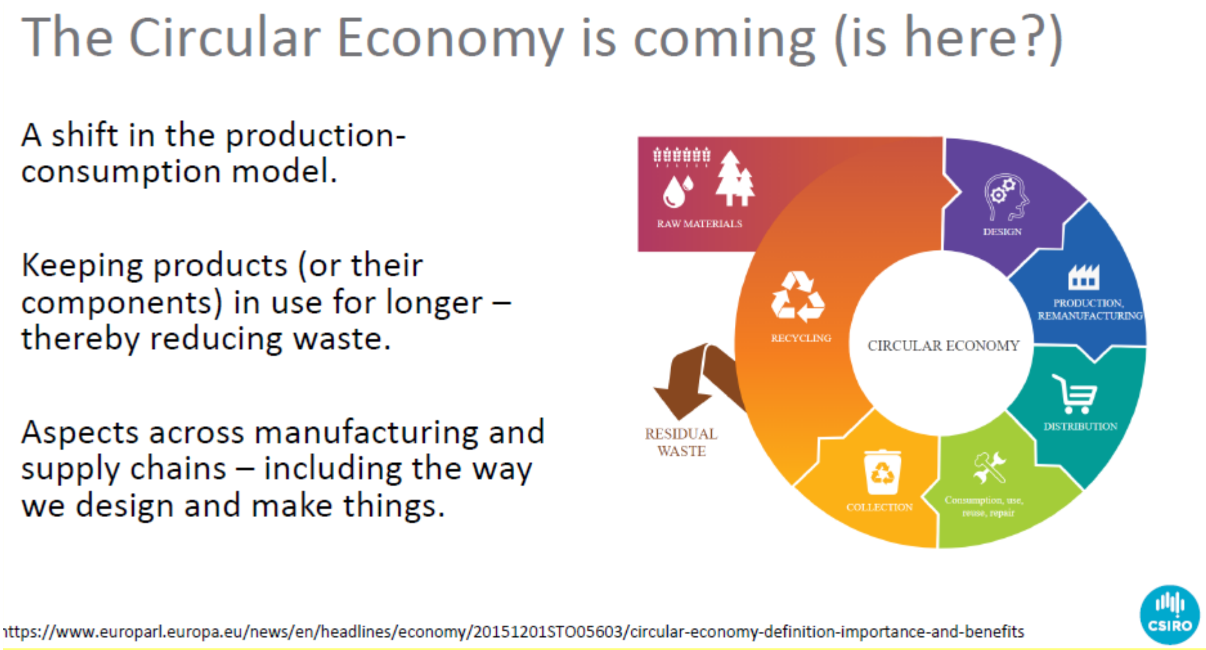
Moderator: Inge Johansson, RISE Research Institutes of Sweden

Speakers/panellists:

- Daniel Roberts, CSIRO, Australia
- Michel Chornet, Enerkem, Canada
- Jitka Hrbek, University of Natural Resources and Life Sciences Vienna, Austria
- Mar Edo, RISE Research Institutes of Sweden

Highlights of the session:

- In the trend to move from a linear towards a more circular economy, **processing of unrecyclable waste fractions is no longer only about producing power and/or heat**. There are real gains in emerging pathways, such as chemical recycling via gasification.
- **Chemical recycling of waste** can lead to low carbon intensity transport fuels or circular chemicals. Enerkem has developed their technology (gasification of waste, followed by methanol or ethanol production) in the past 20 years and is now in commercial roll-out.
- Several other waste gasification projects are in operation / in development worldwide, most still focused on power/heat production; however more complex product-oriented projects are emerging, e.g., to produce methane, transport fuels or chemicals. The **combination with carbon capture and storage is also gaining attention**.
- Companies are under immense pressure to decarbonise in the coming decades. They realise there is no silver bullet and they look for scalable solutions. Waste-derived fuels and chemicals can be a relevant component in their strategies.
- When installing waste-to-energy plants, as well as emerging technologies to process waste, **social acceptance** is key. Waste processing plants can be integrated in urban areas, conditional to openness, communication, and involvement of local communities. The Copenhill WtE plant in Copenhagen (which also feeds into the local district heating grid and integrates recreational functions) is a good showcase.



Circular economy principles. From presentation Daniel Roberts

Enerkem's path to commercialisation for biofuels / circular chemicals from waste through syngas. From presentation Michel Chornet

SESSION 10: INDUSTRIAL SYMBIOSIS AND BIOREFINERIES IN A CIRCULAR ECONOMY

Monday 6 December 2021, 8-10 pm UTC

Moderators: Michael Mandl, tbw research, Austria & Johanna Mossberg, RISE Research Institutes of Sweden

Speakers/panellists:

- Mats Eklund, Linköping University, Sweden
- Bert Annevelink, Wageningen Food & Biobased Research, the Netherlands
- Franziska Hesser, WoodKplus, Austria
- Marzouk Benali, Natural Resources Canada & Paul Stuart, Polytechnique Montreal, Canada

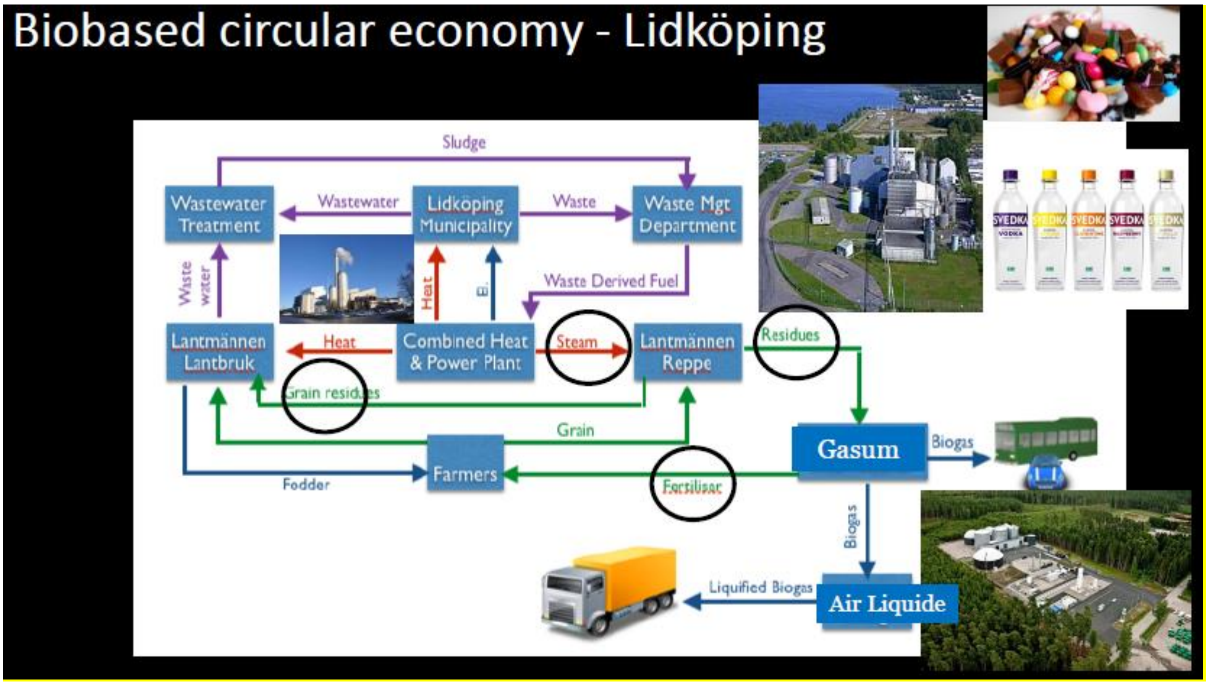
Highlights of the session:

- Green innovation through **industrial symbiosis** is sometimes called 'the science of the leftovers'. Connecting different sectors, with exchange of residual material and energy flows **increases the value of underutilised resources, improves the business case for the different parties, leads to increased resource efficiency and reduces climate impacts.** Biogas is a good example of an inherently symbiotic system, connecting different sectors as it draws on waste and residues, produces a renewable energy source for industry processes or for transport, and co-produces a biofertiliser that can go back to the field.

- Drawing on a masterplan for industrial symbiosis is difficult; **partners need to find each other** (bottom-up) to expand their interactions – this may also involve new intermediary companies to manage some of the interactions between different actors. While the initiative develops bottom-up, it is **important for municipalities to enable it to happen** and create an arena / symbiose centre where different actors can come together.

- **Biorefineries are in the centre of the circular bioeconomy** as they produce a range of bio-products (including energy carriers) in an integrated way. This integration also improves economics and resource efficiency. IEA Bioenergy Task 42 initiated a global Biorefinery Atlas Portal where information on biorefineries from all over the globe is brought together. Available at: https://task42.ieabioenergy.com/databases/

- Innovation and its market roll-out does not purely depend on technical performance. Considering the **market environment** (environmental, political, legislative, economic, social, networking, and institutional factors) is crucial – market knowledge should be developed during R&D activities. Having knowledge on specific barriers and incentives is seen as a key asset towards a successful market diffusion. This involves the analysis of the importance and current performance of factors influencing a broader commercialisation.
- The competitive advantages of oil refineries are huge, building on decades of experience and optimisation, but **environmental impacts are generally not internalised in the production cost**. Policies are needed to transform the market environment for biorefineries to be commercially successful, e.g., through CO_2 taxation or the Polluter-pays-principle. It is also important to support sustainable feedstock supply.
- Canada contains the most biomass per capita in the world. It is the second-largest exporter of forest products in the world and has mature and efficient wood fibre collection systems. Identifying successful bioeconomy strategies remains complex due to uncertainties. **Building on lessons learned and established business models** in other regions, as well as flexible decision support tools enable the assessment of scale-up risks and opportunities for biorefineries.
- Production systems are not static but they keep evolving. **Biofuel production plants are constantly improving their environmental footprint**, and they are more and more evolving to biorefineries producing different products next to biofuel. This also improves their business model. Similar evolutions can be seen in pulp and paper plants, where co-products are gaining importance.



Industrial symbiosis park in Lidköping, Sweden. From presentation Mats Eklund

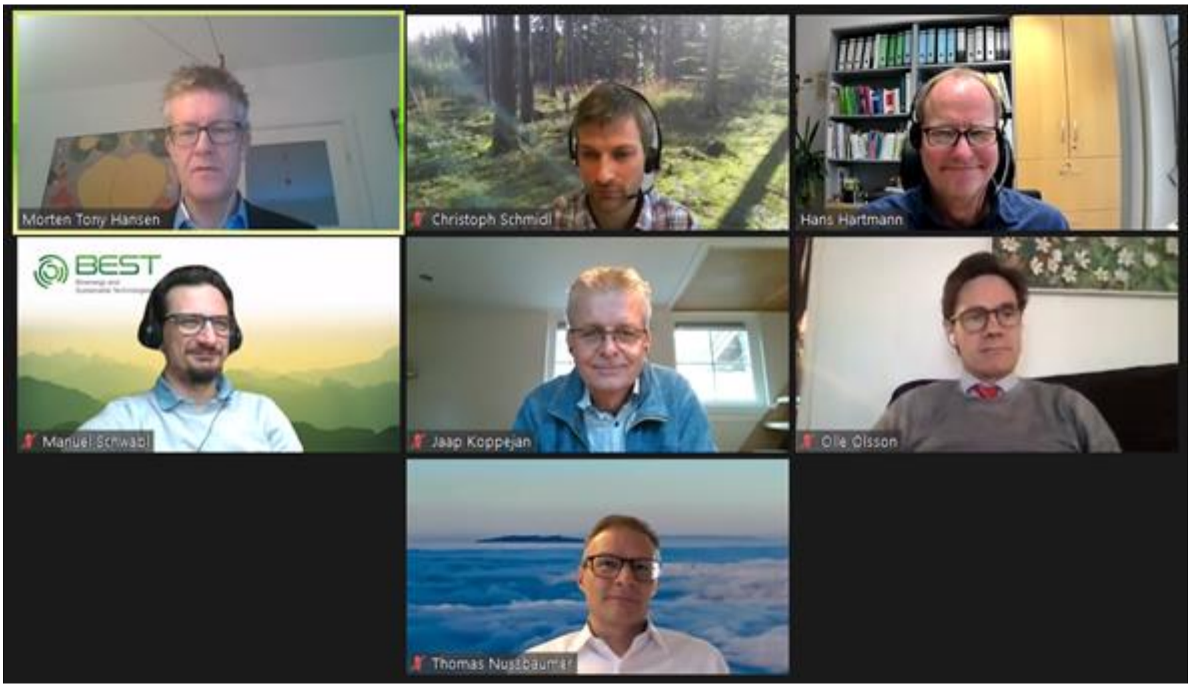
SESSION 11: BIOMASS AND RENEWABLE HEAT

Tuesday 7 December 2021, 7-9 am UTC

Moderators: Morten Tony Hansen, Ea Energy Analysis, Denmark & Christoph Schmidl, BEST Bioenergy and Sustainable Technologies, Austria

Speakers/panellists:

- Jaap Koppejan, Pro Biomass BV, the Netherlands
- Thomas Nussbaumer, Verenum / Lucerne University of Applied Sciences and Arts, Switzerland
- Olle Olsson, Stockholm Environment Institute (SEI), Sweden
- Manuel Schwabl, BEST – Bioenergy and Sustainable Technologies, Austria
- Hans Hartmann, Technologie- und Förderzentrum (TFZ), Germany



Highlights of the session:

Biomass based high temperature heat for industry:

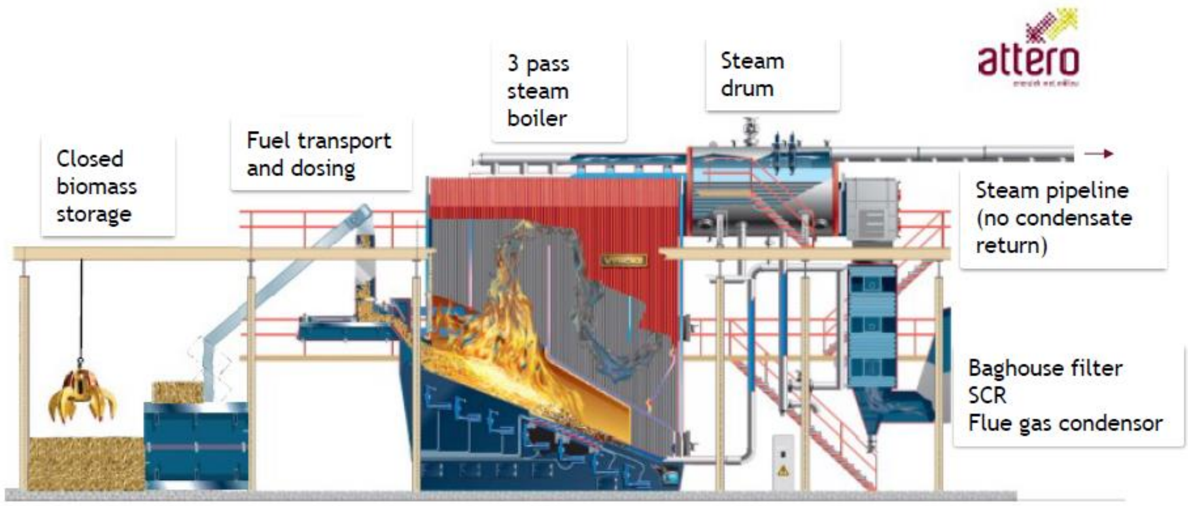
- Industry is responsible for 30% of global greenhouse gas emissions, of which most are related to industrial heat production. Industrial heat is very diverse, with many different applications that vary in temperature, direct/indirect heat, or control & flexibility, so solutions are difficult to generalise. **Decarbonisation options for industries are CCS, electrification, hydrogen and biomass**, each with their pros and cons depending on the application. An extra advantage of biomass is that it can enable negative emissions when combined with CCS.
- Bioenergy in industry has mainly been concentrated in agro/forestry processing industries based on their own process residues. Other industries are now also considering biomass to replace their fossil fuel consumption. The potential is not limited to energy intensive industries (steel, cement etc), **process industries** also represent a large potential. These are usually much smaller,

and the annual amount of fuel needed to cover an industrial heat demand can in many cases be sourced locally.

- The design of the bioenergy plant is very site specific. The choice of solution depends on existing technology, biomass availability, and logistic options. The bioenergy plant should be designed according to accurate fuel specifications, often based on local availability of low-grade biomass resources. These are challenging fuels in comparison to clean wood chips or pellets. There is a **need to further develop technologies for ash-rich biomass fuels** for high-temperature heat in the size range up to 5 MW.

Low emission residential scale biomass combustion:

- Wood combustion in private households is an important source of PM emissions. IEA Bioenergy Task 32 is analysing approaches concerning **emission reduction strategies in the field of residential wood combustion** in its member countries. Some examples: replacement strategies and expiration dates for old wood stoves/boilers; regional (potentially temporary) bans for the use of wood stoves and boilers; tightening of emission limits for biomass combustion; regular on-site inspections for wood combustion appliances; support for the installation of particle precipitation devices or catalysts to limit emissions; specific information campaigns on clean use of wood fuels.
- The way wood stoves are operated can have a major influence, with improper operation leading to much higher emissions. It is important to raise awareness and change behaviour where needed. An Austrian project rolled out a campaign to **demonstrate good operating practices** to users, e.g., how to ignite a wood stove. Pellet stoves are more automated so the user behaviour has less impact.



Converting public green waste to steam for potato processing industries. From presentation Jaap Koppejan

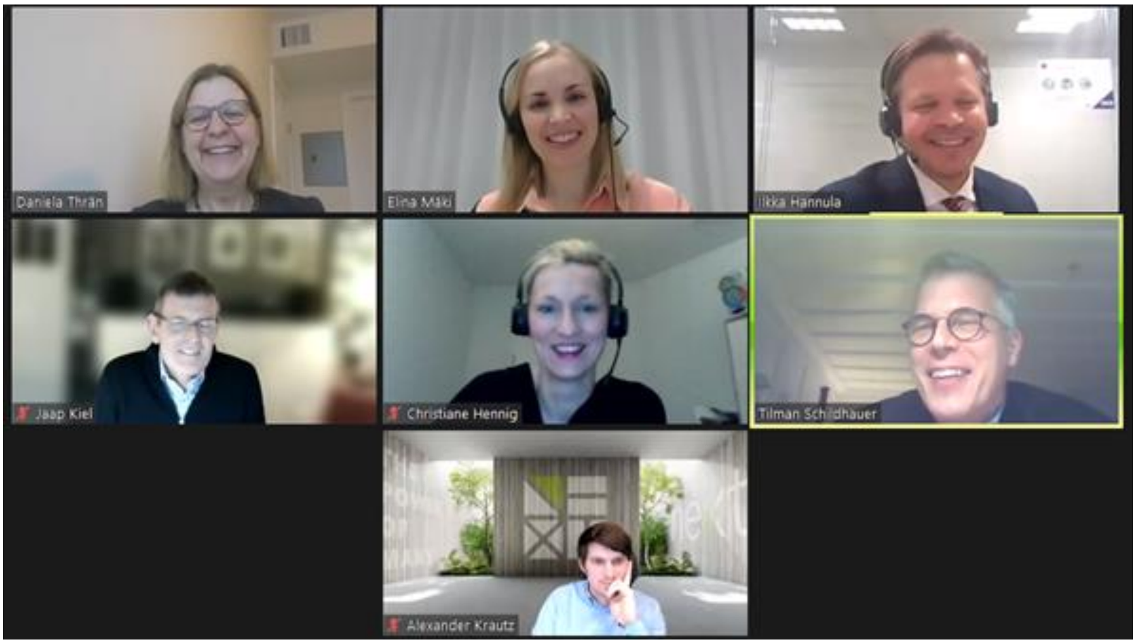
SESSION 12: BIOENERGY'S CONTRIBUTION TO LOW-CARBON ENERGY SYSTEMS

Tuesday 7 December 2021, 2-4 pm UTC

Moderators: Elina Mäki, VTT, Finland & Jaap Kiel, TNO, The Netherlands

Speakers/panellists:

- Ilkka Hannula, International Energy Agency (IEA)
- Tilman Schildhauer, Paul Scherrer Institut, Switzerland
- Alexander Krautz, Next Kraftwerke, Germany
- Christiane Hennig, German Biomass Research Centre (DBFZ), Germany
- Daniela Thrän, DBFZ & UFZ, Germany

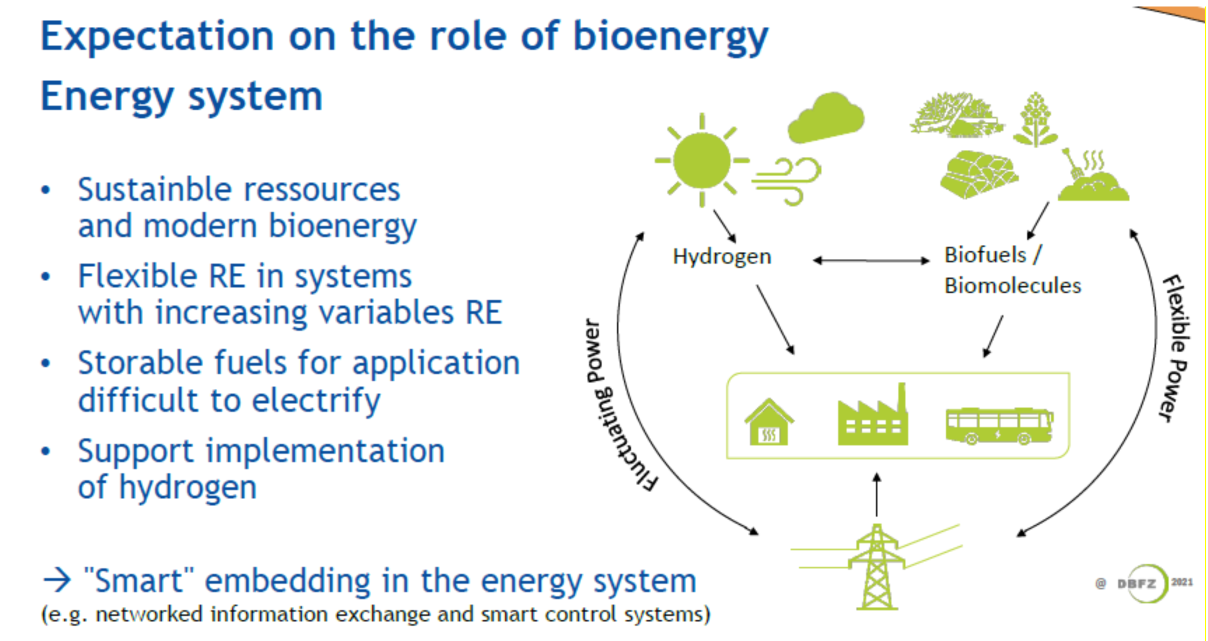


Highlights of the session:

- Reaching net-zero emissions globally by 2050 **requires an unprecedented transformation in how energy is produced, transported, and used**. In the IEA Net Zero by 2050 roadmap, modern bioenergy use rises to 100 EJ in 2050, meeting almost 20% of total energy supply. In an energy mix dominated by wind and solar, sustainable bioenergy plays a major role in flexible energy generation, industry and transport, and is increasingly used in connection with carbon capture, utilisation and storage (CCUS).
- Bioenergy can provide long-term **flexibility services** to the energy system (seasonal heat demand, or upgrading to storable renewable fuels), as well as short term flexibility services (balancing) to an **electricity system with increasing shares of variable renewables** like solar or wind energy. Flexible peak electricity production, CO_2 mitigation and negative balancing power are important building blocks for a future energy system that bioenergy can deliver. There is a **need to value** these services.
- 'Virtual Power Plants' (VPPs) are an aggregation of decentralised assets, which are monitored and controlled to provide dispatch and ancillary services to stabilise the power grid. Demand for

flexibility at the wholesale and ancillary service markets will increase with increasing shares of PV and wind, which lead to higher electricity price differences. A **VPP pool reduces the balancing costs**. Biomass and biogas plants represent an important share of the VPP pool in Germany. For flexible bioenergy plants it is also important to consider the interaction with heat production (in CHPs).

- Bio-CCUS and flexibility are expected to be two of the more important characteristics for bioenergy systems of the future, and there will be interactions (synergies/trade-offs) between these two services. A key aspect of integration of Bio-CCUS in already operating systems is how the **addition of CCUS interacts with existing operation**, in terms of technology, business models and value chain configurations. The type of operation will be guided by electricity market prices or other incentive schemes for providing flexibility services and by the potential revenue generated from CO_2 removal.
- There are important potential **interactions and synergies between bioenergy and green hydrogen** deployment. Bioenergy can provide biogenic CO_2 that can be combined with green hydrogen to produce e-fuels. In that sense, hydrogen can also boost the output of renewable fuels in gasification systems or biogas upgrading systems through its reaction with the CO_2 in these processes.
- It is important to **monitor and showcase good practices** of flexible bioenergy systems, which can lead to further deployment. Policy and market conditions should sufficiently reward the flexibility services provided to the energy system.



Biomass in the future energy system. From presentation Daniela Thrän

CLOSING PANEL 1: HOW CAN BIOMASS/BIOENERGY AID THE TRANSITION TOWARDS CARBON NEUTRALITY (FOCUS EAST ASIA/OCEANIA & NORTH AMERICA)

Thursday 9 December 2021, 12-2 am UTC

Moderator: Paul Bennett, Scion, New Zealand

Speakers/panellists:

- Luc Pelkmans, IEA Bioenergy TCP
- Dongmin Ren, ERI - Renewable Energy Center, China
- Paul Bennett, Scion, New Zealand
- Shahana McKenzie, Bioenergy Australia
- Oshada Mendis, Natural Resources Canada
- Jim Spaeth, U.S. Department of Energy, United States

Highlights of the session:

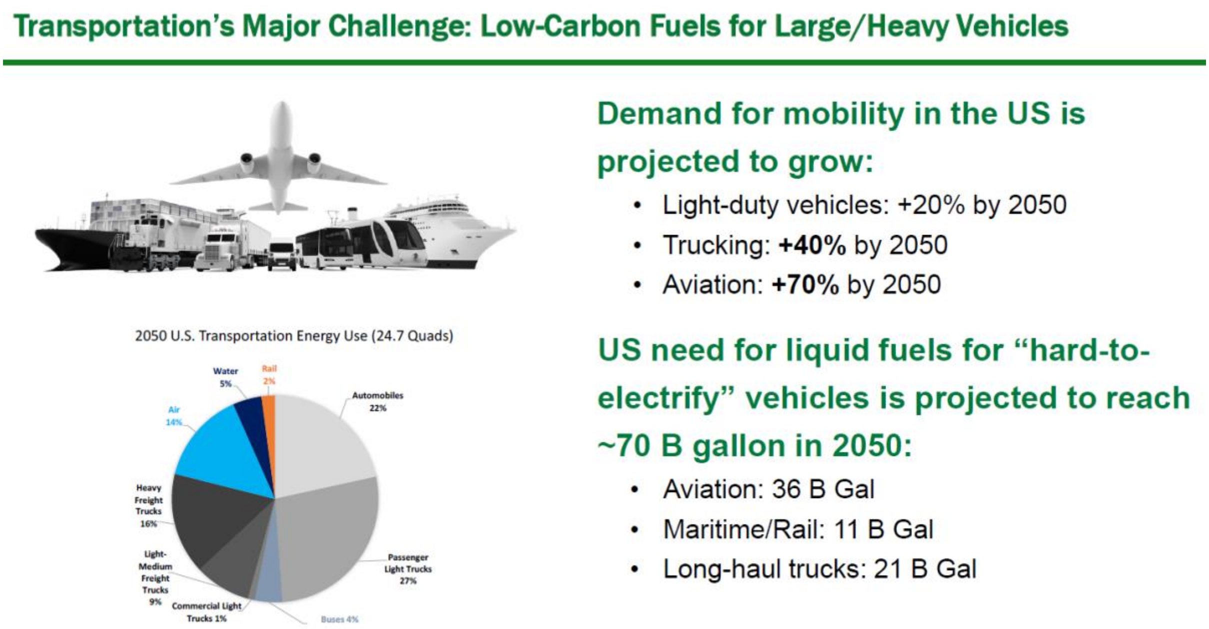
- The establishment of carbon neutrality goals in **China** provides a new basis and impetus for the development of the biomass energy industry. Giving full play to its advantages, realising diversified development, and paying attention to rural energy will be a new choice for China's biomass energy industry in the future.
- **New Zealand** is somewhat behind other countries in terms of bioenergy deployment, but things are changing and moving quickly with several government initiatives to accelerate the implementation of bioenergy and industries now also taking concrete steps. Carbon pricing is a key instrument.
- The Government of **Australia** released a National Bioenergy Roadmap in November 2021 which forms the basis for future bioenergy deployment. The focus will be on hard-to-abate sectors, such as industrial heat, aviation, and renewable gas. Opportunities for bioenergy/biofuels to complement other low emission alternatives in road transport and electricity markets will also be enabled.
- Canada has important biomass supply opportunities. Acceleration of bioenergy development is needed to meet **Canada**’s climate goals. Overcoming its challenges requires a combination of

market-pull policies (clean fuel regulations, carbon pollution pricing) and technology-push funding (fiscal incentives and investment support).

- The **United States** Department of Energy wants to accelerate RDD&D (Research, Development, Demonstration & Deployment) of innovative technologies to transition America to a 100% clean energy economy no later than 2050. Bioenergy can support decarbonisation in multiple sectors of the economy, particularly in transport, industry, and agriculture. Sustainable Aviation Fuels are currently the number one priority in DOE's programme on bioenergy.

General conclusions:

- Different **decarbonisation options should work in synergy and complement each other** as the challenge to reach net zero is huge. Placing different options against each other is unhelpful.
- There is general agreement (also in roadmaps) that **bioenergy is critical, but acceleration is needed**.
- **Sustainable feedstock mobilisation is key for the bioeconomy** and provides many opportunities, particularly in rural areas. There are many misunderstandings on biomass potential and its sustainability. Direct dialogues are needed based on facts.
- Bioenergy is a broad term. It is best to **focus on markets and the solutions** that are provided: cleaner fuels, sustainable aviation fuels, renewable gas, …
- The most important policy measures to support biomass applications are (1) carbon pricing; (2) obligations in specific markets; and (3) support for RD&D to lower costs.



Need for low CI fuels in hard to electrify transport sectors in the US. From presentation Jim Spaeth

CLOSING PANEL 2: HOW CAN BIOMASS/BIOENERGY AID THE TRANSITION TOWARDS CARBON NEUTRALITY (FOCUS EUROPE, AFRICA, SOUTH-AMERICA & INDIA)

Thursday 9 December 2021, 12-2 pm UTC

Moderator: Kees Kwant, NL Enterprise Agency (RVO), the Netherlands

Speakers/panellists:

- Luc Pelkmans, IEA Bioenergy TCP
- Renato Godinho, Ministry of Foreign Affairs, Brazil
- Barry Bredenkamp, SANEDI, South Africa
- Sangita Kasture, Ministry of Science & Technology, India
- Birger Kerckow, FNR, Germany
- Jonas Lindmark, Swedish Energy agency, Sweden
- Francisco José Dominguez Pérez, IDAE, Spain

Highlights of the session:

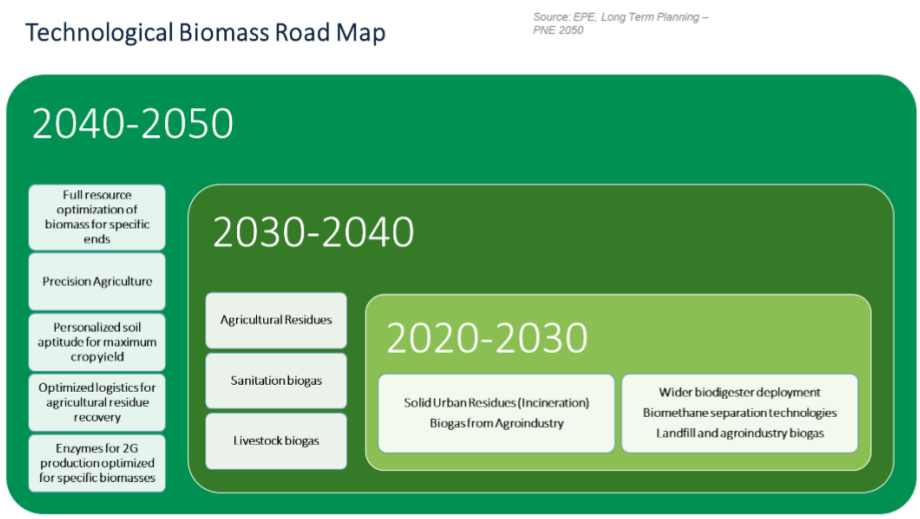
- Bioenergy forms a substantial part of the energy matrix in **Brazil**, with public policies playing an important role. It is anticipated that biomass supply can increase 2.5 times compared to current levels without land expansion, predominantly through better yields and the use of residues. There is a new generation of smart policies, such as RenovaBio (based on carbon footprint reductions) and the Future Fuel Program for the transport sector.
- Bioenergy is currently not embraced to a great extent yet in **South Africa**. The immediate priority is access to reliable grid electricity. Biomass opportunities need to be further developed within the current context in South Africa, with waste and residues considered as best options. Integration with other solutions such as variable renewables and green hydrogen will be key.
- There are many opportunities for biomass in **India**. The main focus so far is on transport biofuels, with specific targets for ethanol blending, biodiesel blending and compressed biogas (CBG), and research programmes for advanced biofuels. Greater investments are needed in innovation and capacity building, also through international cooperation.
- **Germany** recently strengthened its climate and energy targets. A huge contribution is expected from fluctuating energy sources (PV, wind), while bioenergy receives less attention driven by public perception related to food vs fuel and forest biomass. The strengths of bioenergy in flexible energy systems (electricity, gas, fuels) need to be further emphasised and exploited and

public acceptance needs to be increased by fact-based information and sustainable biomass strategies for all uses.

- Biomass is already important in the **Swedish** energy system. The implementation of the CO_2 tax in 1991 changed the heat and power sector, as well as industries, shifting to biomass instead of fossil fuels for their energy requirements. There is also a strong uptake of biofuels in the transport sector, based on GHG reduction targets. The main bioenergy development opportunities are in advanced biofuels, bio-CCS and bio-CCU, and changing business models for CHP plants to fit into the developing energy system. Long term sustainable management of forests and their contribution to the bioeconomy and climate targets is in the centre of the debate.
- Bioenergy policies in **Spain** have a special focus on thermal uses in industries, advanced biofuels (including SAF) and renewable gases. There are important synergies between forest management and bioenergy production for forest fire prevention. Biomass value chains can revitalise rural areas; biogas has a relevant role, particularly in agriculture and waste management.

General conclusions:

- There is a general understanding that **no single technology will solve all problems** and that there is a place for biomass also in a system with electrification and hydrogen. Integration of bioenergy in new energy systems is a key topic, with flexibility as an important asset.
- Sustainability of biomass value chains is another key topic. To de-risk investments there needs to be a **clear understanding of what sustainable biomass means** and how much biomass can be mobilised within sustainability constraints.
- Biomethane is gaining attention to decarbonise gas grids, but also as transport fuel, particularly in heavy duty applications.
- **Reliable and coherent political framework conditions** are of key importance to motivate investments and to scale up new technologies.
- The most important policy measures to support biomass applications are carbon pricing, support for RD&D to lower costs and obligations in specific markets.



Long term planning biomass developments in Brazil. From presentation Renato Godinho

ACKNOWLEDGEMENTS

We want to express a big thanks to everybody who contributed to the success of the conference:

- the organising committee of the conference, consisting of Luc Pelkmans (coordination), Pearse Buckley, Paul Bennett, Jim Spaeth, Kees Kwant, Mark Brown, Shahana McKenzie, Annette Cowie, Uwe Fritsche, Renato Godinho, Birger Kerckow and Dina Bacovsky,
- the ETA Florence team - Marco Luschi, Ernesto Lucarelli and Lapo Braconi - for their excellent support in the preparations, the practical organisation of the online platform and the smooth running of the sessions,
- IEA Bioenergy Task leaders and representatives to set up the agenda for the individual sessions,
- all moderators, speakers, and panellists,
- and the audience for participating and providing input to the Q&A.