Nordic SAF – leadership?

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Opening Session

Welcome
by Svend Søyland NER, Nordic Energy Research

- Guiding Question: Are we leaders or followers?
- The pledge to the Paris agreement is taken very seriously; several meetings to progress on the SAF issue have been carried out over the past few years.
- Nordic advantages within SAF production and implementation include access to suitable biomass and good examples of predictable and minded governments and industries.

The Nordic SAF outlook
by Martin Porsgaard, NISA

- Special Emphasis is put on the importance of discussions and dialogue to progress on the Nordic SAF development.
- Progress has been made, but we still have a big challenge ahead of us, - let's use the day to strengthen Nordic cooperation and coordination

Introduction
by Hariklia Gavala, DTU Chemical Engineering

- SAF is not officially defined.
- Certifications concern overall pathways that production is based on. The FT-Process was the first to be certified, resembling synthesized kerosene.

- The overall importance of blending ratios is stressed, depending on the pathway of production; FT and HEFA allow for high blending ratios of up to 50%.
- A FT Process based on algal or lignocellulosic biomass, fast pyrolysis and liquefaction is not currently approved, but in the pipeline for ASTM approval.
- The Lanzatech Process is based on off-gas of the steel industry, combining biochemical transformation with chemical catalytic transformation; it has been recently certified in 2018.
- Process technologies are available, but SAF production remains limited, as the cost of SAF is currently significantly higher than the average price for fossil-based AF; HEFA are most cost-efficient.

Aviation and climate challenges Denmark
by Per Henriksen, Danish Aviation

- Compared to Sweden and Norway, Denmark has not implemented any fuel or climate taxes. A passenger tax was abandoned a few years ago.
- Concerning the relevant political climate, the Danish government addresses the importance of aviation with regards to growth, connectivity and the Danish economy. An increasing awareness and debate on climate change upon stakeholders and the general public can be observed, increasing the pressure for action.
- Nevertheless, aviation is not mentioned within most recent governmental climate strategies. The political opinion includes that the aviation challenge should be handled by international means.
- It is time for the industry to be active instead of defensive → more proactive strategies are needed.
- SAF are perceived as a key factor in solving this challenge short- and medium-term. For long-term solutions other options are relevant.
- The importance of fact-based discussion with industries is stressed; such have shown to be difficult due to the amounts of emotions involved.
- Suggested steps for further actions concern mainly the establishment of vital partnerships, along with the increase of funds for relevant research and development.
- A basic way to address the climate issue is presented by incentivising; introducing taxes viewed as counterproductive. Everybody has to take responsibility and work together.

Icelandic Views regarding SAF possibilities
by Jon Bernodusson, Islandic Transport Authority

- The Icelandic government issued its most recent climate strategy for 2018-2030.

- Biomass-to-Liquid processing using FT Processes or pyrolysis for the ultimate production of methanol. Long-term, future is neither seen in the production of methanol nor in the use of biomass residues. Jetfuel from methanol has only 40% of energy density of regular jetfuel.
- Icelandic aviation is increasing due to increased tourism. Aviation fuel consumption increased alongside to approximately 300,000 t/a.
- A recent project within their maritime sector included the transition of 160,000 tons fuel for a fishing fleet to rapeseed oil. The required cultivation of substrate would consume an area of 40x40 km. The fishing company produces the necessary energy requirements in-house.
- For aviation fuel production based on rapeseed oil, a 45x45 km land use for substrate cultivation is predicted. Currently, the rapeseed oil produced, has the same energy density as jet oil and will in the future not only be used within the Icelandic maritime sector, but additionally for aviation.

Swedish SAF investigation process and plan
by Maria Wetterstrand, pointed out by Swedish Government as "Investigator for Biofuels in Aviation"

- The presentation was focusing on the ongoing investigation, not presenting final results.
- The increasing discussion on climate change sparked strong public and political engagement.
- A change within road transportation and biofuels was achieved fast, consisting of 20-25 % transition to biofuels on an energy basis; EU-wide the transition is > 30 %.
- Aviation tax implications are emphasized, as they are suggested not to promote technological advancement, but only decreasing overall demands.
- They have started an initiative to encourage individual company plans.
- If the whole domestic aviation is fossil free by 2030, climate neutrality could be achieved by 2035.
- Arising questions: Is political regulation needed to increase the use of biofuels in aviation? What kind is cost-effective? Competition to biofuels in road transport? How to increase production?
- A reduction duty is proposed. Fuel producers have the duty to reduce emissions from their fuel by a certain percentage. No blending target is considered, as they aim to be most supportive to those biofuels that are most efficient in decreasing their emissions, which stands in contrast to Norwegian strategies.
- The interest in the Nordic perspective is driven by the need for a uniform Nordic solution. With increasing the production to levels where costs significantly increase for the aviation industry, the outsourcing of fuel purchases should be avoided.

- The Nordic countries are viewed as a test-market.
- SAF are a start; electro-fuels are considered among other options for long-term solutions.
- The ongoing investigation is expected to be concluded in March 2019.

Global SAF initiatives: EU RED II, CORSIA, Airbus and Boeing
by Frederic Eychenne + Claire H. Guilhot, Boeing and Airbus

Claire H. Guilhot, Boeing

- Global aviation is expected to grow and ultimately double in size within the next 20 years. 4.3 billion Passengers are counted annually. Since 80 % of the population has never flown so far and are expected to start travelling, a 6-7 % annual growth rate is expected on average, predicting 6.9 billion passengers annually by 2035.
- This will require 42,700 new aircrafts within the next 20 years, out of which 50 % will be replacements for current aircrafts, whereas 50 % will be new additions to the current world fleet.
- Growth of traffic will likely impact both economic and environmental sustainability, if no action is taken by all stakeholders: fuel bill remain a major issue for airlines facing unpredictable and variable operating costs and CO_2 emissions of aviation could grow.
- The industry has already managed to de-coupled traffic increase and emissions growth thanks to technological constant improvement and efficiency gains.
- Aviation is the only transport mean that will keep relying on high energy density liquid hydrocarbons fuels in a foreseeable future. Companies like Boeing are working on electricity and hybrid propulsion, batteries, etc. but those seem only realistic for short-term distances and low payload.
- Voluntary "aggressive" targets have been adopted by the industry to continue the sustainable growth of aviation. As a leader in its industry, Boeing is committed to both protecting the environment and supporting the long-term growth of aviation. Biofuel represent the single greatest potential means for achieving those goals. To progress, it is key to collaborate with airlines to identify processing methods and bring all stakeholders together.
- Value chains for production of SAF need to be developed within each specific environment. The main challenges including increasing supply and reducing the cost of production.
- We are working to establish value chains to develop sustainable aviation fuels that are economically viable and environmental sustainable : Focusing on local production development of SAFs, respecting respective environmental criteria, takes advantage of local regulatory mechanisms, e.g. encouraging the use of a certain feedstock. Job creation and social inclusion are mentioned as notable side-effects.

- Boeing has an "all of the above" approach to developing biofuel: No single, unique biofuel production platform is proposed, as different production ecosystems are sourced. Our goal is to identify pathways and feedstock that can be grown, harvested and processed sustainably at a price point that is competitive with fossil fuel.
- Boeing is currently involved in 23 of such projects across the globe. An example of such is the Sustainable Bioenergy Research Consortium in UAE for the combination of Food and Energy production, where biofuel is produced as a co-product of aqua-culture wastewater
- The local environment has a high impact on the choice of the most feasible production concept and Boeing is committed to partnering within Europe for further progress in this field.

Fred Eychenne, Airbus

- A 5 % growth of the aviation sector is estimated per year, corresponding to 2-3 % growth in terms of emissions. A set of measures has to be adopted to achieve the ambitious goals. Sustainable aviation fuels are seen as a key pillar.
- Airbus is currently in an explorative mode in order to prepare future programs. A lot of technologies are not yet matured, but transition has to be started today in order to be completed in 25 years.
- Airbus is addressing emissions reduction with its customers through the "Sustainable Aviation Engagement Programme" aiming to push for extended long-term partnerships and collaborative projects.
- CORSIA is a voluntary compensation mechanism, currently voluntarily adopted by states. It is related to international flights, presenting a route-based approach to monitor and report CO_2 emissions.
- Every airline will have to declare their emissions to establish a baseline for calculation of offsetting obligations. 2019 is the last year for creation of such baseline. All airlines have to be prepared to implement CORSIA (MRV and Offsetting – what is called "capacity building")by having the mechanisms in place for emission reporting and implementing the necessary methods in 2019.
- Not all airlines will have to buy offsetting credits on market but all Airlines will have to report on their international flights. The program remains voluntary until 2027; afterwards it will transition to mandatory phase. CORSIA is presumed as an overall unique reporting system for the future for international flights
- CORSIA was implemented from 2015-2017, together with different projects along the supply chain.
  Implementation of REDII is not yet ready; distinguishing the limitation of food crops and implementation of advanced biofuels is a push for innovation.
- SAF represent a method to reduce GHG emissions at the source; the respective life cycle is considered for carbon footprint calculations, also for SAF-blends.

- The principle of precaution in Europe is addressed regarding sustainability and ILUC (indirect Land-use change). Biofuels will not address all issues long-term.
- At the stage of today, we are perceived to be at the phase of production scale-up of successful previous initiatives and technology development. We are not in a demonstration phase anymore even if the volumes are low and the number of flights limited
- The influence of different political landscapes and regulatory platforms across different states and countries is emphasized. An example is given with an SAF initiative in South East US by the Airbus initiative around its site located in Mobile

Facing the challenge: Decisions, visions and projects in Norway
by Olav Mosvold Larsen, Avinor

- Norway observes issues with sustainability goal No. 13. The air traffic is at current rates growing faster than emission reduction can take place. 15-20 % of emissions from the transport sector are coming from aviation.
- There are ongoing efforts on electric aircrafts for short routes within the last year.
- In 2014 the two first flights using sustainable biofuel took place.
- In January 2016, Avinor's Oslo Airport was the first international hub to offer biojet fuel to all airlines refuelling there. (Project partners: AirBP, Avinor, Lufthansa Group, KLM and SAS)
- SILVA GREEN FUEL is mentioned as an ongoing project. The start of constructing a commercial demo-plant is planned for 2019. Further investment decisions are to be made within the coming years. The production is based on forest residues, with biodiesel as a preliminary target product. (https://www.statkraft.com/about-statkraft/Projects/norway/silva-green-fuel/)
- Quantafuel is producing diesel from waste plastics. Intend to test their technology on forestry residues. The latter will target mainly the production of SAF (https://quantafuel.com/)
- The Biozin initiative focuses on the production of biocondensate. No investment decisions have been made yet. (http://biozin.no/)
- At the Follum Industrial Site production of bioethanol at industrial scale is under consideration. The site has advantages, such as the access to cooling water, electricity grid and its physical location in the middle of the forest.. (www.treklyngen.no)
- Norway has implemented a CO_2 tax, ETS and CORSIA. IN addition there is a passenger duty, approx. 8EUR per flight. This is proposed to change from 1 April 2019 to 7€ on flights in the EU and 20€ on intercontinental flights.
- The QUOTA Obligation (Drop In Requirement) is almost in place; small formalities remaining. 0.5 % advanced biofuel from 1 JAN 2020. Advanced biofuel (wastes and residues only – no food or fodder) is double counted and is intended to to avoid palm oil

and palm oil products. Correspondingly the aviation industry presents itself strong on not having palm oil in their fuel supplies.
- Fuel suppliers are responsible and have to document drop-in.
- SAF is considered a very important part of a low carbon future for aviation, along with more energy efficient aircraft and also future electric aircraft.

Session II Pilot Projects & Initiatives

Sustainable Biorefining Platform
by Lasse Rosendahl, Aalborg University

- A continuous hydrothermal liquefaction (HTL) platform is facilitated in cooperation with Steeper Energy. Further engagement in EU projects with numerous European partners is mentioned.
- HTL represents a wet technology, focusing on the production of a biocrude. This needs to be further upgraded and refined. It is based on a replacement philosophy at crude oil level, where fossil crude is replaced with biocrude.
- Operations are dominated by oxygen removal. Diesel production from wood has recently
- succeeded in collaboration with Steeper Energy, using a series of hydro-treating stages. Other feedstocks included in future projects include e.g. spirulina, miscantus, organic waste and sewage sludge.
- The challenge remains to optimize recovery of substrate energy within the target fuel product. Currently, 33 % of carbon goes to the gas phase, whereas 73 % of carbon remains in the biocrude and approximately 57 % of that can be recovered.
- The majority of CO_2 emissions arise from external electricity and hydrogen needs. These are mainly caused indirectly through its electricity demands. Renewable Hydrogen can potentially be used in the future. This emphasizes the need for linking renewable electricity and renewable carbon in the future.
- HTL technologies are supplying at costs close to the average baseline of fossil costs. Different implementation strategies are considered to target existing concerns.
- The Licella project is set up in Australia, partnering with Canfor in utilization of forestry waste. They are currently in search of investors.
- The Muradel project is not presented with certain status. It is suggested that there is a need for investors.
- The Genifuel initiative is focused on commercializing HTL on sewage sludge.
- There is overall progress on making this technology relevant for aviation and scaling up. Currently it is moving into demonstration scale. Based on the feedstock input, it is possible to operate the process REDII compliant

- Another benefit of the HTL process is mentioned with the opportunity to recycle inorganics, e.g. phosphorus.

SAS/PREEM Sustainable Aviation Fuel agreement and project
by Soeren Eriksson, PREEM

- It is pointed out (based on past examples) that change can happen rapidly, even though it is not directly visible.
- PREEM is planning a production increase for SAF by 2022. The regulatory system in Sweden was not in place previously; since this has changed, future investments can be seen and realized. Change in policy makes change possible. Sweden has implemented a monitoring system to trace the amount of renewables entering and exiting the system.
- A 5% blend maximum in case of co-processing is mentioned.
- The question is imposed, whether the choice of raw material matters, as long as it is ensured that specifications are met? This aligns with the importance of validity of specifications and the necessity to fulfil demands by different authorities. Special interests of parties involved in regulations are making the production of renewable energies/materials more difficult. An example for this is given with regulations on metal content. The political side also has to fulfil requirements.
- Current production yields are subject to regional variations. The construction of a plant for bio-oil valorization is planned for 2019-2021.
- The first lignin-based extraction unit is planned to be built by 2021.
- The question is imposed on how to involve customers in this upcoming journey?

Catalytic Pressureless depolymerisation
by JP Morgan Friberg, Swestep

- The importance of the choice of environment over economy is stressed. Emphasis is put on being ready to take risks, new perspectives, collaborate and move forward. Fossil dependence is a global problem, with traceability as a key to realizing circular economy efforts.
- A choice has to be made either towards a circular economy or towards a CO_2 neutral economy. When using waste materials as a potential feedstock, Swestep's technology poses the option to mix them simultaneously. The possible end-products cover a wide range.
- Today they produce EN-590 certified biodiesel, with the construction of the first Swestep plants to begin in 2019. 2 further plants will be built in Sweden and there is dialogue about 1 more plant for Denmark, 2 plants in Greece and 2 plants in India.

- Gate feeds are differing for each country, making it among other costs difficult to set a specific overall pricing. The technology is said to be extremely competitive tih normal fossil oil. EN-590 certified synthetic renewable diesel is produced.
- The company is open to partnering within the aviation industry to do joint test runs. The importance of collaboration and working together is emphasized.

Production- and delivery-solutions from Neste, Finland
by Virpi Kroeger, Neste

- Neste is focusing on the HEFA technology, utilizing a feedstock consisting of 80 % waste and residue and 20 % oil. All feedstock is certified and traceable. 4 plants are existing, in Finland, Singapore and Rotterdam. Future products include renewable plastics and chemicals. Annual production capacity is 2.7 million tonnes and the existing products include renewable diesel, gasoline, propane, and jet fuel (SAF) with a blending ration of up to 50 %.
- The company is active within advocacy work in EU and US. Previous SAF projects (e.g. with Lufthansa and Oslo Airport) were focused on demonstration, Current projects are to build partnerships and long-term viable business models with airlines and other key stakeholders in aviation. Access to airports presents a significant part to realize concepts.
- They are currently operating with batch-based SAF production in Finland and aiming to scale up towards a continuous production of significant SAF volumes starting from year 2022. A capacity increase is planned in Singapore. Investment decision is expected by the end of 2018.
- Emphasis is put on the need to meet supply and demand at the right time, the need for funding while regulations are still in development phase, and the need to build viable business cases and models.

Production- and delivery-solutions from AirBP
by Thorbjoern Larsson, AirBP

- As an integrated oil company, AirBP is transitioning towards the production of gas and renewable energy, along with reducing their oil production, to align with their low carbon ambitions.
- Airlines and passengers are realizing the potential of SAFs. BP is currently selling fuel at approximately 800 airports and is the first fuel supplier to be carbon neutral.
- The aviation fuel supply chain is complex to get certified. There is a need to integrate into current supply chains to enable quality assurance, lower costs and lower emissions. Therefore a need for stable long-term policies is necessary.

- The Fulcrum BioEnergy investment by BP started in 2016 with the first plant construction in the US. Its production of renewable fuels is based on household waste, using BP's FT process.
- Collaboration with Neste focused on the development of global supply chains in several locations in 2015.
- One of their biggest initiatives remains Oslo airport, but also cooperation with Airbus in the US and enabling a continuous 5 % blend-in at a number of smaller airports.
- Incentives for the necessary investments are crucial.

Haldor Topsoe views on Sustainable Aviation Fuels
by Jostein Gabrielsen, Haldoer Topsoe

- Recent activities involved piloting and certifying jetfuel from pilot-production, along with the testing of sulphate turpentine for production of gasoline. No industrial operation of SAF technologies is currently carried out.
- SPK-HEFA challenge when making jetfuel is to keep the carbon yield; getting as much kerosene without cracking. This requires a stable supply of feedstock with good quality.
- Issues on technical specifications along the process on blending ratios etc. are mentioned
- Contaminant levels are a crucial issue for catalyst employment.

Session III SAF technology solutions

Catalytic hydro pyrolysis for Sustainable Aviation Fuel
by Anker Degn Jensen, DTU

- Carbon based fuels will be a requirement in the future. When exploring a biomass pyrolysis pathway, it is followed by a hydro-deoxygenation step; such strategy is not well explored at current state. It includes the conversion sequence Biomass → Pyrolysis Oil → Fuel + Water (via hydrodeoxygenation). Pyrolysis oil is very acidic etc. and therefore not suitable as a fuel itself without property improvement.
- Hydrogen assisted catalytic pyrolysis + HDO are proposed, using a fluidized bed reactor and utilizing H_2 from other sustainable energy sources, while exploiting energy of co-produced light-gases.
- Shell developed the IH^2 process, which is currently close to commercialization. IH^2 process: 2.25 USD/gallon (13 €/GJ)

- Small-scale processes are run at an excess of gas; the product is obtained with a clear hydrocarbon-fuel phase on top. The oil is essentially oxygen free, very low in nitrogen content; the sulphur content is determined by the organic sulphur compounds and dissolved H_2S.
- Pressure regulation has been discovered as a mechanism for aromatics control
- When catalyst and fuel are mixed, potassium is mobile (transfer from fuel to catalyst); testing did not reveal a significant effect at high operating temperatures.

Biomass gasification as a pathway for Sustainable Aviation Fuel
by Jesper Ahrenfeldt, DTU

- The combination of thermal gasification with electrolysis is proposed. Gasification is a relatively old process, but has so far been primarily used for coal. Synthesis gas is obtained as product, with a tar content very dependent on the respective process; it is aimed to keep synthesis gas production as clean as possible.
- Fuel synthesis through syngas fermentation as a very flexible platform. The FT process is of particular interest to aviation industries.
- Currently liquid biofuel production costs far exceed fossil diesel prices, partially caused by the high investment costs needed for such plants.
- For the production of biomass-based electrofuels, additional hydrogen supply is necessary to ensure efficient conversion.
- GoBiGas is an example of a potential conversion for an FT process or methanol production, but remains currently not feasible.
- Emphasis is put on the influence of political decisions on the feasibility of plant concepts
- Other ongoing projects to produce electric fuels include e.g. SynFuel, BGP, EP2Gas. Unique opportunities are present in Denmark, due to a functioning biomass infrastructure and access to wind power for generating electricity.

Electrofuels/RE- Fuels/Power to X (Power2X)
by Peter Holtappels

- Electrofuels are presented as a long-term solution to extend the use of biomass under the concept of CO_2-neutral electrofuels. This would enable decarbonisation of the entire transport sector.
- The CO_2 cycle is important to be considered in a circular carbon economy.
- Several demonstration projects are located in Germany, e.g. Falkenhagen. Emphasis is put on the benefits of integrating with local industries, e.g. Audi E-gas.
- One of the main development challenges is making the systems durable and cost-efficient.

- CAPFUEL Project: direct air capture as CO_2 source for future exploration
- The opportunity for electrolysis of CO_2 and its conversion into fuel is still under development.
- Kerogreen Project
- The E-fuel concept is viewed as a push for new technological innovation. Shifting to an electro-based fuel would start de-centralizing production of chemicals and fuels.

Bio-refining with focus on Biomanufacturing for SAF
by Hariklia Gavala

- The HEFA process is currently most cost-efficient for SAF production. Its main bottleneck is the limited availability of waste-oils. The predicted feedstock competition within the biodiesel industry enforces the consideration of alternative feedstocks.
- Microbial lipids can enter HEFA process (produced based on lower molar mass organic acids and C3-C6 sugars) – with the challenge being to achieve high volumetric productivities and concentrations - DTU Chemical Engineering is currently developing a reactor system for enhancing volumetric productivities and titers of intracellularly accumulated products.
- The SYNFERON project presents an example of the production of value-added products from synthesis gas – and alcohols for the AtJ pathway. Lanzatech additionally provides an ASTM-certified technology for syngas fermentation towards SAF.
- Beneficial application of mixed microbial consortia. Limitations may apply through chain elongation and other by-product formation along with intermediate accumulation. Control and manipulation of the process based on thermodynamics, towards maximizing the production of alcohols can efficiently address this challenge.
- A highly efficient trickle bed reactor for syngas fermentation has been developed at DTU Chemical Engineering
- DTU Chemical Engineering has in-house access to a 700 m^2 + 500 m^2 (under construction) pilot plant for investigating the scale-up of new technological strategies.

Biobutanol as production pathway
by Helena Junicke

- Focus is on the alcohol-to-jet fuel production. Using waste materials as cheaper feedstocks without competition to food/feed production helps closing the circular economy gap.
- Butanol production from butyric acid and hydrogen (typical intermediates of AD process)

- The GreenLogic Project presents the introduction of a shortcut anaerobic digestion for production of liquid biofuels → high partial pressures of H_2 and low pH required. Testing
- in pilot-scale will be conducted with cooperation partner Novozymes.

CERE Computer Aided Design
by Georgios Kontogeorgis + Philip L. Fosbøl

- Computer aided product design is meant to assist the design of complex products and to help proposing solutions, using a knowledge based system.
- Extensive databases of compounds and properties are required. On their basis, computer aided models can be used for property analysis and composition estimation. In the process, it is essential to divide the problem into sub-problems and prioritize using those properties in the algorithm that are linearly correlated to the group composition.
- Overall, as many needs and properties as necessary can be introduced.
- This concept can be applied to narrowing down a spectrum of blend ratios with regards to meeting imposed specifications. A test design of tailor-made jetfuel blends yielded five different potential blends.
- A last step would include testing the output options on whether they are working with the existing engine concepts.
- This approach can be extended to different feedstocks, costs and products.

PART IV Discussion and Questions on presented solutions

Q1: Any of the presented technologies seem to be relying on the use of hydrogen. How are you all going to get H_2 at the lowest price?

- Transforming water to oxygen and hydrogen via electric currents is an option as a rather cheap technology. Prices of electricity are currently rather low in Iceland. As long as we have water, we will have hydrogen. *(Jon Bernodusson)*
- The process we have looked at is able to run without hydrogen. Otherwise hydrogen can be obtained through electrolysis. *(Anker Degn Jensen)*
- Hydrogen has been a chemical commodity for years. The technology for production is there, the question remains whether we can get it cheap enough, which depends also on the framework. Actual approximate prices range from 3 €/kg to 9 €/kg for hydrogen obtained from electrolysis. *(Peter Holtappels)*
- Fossil-based jetfuel production also uses hydrogen. *(Thorbjoern Larsson)*
- Relevant technologies are being developed in parallel, out of which not all are requiring hydrogen input, an examples fur such are microbial lipids. Renewable hydrogen production technologies are being developed and combining these with other platforms is expected at some point. We should not refrain from developing the pathways; we just need to add research within hydrogen production, so alternatives are available, when technologies mature. *(Hariklia Gavala)*
- Processes are tried to be kept as hydrogen lean as possible with very low external hydrogen supply. The source of this is an important aspect. *(Lasse Rosendahl)*

Q2: I am missing a system analysis perspective on the individual contributions, including elements like cost, availability and speed of introduction in different scenarios. Has someone carried out these studies?

- Within the production of rapeseed oil, 1 ha rapeseed produces 1 ton at a cost of 150 $. That is how we calculate in Iceland on the input side. *(Jon Bernodusson)*
- If we are talking from a system perspective, integration is not only the main driver for technology. Technologies need to be developed in the scope of business cases. *(Lasse Rosendahl)*
- Other groups within for example Process Systems Engineering at DTU do such studies. *(Georgios Kontogeorgis)*
- Selected energy technology initiatives perform such studies. *(Peter Holtappels)*

Q3: I am Curious about the cost-issue. We are looking at the fossil industry, which will further try to outcompete green technology. How do we enable a successful transition?

- For the example of rapeseed oil production, this oil is much cheaper compared to its fossil counterpart, as all parts of the plant are utilized. It is important to close all ends to ensure competitiveness. *(Jon Bernodusson)*
- You have to pay for your emissions, put a price on carbon. *(Thorbjoern Larsson)*
- Implement a tax and ask the consumer to pay. Biofuel is today 2-4 times more expensive than fossil fuel. We have to make competitiveness reality, but do not know yet who is going to pay. We need strict and globally unified regulations. There is a need to get all stakeholders to compensate the arising overcost for several decades. *(Frederic Eychenne)*
- Increasing public awareness is an option. Maybe we need to demonstrate more that costs might be higher, but social and economic benefits have to be factored in. Technologies can bring back jobs locally and have influences on social dimensions. The importance of corporate social responsibility is increasing. The issue of price volatility also factors in; biofuel prices are long-term a lot more predictable. *(Clarie Guilhot)*
- We need to set an increased demand on short-term solutions and find the currently cheapest solutions to reduce emissions. We need to get production going and find long-term solutions at a later point in time. The pressure on airlines in Scandinavia will increase, so we need to find ways to mitigate the costs. *(SAS)*
- Politicians should not only focus on technology, but also be realistic and identify products currently in need of money. Feedstock competitiveness will potentially arise among renewable production. *(Thomas Petersen)*
- We became used to a 1-to-1 comparison, but for biofuels you also buy the sustainability package. For fossil fuels you also pay the over cost, but you do not see it directly on the price. *(Lasse Rosendahl)*
- We need fast readiness and willingness to accept these fuels and make sure we do not use double standards in regulations. *(Anker Degn Jensen)*
- The fossil industry fractures the substrate and produces a range of products. We need to do the same within the bioindustry to become less affected by the volatility of the market. *(Audience)*

Q4: Which alternative fuel is better in terms of other emissions?

- Electricity would be better. Related to partical emissions, all biofuels are a lot cleaner. A couple of studies, at least one Canadian have been done. *(Olav Mosvold Larsen)*
- It is important, e.g. with regards to the content of sulphur and aromatics, to have a certain level of stability to ensure blends. Currently we are testing to go below 8 % of aromatics and check whether it has an effect on e.g. the emissions. *(Frederic Eychenne)*

Q5: What pathways do we have that can reach 100 %?

- Realistically, the industry still needs to learn. Specifications have been built over time. With the particular focus on safety, every step of approval is taken very carefully. We should not restrict ourselves already now, aviation fuel will be a slower sector. *(Thorbjoern Larsson)*
- In 50 years we will likely have alternative technologies. *(Martin Porsgaard)*
- There will not be a certain alternative fuel. Studies are ongoing and problems are solved along the way. *(Frederic Eychenne)*

Q6: What if society will not accept 30 year lead time for production?

- Our purpose is to create value. We hope that the value of travel is higher than the value of money. *(SAS)*

Today's highlights, wrap up and recommendations
by Erik Wormslev

- Most pathways seem to be still in lab- or pilot-scale.
- More efforts and funding are needed.
- Sweden and Norway seem to be going ahead, especially in terms of political initiatives. The Danish government does not yet have the concern for the maritime and aviation sector.
- Research is currently very much working in isolation → a joined Nordic effort is required! (comment from audience)
- We have to move! (comment from audience)