IEA/IIASA BECCS Experts Workshop

Minutes

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Circulation of these minutes limited to the workshop participants only! Background material for participants' feedback, special comments and ideas for further developing BECCS and related research.

Table of Contents

Preface

I was delighted to be asked to facilitate the BECCS workshop organised by IIASA and IEA. Bio-energy Carbon Capture and Storage is a technology that I was unaware of until quite recently, so to explore and learn about new solutions that might help the planet stabilise or even reduce greenhouse gasses in the atmosphere was a real draw – and a challenge.

IIASA and IEA invited several international experts who provided insight into the topic from every angle. Collectively we listened to, and discussed presentations ranging from the logistics of building BECCS plants, through the benefits and risks of including BECCS in climate models, to the difficulties in subsidising carbon capture technology such as BECCS. Many important questions were highlighted, including:

How accurate were the figures regarding BECCS negative emissions when one included processing costs and land use change?
Should incentives be given for carbon capture from bio-energy, and how should this be linked to emission penalties and carbon trading?
How does BECCS affect climate models in scenarios with other technologies such as hydrogen and nuclear power?

This list is by no means exhaustive and I could choose several others which would have equal importance, but they do show the breadth of the discussion. Naturally, there were many common areas of understanding and many areas that require further exploration, and I took this to be a positive sign that our discussions had the depth we were hoping for.

We had designed the second day of the workshop to comprise task based exercises in which sub-groups of participants were given scenarios and had to develop an action plan. The tasks ranged from setting up a BECCS plant in Indonesia to outlining a research strategy to enable BECCS to be rolled out globally. The intention was to try to facilitate a discussion of BECCS from every angle; globally, nationally and regionally, in terms of policy, economics and technology, and from both the top down, and the bottom up.

It was a tall order of course, but worthwhile at least to begin to understand where we are now and where we need to go. The enclosed document is a record of all our discussions, so I will simply highlight below the three ideas that had the most popular support for the proposed next steps.

Firstly was the need for pilot projects in order to more accurately assess the potential of BECCS.
Secondly was the need for public information to foster understanding and acceptance.
Thirdly, the importance of research on storage capacities.
There were many more, and all proposals are listed at the end of this document.

I will make one final mention of a vote we took to assess BECCS based on what we had learned during the workshop. The vote had three options;

1. Whether BECCS was considered essential for combating climate change and stabilising the Earth's temperature.
2. Whether BECCS was considered merely an insurance policy for combating climate change and stabilising the Earth's temperature.
3. Whether BECCS could not be assessed either way at this stage.

Acknowledging that the vote assumes support for BECCS research in every option - appropriate in this early stage of BECCS development - the results showed a small majority, 56%, who believed BECCS to be an insurance, but a significant minority, 38%, who believe it is a necessity.

The point of the workshop was to highlight our major questions, and I think we achieved this aim more than adequately. I very much look forward to taking part in future events, should they occur, if only to see how voting might change year on year.

Shortly after the workshop ended, I was interested to read the latest IEA press release detailing the results of its World Energy Outlook 2011. The main finding was that "Without a bold change of policy direction, the world will lock itself into an insecure, inefficient and high-carbon energy system, -". This timely warning suggests urgency in many directions, no doubt including BECCS.

Phil Moran, Moderator

Workshop Executive Summary

The two-day meeting at IIASA updated participants on current research on biomass-based energy with carbon capture and storage (BECCS) and provided participants with an opportunity to discuss necessary next steps for action.

Ten presentations by invited experts during the afternoon of Day II covered the fields of economics, Technology and Policy of BECCS. Motivated and inspired by the presentations, the group discussed some major pillars of BECCS, such as that Carbon Capture & Storage (CCS) plays a role in meeting low-concentration targets associated with limiting warming to 2°C (Eisentraut). There is increasing interest in promoting biomass as an energy source within the EU (Böttcher) and elsewhere in the world (Wicaksono, Putro, Pacca). Without adding CCS, however, the chance of not meeting ambitious targets rises (McCollum). A model identifying potential bioenergy plant sites was presented (Leduc). Furthermore, land use change considerations play a major role (Havlík). Yet with the potential of reducing future levels below present CO_2 concentration ("managing the climate", Obersteiner) comes the risk of (initial) overshooting 350ppm and postponing other forms of abatement. There were also concerns that CCS and BECCS could shift resources away from de-carbonizing technologies (Mattson, Obersteiner, Smit).

Day II ended the suite of presentations from the day before with a remote presentation by Prof. Yan on the situation of bioenergy and CCS in China and a discussion on the outlook of the combination of the two (BECCS). This presentation was preceded by an IEA presentation given by Dennis Best, who reported on IEA activities with China with respect to CCS, putting CCS into a BECCS context for the following discussion. Finally, the presentation by Andrea Ramirez from Utrecht University offered a lot of insight into the technical details of CCS and BECCS, but also raised many caveats in this context – not only related to technology, storage and transport, but also in terms of social acceptance, which was a recurrent theme in the second day's discussions.

The major part of the day was then devoted to work in break-out groups, with subsequent discussion of the results in plenum. Preliminary agendas (and eventually also timelines) were drawn up for BECCS research including issues pertaining to biomass potentials, capture technology and the associated energy penalty, environmental impacts, transportation and storage, but also to examine BECCS as one component of a wider mitigation portfolio.

In a second set of break-out sessions strategies were elaborated on the incentive schemes and the associated policy processes and on setting up pilot and demonstration projects (which triggered a discussion on how much we can learn from fossil CCS plants and whether pilots should then be capture ready biomass plants), so implementation of BECCS was examined both from a top-down and bottom-up perspective.

In terms of timing, it was agreed that any research activity needs at the same time to be complemented by research in policy mechanisms, incentivizing schemes and issues of social acceptance, which could otherwise significantly delay the process of BECCS adoption, whereas at the same time a lot of research is still needed on the availability of biomass, leakage effects, climate impacts on biomass potentials in the medium to long-term, environmental effects and logistics. With respect to the latter, there was a discussion as to whether CO_2 transport can be compared to the use of gas pipelines. The point made by Andrea Ramirez was that although CO_2 transport can indeed be compared to gas

pipelines, there remain significant differences in CH_4 and CO_2 is transported (e.g. the role of impurities in the thermodynamic behaviour of CO_2), which implies that part of the knowledge and learning still needs to happen (recognition of this is the fact that R&D on CO_2 transport is being funded by several calls in FP7 framework program).

Day 1, 3 November 2011, Presentations on Economics, Technology and Policy (Why, What, How)

Presentations by Experts

During the afternoon of Day 1, 10 expert talks were presented to the plenary with following titles, content and chronology (see also agenda attached, power point slides are included in the Annex):

1 Analysis of BECCS in a Global Policy Context *(Anselm Eisentraut, IEA)*

Anselm Eisentraut from the International Energy Agency gave the opening presentation of the workshop putting BECCS into context both from the scientific and from the policy point-of-view. He furthermore informed participants about the different activities of the IEA with respect to bioenergy and CCS. Two important sets of questions were put up for discussion, one pertaining to the task of incentivising BECCS and one related to international GHG accounting, most importantly that BECCS is not recognised under existing carbon reporting and accounting rules. New IPCC Greenhouse Gas Inventory Guidelines do allow reporting of negative emission from 2015 onwards, but complete LULUCF reporting is not compulsory. For BECCS to fulfil its promise there is a need for complete and robust carbon accounting.

2 The role of BECCS in achieving ambitious temperature targets *(Niclas Mattsson and Christian Azar, Chalmers University, Sweden)*

Niclas Mattson presented the new work done at Chalmers using the GET model (cost minimizing "bottom-up" systems engineering model of the global energy system) to look at the importance and implications of BECCS in the energy mix. The new version of GET has a fully integrated, hard-linked climate module allowing detailed analysis of BECCS effects and impacts on temperature. However, it does not consider uncertainty, e.g. with respect to the risks undergone during periods of overshooting. An interesting finding that was discussed after the presentation was that BECCS turns out to make a difference only in the presence of hydrogen, as hydrogen permits increased use of (intermittent) solar energy in all sectors (electricity, industry, transport). Quoting his own words: "the value of BECCS is system-specific"; so a key message is that synergies with other technologies need to be scrutinized in any future BECCS study.

3 BECCS in the Global Energy Assessment *(David McCollum, Energy Program and GEA, IIASA, Austria)*

David McCollum gave an overview of the work conducted under the Global Energy Assessment, which uses IIASA's MESSAGE model to optimize the energy mix complying with multiple objectives (mitigation targets, energy security, energy access, health benefits). The main message was that without BECCS low stabilization levels can only be reached in those scenarios, which are optimistic about the development of energy demand and efficiency gains. However, given current projections on demographic developments, it seems likely that we will need BECCS to avoid higher temperature increases.

4 The Influence of Negative Emission Technologies and Technology Policies on the Optimal Climate Mitigation Portfolio *(Michael Obersteiner, Ecosystems Services and Management Program, IIASA, Austria)*

Michael Obersteiner presented a model optimizing the selection of a dynamic portfolio of abatement, research and development (R&D), and negative emission policies (here: BECCS) under an exogenous CO_2 constraint and with stochastic technological change. He showed that near-term abatement is not sensitive to the availability of R&D policies, but the anticipated availability of BECCS can reduce the near-term abatement optimally undertaken to meet 2°C temperature limits. Planning to use BECCS also shifts optimal R&D funding from "carbon-free" technologies into "emission intensity" technologies. Making BECCS available enables an 80% reduction in the cost of keeping year 2100 CO_2 concentrations near their current level. However, BECCS is less important if the possibility of tipping points rules out using late-century net negative emissions to temporarily overshoot the CO_2 constraint earlier in the century.

5 Optimizing BECCS – Locating Supply and Demand *(Sylvain Leduc, Ecosystems Services and Management Program, IIASA, Austria)*

Sylvain Leduc presented the BEWHERE model, which calculates the optimal spatial distribution and size of bioenergy plants, pulp and paper mills and sawmills given the spatial biomass supply distribution from biophysical models to assess economies of scale and scope under polyproduction. In particular, he showed how the model has been used to optimally locate bioenergy plants combined with CCS in Europe. One major bottleneck in such an analysis is the lack of appropriate prospectivity maps and the assumptions, which have to be made with respect to transport and storage costs. However, the participants agreed that such spatial analysis based on the distribution of biomass potentials will be of paramount importance in any future BECCS study.

6 Direct and Indirect Landuse for Bioenergy Feedstock *(Petr Havlik, Ecosystems Services and Management Program, IIASA, Austria)*

Petr Havlík presented the Global Biosphere Management Model (GLOBIOM), which is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to give policy advice on global issues concerning land use competition between the major land-based production sectors. The applications he showed made clear that global analysis is needed to comprehend the full implications of BECCS, e.g. issues of leakage and competition for land with other land uses than bioenergy feedstock supply need to be considered to get the full picture on the suitability of BECCS to meet ambitious mitigation targets. There is no constant link between GHG emissions from iLUC (indirect land use change) and biofuels, policies play a major role and sustainability is not only about GHG emissions, but also other factors (biodiversity etc).

7 Biomass Aspects and Potentials in Europe *(Hannes Böttcher, Ecosystems Services and Management Program, IIASA, Austria) - taken earlier into the program (from day 2) – exchanged with A. Ramírez*

Hannes Böttcher presented the preliminary outcomes of an EU-funded project "Biomass Futures", the objective of which has been to assess the biomass role in achieving the climate change and renewables EU policy targets, where it focused on demand and supply dynamics from the perspective of stakeholders. The main conclusions from the project so far are that there is substantial potential for biomass in EU27, but some biomass categories (for example residues) are underutilized. Also, additional sustainability criteria reduce the potential significantly, which ties back to the messages which came forth from Petr Havlik's presentation. Finally, biomass use in the EU27 is found to have implications on crop prices and the LULUCF sink.

8 Toward Indonesia's Cleaner Energy Policy *(Agung Wicaksono, UKP/PPP, Indonesia, and Utomo Sarjono Putro, Institut Teknologi Bandung)*

Agung Wicaksono gave an overview of the current situation of the energy sector in Indonesia, which is still dominated by oil and coal. In the pursuit of the government aims to increase energy access and meet rising demand, the first phase of new energy infrastructure will still be focused on coal-fired power plants. However, the second phase will rely to a larger extent on renewable energy carriers, which is in line with the national commitment to reduce 26% of carbon emissions by 2020. Further to the potential of reducing GHG emissions in Indonesia, the LULUCF sector is projected to play a major role. Post-combustion fossil CCS plays a role in this GHG emission reduction strategy, as does bioenergy (cf. Energy Self-Sufficient Villages (ESV) based on biomass), but NGOs are generally opposed to CCS.

Utomo S. Putro then continued to present an Indonesian research example of a CO_2 emission review of plastic recycling in order to identify emission reduction potentials. During the entire recycling process, granulating is the biggest consumer of fossil fuels: 2 Scenarios were presented: 1. Changing truck capacity reduced fossil fuel consumption by 0.7 per cent; 2. Granulating: introduced biomass energy (blue tower gasification process). Biomass material was compost from municipal solid waste. Result: Reduced CO_2 emissions by 65 per cent. Conclusions: The success of the second scenario could also be a good example for other industry sectors. CO_2 emissions can first be reduced significantly and potentially combined with CCS (also co-firing).

9 Bioenergy and BECCS in Brazil *(Sergio Almeida Pacca, the Brazilian National Biomass Reference Centre – CENBIO, Brazil)*

Sergio Pacca provided a talk about sugar cane-based biomass use for biofuel and electricity in Brazil. He showed an example on how to fuel the global car fleet with biofuel from sugar cane. It was explained that – under the use of currently available and cost competitive technology (all cars electric or hybrid; sugarcane's harvested energy density equal 306 GJ/ha/yr, roughly 1.7 times the value usually reported for biofuels) – only 4 % of the world's available cropland area would be enough to power the global car fleet. Further, it has been demonstrated that sugar cane is efficient as energy carrier, for ethanol, electricity and steam with up to 65 -67 % energy efficiency. The calculated minimum land area needed to power global fleet of cars: 67 million hectares to power global fleet (in

US 25 million hectares, in Brazil 24 or 25 m capacity). Results of this study indicate that only 4% of the world's available crop land can power world's transport needs, the emissions could be reduced by 91 per cent if biomass replaces fossil fuels and if the fermentation process alone could be captured, CO_2 could be reduced by 114% (i.e. negative emission) – challenge would be the storage. Conclusions: Biomass policies need to be coupled to end-use policies; spatial distribution of source and sink need to be identified; sugar-cane biomass has – especially with BECCS – significant potential for CC mitigation. Sugar Cane is not influencing directly the Amazon forest since it is not grown there – indirect effects might exist and need to be identified (LUC/iLUC modeling).

10 BECCS from a Green NGO's View *(Harmen Smit, WWF International, UK)*

According to Harmen Smit, WWF's vision on renewable energy future for 2050 foresees a future with 100% renewables. He further stated that the role of CCS is to limit damage from existing power stations, some of which will be with us for decades. CCS should be used as we continue to use existing power stations. WWF's Vision: Demand will rise until 2020, then decrease drastically until 2050. Electricity, heat and fuel consumption is expected to increase. The WWF sees bioenergy as one of the main sources of energy in the future. By 2050, photovoltaic and wind will also play a large role. Fossil fuel, however, will not be completely replaceable instantaneously, so CCS could play a large role to reduce emission. Also, there is great hope at WWF that transport fuels will come from biomass. The application of CCS may lead to a further decrease of emissions from industrial and electricity- generating use of fossil fuels and biomass in later years. However, employing CCS to the majority of emissions in this scenario is not very attractive primarily because it is expected to mature too late. Expert opinions need to be better communicated. Concluding the WWF contribution, the following needs have been highlighted:

- Reduce or replace the left-over fossil energy use that remains until and after 2050
- Reduce the CO_2 emissions from the combustion of biomass
- Reduce CO_2 emission from industrial use of biomass
- Reduce the lifecycle of CO_2 emission from the production of biofuels
- Employ CCS systems that start on fossil fuels, but that are suitable for later conversion into BECCS.

Besides the issue that the WWF assumptions regarding a decarbonized energy portfolio by 2050 are extremely optimistic (utopia), it has been stressed that CCS is viewed negatively in the public. It has been mentioned that in this case BECCS could be used as a lever to help convince public that CCS is acceptable. It was considered important to have an NGO supporting the BECCS idea. For WWF to use it, scientists need to show that CCS has a renewable future and that the technology is not dangerous, problems with transport and storage will imply no health risk (in case of leakage). So communication is key. So far there is great lack of knowledge on CCS on part of the general public. Interestingly, opposition from the informed public is reported to be very low.

11 CCS in China: Status and Future Options *(Dennis Best, IEA) – provided on day 2, 4 November 2011;*

Dennis Best provided a concise overview on CCS in China, stating that CCS in China is fundamentally important to abating carbon. Renewables, CCS and nuclear are needed to decarbonize the power sector. Coal combined with CCS plays an important role already in today's strategy. As key drivers and milestones, the following points have been identified related to CCS:

- Energy security, economic development, sustainability
- Significant steps to address climate change and develop cleaner technologies include CCS R&D, but it remains a long march ahead as long as there is no globally binding commitment to cut CO_2 emissions
- Focus on CCUS Carbon Capture and CO_2 utilization – EOR, ECBM, etc (NB: if used it cannot become negative!)
- Carbon price, carbon tax and domestic ETS under discussion (pilot phase) however costs of CCS would be likely too high at onset

In China, there are 9 projects either announced or already capturing CO_2. One captures and uses it for the food and beverage industry. All are small-scale projects, which don't necessarily have a storage component. From a stakeholder perspective, fundamental challenges are: costs, storage capacity, limited but growing understanding of potential and role, trading scheme.

12 Remotely: Bioenergy and BECCS in China *(Jinyue Yan, KTH, Sweden) – provided on day 2, 4 November 2011;*

Professor Yan provided a bioenergy overview on China, stating that China is the 3rd largest ethanol producer after the US and Brazil - still small in total fuel supply for transportation. Ethanol mostly comes from corn, wheat and cassava. Additionally, there are more than 30 biomass power plants in China.

Reasons to further develop bioenergy in China are as follows:

- Energy security
- Rural development and poverty alleviation
- Environmental issues, esp. waste treatment
- Land use changes and food security
- Climate change and CO_2

And the following points indicate the bioenergy constraints for China:

- Food security
- 12th FY permanent arable land protection. Cannot compete against food.
- Guarantee cultivation land of 104 million ha
- Competing uses
- Fertilizers & soil improvement
- Materials
- Fodders
- Other projects
- Water resources bottleneck: water considerations are a major problem

Furthermore, it has been stated that financial incentives have to be provided: need guarantee from grid price for power generation and with respect to biogas, subsidies for farmers needed. Another challenge was seen in the institutional arrangements. Six different ministries are involved. Among other issues it has been concluded that there is a need to also look into non-agriculture feedstock such as forest as e.g. presented by IIASA (Leduc).

13 Sustainable Potentials for BECCS *(Andrea Ramíez, Utrecht University, Netherlands) – provided on day 2, 4 November 2011;*

Andrea Ramírez stated that while CCS plays a role in de-carbonizing the energy sector, the potential for BECCS is still large in transport sector with hardly any additional investment costs – this is an important message to give out. There are still areas related that are not studied yet, such as:

- Assessing BECCS in full potential (power, industry and transport)
- Assessing limitations
- Thinking about transitions, i.e. poly generation facilities, and how to foster choices that increase learning
- Gasification could be a no-regret option for BECCS
- Constraints to CCS have been mainly identified in sustainably resource flows, effective infrastructures and social acceptance. She further suggested to first look at biomass availability, technological and economic potential, access, timing and environmental impacts. Then you need to look at CO_2 storage availability, its capacity, access, timing, risks. Additionally, it has been stated that there are limitations in degraded land, protected lands and water. However, it is a no-regret option to use marginal and degraded land. Sub-Saharan Africa, salt-affected soils, etc.

Key uncertainties have been identified in:

- Improvement of agricultural management
- Crop choices
- Food demand and human diet
- Use of degraded land
- Water competition
- Geological assessment
- Risk management/leakage/liability
- Is it all negative, how much is this for different technologies of BECCS?
- No studies on environmental issues on BECCS

Issues needed for the discussion:

- Full assessment of potential and limitation of BECCS (energy, transport, industry)
- Indirect land use change
- Storage capacity risks
- Development of infrastructures
- Water use
- Biodiversity
- Social environmental and economic criteria development
- Transitions

Issues that arose from the questions and discussions during and after presentations

- The risk of overshooting: threshold effects, irreversible damages, effect of higher temperatures on availability and quality of biomass, etc.
- Uncertainty about emissions from transport, harvesting and land use change (systems boundaries)
- How should incentives be applied (BE v BECCS v CCS). Who should receive credit for what? At which point of the chain?
- Distribution of temperature in the future
- Health and environmental risks: little is known of environmental impact of CCS – e.g. water, leaching, biodiversity.
- Too little is known about storage potential and the necessary time for geological identification: need of comprehensive prospectivity maps.
- Too few stakeholders are involved. Therefore, their issues and problems are not known. Public knowledge/acceptance is low: surveys and campaigns needed.
- Funding and Costs. Who funds what? Which incentives should be encouraged? Carbon market? Inclusion in CDM process? Would no-carbon technologies compete for public money? A call was made for clear definition of all cost concepts to facilitate the discussion with stakeholders: system costs, abatement costs, policy costs, etc.
- Time issues – time for technological maturity and BECCS vs. Delays in abatement benefits. This also connected back to a discussion on infant industry argument versus option values versus no-arbitrage market arguments. And to the discussion on overshooting.
- What is the role of hydrogen and other technologies? The presentation by Chalmers University showed that BECCS will only thrive in the presence of hydrogen. Also the presentation on GEA showed the implications of the whole mix of options available.
- Marginal abatement cost curves: where is BECCS? Is it not too expensive? Should 1 ton of emitted CO_2 have the same price/cost like 1 ton of stored CO_2 (as negative emission)? Should there be a higher price to subsidize the technology for accelerating maturation?
- Role of discounting in economic models.
- Economies of scale?
- Can economic models currently already take into account the burden on water?
- What about using CCS in combination with pulp and paper production in Indonesia?
- Capture-readiness in coal-rich countries?
- Deforestation and crop land implications of BECCS in Brazil
- Additional (hidden) CO_2 (system boundaries)?
- WWF seems to have very optimistic outlook for the role of bioenergy (100% renewable by 2050 – Ecofys scenario).
- BECCS as a lever to increase social acceptance also of CCS?
- Hard to forecast importance of BECCS in China at this stage.
- Carbon trading scheme in China seems to be in pilot phase, options to include BECCS?
- Economic benefits of EOR?
- Biomass collection costs seem to be major problem for biogas in Southern China.
- Feedstock issues in China and role of the Chinese forest: it appears to be very difficult to coordinate collaboration between ministries, so such studies lag behind.
- Onshore versus offshore storage?

- Will there be a future value of stored CO_2?
- If CO_2 will be used instead of stored, there is no negative emission and the concept is different. In that case, there will be an economic benefit from capturing the CO_2, but no permanent storage raising important questions about accountancy and adaptation of incentive schemes.

Day 2, 4 November 2011, Group Work

Morning Session - Scenario ONE (Thematic Groups 1-3)

Overall instructions:
It has been recommended that countries pursue BECCS technology as one important contribution to achieving the 2°C target. In response, BECCS would need to be implemented in the most efficient way possible in terms of geography, shared costs and fairness to achieve CO_2 reduction.

Group 1

(Pacca, Mattson, Ramírez, Holloway, Putro, Leduc, Böttcher)

Task 1

You have significantly increased resources to carry out BECCS scientific research. Please develop a research framework prioritizing at least five important technological questions that need to be answered in order for BECCS to be rolled out globally in each of the following areas:

1. Bioenergy from biomass production + CO_2 capture;
   - How does biomass with CO_2 capture affect the efficiency of power plants? Is there an additional energy penalty? Incremental penetration of biomass displacing coal
     ⇒ Traditional coal technology vs. gasification (pre combustion)
   - Given the different conversion technologies how can we proceed to implement BECCS (gasification, co-firing, fermentation)?
     ⇒ What are the technological and economic aspects of each technology?
   - Demonstration pilot projects
     ⇒ Small scale biomass based projects vs. collection of various large scale projects
   - Effect of flue gas composition in the CC unit

2. Environmental aspects (sustainability, land use change, iLUC effects, etc)
   - We need to have the whole picture. Life cycle assessments (LCA). Necessity of including BECCS in LCAs and LCCs
     Which biomass feedstock in combination with CCS is qualified when we apply certain sustainability criteria?
   - Take into account other environmental aspects
     - What are the impacts on water consumption?
     - Residues, ashes, closing cycles?
     - Other air pollutants
   - Depending on the technology route some impacts are amplified, we need diverse pilot projects to understand the outcomes.
   - What is the difference in terms of public perception between BECCS and CCS?
   - Include multiple perspectives of stakeholders; different sorts of organizations

3. Logistics of production (geography, transport, storage, etc)
   - Transport of the gas, corrosion
     - What is the flue gas composition in terms of CO_2, condensable gases, moisture?

- Availability, timing
  - when is the reservoir available – it is better to keep a constant flow over the year
  - when the CO_2 is available – e.g. seasonal production in fermentation
- Find out more about mismatches between expected CCS potential and storage availability
- Data availability: storage location, maps, global coverage, how deep, number and location of wells (access points)
- Centralized vs. decentralized BECCS (production to storage)
  - What are the implications of different BECCS location options (closer to cities, ag. regions, forests)?

Discussion issues / Q&A Session:

- Geological/Technical
  - It is better to have a constant flow into the injection well
  - Time to identify ideal wells: between 2 – 8 years. Time is not a massive obstacle but does play a role
- Monitoring
  - Absorption into rock needs to be monitored
  - Monitoring costs would be small; less than five per cent of any major project (one dollar a ton).
  - Company monitors during storage… after ten or 20 years, they hand it over to state. To do that, they must demonstrate the site has met certain criteria. The operator is responsible for a period until they can prove that CO_2 is either immobile or reaching state of immobility. After that, the state takes responsibility. Reasoning: the state is the only entity which will be around in 1,000 years. Liability question is unclear.
- Costs
  - Order of magnitude? Is there agreement in how much we can store, i.e. order of magnitude? Order of magnitude we know. We also know how much carbon is in biomass and how much we can capture. One GW corresponds to one million tons of CO_2 of negative potential @ 15-200 €/ton of CO_2.
  - CO_2 from fermentation is much cheaper (from ethanol production it is easy to capture). That should be one of the first projects. Also pulp.
- Social/Environment
  - The big question isn't cost, but acceptability. Therefore, we should start off-shore, below sea shore.
  - Also, the environmental impact is unclear.
  - If we use CO_2, we lose the point. The point is to eliminate it from atmosphere.

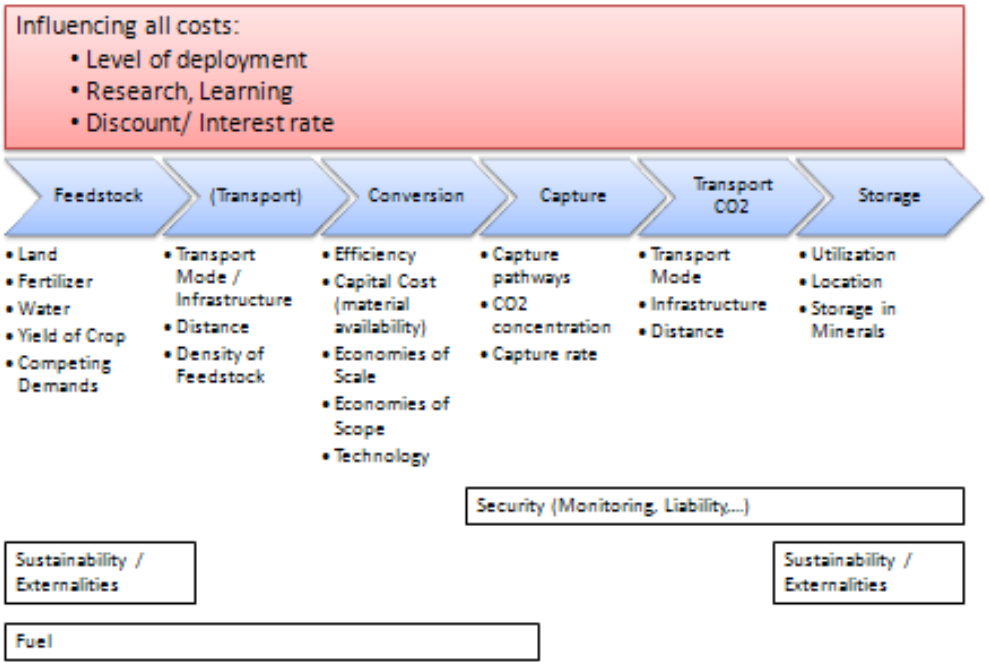
Group 2

(Azar, Havlik, Obersteiner, Reuter, Eisentraut, Remme)

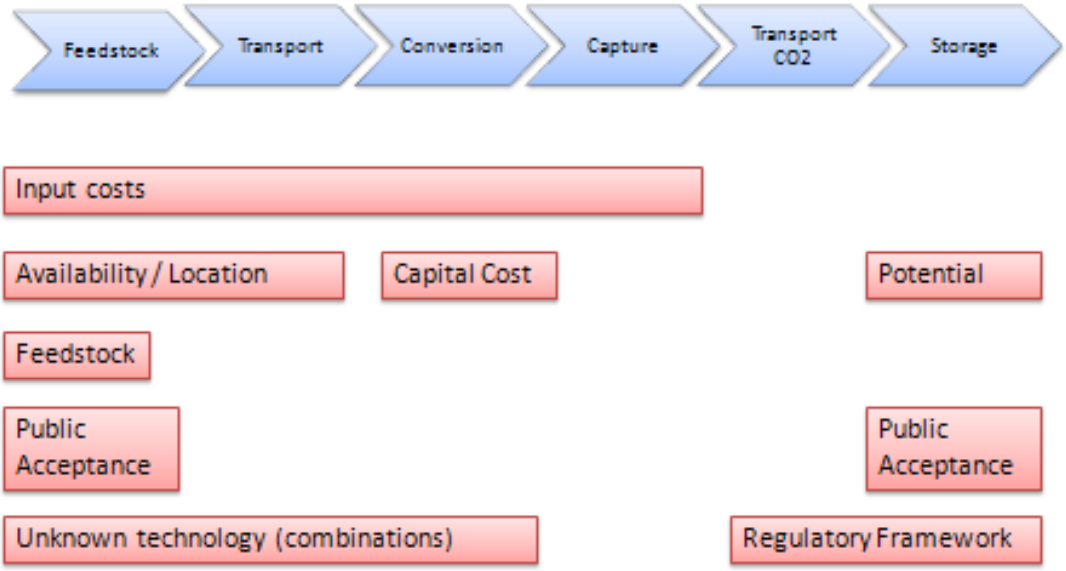
Task 1

Please model a BECCS strategy for reducing atmospheric CO_2. Develop a list of the five most important areas of research needed to understand the cost of BECCS in a high and low energy demand scenario. Please focus on the role of uncertainty as well.

Cost Factors



Key Uncertainties



5 research questions:

1. Research strategies
2. Identify low-hanging fruits
3. Research in new feedstock
4. Location of various supply chain steps
5. Research in storage, capacity cost, technology

Discussion issues / Q&A Session:

- CO_2 transport
  - Models use oil and gas data as a base and develop correlations analysis. Transport CO_2 uncertainty could cost a lot of money.
  - Actual cost of transport. In the US, they transport CO_2 in pipelines. …
  - Too many uncertainties… too little data on CO_2 pipelines known. Somehow we must resolve. Not a big deal, but must be resolved before we get infrastructure in place.
  - Cost of transport is low but initial investments are high
- Modelling
  - Triple biomass production,
  - Conversion and CO_2 storage.
  - Geographical interplay is critical.
  - With exception of Sylvain Leduc's work, there is not much research in this respect, yet! We need to do more work on this.
  - Intermittence in modelling affects? Interplay with other technologies, i.e. hydrogen
- Economics
  - Economies of scale. How do we catch that?

Group 3

(Smit, Loo, Wicaksono, Heidug, Fuss, Best)

Task 1

Produce a report that will set out a roadmap for global co-operation to implement BECCS. Develop a list of five policies that countries must adopt in order for BECCS to have smooth passage and be implemented. Develop a list of the five main obstacles that are likely to occur to implement BECCS at the local scale. Develop a list of three possible global scenarios that would create a need for significant modifications of the earlier lists (e.g. different population, different global temperature increases, etc).

5 main obstacles for BECCS

- Biomass availability
  (Regional vs. central)
- Amounts
- Costs of both capture and storage
- Availability of storage capacity

- Accountancy issues GHG calculations (what is included in the calculations of emission reduction?)
- Lack of awareness of policy makers

Policies to eliminate obstacles

- Create price advantage for non-food competing biomass
    - Decrease subsidy for fossil fuel use while providing subsidies for sustainable bioenergy production on marginal land
    - Reduce protectionist barriers to promote a global biomass market

Policies: Costs

- For demonstration projects
    - Subsidies
    - Stimulate capacity building, Governmental facilitating demo's (bureaucratical hurdles, tax incentives,, etc)
    - Risk guarantees
- For full scale commercial projects
    - Promote carbon market
    - Portfolio standars (% BECCS)
    - Stimulate international cooperation
- Explore international funding mechanisms
    - CDM, NAMAS, etc

Policies: Storage capacity:

- IEA harmonization of assessment requirements

Policies: Accountancy issues:

- Standardize international greenhouse gas calculations
- Sustainability reporting should be mandatory

Public Awareness / Lack of Awareness

- Bridging the science-policy gap
- Stakeholder engagement

THIS IS ALSO OUR TASK

Scenarios:

- Reprioritization of objectives
  (Financial situation, adaptations vs. mitigation)
- Change in international security level
- Significant change in trade regimes
- No global climate agreement

<u>Discussion issues / Q&A Session:</u>

Food versus Fuel

- What is the rationale behind growing biomass on marginal land? Why subsidize land that yields very little?

Land-use

- It can be beneficial for countries to go into "marginal" land to help villages, economies.
- We must have clear environmental/social co-benefits. Ecological and social co-benefits.

Policy

- What is rationale for subsidizing marginal lands?
- In Indonesia, there are a few million ha of land classified as degraded. It is covered with grassland that is invasive and susceptible for burning and will result in degradation. No other ecosystem can compete. So it expands. But in practice, the soil is not degraded. With fertilizers, you can do something. Companies don't want to do it because of the extra costs. If we give subsidies, we can prevent these lands from falling to pure degradation. If the money can be provided, we eliminate one barrier to development.
- Rationale for subsidy can solve a problem society wants to solve. We must be careful each time you introduce a subsidy. You cannot solve climate problems with subsidies. Once BECCS is commercially available, costs come down and there is no point for subsidies.
- We are now in a situation where there is an imbalance between fossil fuel and biofuel. So either subsidize biofuel or eliminate incentives on fossil fuels. Japan charges high fee on landowners not using their land properly.
- Lack of global climate agreement does not prevent regions, i.e. EU, from developing its own policy.
- Waterways, off-shore storage of problematic seas, i.e. South China Sea. These need to be noted.

Economics

- Storing CO_2 is good idea, but you did not elaborate the value.
- Problem is broader than use BECCS. There is an economic dimension in storage concepts. Economics must be taken into account. We need to develop a marginal storage cost curve.

Afternoon Session - Scenario TWO (Thematic Groups A-C)

Group A

(Pacca, Loo, Obersteiner, Halloway, Fuss, Eisentraut)

Task 2

Imagine that the upcoming IPCC report leads to recommendations that countries pursue BECCS technology in order to reduce CO_2 in the atmosphere. A study has been published by the UN regarding implementation of a global BECCS initiative. The document lists the most important areas of research needed in the areas of technology, economics and policy, in order to implement this BECCS initiative. Your mission is to produce a research strategy that will include the following:-

a) An action plan

b) Prioritisation

c) A time plan

d) Monitoring system to include mile stones. You will have only 5 - 10 minutes to present your report to the group.

Priorities

- Determine costs and CO_2 emission reduction of different conversion routes
  - Ethanol, co-firing, different kinds of biomass
  - Level of subsidy required

    - Integration and place within wider energy structure
- Identify low cost chains with high potential and expectations for emissions reduction
    - Estimate cost reductions through learning

Action Plan

- Invitation to submit proposals for one full chain demonstration and capture-ready pilot plants, providing subsidy determined in previous steps
- Learn by doing
- Research topics to include:
    - Capture (bringing down the energy penalty for different bioenergy conversion routes)
    - How to connect distributed CO2 sources to storage
    - Seasonality of sugarcane/ beet bioenergy production

- International knowledge transfer from demos and research
- Policy
    - Stable policy framework/ financial incentives
    - International regulation e.g. of credit transfers
    - include BECCS in CDM
    - Allow reporting of negative emissions
- Research into
    - Trade issues

- Take advantage of existing knowledge about storage locations/pipeline infrastructure from CCS on fossil

Prioritization

Determine costs and CO_2 emission reduction of different conversion routes

- Ethanol, co-firing, different kinds of biomass
- Level of subsidy required
- Integration and place within wider energy structure

Identify low cost chains with high potential and expectations for emissions reduction

- Estimate cost reductions through learning

Time Frame

2011: Determine costs and CO2 Emission reduction for different conversion routes
LCA + global context (i.e. trade, leakage)

2013 (Overlaps with cost): Capture-ready Demo

2014: Learning by doing phase/knowledge transfer (continues to 2020)

2011 – 2020: Research topics (technology and economics)
Conversion (bring down energy penalty – lost from capture)

How to connect distributed sources to storage
Seasonality (only during a specific season can you grow certain crops)

2011 – 2010 Research topics (policy)
International regulation (credit transfers)
Allow reporting of negative emissions
How to include BECCS in CDM (crediting scheme)
Develop a stable policy framework and financial incentives (what about sites in international waters?)

Monitoring system which includes milestones

These are all easy to monitor. Based on outcomes of research, cost, demonstration projects.

Discussion issues / Q&A Session:
Economics

- What is the reason to include BECCS in CDM? Especially considering future of CDM is in question
- There was a short discussion on how to value benefits accruing from BECCS.

Group B

(Mattsson, Reuter, Putro, Best, Remme, Böttcher)

Task 2

The UN has brought together a powerful working group with representation from every country that in time will implement the global BECCS initiative. It is thought likely that variables such as population growth, CO_2 reduction targets, public opposition, migration etc. will have significant affect on the decisions you make. Your mission, therefore, is to produce a report that gives details of the following:

a) List and prioritize known variables that are likely to affect the work of your panel.

b) Produce a monitoring system of these variables, including a time plan.

c) For each scenario above, produce a summary research recommendation in any field that will be needed for your panel to do its work.

d) Consideration of possible incentives mechanisms for BECCS. You will have only 5 - 10 minutes to present your report to the group.

Incentives & Policy Steps		
Short 2025	Medium (2025-2040)	Long-term (post 2040)
• BECCS R&D Policy & Pilot programs • Infrastructure planning for BECCS •Public Information	• Subsidies for demonstration • Commercial scale tax credits	Carbon Market

Milestones		
Biomass supply for BECCS		
Technology feasibility	Industry engagement	100% private financing
Cost reduction	Large scale operations	Competitiveness
Public understanding of BECCS	Niche Competitiveness	
	Negative Emissions	

Indicators		
•Number of operational plants • Costs	• Project financing from private industry • Share of energy production •Marginal abatement cost	• Long-term profitability •Market Share •CO2 reduction from BECCS
Sustained Public Acceptance		

Group C

(Ramírez, Smit, Azar, Leduc, Havlík, Heidug, Wicaksono)

Task 2

You are a research committee in Indonesia/Sweden that has been asked to set up a new BECCS plant as an initial trial for global rollout of the BECCS initiative. The intention is that the whole process will be a robust field trial to learn lessons for other plants around the globe. Your mission is to produce a research strategy that will assess the new plant in all aspects of its operations including technology, affect on both local and wider economy, public policy, acceptance and any other aspect you thing important; and to devise a plan for implementation.

Your report must include:
a) An action plan
b) Prioritisation
c) A time plan
d) Monitoring system to include mile stones You will have only 5 - 10 minutes to present your report to the group.

Action plan

SWEDEN:

- Pulp & paper industry + compression+ transport + Offshore storage
- Quantify energy requirements and (negative) CO_2 emissions (CO_2 accounting)
- Analyze competing claims on heat and material streams (material residues)
- Identify storage capacity availability - costs
- Monitor (from capture to storage-base lines)

- CO_2 impurities (model effect on phase behavior of CO_2 transport and on long-term behavior in the reservoir)
- Environmental Impact Analysis - Social Impact Analaysis
- Impact on local community
- Not included in the ETS...funding available for demonstration from Swedish Energy Agency-
  - Need to include negative emissions in ETS (incentive mechanism)

Indonesia
Same actions, except one added (point 3):

1. Funding
2. Storage
3. Potential energy requirement and CO2 emissions
4. Quantify
5. Environment
6. Competing claims on heat and material stream
7. Monitoring
8. CO2 impurities

Prioritization
1. Funding
2. Storage
3. Quantify
4. Environment
5. Competing claims on heat and material streams
6. Monitoring
7. CO2 impurities

Time frame
2011 – 2014: Funding
Next: Construction
Then Simultaneously: Point 3,4,5,7
After seven years: Done

Monitoring system with milestones

Discussion issues / Q&A Session:
Technical
- Don't begin a demo with fully integrated system. Go for the low-hanging fruits. Start with what already is there.
- Demonstration would be interesting for NGOs because we can convince the public of feasibility. I feel some are more optimistic than others as to what is realistic.
- Start with global targets that can be achieved by BECCS. Policy model, demo plan, modeling on local level. Broad gap between global, national, local level. BECCS is very dependent on geographical breakdown.
- BECCS as a technology can be mature, but may not have a big role to play in global system until later. Large scale penetration may come later because other low cost abatement options will come first.

Overall questions/comments during final discussion session in panel:

Andrea: Ceiling targets because there is a policy function. Our position should be no overshooting.

Petr: Cannot overshoot without the earth collapsing…

Amselm: Even now we do not know impact of overshoot on biomass. Overshoot could seriously impact chances of growing. That is why the message of overshooting is important. We don't know how it messes up environment.

Christian: 2°C temperature change will not change so much.

Amselm: Models cannot predict 5 years of unpredictable weather. Reality of extreme weather conditions could seriously threaten biomass / models.

Niclas: Overshoot and value of BECCS: Requires very nearly de-carbonize rest of energy system. BECCS should not be seen as only alternative, only a tool.

Wolf: Overshooting, temperature rising. It can happen because of outside forces. We must have BECCS if we misinterpreted the uncertainties.

Christian: Economic benefits are higher if you allow overshoots.

Andrea: BECCS has a function. For some of cases CO_2 flows are already there. There is still so much learning to be done on storage, monitoring, close-down, remediation, etc. getting countries to cooperate. BECCS could help bypass some of the problem, CO_2 flows are available so they can get system to move on, e.g., learning on transport, and other issues. We need learning, but for learning, we must have critical mass in projects. We must get projects going.

Michael: Feedstock value is a big uncertainty. Today: Secure land use and biogenic carbon for big BECCS machinery. Exponential growth (unlikely). Must do a lot of agricultural research to free up land.

In all models that added BECCS, BECCS does not add problems to food scarcity issues. Land prices – do they change or not? Conventional wisdom: Land prices higher, food prices higher, tropical land higher, etc. But: with BECCS, carbon prices drop, so land prices and food prices would be even lower. That contradicts the initial interpretation.

Additional demands for biomass in future, e.g. agriculture, transport, etc. This points to huge uncertainties. There is no agreement of world land cover products? This leads to additional inefficiencies in land use. Not just livestock, but … when we talk, must have serious research about potential climate change impacts on land.

Florian: I get the impression many people think first there is CCS then BECCS. Any thoughts on order or priority?

Christian: Two options: Sugarcane and pulp. In contrast to those who say BECCS will come much later, I say that there will be pockets of opportunities for BECCS.

Wolf: Opportunities are smaller. Smaller scale projects.

Florian: BECCS might be door-opener for public opinion.

Harmen: Very true. Capturing emissions is something we have not considered. Useful for us to determine a strategy with industry and policy.

Wolf: There is **no industry champion for BECCS.** CCS champion: Fossil industry. This needs to be changed.

Harmen: Supporting biofuels, but very controversial. A champion to promote: be very careful as to who champion is, what looks like a bio champion may not be one.

Wolf: Emitting carbon costs X, capturing carbon costs Y. Shouldn't the entity capturing be paid more?

Christian: No. If economic efficiency is strived for, the carbon credit received by the company capturing and storing CO_2 from the atmosphere should be the same as the carbon tax that emitters pay. Why? The reason is that there is no extra value in removing one ton of CO_2 from the atmosphere compared to not emitting one ton. Or alternatively, if the prices are different, it would open up the potential for arbitrage. Consider the following argument: Assume that I capture CO_2 and my colleague emits CO_2. Assume that I would get 30 USD/ton CO_2 for capturing and storing (via BECCS), and that he would pay 20 USD/ton CO2. If I capture one ton, build a pipe to him who then re-emits the same ton of carbon) there would be no carbon benefit for society, but society would nevertheless pay us 10 USD/ton of CO_2 for doing this (i.e., doing nothing to mitigate climate change), this would clearly not be meaningful. Thus the price has to be the same for emitters and "capturers".

Wolf Heinrich: Graph only works for current emissions. If we allow overshooting, we need more incentives. I take emissions that are worth more. I emit 1 ton in year 0. In year 100, you take out 100.

Christian: Yes, if we overshoot, we need to get to negative emissions. Then the carbon tax may have to increase, but the price on emitting and capturing should still be the same even if the total emissions are negative.

Let us ask a separate question, not if the price on carbon should be same for those who capture and those who emit, but whether there should be *a special extra premium for putting money into developing BECCS*. Well, then I think that the answer is yes. Why? Assume that there are say five technologies, each of which can substitute fossil fuels and thereby avoid carbon emissions to the extent that we get down to zero emissions. However, the fifth technology can also achieve negative emissions. There is thus an extra value to BECCS, which the other technologies do not have assuming that we want to develop the capacity to withdraw carbon from the atmosphere. For that reason, there is an argument in favour of spending extra R&D money into developing this option because it can (if it works at a reasonable cost) buy us something (negative emissions) that the other technologies cannot (even if the price on emitting and capturing should be the same once the technologies are fully operational and in use).

Michael: Issue of energy sector and geopolitics. BECCS and renewables change the geopolitical dynamics of globe. If we ramp up BECCS on large scale, there is a potential of large wealth transfers.

Next Steps for BECCS

(listed in order of agreement)

1. Pilot projects: (10 votes) 10 – 20 small pilot projects to establish a wide portfolio) esp. pulp and paper; Identify a BECCS Champion and get a successful pilot (bioethanol) existing and new technologies.

2. Public information campaign (6 votes) (perhaps good we start with CCS)
Awareness/stakeholders. Frame a system analysis from a public perspective. Co-benefits.

3. Research on storage capacities (3 votes) – where to put CO2. Need data.

4. Need more perspectives from other regions and stakeholders/ Stakeholder issues: BECCS can be used to win buy-in from some stakeholders concerned about CCS (2 votes)

4. We need clarity on accounting. (2 votes)

4. Is biomass-based energy really neutral to begin with? Really negative emissions? (2 votes)

4. Research CCS to learn about BECCS (2 votes)

<u>Other points of view:</u>

- Responsibility in IEA, UNIDO to steer integrated country studies with special emphasis on points that Petr indicated in terms of supply. Cannot be independent because markets are interdependent
- Converting coal fire to renewables; need technology knowledge.
- LCA and LCC analysis in global context.
- BECCS creates flexibility, there are so many uncertainties, must make assumptions and decisions. What are robust strategies?
- Sustainable upscaling (global scale) of global targets is feasible.
- CO_2 utilization – fertilize sugar cane in Brazil?
- Transition planning – land use and for entire chain of BECCS
- Address liability issues – what happens if it leaks.
- Drop EU subsidies for wheat-based biofuels, etc. creates a backlash.
- Methodology to learn more about CDM
- Research on logistics for smaller storage systems – transport, etc.
- Medium steps between low hanging fruits and large scale projects between 2050 and end of century.

Is BECCS an insurance policy or essential for stabilizing earth's temperature / environmental reasons?

Insurance: 9
Need: 6
Not sure: 1

What are next steps? What do we do now? How to follow up? Who else should we include?

- Industry leaders come with their own issues that we do not know. (Pulp and paper/sugar cane/palm oil) (plant managers has better working knowledge than COO or CEO)
- Politicians: Local policy makers
- IEA
- What is scale? What is size? Q: We need a ball park figure. A: Depends on carbon price, no?
- Sergio: Sugar mill where CO_2 is collected and sold to soda plants. A: Must have a champion.
- Bridge gap between industry and academia
- Stakeholders:
- Research gaps
- EC: Which rules should prevail in the EU trading commission scheme
- Difficult to show a compelling business case b/c need it only in future
- Alliances are possible. Research on who are our alliance partners. For our own survival but also solving global change problem.
- Solar: Any technology advances to bring others on board?
- Agree that bridging is very important. Partnering with other renewable energy groups.
- Geographic components. Long-term interests.
- Funding question is fundamental. IIASA gets a lot of money from EU. Perhaps we need a lobby to build up interest in BECCS. Land use, feedstock.
- Dennis: If there is funding for CCS projects, BECCS realm could be a bit off focus, so we need to know how to frame discussion.
- Bio economy.
- There is a platform of CCS in Zero Emissions Platform, another option to explore?
- Good to know from collaborative research institutes here: Are there other institutes which could strongly add to this discussion and how can we engage them? Please contact us (D. Best) and let us know so we can contact them. **Additional opportunities and links mentioned during the workshop and disseminated afterwards by partners are to be integrated in the final workshop report.**
- Identify where the low-hanging fruits are.

Annex including agenda, list of participants and presentation slides (in chronological order)

IEA-IIASA
BECCS - EXPERTS WORKSHOP

03–04 November 2011
International Institute for Applied Systems Analysis (IIASA)
Laxenburg, Austria

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IEA-IIASA
BECCS - EXPERTS WORKSHOP

AGENDA

03-04 November 2011

International Institute for Applied Systems Analysis (IIASA), Ecosystems Services and Management Program (ESM) Schlossplatz 1, A-2361 Laxenburg, Austria

Program – Day 1, Thursday, 3rd November 2011 *GVISHIANI ROOM*

11:00 -12:00	***Arrival at IIASA, Registration, Coffee & Come Together***
12:00-13:30	***Lunch at the Restaurant Gallo Rosso, Kaiserbahnhof*** *(hosted by IEA and IIASA)*

OPENING & INTRODUCTION

13:30 – 14:00	**Welcome Addresses by IIASA, IEA and the Moderation Team Introduction, Overall Objectives and Procedure** *(Michael Obersteiner, Wolf Heidug, Phil Moran)*

SETTING THE STAGE – SESSION I "WHY"

14:00–14:10	**Analysis of BECCS in a Global Policy Context** *(Anselm Eisentraut, IEA)*
14:10-14:30	**The role of BECCS in achieving ambitious temperature targets** *(Niclas Mattsson and Christian Azar, Chalmers University, Sweden)*
14:30–14:50	**BECCS in the Global Energy Assessment** *(David McCollum, Energy Program and GEA, IIASA, Austria)*
14:50–15:10	**The Influence of Negative Emission Technologies and Technology Policies on the Optimal Climate Mitigation Portfolio** *(Michael Obersteiner, Ecosystems Services and Management Program, IIASA, Austria)*
15:10–15:20	***Coffee Break***

SETTING THE STAGE – SESSION II "WHAT"

15:20–15:40 **Optimizing BECCS – Locating Supply and Demand** *(Sylvain Leduc, Ecosystems Services and Management Program, IIASA, Austria)*

15:40–16:00 **Direct and Indirect Landuse for Bioenergy Feedstock** *(Petr Havlik, Ecosystems Services and Management Program, IIASA, Austria)*

16:00–16:20 **Sustainable Potentials for BECCS** *(Andrea Ramirez, Utrecht University, Netherlands)*

16:20–16:30 ***Coffee Break***

SETTING THE STAGE – SESSION III "HOW"

16:30–16:50 **Toward Indonesia's Cleaner Energy Policy** *(Utomo Sarjono Putro, Institut Teknologi Bandung, and Agung Wicaksono, UKP/PPP, Indonesia)*

16:50–17:10 **Bioenergy and BECCS in Brazil** *(Sergio Almeida Pacca, The Brazilian National Biomass Reference Centre – CENBIO, Brazil)*

17:10–17:30 **Interview: Reflections on the BECCS topic – what green NGOs are concerned about** *(Harmen Smit, WWF International, UK)*

CLOSING DAY 1

17:30-18:00 **Wrap-Up of Day 1** *(Phil Moran)*

Outlook Day 2

18:30 ***Transport to Hotel, check-in and Social Event Dinner at "Salmbräu", Rennweg 8, Vienna*** *(hosted by IEA and IIASA)*

Program – Day 2, Friday, 4th November 2011 *GVISHIANI ROOM*

7:00 ***Pick-up at Hotel Prinz Eugen by IIASA staff***

8:00 -8:20 ***Good Morning Coffee & Come Together***

SETTING THE STAGE – SESSIONS II & III CONTINUED

8:20–8.30 **CCS in China: Status and Future Options** *(Dennis Best, IEA)*

8:30–8:50 **Remotely: Bioenergy and BECCS in China** *(Jinyue Yan, KTH, Sweden)*

8:50–9:10 **Biomass Aspects and Potentials in Europe** *(Hannes Böttcher, Ecosystems Services and Management Program, IIASA, Austria)*

SCENARIO & TASK SETTING

9:10-9:30 **Introduction to Day 2, Explaining the Tasks and Scenarios** *(Phil Moran)*

BREAK-OUT GROUPS – SESSION I

9:30-11:00	**Break-Out in Groups 1-3 with Special Tasks and Targets** **Rooms:** **Gvishiani (1), Schloss Forty Six (2), FOR Seminar Room (3)**

PRESENTATIONS OF GROUP WORK IN PLENARY

11:00–11:20	**Rapporteur Group 1**
11:20–11:40	**Rapporteur Group 2**
11:40–12:00	**Rapporteur Group 3**

IN PLENARY

12:00-12:20	**Plenary Discussion** *(Moderation Phil Moran)*
12:20-12:30	**Wrap-Up of Break-Out Groups Session I** *(Phil Moran)*
12:30-14:00	***Lunch at the Restaurant Gallo Rosso, Kaiserbahnhof*** *(hosted by IEA and IIASA)*

IN PLENARY

14:00-14:30	**What has been reached so far, what are we aiming at** *(Phil Moran)*

BREAK-OUT GROUPS – SESSION II

14:30-15:30	**Break-Out in Groups A-C with Special Tasks and Targets** **Rooms:** **Gvishiani (A), Schloss Forty Six (B), FOR Seminar Room (C)**
15:30–15:40	***Coffee Break***

PRESENTATIONS OF GROUP WORK IN PLENARY

15:40–15:50	**Rapporteur Group A**
15:50–16:00	**Rapporteur Group B**
16:00–16:10	**Rapporteur Group C**

IN PLENARY

16:10-16:40	**Consensus Discussion** *(Moderation Phil Moran)*
16:40-17:00	**Wrap-Up of Break-Out Groups Session II** *(Phil Moran)*

NEXT STEPS & CALL FOR ACTION

17:00-17:30	**Next Steps: Recommendations from the Experts Group for Direction of IEA-IIASA Activities and experts group** **Concluding Remarks and Closing of the Workshop** *(Florian Kraxner, Wolf Heidug)*

Optional Drinks and Dinner at the Restaurant Laxenburger Hof / waiting for taxi pick-ups