Sustainable Development of Bioenergy

Proposed Scope of Work

For Feedback from Members

(IRENA Draft 2017 0104)

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Sustainable Development of Bioenergy - Overview

Meeting the Need for More Bioenergy

The United Nations Sustainable Energy for All initiative, SE4All, envisions a doubling of renewable energy use by 2030. Modeling for IRENA's Renewable Energy Roadmap, REmap, has found that the most cost-effective path to this doubling involves more than a **tripling of modern bioenergy use.** But achieving such an increase in just the next fifteen years will require a vigorous and determined effort by public and private partners. And such an effort will require consensus that bioenergy use is compatible with growing food needs and environmental protection.

Biomass is the most versatile form of renewable energy and the most widely used today. It can be used to generate **electricity**, to supply **heat** for industrial processes and buildings, and to provide **liquid fuel** for transport. In the power sector, unlike variable renewable resources such as wind and solar, biomass can generate electricity continuously; energy is stored in the feedstock until it is combusted. When converted to biofuel for transport, biomass can be stored indefinitely and shipped over long distances, displacing petroleum in global energy markets.

Heat production from biomass dates to the very discovery of fire, and traditional use of woody biomass for heating and cooking still accounts for half of biomass use worldwide, mostly in developing countries. Combined heat and power production from biomass dates back over a century, as residues in the pulp and paper industry have long been used for this purpose. REmap foresees that as traditional heating uses fade away, ***modern heat and power applications of biomass should more than triple*** from 26 exajoules in 2010 to 94 exajoules in 2030.

Biofuels today provide about 3.7% of liquid fuel use for transport globally but substantially higher shares in certain countries. Bioethanol, mainly from sugar cane (in Brazil) and corn (in the United States), provides the equivalent about 5.4% of gasoline (petrol) use. Biodiesel, mainly from palm (in Indonesia and Malaysia) and rapeseed (in Europe), provides about 1.5% of global diesel supply. Advanced biofuels from lignocellulosic feedstocks like farm and forest residues, grasses and wood account are being produced only in much smaller amounts. REmap foresees that as lignocellulosic conversion technologies mature and become more cost-effective, ***use of biomass for liquid biofuel should more than quadruple*** from 5 exajoules in 2010 to 23 exajoules in 2030.

Achieving this major expansion of bioenergy markets will require a much larger supply of sustainable biomass feedstock, cost-effective technology for converting the feedstock to energy, and successful models for scale-up. But bioenergy expansion has stalled in recent years due to international controversy over potential conflicts between food and fuel production and potential land-use impacts of bioenergy production on global carbon balances, as well as declining cost-competitiveness as oil prices have declined by half and the global carbon talks have not produced a global carbon pricing regime. So policy-makers around the world must be persuaded that the necessary biomass can be made available for energy while still meeting the world's growing food needs and without reducing carbon sequestration. And technology development must accelerate to further reduce the costs of bioenergy conversion. Further, successful bioenergy business models must be identified and replicated.

Accordingly, IRENA proposes a programme to expand the global role of bioenergy with three areas of focus:

1) sustainable **supply** of bioenergy **feedstock**,
2) cost-effective **technology** for bioenergy **conversion**, and
3) successful **strategies** for bioenergy **scale-up**

1. **Sustainable Supply of Bioenergy Feedstock**

Sustainable, affordable and reliable biomass feedstock is key to successful expansion of bioenergy. There is a large physical potential to increase the supply of biomass for energy use while providing for the world's growing food needs and protecting the environment. Part of this potential comes from ***more systematic collection of non-food biomass*** such as residues attached to food crops, complementary fellings in forests, and a variety of household, agricultural and industrial wastes. Much potential also lies in ***more productive food and material supply chains:*** sustainable intensification of agriculture through accelerated improvement of crop yields, modern management of livestock production, and reductions in the one-third share of food that is currently lost or wasted can free up land for a mix of food and biofuel crops to be determined by local communities. Further potential lies in ***planting new forests*** (per the Bonn Challenge to reforest 150 million hectares of land by 2020 and the New York Declaration to reforest another 200 M ha by 2030) and ***better managing existing forests.***

In view of this enormous potential, IRENA proposes to undertake a suite of activities on sustainable feedstock supply, including consensus-building on the potential to sustainably increase food and fuel production, development of tools to identify biomass opportunities, compilation of success stories and best practices for raising food and energy crop yields, evaluation of bioenergy potential from municipal and industrial wastes and farm and forest residues, assessment of bioenergy potential through sustainable forestry and reforestation. Partners would include the Food and Agricultural Organization (FAO), IEA, development agencies, business associations, research institutes, and government ministries of agriculture, energy, forests and environment.

- 1.1 Project Underway: Assessing Global Sustainable Bioenergy Potential:
    - Assess sustainable potential for bioenergy from farm and forest residues, land freed by higher crop and livestock yields (sustainable intensification of agriculture), land freed by reduced waste and losses in the food chain, and reforestation.
    - *Communicate analytic results* through the web, printed reports, and presentations at international energy workshops.
- 1.2 Project Underway: Bioenergy Simulator and Data Tools to Identify Biomass Opportunities:
    - Collect data on biomass supply and bioenergy production, by feedstock, end-use sector and country.
    - Develop an online bioenergy yield simulator to help farmers identify promising energy crops for their land.
    - Superimpose maps of agro-economic zones for biofuel crops (such as rapidly growing trees and grasses) upon maps of land cover (such as forest, pasture, farm, and infrastructure) to suggest promising areas for biomass development.
- 1.3 Project Underway: Success Stories in Boosting Food and Fuel Yields in Developing Countries:
    - Work with international partners to document success stories in jointly boosting food and fuel production:
        - *Technology and crop yields* (mix of crops put in place, on what scale, increase in yields obtained)
        - *Political engagement* (process to help stakeholders decide the mix of food and fuel crops to plant)
        - *Market development* (measures put in place to support commerce in bioenergy crops produced)
        - *Investment security* (measures to reinforce land tenure as the essential basis for investment in higher yields)
    - Suggest effective actions that development agencies can apply to boost food supply and expand energy access.
- 1.4 Project Proposed: Bioenergy Potential from Recovering Waste and Residues:
    - Assess the practical potential for additional harvesting of agricultural and forest residues in different regions.
    - Assess available amounts of municipal solid waste, industrial waste and construction waste in different countries.
    - Examine logistical strategies for reliable supply of waste or residue feedstock to bioenergy facilities of different sizes.
    - Survey best practices, policy measures and capacity building to support more thorough collection of residues.
- 1.5 Project Underway: Bioenergy Potential from Restoring Degraded Land:
    - Assess the amounts of degraded forest land sufficiently accessible to population centers and energy markets.
    - Assess the yields achievable on degraded land in view of experience in China, the Sahara and elsewhere.
    - Compile, evaluate and promote proposals to restore degraded lands in Africa, Asia and other continents.
    - Build consensus on practical approaches to meeting the Bonn and New York goals for 350 M ha of restoration.
- 1.6 Project Underway: Best Practices for Sustainable Forestry:
    - Document forest industry best practices to expand output of forest products and energy while storing carbon, with particular attention to boosting yields of planted forests, using wood to displace concrete in construction, and using forest residues to displace fossil fuels for generation of heat and electricity.
- *Further projects on sustainable bioenergy supply to be developed in consultation with interested IRENA members.*

2. Cost-Effective Technology for Bioenergy Conversion

A second key to expanded bioenergy use, on top of sustainable feedstock, is the availability of cost-effective technologies for converting feedstocks to heat, electricity and liquid biofuels**.** Modern technologies for ***heat and electricity generation*** are well established, based mainly on combustion of wood and agricultural residues. They are urgently needed in developing countries to displace traditional wood use which is unhealthy and inefficient, and they could more widely displace fossil-fuelled heat and power in developed countries with abundant forest. ***Biofuel production*** has also gained a foothold from first-generation technologies for conversion of feedstocks like sugar cane, maize and palm oil. But second-generation technologies, still under development, will be needed to convert the much larger increments of sustainable biomass that could be available from lignocellulosic feedstocks like trees and grasses, and third generation technologies will be needed to produce biofuels from algae.

IRENA therefore proposes to build consensus on the most cost-effective bioenergy technology options and to develop sectoral roadmaps for deploying these technologies in buildings, industry and transport. Partners would include government technology programmes, national laboratories, and bioenergy companies.

- 2.1 Project Underway: Technology for Advanced Liquid Biofuels in Transport:
    - **Assess the status of technologies for converting lignocellulosic feedstocks to liquid biofuels**, the technical and non-technical barriers such technologies face, and the prospects for making these technologies cost-competitive by 2030.
    - **Outline a roadmap to accelerate market introduction of advanced biofuels**, including recommended research and development and policy measures to support progress of the most economically promising technology pathways.
- 2.2 Project Underway: Technology Pathways for Ethanol from Agro-Processing Residues:
    - **Investigate technologies for converting agro-processing residue to ethanol**, with focus on conditions to improve fuel yield from fermentation of cassava residue with heat- and acid-tolerant yeast and high-temperature decontamination.
    - **Evaluate the economic feasibility** of ethanol production from agro-processing residue in Ghana and Nigeria.
    - **Assess the social and environmental benefits** of using more agro-processing residues for fuel in the two countries.
- 2.3 Project Underway: Biogas Technology Assessment for Different End-Use Sectors:
    - **Evaluate the status, costs, and cost-competitiveness** of technologies for producing biogas from different feedstocks.
    - **Assess the economic, employment and environmental benefits** of deploying biogas technologies.
    - **Examine the barriers to biogas technology** and practical policy measures for surmounting these barriers.
    - **Develop a roadmap to accelerate deployment of biogas** for cooking, combined heat and power, and transport.
- 2.4 Project Proposed: Technology Roadmap for Accelerating Modern Biomass Use in Buildings and Communities:
    - **Analyse the best available options for modernizing wood fuel use,** in terms of capital and operating costs, durability, feedstock supply, efficiency of fuel use, and user acceptance (including cook stoves, and modern wood furnaces)
    - **Assess fuel wood savings and associated economic, social and environmental benefits** of deploying modern options.
    - **Develop roadmap to accelerate deployment of modern technologies for heating and cooking with biomass** (both where displacing traditional wood use, as in developing countries, and where competing with fossil or electric heat)
- 2.5 Project Proposed: Technology for Biomass Energy with Carbon Capture and Storage (BECCS):
    - **Catalogue current and planned projects for biomass use with carbon capture and storage,** noting process advantages in concentrating carbon, costs of CCS equipment, and marginal costs of providing CCS per unit of energy output.
    - **Detail research, development and demonstration efforts for CCS** including for fossil-fuelled power plants.
    - **Assess the scale at which individual BECCS projects might be affordable** at different market values of carbon
    - **Suggest further steps needed** to develop cost-effective CCS technologies in producing fuel or power from biomass.
- 2.6 Project Proposed: Energy Cane for Biodiesel: Technical and Economic Assessment
    - **Evaluate the technical and economic potential of energy-cane** as a replacement for conventional sugarcane, weighing the potential benefits (reduced land use impacts and lower feedstock costs due to much higher yield per hectare) against the potential drawbacks (more complex and less efficient process leading to higher capital and operating costs)
    - **Propose a suite of targets and incentives to foster a shift to energy cane** in countries with substantial sugar production.
- *Further projects on bioenergy technology roadmaps to be developed in consultation with interested IRENA members.*

3. Successful Strategies for Bioenergy Scale-up

Even with abundant feedstocks and cost-effective technologies, focused strategies will be needed to quadruple modern bioenergy production in just 15 years to meet the REMAP 2030 target for doubling renewables. ***There are strategies that work, with a mix of public incentives to attract private investment***, but they have so far been limited in geographic scope and impact. We need to draw out the best elements and spread them more widely.

Scandinavian forest industries have developed effective models for managing production of wood for lumber and energy while enhancing the forest area and associated carbon sequestration. ***Brazil and United States*** have successfully promoted specific biofuel crops with a mix of biofuel targets and financial incentives, which could be applied to other crops and other places. ***India and Sub-Saharan African countries*** have promising agroforestry initiatives, with a mix of food and energy grasses and trees, which could be expanded and replicated elsewhere. IRENA proposes to document the key elements of these strategies and develop public-private partnerships to implement them more widely, while assessing standards and certification schemes to promote bioenergy trade.

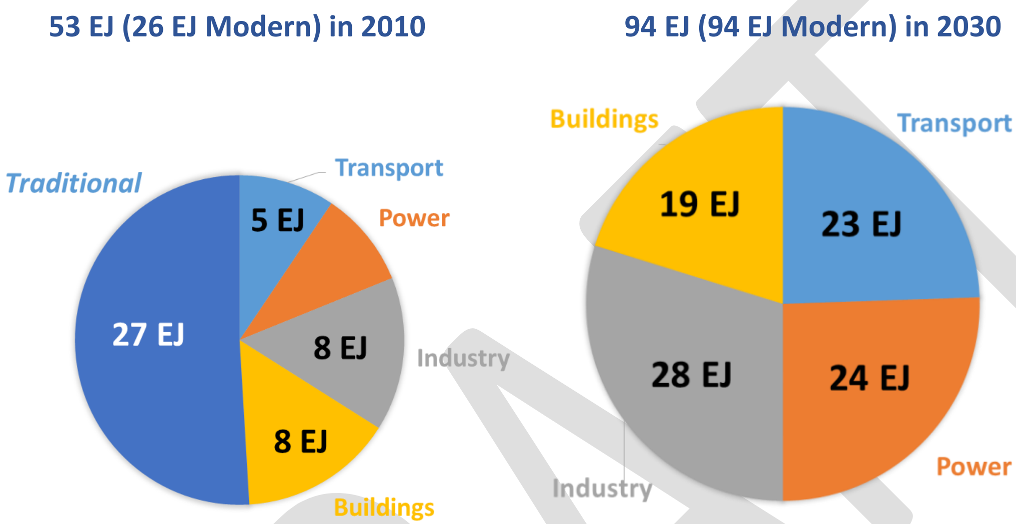
- 3.1 Project Underway: Project Navigator for Biomass to Heat and Power
    - **Add bioenergy module to IRENA's Project Navigator,** which guides users through project identification (stakeholders, problems, objectives, alternatives), screening (strengths, weaknesses, opportunities, threats; competencies, resource needs), assessment, selection, pre-development (stakeholder analysis, technical/economic/operational/political framework, success factors, monitoring mechanisms, project brief, business viability analysis), and development.
    - **Market the Project Navigator to potential bioenergy project developers and investors.**
- 3.2 Project Proposed: Forest Biorefineries with High-Value Coproducts
    - **Assess potential for increased power output from the pulp and paper industry** in light of declining paper demand.
    - **Assess potential for producing advanced biofuels and high-value co-products** from sustainably managed forests.
    - **Survey feed-in tariffs and other policy options** to elicit the investment needed to realise the potential identified.
    - **Evaluate the combined effect of co-products on the net production cost of biojet fuel for aviation.**
    - **Organise a regional workshop in Europe** to disseminate the findings and build consensus on needed action.
- 3.3 Project Proposed: Renewable Energy Approaches to Reducing Food Waste and Freeing Land for Bioenergy Crops
    - **Evaluate the technical and economic potential for renewable refrigeration and food drying** in developing countries
    - **Analyse the resulting potential to reduce food distribution losses and land requirements for food** in different regions
    - **Propose a renewable refrigeration and food drying program for Africa** in partnership with development agencies.
    - **Organise a workshop in Africa** to highlight the findings and build support for action from development agencies.
- 3.4 Proposed Activity: Turning Biomass to Bioenergy on Islands
    - **Screen islands for availability of sufficient sustainable biomass feedstock** for electricity, heat and fuel production, considering sugar cane, bagasse and other agricultural crop residues oil crops, grasses and municipal waste.
    - Develop **roadmaps for bioenergy expansion on three selected islands**, in consultation with stakeholders (promising candidates might include Samoa in the Pacific, Mauritius in the Indian Ocean, and Martinique in the Caribbean)
- 3.5 Proposed Activity: Expanding Global Bioenergy Markets and Trade
    - **Develop improved statistics** on biofuels production and trade
    - **Promote biofuel quality standards**, in cooperation with standards bodies and trade organizations
    - **Develop policy recommendations for biofuels trade** that is free and fair, including small-scale suppliers and users
    - **Disseminate best practices for sustainability certification** of biofuel feedstocks
- 3.6 Proposed Activity: Country Advisory Services for Expanding Bioenergy Supply and Use
    - **Develop country strategies for expanding bioenergy** in the context of Renewable Readiness Assessments.
    - **Assess the potential role of biomass on power grids** for enhancing the renewable share of electricity generation.
    - **Customise recommendations for bioethanol production** through technology transfer and development cooperation.
- *Further projects on bioenergy scale-up strategies to be developed in consultation with interested IRENA members.*

Sustainable Supply of Bioenergy Feedstock: Project 1.1 (in progress)

Assessing Global Sustainable Bioenergy Potential

Background

Bioenergy is one of the six key renewable energy forms which are in IRENA's remit to encourage. The agency's REmap analysis finds that bioenergy constitutes about half of the available and cost-effective options to double the share of renewable energy in the energy mix by 2030. These options would nearly double overall bioenergy use and more than triple modern bioenergy use from 2010 levels. This raises the question of where biomass feedstocks for long-term expansion of bioenergy use would come from.



Sustainable biofuel pathways include boosting yields of food crops and associated residues on existing farmland, freeing up existing farmland for biofuel crops through further yield improvements, reducing losses and waste in the food chain to free up additional farmland for biofuel crops, and improving livestock management to free up pastureland for biofuel crops. There is also biofuel potential from better residue and yields in planted forests, reforestation of degraded land with rapidly growing tree species, and cultivation of algae from organic waste streams or carbon dioxide. A better and more widely shared understanding of the biofuel potential, as well as practical policies and measures for developing this potential, can help to build consensus on a constructive path forward to expanded biofuel supply.

Approach and Accomplishments

IRENA's approach to sustainable bioenergy potential has two elements: analysis and communication. The analytic work includes an in-depth study on *Boosting Biofuels: Sustainable Paths to Greater Energy Security*, with associated spreadsheets of calculations and explanatory notes on the calculations, and follow-up regional studies. This builds on *Global Bioenergy Supply and Demand Projections*, an earlier working paper for Remap 2030. The communications effort includes publishing the studies, posting the associated calculations and notes on IRENA's website, highlighting the work at international bioenergy conferences, organizing expert workshops, and preparing summary briefs for policy-makers.

Boosting Biofuels: Sustainable Paths to Greater Energy Security

The analysis reveals a tremendous bioenergy potential through sustainable intensification of agriculture:

- ***Closing the Yield Gap:*** The Food and Agricultural Organization projects that global average yield for major food crops could reach 10.4 t/ha, double the yield projected for 2050. If the gap were closed, so food could be grown on half as much land, ***550 M ha*** would be left for biofuel crops***.***
- ***Better Use of Pastureland:*** Beyond the 1.5 billion hectares of land that is used today to grow food crops, 1.4 billion hectares of prime and good pasture land is available. If the pasture land were used more intensively, ***950 M ha*** could be freed up for cultivation of bioenergy crops.
- ***Reduced Food Waste:*** The FAO reports that one-third of food for human consumption is wasted. If losses throughout the world were reduced to best practice levels for each crop and food chain stage, as indicated by the best-performing region, ***300 M ha*** could be freed for bioenergy crops.
- ***Restoration:*** The "Bonn Challenge" calls for ***150 M ha*** of degraded and deforested land to be restored by 2020, and the New York Declaration calls for another ***200 M ha*** by 2030.
- ***Overall:*** Sustainable intensification of agriculture could free ***over 2 billion hectares*** of land for bioenergy. With a yield 10 t/ha and 15 GJ/t, it could grow over 300 EJ of biomass, converting at 40 to 80% efficiency to 120 to 240 EJ of energy use, more than today's energy use for transport.

There are further substantial potentials from more effective collection of agricultural residues and better management of planted forests. The resulting end use potential – whether from combined heat and power (80% efficient) or biofuel (40-80% efficient) is summarized in the report as follows:

Summary of Bioenergy Potential in 2050 (Exajoules)
[Aspirational Target] – [Theoretical Potential]

Category	Primary Biomass Energy Content	End Use Bioenergy with 1st/3rd Generation Biofuel or Combined Heat and Power (80% Efficiency)	End Use Bioenergy with 2nd Generation Biofuel Conversion (40% Efficiency)	REMAP 2030 Assumptions for Primary Biomass Energy (Reference)
Agricultural Residues	46 - 95 EJ	36 - 76 EJ	18 - 38 EJ	19 - 48 EJ
Higher Crop Yields	47 - 88 EJ	37 - 70 EJ	19 - 35 EJ	0 EJ
Pasture Land	71-142 EJ	57-114 EJ	28 - 57 EJ	33 - 39 EJ
Reduced Food Waste	40 - 83 EJ	32 - 66 EJ	16 - 33 EJ	18 EJ
Cultivating Forests	83-141 EJ	66-112 EJ	33 - 56 EJ	41 - 58 EJ
Total	**287-549 EJ**	**228-438 EJ**	**114-219 EJ**	**112-162 EJ**

The study also highlights **key steps** that countries and partners should consider to ***develop*** the potential:

- ***Demonstrate cost-effective technologies*** for production of biofuels from lignocellulosic feedstocks (grasses, wood, farm and forest residues) and from algae.
- ***Accelerate improvement of crop yields*** by expanding capacity building and extension services to promote modern farming techniques in developing countries, and by enhancing access to fertiliser and water storage.
- Improve understanding of ***logistical approaches*** for cost-effective harvesting of farm and forest residues.
- Collect ***comprehensive data*** on land that could be used for sustainable biofuel crops, including achievable yields.

- Conduct in-depth research on ***practices for cultivating rapidly growing trees and grasses*** on pastureland that could sequester carbon and enhance biodiversity.
- ***Reduce food waste and losses*** through more flexible labelling and investment in refrigeration and transport infrastructure to bring more food to market fresh.
- ***Accelerate afforestation*** through incentives to cultivate trees on degraded lands and through sharing best practices for sustainable forest management.
- Expand ***registers of origin*** to include sustainable feedstock sourcing and promote expanded trade.
- Institute ***more secure land tenure*** and ***better land governance*** in developing countries to provide incentives for more intensive land management.
- Develop ***new business models*** that focus on sustainable feedstock supply, supported by policy instruments such as biofuel targets, feed-in tariffs, and carbon value.

Results of the analysis have been disseminated in a range of international fora, such as:

- World Future Energy Summit (Abu Dhabi, January 2016)
- Expert Exchange Workshop on Sustainable Wood Energy Value Chains (Frankfurt, March 2016)
- Nordic Baltic Bioenergy Conference (Vilnius, April 2016)
- IEA/FAO/IRENA Workshop on Mobilising Sustainable Bioenergy Supply Chains (Rome, May 2016)
- 24th European Biomass Conference and Exhibition (Amsterdam, June 2016)
- Argus Biomass Asia (Singapore, June 2016)
- Bioenergy 2016 (Washington, July 2016)
- Tokyo International Conference on African Development – TICAD VI (Nairobi, August 2016)
- Ukraine Biomass for Energy Conference (September 2016)
- Workshop on Bioenergy and Sustainability: Latin America and Africa (São Paulo, November 2016)

Adjunct articles have appeared in professional journals:

- *Natural Resources* (2016) 7, "Potential for Biomass and Biofuel through Sustainable Intensification of Agriculture and Reduction of Food Losses and Waste"
- *BE Sustainable – Outlook on the Bio-Based Economy* (May 2016), "The Untapped Potential of Sustainable Biofuels"

Regional Supply Potential Studies

As a follow-up to the *Boosting Biofuels* study, a report is being prepared on *Resource Potential for Advanced Biofuels in Southeast Asia.* It focuses on lignocellulosic resources such as wood and agricultural residues that can be converted to ethanol, diesel and other liquid biofuels by advanced ("second generation") processes. It will highlight the long-term potential for developing these resources in five specific countries of Southeast Asia: Indonesia, Malaysia, Philippines, Thailand, Vietnam. These countries have been selected because they are members of both the Association of South East Asian Nations (ASEAN) and the Asia Pacific Economic Cooperation (APEC). In the agricultural sector, drawing upon detailed calculations made for *Boosting Biofuels*, detailed information will be presented on the potential for enhanced residue collection and energy crops planted on land made available by closing the gap between projected and potential yields of food crops and by reducing waste in the food chain. In the forestry sector, wood potentials of tree species grown in the region are assessed and presented. The countries' readiness for adoption of advanced biofuel conversion technology is also surveyed.

A companion follow-up study is being considered on *Resource Potential for Advanced Biofuels in Sub-Saharan Africa.* This would focus on five countries in the eastern and western parts of the continent.

Roundtable on Sustainable Bioenergy Supply

Pursuant to the IEA/FAO/IRENA Workshop on Mobilising Sustainable Bioenergy Supply Chains (Rome, May 2016), IRENA and IEA organized a *Roundtable on Sustainable Bioenergy Supply: Potential, Scenarios and Strategies.* Global models and resource assessments have come up with different estimates of the technical and practical potential for sustainable biofuel development. The roundtable aimed to build consensus on the practical scenarios that could be realized by 2030 and 2050 for the sustainable expansion of bioenergy from farm and forest residues, short-rotation forests, higher yields on farms and in planted forests, more efficient livestock husbandry, reduced waste and losses in the food chain, enhanced utilization of municipal and industrial waste streams, and other sources.

The event, which took place in Berlin on 28 September 2016, discussed global scenarios by IRENA (*REmap* and *Boosting Biofuels*), IEA (*World Energy Outlook* and *Energy Technology Perspectives*), Greenpeace (Energy [R]evolution Model), PBL – Netherlands Environmental Assessment Agency (IMAGE Model), Shell (World Energy Model) and World Energy Council, as well as regional scenarios for the European Union and the United States. Bioenergy experts from Ecofys, German Aerospace Center (DLR), German Biomass Research Center (DBFZ), Imperial College London, Netherlands Environment Agency (PBL) and Oak Ridge National Laboratory joined an in-depth roundtable discussion. German ministries with responsibilities for energy, environment and agriculture also participated. Brief qualitative and quantitative highlights of the discussion were prepared and circulated.

It was generally agreed that sustainable bioenergy supply should not conflict with food use, convert peat or forest to farmland, deplete the quality of soils, increase net carbon emissions, or reduce biodiversity. In this context, estimates of resource potential should consider farm and forest residues, enhanced biomass production on existing farm and forest land, energy crops on additional farm and forest land that might become available, increased biomass end use efficiency, and post-consumer waste. In terms of potential for energy crops, it was noted that estimates should consider restoration of degraded land as well as land freed by higher crop yields, more efficient use of pastureland, and reduced waste and losses in the food chain. However, the discussion revealed that not all estimates have done so.

Global estimates vary widely, but all show the potential is substantial. Supply potential estimates for 2030 range from 110 EJ (by PBL) to 181 EJ (by IEA), with IRENA (140 EJ) in-between. End use estimates for that year range from 56 EJ (by IEA) and 93 EJ (by IRENA), with Greenpeace (61 EJ) and PBL (71 EJ) in-between. Further work would be needed to fully understand the reasons for the differences. But broad agreement on substantial potential suggests a need to focus on actions to put the potential in place.

Paper on Approaches to Sustainable Expansion of Bioenergy

The IEA/FAO/IRENA Workshop on Mobilising Sustainable Bioenergy Supply Chains (Rome, May 2016) found that a fundamental obstacle to expanding bioenergy has been public concerns about how this might interfere with providing adequate food and preserving the environment. It was therefore agreed that the three agencies should collaborate on a brief (four-page) paper on *Approaches to Sustainable Expansion of Bioenergy* to explain how bioenergy can be expanded to help achieve the goal of Sustainable Energy for All while also contributing to food security and environmental protection. As of late 2016, the paper was in advanced stage of preparation for presentation to IRENA members.

Sustainable Supply of Bioenergy Feedstock: Project 1.2 (in progress)

Bioenergy Simulator and Data Tools to Identify Biomass Opportunities

Background

IRENA is a global locus for information on renewable energy resources and their use. Information on resources has been made available through IRENA's Global Atlas, which initially focused on wind and solar resources but is being expanded to include geothermal and biomass resources. Information on the use of renewable resources in the energy sector, such as the primary energy that each type of renewable resource has supplied in each end use sector, has been made available through IRENA's data collection.

Biomass Resource Information – which is fundamentally about forestry and agriculture – has been collected on a systematic basis for many years. This has been provided to the public by the Food and Agricultural Organization (FAO) and others, and IRENA's data tools can build on it. For example, the FAO's Global Agricultural Economic Zones (GAEZ) database has global maps of crop suitability and yields for every major food and grass crop, under different assumptions about rainfall, irrigation, and application of fertiliser. IRENA may apply such information in particular countries or regions to help farmers think about the best mix of crops to consider planting, in terms of food and energy yields and returns on investment.

In this context, it may be of particular interest to consider **agro-forestry strategies**, in which a variety of crops work together to raise overall yields. Neem oil trees in India, for example, provide diesel fuel for farm equipment and oil cake for fertiliser, while repelling insects so that food yields increase and villages become more prosperous.[1] Gliricidia, a fast-growing nitrogen-fixing tree, boosts yields of coconut in Sri Lanka and maize in Malawi and Zambia.[2] Data tools may help farmers identify the most promising crop species, in terms of yields that can be achieved on their particular land, in choosing their desired mix.

It may also be of interest to consider the potential for growing particular types of **high yielding grasses**. For example, *Miscanthus x giganteus* grows well in most countries and regions with abundant available pasture land.[3] It has very high yields without fertiliser due to nitrogen-fixing bacteria in its roots. It is sterile and thus non-invasive to native species.[4] It enhances biodiversity by providing cover for a variety of shade-tolerant plants, invertebrates, woodland bird species and butterflies.[5] Finally, it may well sequester large amounts of carbon in the soil.[6] Sugarcane, bamboo and switchgrass are other high-yield options. IRENA could superimpose maps of agro-economic zones upon maps of land cover (such as forest, pasture, farm and infrastructure) to suggest promising areas for bioenergy development in member countries.

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[1] S. Puri and P. Panwar (2007). *Agroforestry: Systems and Practices.*

[2] Evergreen Agriculture Partnership and World Agroforestry Centre (2015). *Creating EverGreen Food-Energy Systems for Rural Electrification in Africa.* See http://evergreenagriculture.net.

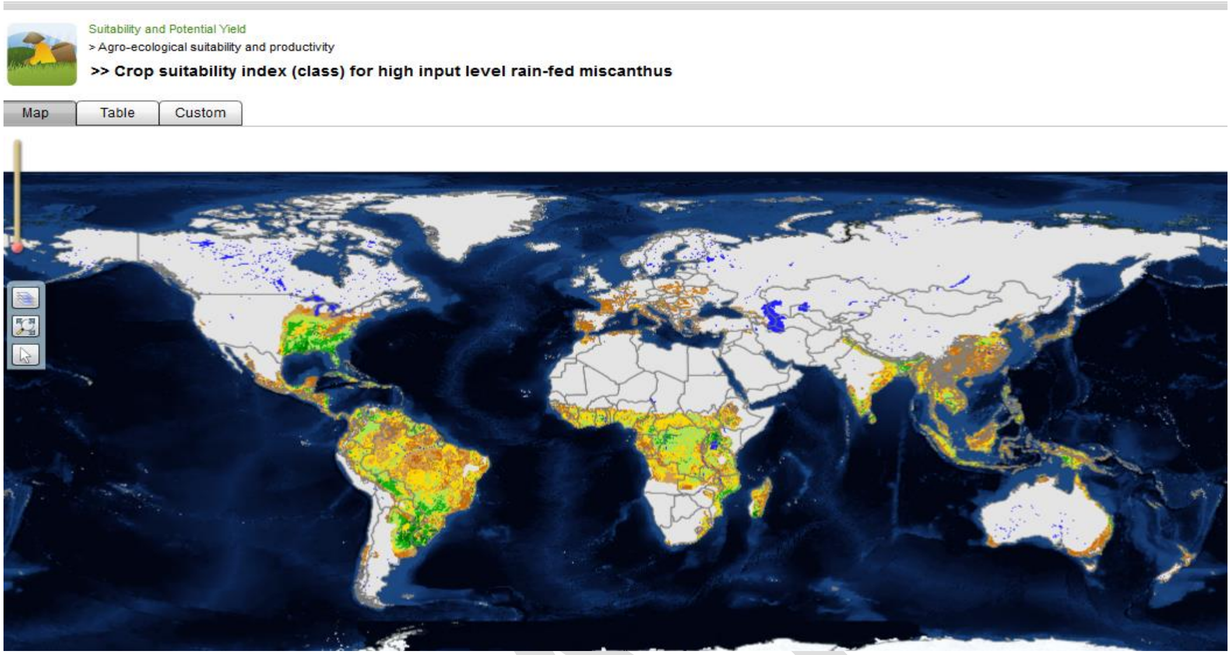
[3] FAO, *World Agriculture towards 2030/2050* (2012) notes that countries with the most available pasture, including Australia, Canada and United States among developed countries; Democratic Republic of the Congo, Madagascar, Mozambique and Sudan in Africa; Argentina and Brazil in Latin America; and China in East Asia. FAO/IIASA, *Global Agro-Ecological Zones* (GAEZ 3.0) shows all of these within climatic boundaries for effective cultivation of miscanthus.

[4] Scientific Committee on Problems of the Environment (SCOPE), *Bioenergy & Sustainability: bridging the gaps*, São Paulo (2015), notes yields of 193 GJ/ha of cellulose plus 132 GJ/ha of combustible residue are reported from ten-year trials without fertiliser in Illinois (as reported by Arundale, et al. "Yields *of Miscanthus × giganteus and Panicum virgatum* decline with stand age in the Midwestern USA," *Global Change Biology Bioenergy* (2013) 6, 1-13. 2013). Twenty years of trials in England and Denmark showed no significant response to fertiliser.

[5] Donnelly, et al., "A proposed frame-work for determining the environmental impact of replacing agricultural grassland with *Miscanthus* in Ireland," *GCB Bioenergy* (2011) 3, 247-263.

[6] Anderson-Teixeira et al. "Changes in soil organic carbon under biofuel crops," GC*B Bioenergy* (2009) 1, 75-96, suggest 1.0 tonnes of carbon per ha per year (tC/ha/yr) could be sequestered. Dunn et al. "Land-use change and greenhouse gas emissions from corn and cellulosic ethanol," *Biotechnology for Biofuels* (2013) 6:51, figure 4, shows sequestration of 0.4-0.5 tC/ha/yr for grassland and 0.55-0.65 tC/ha/yr for cropped land/pasture in Agro-Ecological Zones 7 and 10.

Global Range of Suitable Soil and Climate Conditions for Miscanthus



Approach and Accomplishments

Data Collection: Data are collected for bioenergy supply (amounts of biomass from different feedstocks) and demand (in transport, power, industrial and buildings sectors). These statistics show how each of the main types of bioenergy are developing in different parts of the world and can be used to compare production trends with potential supply or projected demand in each main end-use sector.

Global bioenergy supply and demand statistics have been collected by IRENA since 2012. These include data for production, trade, transformation and final end-uses of each main types of bioenergy (solids, liquids, gases, and renewable municipal waste) in over 100 countries. They also include more detailed bioenergy data (4 types of biogas, 6 liquid biofuels and 11 solid biofuels) for about 40 of these countries.

Statistics about electricity generation from biofuels have been collected by IRENA since 2000. These statistics are comprehensive, covering every country in the world and showing electricity generation for each of the main types of bioenergy (solids, liquids, gases and renewable municipal waste).

IRENA Online Bioenergy Yield Simulator: IRENA has created a free, publicly available simulator for bioenergy development. The online tool allows users to investigate numerous combinations of source, technology and end-use in a user-friendly manner. The simulator includes 4 modules on potential bioenergy sources (14 bioenergy crops, 30 types of agricultural residues, 9 types of livestock waste, 52 species for forest plantations), 25 production processes, and 3 end uses (transport, heating and electricity). Based on the geographic area selected by the user, the simulator indicates crops or residues suited to local agricultural and ecological conditions, productivity factors (yields); applications for the bioenergy produced, and potential issues around population density, protected areas or water scarcity.

The simulator builds on extensive literature review and expert advice. Indicated conversion values are to be taken as suggestions. Users are encouraged to provide continual advice and expert input through an included feedback form. The simulator aims to raise awareness and help users explore initial options; it is not intended as the basis for final technology choices or investment decisions.

Opportunities for Expansion

Bioenergy Data: Meeting future renewable energy targets will likely require considerable expansion of bioenergy production and use. To mobilise the large volumes of feedstock required, it would be useful to make detailed bioenergy balances available for more countries. To assess the potential for bioenergy to meet the heating and fuel demand in industry and business, it would be helpful to divide the bioenergy balances by sector. To understand the energy potential from biomass waste streams, better co-ordination between energy, agriculture, forestry and waste management statistics is needed.

While the FAO GAEZ programme has developed data for food and grass crop yields at high levels of resolution, it has not done so for wood crops, for which global average data must sometimes be used. IRENA may therefore seek to work with FAO and others to develop more detailed data for wood crops, starting at country level. It would also be useful to develop still higher-resolution data on crop and residue yields and updated data on land use and land cover for each square kilometre or smaller unit of area. Such enhanced data would improve the advice the bioenergy simulator can provide to farmers.

Sustainable Supply of Bioenergy Feedstock: Project 1.3

Success Stories in Boosting Food and Fuel Yields in Developing Countries

Background

There is huge potential to boost agricultural yields in developing countries, allowing them to provide the food they need on less land and to grow bioenergy crops on the remaining land. FAO has assessed the gap between current and potential crop yields, assuming the current mix of irrigated and "rain-fed" land. For maize, a leading cereal feedstock in biofuel production, actual yield is less than 25% of potential yield in most of Africa and India and less than 40% in most of Latin America and Former Soviet Union. Similar disparities exist for other crops. To close the gap would entail raising average global crop yield to 10.4 t/ha, more than double the 5.1 t/ha that FAO assumes in baselines projections for 2050. In this case, 527 M ha would be needed for food instead of the 1,079 M ha FAO projects, leaving 552 M ha for bioenergy crops. Biofuel from rapidly growing trees and grasses on this land could displace a third of today's transport fuel.

Several courses of action could help to raise agricultural yields. Capacity building and extension services could be expanded to spread modern farming techniques in developing countries. Fertilizer and water storage could be made more widely available. Land tenure can be strengthened to provide incentives for investment in intensive land management. Agroforestry strategies for growing a mix of high-yielding food and fuel crops could be encouraged, based on successful country experiences. In India, for example, neem oil trees provide diesel fuel for farm equipment and oil cake for fertilizer while repelling insects so that food yields increase and villages become more prosperous. Gliricidia, a fast-growing nitrogen-fixing fertilizer tree, has boosted yields of coconut in Sri Lanka and maize in Malawi and Zambia, as much as tripling yields of associated food crops. There are many examples, often described in cursory fashion in the literature, which could be detailed and disseminated to accelerate their uptake.

Objectives and Approach

The project aims to compile sustainable "success stories" in developing countries where bioenergy production has been increased without harming food production or resulting in increased land use. The stories would be elaborated through a series of brief case descriptions with four key elements:

1) ***Technology and crop yields*** (mix of crops put in place, on what scale, increase in yields obtained)
2) ***Political engagement*** (process to help stakeholders decide the mix of food and fuel crops to plant)
3) ***Market development*** (measures put in place to support commerce in bioenergy crops produced)
4) ***Investment security*** (measures to reinforce land tenure as the essential basis for investment in higher yields)

Cooperation with the IEA Bioenergy Agreement, UN Environment Programme, FAO and World Agroforestry Centre (ICRAF) would identify such success stories and provide the key elements. Project proponents would be asked to provide the details, which IRENA would edit and compile into a report. Based upon analysis of which approaches have succeeded best, IRENA would draft and vet an executive summary and suggest priorities for capacity building to help put these approaches more widely in place. The success stories would also provide useful background for country advisory services upon request.

Specific Activities Planned or Underway

Case Studies on Food and Fuel Success Stories

- IRENA will cooperate with ICRAF, the World Agroforestry Center, on a report to document cases where agroforestry strategies have been successfully implemented to jointly boost food and fuel production. The intended product is a short report on *Food and Fuel.*
- For each of six food and fuel case examples, the report will include background tables, charts, text and documentation according to a common template, to include the following technical elements:
    - The mix of crops put in place (at least one food crop and one energy crop)
    - The scale of planting (land area covered, number of farms involved, population affected)
    - Measured yields before and after the agroforestry approach was put in place,
    - Detailed plot of planting patterns (for a representative 1 ha grid of 100m x 100 m)
    - Suitability map of the range of soil and climate conditions that are applicable
    - Yield gap map showing yield improvement potential for the food crop concerned
    - Photograph of the food and fuel crops growing and the stakeholders growing them
- For each case study, as available from published literature and information available from experts at ICRAF and elsewhere, the report will also summarize assistive policies and measures put in place:
    - Technology - Crops: What advisory services were provided to stakeholders on the mix of crops that could be put in place and how they could boost yields?
    - Politics - Stakeholders: What process was put in place for stakeholders to consider and decide upon the mix of food and fuel crops to be grown, and then to help them grow that mix?
    - Economics – Markets: What process was put in place to support or develop bioenergy markets (markets for fuel, heat and power applications of the bioenergy crops being produced)?
    - Finance – Investment: What legal and regulatory measures were put in place to provide secure land tenure (the fundamental predicate for investment in higher yield practices)?

Workshop and Sourcebook on Food and Fuel Strategies for Africa

- A workshop on Sustainable Food and Energy for Africa will be held with an FAO meeting in early 2018. The workshop will focus on three interrelated topics:
    - Agroforestry/agroecology practices which strengthen both food and energy production
    - Policy measures which support local sustainable bioenergy and food production
    - Business value chains which benefits sustainable food and fuel production and supply locally
- A Food and Fuel Sourcebook will be prepared with 2-pages summaries for each of 30 to 40 wood and grass species of interest, including the following elements of agroforestry action:
    - favorable/necessary local conditions (elevation, slope, soil type, rainfall)
    - recommendations on suitable companion species to plant
    - map showing planting pattern of each food and fuel crops on a typical hectare
    - photo of the species
    - estimation of bioenergy supply (tons of wood, petajoules of energy),
    - estimation of potential carbon sequestration in air and soil

Sustainable Supply of Bioenergy Feedstock: Project 1.4

Bioenergy Potential from Recovering Waste and Residues

Background

As food production expands to meet the nutritional needs of growing populations, there is also increased production of agricultural residues. If sustainable shares of these residues were fully collected while allowing for residues that are fed to animals for meat and dairy production, substantial amounts would be left over. These could provide fuel for combined heat and power plants, process heat for first-generation biofuel production, or lignocellulosic feedstock for second-generation biofuel processes. As documented in IRENA's study on *Boosting Biofuels: Sustainable Paths to Greater Energy Security*, by collecting 25 to 50% of harvest residue and 90% of processing residue, enough advanced biofuel could be produced for a third of all current transport, or all of today's aviation, shipping and trucking needs.

Population growth, economic development, industrialisation and urbanisation are together generating larger and larger amounts of municipal solid waste, industrial waste, and construction waste. These too can provide feedstock for substantial amounts of bioenergy production, mostly likely using direct combustion in large facilities or gasification in smaller facilities to generate combined heat and power.

Various policies and measures can enhance skills and incentives to collect wastes and residues for bioenergy. Best practices on **logistics for cost-effective, sustainable residue collection** can be disseminated. Investment in cogeneration plants, with wastes and residues as feedstock, can be promoted through **standardised feed-in tariffs and power purchase agreements**, which help ensure a steady stream of revenue without a lengthy negotiating process. If these are clearly set forth and well enforced, potential investors can have confidence in their returns and assemble the needed capital. National bioenergy policies, with clear and realistic **targets** for producing electricity or biofuel from residues, as well as **financial incentives** to collect wastes and residues for energy purposes, can help ensure that cogeneration plants and biorefineries are supplied with a steady, reliable flow of feedstock.

In rural areas of developing countries, where much of the agricultural residue is located, **revenue sharing** schemes can help ensure that farmers and villagers receive a portion of the revenue from electricity and heat sales to encourage their collection efforts. **Capacity building** efforts can also play an important role by providing skills to carry out feasibility studies for finance and engineering studies to design the plants, as well as skills to build, operate and maintain steam turbines, boilers and gasifiers.

Objectives and Approach

The project would develop more detailed estimates of residue potential for biofuels and practical approaches to mobilize this potential. Several distinct lines of inquiry and action are envisioned:

- Improved estimates of practical residue potential
    - Refinement of ***agricultural*** residue potential estimates based on land use data.
    - More granular and specific estimates of ***forest*** residue potential through land use data
    - Expansion of residue potential estimates to include ***municipal solid waste***.
- Mobilization of residue potential
    - ***Best practices*** for cost effective residue collection
    - ***Policy support*** to encourage residue collection
    - ***Capacity building*** to enable residue collection

For ***agricultural*** residue, comprehensive estimates of potential have already been developed by IRENA and others at global and regional scale, using detailed data on projected food crops and yields. But there is room to refine these estimates with an overlay of land use, including infrastructure, to assess the portion which can most practically be collected in different countries. For ***forest*** residue, a similar analysis is needed. There is also a fairly large potential from ***municipal*** solid waste and construction waste, which remains to be fully evaluated for different countries and metropolitan areas. The project would develop more detailed information on the ***practical potential*** of all three major residue streams.

Best practices can be revealed through a survey of which countries, which types of farms, which management methods for planted forests, and what structures of city government and civil society for municipal and solid waste have resulted in collection of the highest shares of residues in each sector. The project would assess best practices for residue collection from farms, forests and cities. It would then work to disseminate these best practices so that IRENA members and others can adopt them.

Policy support for residue collection and use will be assessed on a comprehensive basis by examining enabling the measures that have been put in place across a range of IRENA member countries. In terms of measures to encourage the more systematic ***collection*** of residues on farms, in forests and in cities, the project will examine what financial incentives have been put in place for such collection, with a particular focus on approaches to ensure effective revenue sharing for smallholders in rural areas. With respect to measures for encouraging the ***use*** of residues, attention will center on the availability of feed-in tariffs (FIT) and power purchase agreements (PPAs) to electricity that is generated from residues, as well as on national targets for bioenergy in general or electricity generated from residues in particular.

Capacity building activities to support more thorough collection of residues for bioenergy will start with a needs survey. First the project will identify key capacities needed for effective residue collection, such as knowledge of what share of residues from different crop streams and waste streams can be collected, logistical and planning skills to collect residues efficiently, and economic and financial skills to evaluate which residue steams can be collected cost-effectively in view of local equipment and labour costs. Then the project will assess the gaps in such capacities in different regions or countries with major residue potential and suggest ways to address these gaps. Finally, the project may work with partners to develop and implement specific training activities that are tailored to the capacity building needs.

Bioenergy Potential from Restoring Degraded Land

Background

The United Nations Convention to Combat Desertification (UNCCD), which entered into force in 1996, aims to mitigate the effects of drought through national action programmes that incorporate long-term strategies supported by international cooperation, particularly in Africa. A key priority of the UNCCD is to promote Land Degradation Neutrality (LDN) which is part of the 15th Sustainable Development Goal to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." The LDN goal is to "by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world."

Substantial amounts of biomass could become available through landscape restoration efforts. Some 394 million hectares of land around the globe that has been degraded by soil erosion or other factors and is not in use as farmland, pastureland, or forest. If such land were planted with rapidly growing trees like poplar or willow in temperate climates and acacia or eucalyptus in the tropics, the land could be converted to productive managed forest, providing wood, energy and carbon uptake.

The "Bonn Challenge" which was issued by civic, business and government leaders in 2011, calls for 150 million hectares of degraded and deforested land to be restored by 2020. IUCN, the International Union for Conservation of Nature, has found that meeting this goal could sequester a billion tonnes of carbon dioxide per year. The New York Declaration, promulgated in 2014, calls for another 200 M ha to be restored by 2030, reducing yearly carbon dioxide emissions by as much as another 1.7 billion tonnes. Substantial progress is being made towards these goals; the second international Bonn Challenge conference reported in March 2015 that 60 M ha had already been restored by Challenge participants. There are also specific regional initiatives that contribute to these goals, such as the 20 x 20 program for Latin America and the Caribbean (20 M ha by 2020), the Great Green Wall in Sahelo-Saharan Africa and the AFR100 initiative to restore 100 M ha (two thirds of which has been pledged by 17 countries).

But how much bioenergy supply could be associated with these reforestation efforts is not well understood. This is largely because the degraded land has not been completely surveyed as to its suitability for different crops and the yields that could be obtained. Since rapidly growing tree species in different climates typically yield around 10 t of wood[7] or 190 GJ per ha[8] per year under average water conditions, meeting these goals could perhaps provide 67 EJ of primary bioenergy. But since degraded forests often have hard or eroded topsoil, it is possible that lower yields would be more typical. To judge from yields in China's ongoing efforts, perhaps just half this amount (33 EJ) would materialize.[9]

[7] German Poplar Commission, *Poplars and Willows in Germany: Report of the National Poplar Commission*, German Federal Ministry of Food, Agriculture and Consumer Protection (2012), notes poplar yields of 10 t/ha under average water conditions, ranging from 6 t/ha with poor water supply to 20 t/ha with high rainfall. M.J. Aylott, E. Casella, I. Tubby, N.R. Street, P. Smith and G. Taylor, "Yield and spatial supply of bioenergy poplar and willow short-rotation coppice in the UK," *New Phytologist* 2008; 178(2): 358-70, report mean yields of 4.9-10.7 t/ha but also note varieties with mean yields up to 13.3 t/ha in the second planting rotation. IPCC, *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (2003), Annex 3A.1, suggests yields of 6-15 t/ha for pine, 10-15 t/ha for acacia, and 11-26 t/ha for eucalyptus if ranges of growth in table 3A.7 are multiplied by densities in table 3A.9.

[8] Biomass Energy Centre, www.biomassenergycentre.org.uk notes energy content of 19.0 GJ/t at 0% moisture.

[9] Z. Jiang and S.Y. Zhang, "China's Plantation Forests for Sustainable Wood Supply and Development," XII World Forestry Congress (2003). Some 13.33 M ha of plantation forest are to yield 130 M m^3 of wood or around 10 m^3/ha. For the species

In addition, there is little agreement on how much wood and residues could be harvested from the reforested areas for energy use on a sustainable basis. How much could be harvested consistent with maximizing carbon sequestration over time? How does this depend on the pace at which trees grow over their life cycles? Which species could sequester the most carbon and provide the most biomass feedstock in different places? What are effective strategies for balancing carbon sequestration objectives with wood harvest, cascading use of wood products, and conversion of wood to energy?

Objectives and Approach

The project has two distinct but interrelated areas of focus:

1) Survey of degraded lands and potential yields from their restoration
2) Assessment of sustainable bioenergy extraction from restored landscapes

For the survey of ***potential yields*** from restoring degraded lands, several elements of effort are foreseen:

- Confer with Global Partnership on Forest Landscape Restoration (GPFLR), which is coordinating pledges towards the Bonn Challenge, on what pledges have been made by which organisations in which countries and regions, to restore how much land in what specific places, as well as what specific trees or other crops they may anticipate planting, with what projected yields. Also confer with partners involved in implementing the New York Declaration for similar information.
- Work with the Food and Agricultural Organisation (FAO) and other partners to overlay Bonn and New York pledges on maps of degraded forest and crop suitability, in order to understand which degraded lands are still available for further restoration efforts and what could be planted there.
- Review literature and consult with member countries and partner organisations to catalogue forest restoration efforts that have been conducted so far and the yields they have achieved.
- Based on the wood yields obtained or anticipated on restored forest land, assess the amount of wood growth per annum that could be expected from achieving the Bonn and New York goals.

For the assessment of ***sustainable bioenergy extraction***, analysis could include the following elements:

- Confer with forest associations, research institutions and non-governmental organisations about yearly harvest that is typical in planted forests, as a share of annual biomass accumulation.
- Assess what portion of the yearly harvest could be considered sustainable, assuming that the carbon accumulated in the harvested wood were paid back in carbon savings within 20 years, considering different scenarios about the fossil fuels displaced by the bioenergy produced.
- Based upon the assessment of sustainable annual harvest per amount of biomass accumulated, and the survey analysis of wood growth per annum from reaching the Bonn and New York goals, evaluate the sustainable annual harvest that might be anticipated from achieving these goals.
- Convert the sustainable annual wood harvest from achieving the Bonn and New York targets to billions of kilowatt-hours of electricity that could be generated or billion litres of fuel refined.
- Assess the portion of sustainable harvest potential and associated energy production that could practically and economically be collected, in view of the anticipated density of crop production, availability of labour to harvest the crops, and availability of infrastructure to transport the crops.

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planted, weights of 530 kg/m^3 for fir, 350-560 for pine, 590 for larch, 670 for birch and 420 for willow are given at www.simetric.co.uk, implying typical yields of 3.5 to 6.7 t/ha.

Specific Activities Planned or Underway

Three specific activities related to bioenergy potential from landscape restoration are commencing:

- Working paper on how bioenergy can contribute to land degradation neutrality
- Assessment of sustainable bioenergy potential from AFR100 pledges.
- Evaluation of sustainable energy extraction from REDD+

Working Paper on Sustainable Energy Options and Implications for Land Use (with UNCCD)

- IRENA and UNCCD are cooperating to assess how bioenergy and other renewable energy resources may contribute to the goal of Land Degradation Neutrality. Increased use of renewables can require a great deal of land. Conversely, land-based activities such as agriculture and forestry depend upon the availability of energy and water. Thus, joint analysis of land and energy is key to understanding effective and practical strategies for halting land degradation, ensuring food security, and providing sustainable energy for all. The objective of the project is to help policy makers understand how renewable energy technologies can help restore degraded land or prevent land degradation.

- A working paper and policy brief will be prepared, with elements including
  - A brief assessment of emerging renewable energy technologies and their infrastructural and distribution impacts on land resources both on-site and downstream.
  - A review of incentives, policies and governance regimes that affect energy production and land use, with examples of best practices that show ways to protect and manage land resources while scaling up investments in clean energy production and distribution.
  - An assessment of how renewable energy can contribute to meeting the sustainable development challenges for food and water security.
  - A review of climate change impacts on the land, energy and water nexus, with land use planning and management options for massive scale-up of renewable energy production.
  - An explanation of how achieving land degradation neutrality will contribute to ensure access to affordable, reliable, sustainable and modern energy for all.

REDD+ (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries)

- Article 5 of the Paris Agreement of the UN Framework Convention on Climate Change (UNFCCC) calls for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. As of late 2016, 47 countries had initiated REDD+ preparations including 18 in Africa, 18 in Latin America and 11 in the Asia-Pacific. Each country is to examine its land use and forestry policies which may include reviewing the balance between wood energy potential and other roles of forests.

- This study will assess global wood energy potential in light of developing countries' climate change mitigation polices as indicated in their pledged Nationally Determined Contributions (NDCs) and REDD+ strategies. Both theoretical potential and potential through 2030 will be addressed. The study also aims to analyze how countries are planning to meet the energy production needs in reconciling with REDD+ safeguard policies such as adequate food supply, health, economic livelihoods, rights of indigenous peoples, ecosystem services, and conservation of biodiversity.

- The study will examine wood energy use in all countries that have initiated REDD+ preparations. GIS mapping will be used to develop a consistent baseline of current wood use. Country policies for implementing REDD+ will be catalogued, and their likely impacts on wood supply will be assessed. Sustainable wood supply potential for bioenergy use from REDD+ measures will then be projected.

Sustainable Bioenergy Potential from AFR100 Pledges

- Africa is seen as the leading continent for the Bonn Challenge, as pledges under the AFR100 initiative account for half the total commitments made so far. Several countries have underlined their pledges by assessing their restoration potential. Rwanda and Kenya have already published national restoration opportunity maps, and other countries are expected to follow.
- IRENA will evaluate the sustainable bioenergy extraction from Bonn/AFR100 pledges. The initial focus will be on Rwanda and Kenya, utilizing data from the restoration opportunity assessments by World Resources Institute and IUCN. Yields for each suitable restoration type will be estimated using literature research, expert interviews and a dynamic global vegetation model called LPJmL. The methodology should be easily adaptable to study additional countries as further restoration opportunity assessments are undertaken and completed.

Sustainable Supply of Bioenergy Feedstock: Project 1.6

Best Practices for Sustainable Forestry

Background

Greenhouse gas balances from forestry play a vital role in keeping global emissions in check. While carbon is emitted in the mnufacture of wood products and combustion of wood and forest residues for heat and power, and while methane is emitted from wood and paper in landfills, greenhouse emissions are avoided through recycling, through substitution of wood for other materials in building construction, and through substitution of electricity from pulp and paper mills for electricity generated from coal or gas.[10] By providing economic incentives to maintain and expand forests, production of biofuels and wood products can enhance carbon sequestration while displacing oil and boosting energy security.

Forests cover roughly 40% of all the land in Europe - some 1,020 million hectares – accounting for roughly a quarter of global forest resources. They are expanding by some 800,000 hectares per annum – nearly one percent per year – while providing a variety of useful wood products and energy.[11] Scandinavian countries have had particular success in extracting value from forests while supporting forest expansion, and their experience could serve as a useful model for others. In Sweden, for example, forest cover has increased by 80% in the last century, and output of wood has also grown.[12] A recent report indicates that a further increase of 80% is possible in forest output, with "a potential for increasing extraction of forest fuel in Sweden, from current levels of approximately 50 PJ to almost 90 PJ, without negative consequences for the environment or forest production objectives."[13]

Yet policy makers and the public are generally unaware of the dynamic at work in productive forests. From a static perspective, harvesting wood from planted forests brings an end to carbon sequestration by the trees that are harvested, while converting the wood to useful energy results in carbon emissions. But from a dynamic perspective, the ability to profit from wood and wood energy creates incentives for foresters to plant new trees which will sequester carbon more rapidly than the old trees they replace, and to grow more trees on each hectare of land to boost wood and energy output and carbon uptake. Meanwhile, increased wood output means greater substitution of wood for more carbon-intensive concrete in buildings, and increased energy production from wood pellets and residues means greater reduction of carbon emissions from fossil-fueled furnaces and power plants. If the dynamic process can

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[10] FAO – Food and Agricultural Organization (2010), "Impact of the global forest industry on atmospheric greenhouse gases," *FAO Forestry Paper 159*, reports in detail on greenhouse balances of forestry in 2006-7. Gross emissions of 890 Mt CO_2-e included 490 Mt in manufacturing (due to fuel combustion and electricity purchases), 238 Mt from the end of wood product life cycle (almost all methane emissions from rotting wood and paper in landfills), and 162 Mt from wood production, chemicals and fossil fuels upstream of manufacturing plants, and transport of wood products to market. These emissions were countered by 424 Mt sequestered in forest products, leaving 467 Mt CO_2-e of net emissions from forestry. There were also avoided emissions of 809 Mt outside of forestry, including 300 Mt from recycling (avoided landfill methane emissions) and 483 Mt from substitution of wood for other building materials, resulting in *net sequestration* of 342 Mt even without avoided emissions from substituting electricity in pulp and paper mills for fossil-fueled electricity and from keeping land in forest.

[11] UPM Biofuels, "UPM – Driving Cleaner Traffic" – Presentation at International Advanced Biofuels Conference, Stockholm, September 16-17, 2015.

[12] Cecilia Ruthström-Ruin, Ambassador, Swedish Embassy in Vilnius, keynote address to Nordic Baltic Bioenergy Conference, Vilnius, Lithuania, 19 April 2016.

[13] J. de Jong, et al (2014), *Consequences of an Increased Extraction of Forest Biofuel in Sweden – A Syntheses from the Biofuel research Programme 2007-2011: Summary of Syntheses Report*. Swedish Energy Agency report ER2014:09 IISSN 1403-1892) and IEA Bioenergy Agreement, Task 43, report 2014:01.

be carefully explained, showing how active engagement can increase net forest cover and carbon sequestration over time, it should be possible to build support for wood bioenergy.

Objectives and Approach

The project would carefully document the forestry management practices in Finland, Norway and Sweden, in cooperation with forest product companies and research institutions. Documentation would include the mix of trees planted, the yields obtained, the means employed to boost yields, the life cycle of planting to optimise yields and carbon sequestration over time, increasing output of wood products and energy over time, and assessment of forest growth and net carbon sequestration achieved. Based upon historical practices and trends, the future potential for further increases in wood output, energy production from wood and wood residues, and forest carbon sequestration would be projected. The mix of skills and management techniques employed would also be assessed with a view to designing capacity building activities to transfer best practices to other countries with major forest industries.

Sweden could be the first country of focus, in light of work on sustainable forest potential so far. Discussions with Swedish government, forest industry and research institutions would assess the pace at which wood and energy output from forests could grow over time in Sweden. Considering the increase from 50 PJ to 90 PJ of annual forest fuel extraction that has already been assessed as sustainable, what period of time would be required to reach this potential, under realistic assumptions about relative prices in wood, heat and electricity markets going forward and policy supports such as feed-in tariffs? What would be the associated annual increment in wood and energy production? What would be the potential contribution to IRENA REmap projections of bioenergy needed to double RE by 2030?

In addition to assessing the technical and practical resource potential, the work would focus on the key success factors that have made it possible for Swedish forestry to be managed so sustainably. Interviews would be conducted with lead experts at government agencies and forestry associations about the success factors behind sustainable forestry in Sweden. The main success factors identified would be distilled from the interviews and incorporated in the project report for communication to other countries wishing to increase investment in sustainable energy production through forestry.

Ideally, such analysis would provide the technical underpinning for pledges by forest industries in different countries to boost carbon uptake in forests along with wood and energy output. Results could be shared with a broad range of interested countries, which would likely include Canada and the United States in North America, as well as a wide range of heavily forested countries in Europe and Asia. Outreach would be done in through workshops organized in partnership with the United Nations Economic Council for Europe (UNECE) and the Food and Agricultural Organization (FAO), among others.

Cost-Effective Technology for Bioenergy Conversion: Project 2.1 (in progress)

Technology for Advanced Liquid Biofuels in Transport

Background

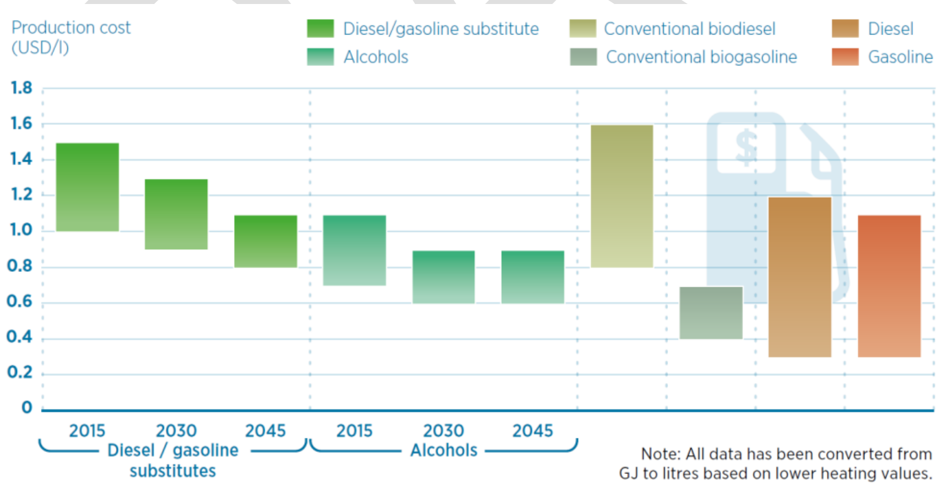
Liquid biofuels provide the only practical alternative to fossil fuel for airplanes, ships and heavy freight trucks. Advanced biofuels, using lignocellulosic feedstocks, waste and algae, can vastly expand the range of resources for fuelling light and heavy transport alike. Such advanced biofuels can be refined from agricultural residues (associated with food crops), forest residues (such as sawdust from lumber production), rapidly growing grasses (like switchgrass and miscanthus), and short rotation tree species (such as poplar and eucalyptus). Residues do not compete with food or lumber production but grow along with it. High-yielding grasses and trees can grow more energy per unit of land area than conventional biofuel crops, avoiding carbon-releasing land use change and leaving more land for food crops.

Approach and Accomplishments

IRENA's study of ***Renewable Energy Innovation Outlook: Advanced Liquid Biofuels*** provides a comprehensive view of advanced biofuel potential and steps to achieve this potential. It examines:

- Practical and economic potential for advanced liquid biofuels
- Biofuel technology pathways and innovation opportunities
- Trends in advanced biofuel technology deployment
- Measures to support advanced biofuel commercialisation.

The analysis indicates that by 2045, advanced biofuels would likely cost US$0.60-$1.10 per litre to produce. At oil prices under $80 per barrel, it would be hard for advanced biofuels to compete with fossil based gasoline and diesel. But at oil prices above $100, most advanced biofuels could compete effectively.

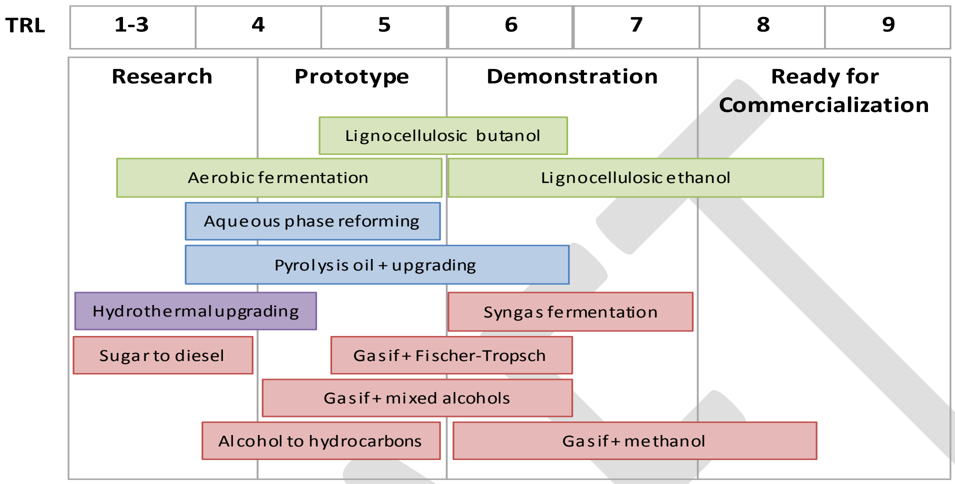


Current and Projected Fossil Fuel and Biofuel Production Costs

The study identifies opportunities for innovation across a wide spectrum of advanced biofuel conversion pathways, with apecific focus on improvements in process integration and energy system integration:

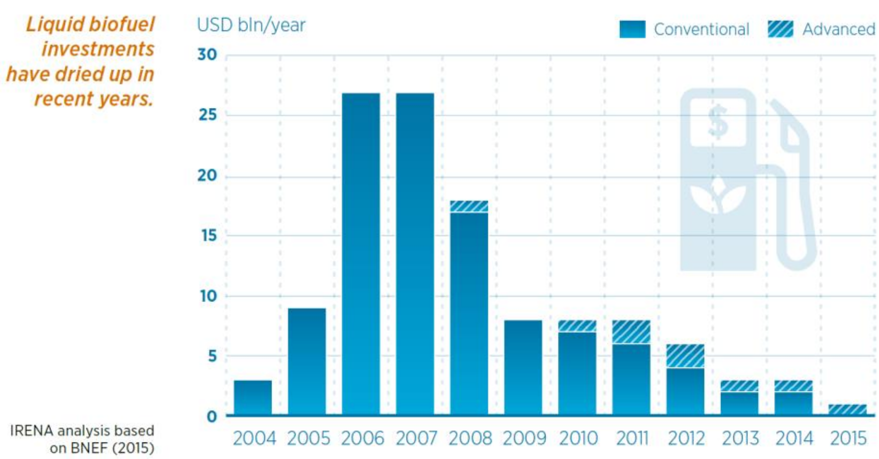
- **Hydrolysis and fermentation** could be greatly reduced in cost by integrating the two steps to reduce enzyme loading, modifying fermentation organisms, and applying membrane separation.
- **Pyrolysis** has high efficiency and potentially low processing costs with decentralised production, but more effective catalytic upgrading processes are needed.

- **Gasification** needs to prove reliable long-term operation in view of feedstock contaminants. Process optimisation is also needed to achieve target syngas composition.
- **Fischer-Tropsch processes** need proof at commercial scale. Small-scale modular units may help.
- **Alcohol (ethanol and methanol) fermentation from syngas** could benefit from modification of fermentation organisms to improve tolerance to contaminants, raise yields and boost selectivity.



Commercialisation Status of Various Advanced Biofuel Conversion Technologies

Despite the economic and practical promise, investment in advanced biofuel plants has slowed. A variety of measures to support technology development, markets and enterprise formation are identified. These include grants to build pilot plants that can test technical concepts at commercial scale, loan guarantees to reduce the risks of such plants to lenders, incentives and targets to encourage biofuel conversion from lignocellulosic feedstocks, public procurement initiatives in subsectors like aviation and freight shipping and identification of co-products like fuel additives, chemicals, plastics and cosmetics to boost profits.



Declining Global Investment in Advanced and Conventional Biofuels

Results of the analysis were published in 2016 and disseminated in a range of international fora, such as the 24th European Biomass Conference and Exhibition (Amsterdam, June 2016) as well as the *Journal of the American Chemical Society*. A follow-up technology brief on biojet fuel for aviation is anticipated.

Cost-Effective Technology for Bioenergy Conversion: Project 2.2 (in progress)

Technology Pathways for Ethanol from Agro-Processing Residues

Background

Many countries with substantial agricultural output have large agro-processing industries to process and package the food produced in agricultural areas so that it can be distributed to broader markets. Typically the agro-processing facilities are located near the farms where food is produced to minimize transportation costs, as the raw food products and associated residues are bulkier than the finished food products. This means that the residues associated with food crops, which account for a substantial percentage of the overall calorific value, can be used to provide process heat for agro-processing plants. Alternatively, the residues gathered within agro-processing plants can serve as a convenient feedstock for production of ethanol as a liquid biofuel for transport, which can be transported over long distances.

The pattern of residue streams in Ghana offers a sense of which types of residues are most important:

Type of Residue	Estimated Methane Potential (Thousand Cubic Meters Per Year)	Potential Electric Capacity (Kilowatts Installed)
Oil Palm Processing	[11.755/h [x.5 x 8760 =] 51,487	37,617 – 45,846
Fruit Processing	5,324 – 7,756	1,639 – 2,725
Cocoa Processing	4,720	2,013 - 2,454
Starch from Cassava	6,133	2,620 – 3,190
Brewery Process	630	325 – 395
PROCESSING TOTAL	**70,726**	**44,214 – 54,610**
Livestock: Cattle	119,087	50,813 – 61,925
Livestock: Sheep	54,305	23,170 – 28,239
Livestock: Goats	89,725	38,283 – 46,657
Livestock: Pigs	24,632	10,510 – 12,809
Livestock: Poultry	17,509	7,471 – 9,105
LIVESTOCK TOTAL	**305,258**	**130,247 – 158,735**
Maize Cobs and Stalks	353,430	150,797 – 183,784
Millet Straw	34,697	14,804 – 18,042
Rice Straw	186,126	79,414 – 96,786
Sorghum Stalks	17,909	7,641 – 9,313
Yam Straw	661,745	282,344 – 344,108
LIGNOCELLULOSE TOTAL	**1,253,907**	**535,000 – 652,033**

Source: German International Cooperation Agency (GIZ), Biogas in Ghana (2014)

Approach and Accomplishments

IRENA has pursued two specific areas of activity related to conversion of agro-processing residues to ethanol, in cooperation with the Japan International Research Center for Agricultural Sciences (JIRCAS). The first activity area is to help develop ***technology*** for bioethanol fermentation from cassava pulp. The second is ***economic and environmental impact assessment*** of ethanol production from cassava.

In the first area, technology, a major outcome has been to identify robust yeast for ethanol fermentation from local environment which is tolerant to both high temperature and acid environment. This is expected to improve ethanol fermentation performance from agro-processing waste, which is usually contaminated with different types of bacteria producing organic acid. Follow-up investigation will focus on optimal fermentation conditions using identified yeast and cassava residue.

In the second area, the economic feasibility and greenhouse gas impact of ethanol fermentation from cassava residue has been assessed, and an integrated indicator for sustainable bioenergy conversion from cassava has been developed. Bioethanol from cassava residue in Western Africa was found to be cost-competitive with imported ethanol but not with local gasoline. Impacts of feedstock transport distance on delivered fuel costs and greenhouse gas emissions were assessed. A simple tool based on Geographical Information Systems (GIS) was developed to assess logistical options to match fuel supply and demand. Potential for briquette or electricity production from agricultural residues such as groundnut shells, cocoa husks, corn cobs and oil palm empty fruit bunches was matched with heat and power demand in Ghana.

Follow-up work is investigating the feasibility of smaller scale ethanol fermentation system (2.5 kL annual ethanol production, for example) to simplify feedstock logistics and lower transport costs and greenhouse gas emissions. The assessment of transport costs and emissions is being refined to explicitly include road networks and other geographic feature. Data will be analysed to assess the job, income and emissions benefits of using cassava for transport fuel as compared with heat, power, or combined heat and power.

In 2016-2017, the IRENA-JIRCAS cooperation project is focusing on two main objectives:

(1) Develop the guidelines to find economically, socially and environmentally optimum pathways for bio-ethanol generation from cassava residues and other residues (to be conducted by JIRCAS) and

(2) Development of tools and frameworks to support feasible investments and adoption of relevant technologies at country level in Ghana and Nigeria (to be conducted by JIRCAS and IRENA)

   (i) a comprehensive assessment of policy guidance, resource availability and technical potential
   (ii) a detailed evaluation of farming and processing costs, including all investment costs, and
   (iii) a comparison of price trends for agricultural residues and bioenergy made from them.

Using the collected data and information, together with results of on-going JIRCAS research on optimal fermentation technology to produce quality ethanol from cassava residues in Nigeria, a tool will be developed to analyze the sustainability, feasibility and social and environmental benefits of the proposed investments. Gender-specific employment opportunities (social impacts), GHG emission reductions (environmental impacts) and financial cash flow analysis (economic impacts) will be assessed. In 2017, the tool will be tested for agro-processing residues in Ghana with a view to finding the simplest possible guidelines for bio-ethanol production from such residues in developing countries of Africa.

The following tools have been developed or are slated for development by the JIRCAS-IRENA cooperation with a view towards possible incorporation into the IRENA Project Navigator.

(a) an ***integrated socioeconomic evaluation tool*** for IRENA's Project Navigator to assess social, economic and environmental impacts using GBEP bioenergy sustainability indicators and FAO's Bioenergy and Food Security (BEFS) Rapid Appraisal tool (tool developed and initial analysis attempted in 2013-2014, analysis to be completed in 2017).

(b) a ***GIS analytic tool*** to find locations of 100 kW biomass combined heat and power plants by identifying where more than 2500 t/y of biomass can be collected (tool developed and initial analysis attempted in 2014-2015, analysis to be completed in 2017).

(c) a ***planning tool*** to develop financially feasible and sustainable bio-ethanol production investment plans from cassava farming and residues (to be completed in 2017).

Cost-Effective Technology for Bioenergy Conversion: Project 2.3

Biogas Technology Assessment for Different End Use Sectors

Background

Biogas is a modern form of bioenergy produced through anaerobic digestion or fermentation of food waste, agricultural residues, manure, and sewage, or collected from landfills. It is an exceptionally versatile fuel form which can be used for heating, cooking, combined heat and power (CHP) generation, and (when upgraded to methane) transport. It can also provide dispatchable energy to power grids so that a higher share of electricity can be generated from variable wind and solar energy. Biogas typically contains 50% to 75% methane, which provides its energy content, and 24% to 50% carbon dioxide.

With its wide variety of feedstocks and applications, biogas has a very substantial energy potential. But only a very small portion of the potential has been realised. Biogas accounted for just 1% of renewable energy use in 2010. Yet IRENA's REmap analysis indicates that a cost-effective pathway to doubling renewable energy by 2030 would also entail a four-fold increase in biogas use to contribute 2% of the doubled renewable output in 2030[14]. Over the longer term, the World Bioenergy Association estimates that biogas could provide 6% of total (renewable and non-renewable) global primary energy supply[15].

Biogas for Combined Heat and Power (CHP): Several countries have used biogas from agricultural residues for combined heat and power production to energize rural communities and industries. But there are also other technical pathways to utilise residues for CHP, most notably direct combustion. These other pathways may be particularly attractive for lignocellulosic residues, which form the greatest share of agricultural residues available, because these residues are relatively hard to digest into gas and require relatively complex and costly predigestion processes. But there are prospects for lowering the costs of such treatment processes over time, and biogas has significant advantages over direct combustion such as higher system efficiency and reduced emissions of carbon dioxide.

In this light, it is of interest to assess the current and projected costs and greenhouse emissions of biogas for combined heat and power in relation to alternative uses of agricultural residues such as direct combustion or conversion via thermochemical or biochemical pathways to liquid biofuels. It is also of interest to assess the mix of policy measures and financial incentives that have been used to introduce biogas for combined heat and power applications, to disseminate those which are most effective.

Biogas for Cooking: Biogas is an important option for fueling modern cookstoves to displace the use of traditional cookstoves in developing countries. Traditional cookstoves, typically fueled by wood or charcoal, are inefficient and therefore require rural households to spend more than necessary to purchase fuel, require women and children to spend more time than necessary to collect fuel, and put more pressure than necessary on wood resources in forests. They are also dirty, generating indoor air pollution which results in significant sickness and death. Modern cookstoves, which are two to three times efficient and much cleaner, can significantly alleviate all of these problems. Such modern cookstoves can also use wood or charcoal fuel, but biogas provides additional advantages including easier transport and storage. Direct use of biogas for cooking is a common practice in several emerging and developing economies in Africa and Asia. Some 50 million biogas cookstoves have been installed.

Biogas for Transport: Biogas can be upgraded to methane for use in vehicles fueled by natural gas. There were some 23 million natural gas vehicles worldwide in 2015, with the largest numbers operating

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[14] IRENA (2014), *Remap 2030 – A renewable energy roadmap*.
[15] World Bioenergy Association (2013), *Biogas – an important renewable energy source*.

in Argentina, Brazil, China, India, Iran, Italy, Pakistan which had more than 1 million each. The methane can also be converted to compressed natural gas (CNG) for use in freight trucks and marine shipping.

Biogas for Power Grids: Biogas can play a useful role in regulating the operation of electric power grids, helping to mediate the fluctuations in generation from intermittent wind and solar resources so as to facilitate a larger share of renewable generation in the electricity mix. For example, in countries with substantial wind resources that are sometimes in excess of immediate demand (such as Denmark and Ireland), surplus wind generation can be used to hydrolyze water into hydrogen and oxygen, and the hydrogen can be combined with carbon dioxide emissions from fossil-fueled plants to make methane.[16]

Objectives and Approach

Biogas technology assessment is being undertaken through technology briefs prepared by IRENA in Cooperation with the IEA Energy Technology Systems Analysis Programme (ETSAP). These technology briefs contain four standard sections: technology process status, cost-competitiveness, market potential, and barriers and opportunities. A technology brief on biomass for heat and power, including biogas in relation to other options, was published in January 2015. Technology briefs on biogas for ***cooking*** and on biogas for ***transport*** are in advanced stage of preparation as of late 2016. These technology briefs incorporate information on technology options for converting different biomass feedstocks to biogas, as well as on technology options for converting biomass to useful energy services. A technology brief on gasification of biomass for ***power*** is under consideration.

A follow-up project for more in-depth analysis of biogas for combined heat and power could assess the costs and greenhouse gas emissions of producing CHP from residue-derived biogas as compared with direct residue combustion. It could identify several countries where CHP from biogas has gained considerable traction and highlight the policy mechanisms that have led to success.

[16] See IEA Bioenergy, Task 37- Energy from Biogas, *A perspective on the potential role of biogas in smart energy grids.* Presentation by J.D. Murphy, the task leader, at IRENA/IEA Workshop on Mobilising sustainable bioenergy supply chains, Rome, 17 May 2016, notes per experience in Ireland that electrolysis can be accomplished at 70-90% efficiency, methanation at 8-90% efficiency, for an overall efficiency of methane production of 55-80%

Cost-Effective Technology for Bioenergy Conversion: Project 2.4

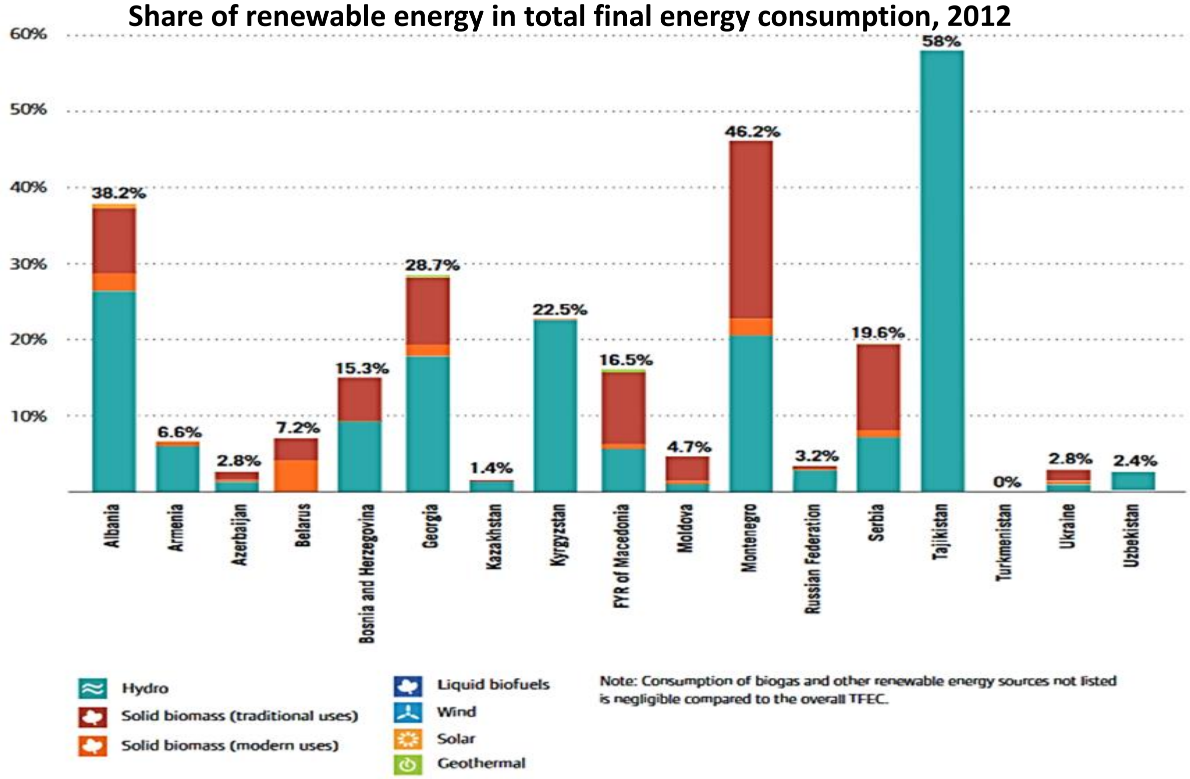
Biomass Heating Technology for Buildings and Communities

Background

Modern technologies are available to make highly efficient use of biomass to heat and cool buildings. Modern furnaces and district heating systems can provide efficient, affordable heat production from abundant wood resources in heavily forested developed countries, displacing the use of fossil fuels and thereby reducing carbon emissions and energy import bills. In Lithuania, over 60% of district heating is supplied by modern furnaces and boilers, converting wood chips to heat at 85% efficiency. In Germany, over 8 million modern furnaces, also highly efficient, use wood pellets as fuel to heat around two-fifths of all homes. In Asia, where some densely populated office districts in urban areas are using district cooling systems fuelled by natural gas, it could be possible to fuel them instead by biomass.

But potential far from fully realized. For example, several countries in Southeast Europe rely on solid biomass for 10 percent or more of their total final energy consumption. As shown in the chart below, these include Albania, Georgia, FYR Macedonia, Montenegro and Serbia. Yet in each of these countries, modern uses (in orange) are only around 10% or 20% of the total solid biomass use (orange plus red).[17]

Share of renewable energy in total final energy consumption, 2012



In this light, it is of interest to catalogue the range of modern biomass technologies that have been put in place for heating applications in buildings and communities, and to assess their cost-effectiveness and environmental benefits relative to fossil-fueled alternatives. It is also of interest to assess the mix of policy measures and financial incentives that have been used to encourage the use of modern biomass furnaces and district heating systems, so that countries may adopt those which are most effective.

[17] Gianlcuca Sambucini, UN Economic Commission for Europe (UNECE), "UNECE Renewable Energy Status Report: Focus on Bioenergy." Fourth Bioenergy Week, Global Bioenergy Partnership (GBEP), Budapest, 21 June 2016.

Objectives and Approach

The project would survey the countries with the highest shares of modern biomass use for heating, including those with the highest share of solid biomass use in district heating systems for urban communities and those with the highest share of biomass use in furnaces for individual dwellings. The survey would examine the technologies applied, the economic and environmental effectiveness of these technologies in displacing fossil fuels for heating, and the policies used to promote these technologies.

Each technology would be characterized in terms of capital and operating costs (both total costs and cost per unit of heat supplied), the types of solid biomass feedstock used (such as wood from different tree species in forms such as pellets or chips, or agricultural residues from different crops), unit size and corresponding volume of feedstock required, and overall efficiency for converting solid biomass to heat. Based upon the characteristics compiled and documented, an assessment would be made of the best biomass district heating systems for communities and the best available biomass furnaces for homes.

For the countries with the highest shares of modern biomass use for heating, an analysis would be done of the cost savings and emissions reductions achieved (and projected to be achieved in future) through the displacement of fossil fuel (either direct fossil fuel use for heating or fossil fuel use for electric heat), as well as the amounts of fossil fuel displaced as a share of overall fossil fuel use and fossil fuel imports. In addition, the project would catalogue the policies used to promote biomass use for heating, such as mandatory or voluntary targets, grants, loan guarantees, investment credits, preferential tariffs, and competitive bidding to supply heat to district heating systems or large orders of furnaces for homes. Based upon analysis of which types of policies have yielded the highest shares of technology penetration in the marketplace, the project would recommend policy packages for countries to consider.

Cost-Effective Technology for Bioenergy Conversion: Project 2.5

Technology for Biomass Energy with Carbon Capture and Storage – BECCS

Background

BECCS – bio-energy combined with carbon capture and storage - could make possible carbon negative energy production and use. IPCC assessments indicate that around 600 Gt of CO_2 needs to be removed from the atmosphere over this century, or about 6 Gt per year. Primary bioenergy use is currently around 60 EJ per year, equivalent to about 4 Gt dry biomass or 6 Gt of CO_2 per annum. It is projected that primary bioenergy deployment can nearly double by 2030, if proper policies are put in place, bringing the total amount of CO_2 from biomass to some 12 Gt per year by 2030. Nearly half of this biomass, containing over 5 Gt of CO_2, could be used in large scale industrial processes such as combined heat and power plants or biofuel refineries where CCS can be cost-effectively deployed. That would provide a very large share of the yearly storage requirement identified by the IPCC. Indeed, recent analysis indicates CCS and BECCS may be essential to meeting emissions reduction targets.

Research, development and demonstration efforts have made significant progress over the last two decades in reducing capture costs and identifying storage potential. Combustion of biomass in large-scale plants for electricity or for combined heat and power should generate exhaust streams with similar concentrations of carbon dioxide to combustion of fossil fuels for these purposes, which are typically 10 to 20 percent, so the costs should be similar. For carbon capture from advanced biofuel production processes, which may generate gaseous mixtures with up to 90 percent carbon dioxide, the capture should be easier and the costs should be lower. With respect to storage, the vast capacity which has been identified in RD&D efforts focused on the fossil fuel industry can equally benefit potential storage of carbon dioxide from power plants and combined heat and power plants fueled by biomass.

Objectives and Approach

In this light, the Outlook will document the projects for carbon capture and storage that have been put in place, including those in which biomass has played a role and in which just fossil fuels are involved. It will assemble information on the current and projected costs, the amount of carbon storage capacity relative to projected energy requirements and associated emissions, and the anticipated timeframes for cost reduction and storage capacity expansion. It will also catalogue the mix of R&D programs, policy measures and financial incentives that have been put in place to support the development of carbon capture and storage technologies and suggest desired adjustments to accommodate biomass.

The Outlook will then assess the prospects for bio-energy with carbon capture and storage (BECCS) with particular focus on specific technologies to be utilized, the scale required, and the costs anticipated. The assessment will be based as much as possible on current and planned projects, involving the use of biomass either exclusively or in combination with fossil fuels. The assessment will also model likely costs from BECCS projects on the basis of CCS projects already completed, making use of statistical and econometric tools to relate the costs per unit of energy and carbon capture to the project scale. Based on projections of biomass use in different markets (transport, power, industry and buildings) and the scale of individual projects associated with such use, along with analysis of projected scale at which CCS is likely to be cost-competitive in 2030, the Outlook will estimate the potential for cost-effective BECCS.

Cost-Effective Technology for Bioenergy Conversion: Project 2.6

Energy Cane for Biodiesel: Evaluation of Technical and Economic Potential

Background

Among the crops used to produce biofuel today, sugar cane is one the most of the most widespread and highest yielding. Its typical yields per hectare are substantially higher than those for maize and palm.

Feedstock	Total Dry Biomass (t/ha)	Grain or Sugar (t/ha)	Easy Access Biofuel (GJ/ha)	Cellulosic Content (GJ/ha)	Residue Content (GJ/ha)	Total Energy Content (GJ/ha)	Combustion of Total Biomass (GJ/ha)
Sugarcane (Brazil)	38.0	12.0	156.8	167.0	113.9	437.7	684.0
Maize (USA)	18.4	9.2	72.8	40.4	27.6	140.8	331.2
Oil Palm (Indonesia)	34.0	17.0	128.8	149.4	50.9	329.2	685.4

Source: SCOPE 72 Study, Chapter 10, Feedstocks for Biofuels and Bioenergy

Brazil, the world's leading producer of sugar cane for energy, has pioneered its use primarily for ethanol production. The process is highly efficient, with the sugar portion of the cane converted to biofuel and the residue (bagasse) portion used to provide process heat (reducing fossil fuel inputs). With fuel flexible vehicles, Brazil targets a high share of light vehicle transport to be provided by the ethanol produced. While there has been concern about the land required for this fuel, Brazil has reduced its need for new land by raising the efficiency of livestock production on pasture land, which can be used to grow cane.

Recently, Brazil has begun to focus more on the long-term potential for cane to produce biodiesel, which is essential for transport provided by aviation, marine shipping and heavy trucks. There are official claims that a new breed of "energy cane" has four times the energy content per hectare as conventional sugar cane. (While sugar cane breeding has historically focused on getting more sugar, this lowered total yields because it requires more energy for the plant to produce sugar than to produce bagasse.) Such energy cane could be used in a lignocellulosic process directly to produce biodiesel and jet fuel.

But the technical and economic potential of energy cane for diesel production remains unclear. Against the advantages of lower feedstock costs and reduced land use impacts, it is necessary to weigh the disadvantages of higher process costs and lower process efficiency. While the first-generation process for producing ethanol from sugar cane can convert about 80% of the plant's energy content to fuel, the second-generation process for producing diesel from energy cane would convert only 40% to fuel. And at the present stage of technology development, the second-generation process has far higher costs.

In this context, it is interesting to evaluate the first and second generation options side by side, to assess the point at which the capital costs of second generation technology would be low enough, while still perhaps higher than for first generation technology, to compete on the basis of lower feedstock costs. From the perspective of biodiesel markets for aviation and heavy freight transport, a fair economic comparison would include the extra costs of refining diesel from first generation bioethanol. It is also interesting to evaluate the relative impacts of first and second generation options (conventional sugar cane vs high-yielding energy cane) on land use and carbon sequestration in the air and soil.

Objectives and Approach

The project would make a side-by-side economic and environmental comparison of first-generation bioethanol and biodiesel production from conventional sugar cane, on the one hand, and second-generation biodiesel production from high-yielding energy cane, on the other. Technical assumptions for crop yields and feedstock costs, as well as for capital costs of first-generation biorefineries, would be developed in cooperation with FAPESP – Sao Paulo Research Foundation. Assumptions for second-generation biorefineries would be developed from previous technology assessments by IRENA.

Successful Strategies for Bioenergy Scale-up: Project 3.1 (in progress)

IRENA Project Navigator
Technical Concept Guidelines for Bioenergy Projects including Combined Heat and Power Applications

Background

IRENA's Project Navigator provides clear Project Development Guidelines for implementing bankable renewable energy projects, to facilitate the uptake of renewable energy worldwide. The Navigator highlights easy-to-access knowledge products, practical tools, real-life case studies and industry best practices that can be mobilized to ensure the successful completion of renewable energy projects. It also provides a regularly updated online database on International Financial Institutions that provide financial instruments for renewable energy projects, helping project developers locate financing by listing all major requirements these institutions impose as to location, size, technology and other features. It links as well with other IRENA financial platforms such as the IRENA/ADFD Facility and Sustainable Energy Marketplace.

The Guidelines feature technology-specific information and practical experience covering the complete lifecycle of a project: identification, assessment, selection, pre-development, development, construction, operation and decommissioning. Key technical aspects are considered along with the risks and rewards of decisions made throughout the development process. Financial models, checklists and evaluation forms are provided at no cost to renewable project developers to help them structure projects that are bankable.

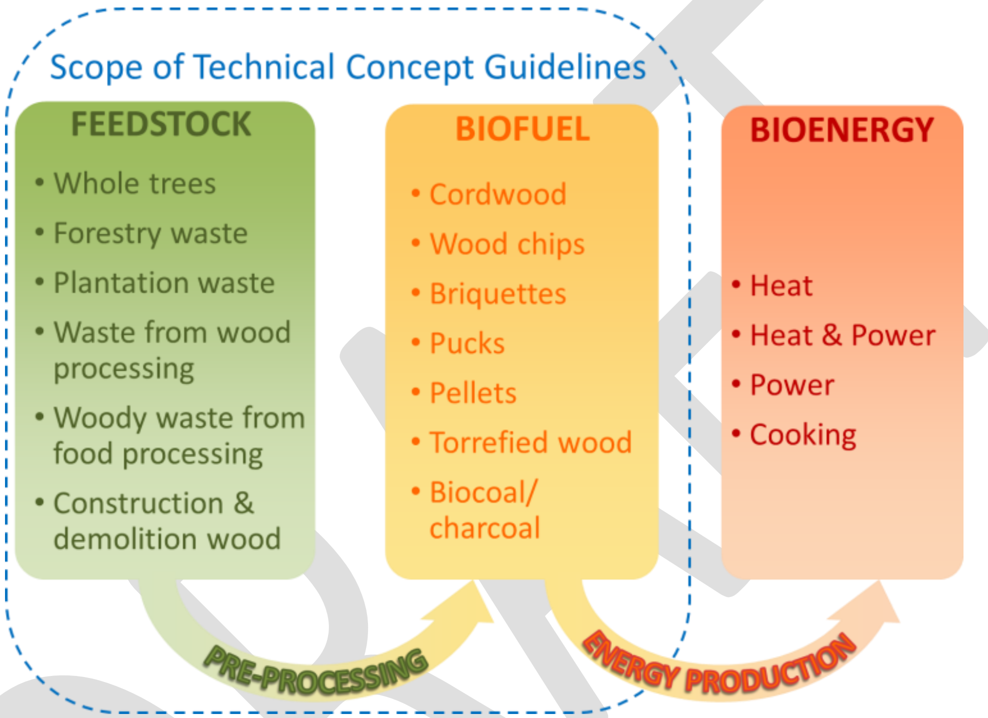
IRENA's Project Navigator aims to guide potential investors through all the steps needed to put a renewable energy project in place. The Project Navigator guides users through project identification (stakeholders, problems, objectives, alternatives), screening (strengths, weaknesses, opportunities, threats; competencies, resource needs), assessment, selection, pre-development (stakeholder analysis, technical/economic/operational/political framework, success factors, monitoring mechanisms, project brief, business viability analysis), and development, execution, operation and decommissioning. The Project Navigator has previously been developed for solar, wind, and is also under development for geothermal and renewable micro/mini-grid projects. It is now being extended to bioenergy.

The initial focus would be on projects for conversion of woody biomass feedstocks to woody biofuel suited to later conversion to bioenergy in combined heat and power (CHP) or district heating (DH) systems. CHP makes use of a wide range of readily available and sustainable feedstocks, notably including forest residues (chips and pellets from complementary fellings to logging operations) and farm residues (combustible material associated with crops, such as sugar cane bagasse, palm kernel husks, corn stover, and rice straw). It is proven and cost-effective at commercial scale, with widespread use in the pulp and paper industry and growing use for agro-processing operations, where the residues provide needed energy for industry. CHP plants typically convert fuel to energy with efficiencies of over 80% -- with 10-25% conversion to electricity and 50-80% conversion to heat. District heating systems typically reach efficiencies of 75-85%.

For CHP projects, there is a dual challenge to be addressed in obtaining sufficient biomass feedstock and finding a market for heat and power. Investors will not fund a project at a given scale of output (in megawatt hours of heat and electricity) unless there is a reliable source of feedstock (in tonnes of residue) to supply the production of that output on a regular and consistent basis. Likewise, investors will not fund a CHP project unless there is market for both the heat (usually an identified industrial operation) and power (usually through contractual revenue from the local or regional electrical power grid). The Technical Concept Guidelines for Bioenergy Projects are designed to help project components gain assured inputs and outputs to persuade investors. In the first phase, the *Technical Concept Guidelines for Bioenergy Projects* cover the steps from feedstock sourcing over the required pre-treatment steps to produce a viable fuel, to the logistics and conditions for selling biomass fuels to local and regional markets.

Objectives and Approach

The initial *Technical Concept Guidelines for Bioenergy Projects* will focus on biomass fuel from woody feedstocks. They will support projects for conversion of **woody feedstocks** (such as forestry waste, plantation waste, waste from wood processing, woody waste from food processing, and construction and demolition wood) into **wood-based solid biofuel** (such as logs, chips, briquettes, pellets, torrefied wood, and charcoal). They will not cover the conversion of wood-based biofuel to bioenergy (heat and power) though later work may do so. They will also not yet cover production of liquid biofuel (such as biodiesel and bioethanol) or gaseous biofuel (like biogas or syngas). Work began in the second quarter of Q2 2016, and the full *Guidelines*, including tools and checklists, are expected to be released later in the year.



Although conversion to bioenergy is not covered, the mapping of biofuel types into bioenergy is clear:

- Firewood is suited to log boilers for commercial and public buildings (50-200 kilowatts), firewood boilers for homes and small commercial buildings (40-150 kW), and residential stoves (3-15 kW).
- Pellets are suited to pellet boilers for commercial and public buildings (100-500 kW), central heating systems for homes and small commercial buildings (30-150 kW), and stoves (3-15 kW).
- Wood chips are suited to boilers for commercial and public buildings (150 kW – over 500 kW), as well as for district heating systems serving towns and cities (roughly 5-10 megawatts per boiler).

IRENA Project Navigator's *Technical Concept Guidelines for Bioenergy Projects* include:

- Identification
  - stakeholders (forest owners, forest harvest licensing agencies, wood processors)
  - problems (market structures and barriers for industry, export, heating, cooking)
  - objectives (how biomass will affect energy costs, emissions, employment)
  - alternatives (assess different sites, feedstocks, plant sizes)
- Screening (strengths, weaknesses, opportunities, threats; competencies, resource needs)
  - tools and procedures to assess biomass supply potential and cost

- sustainable biomass supply chain development
  - Are multiple sources of feedstock available that the project can utilise?
  - Are logistical arrangements in place to assemble sufficient feedstocks?
  - Are provisions made for feedstock storage to ensure steady supply?
- Feedstock quality (age, composition, impurities) versus quality requirements
- Security of feedstock supply across seasons and plant lifetime
- Cost per tonne of feedstock and per gigajoule of energy delivered
- Successful demonstrated business models that might be applied

- Assessment
  - Market potential and barriers and possible means to overcome the barriers
  - Market trends of biomass use for energy and non-energy purposes
  - Intended end-use applications (CHP, process heat, district heating, cooking)
  - System sizes and configurations based on resource availability and demand
  - Economic and financial evaluation of alternative sizes and configurations
- Selection (based on assessment)
- pre-development
  - identify stakeholders and their roles
  - develop a risk management plan
  - assess critical success factors
  - size the pre-processing plant
  - evaluate capital and operating expenditures
  - evaluate financial needs and modalities
  - chart necessary processes and timelines
  - develop memorandum of understanding with biomass off-taker
  - develop business plan
  - draft project brief for potential partners
  - source capital for required investment
- development
  - consult with stakeholders directly and through the web
  - make contractual agreements with investment partners
  - obtain permits, licenses and insurance
  - create a bankable financial model
  - obtain warranties for components
  - arrange construction contracts
  - plan for operations
- execution
  - contract for construction
  - hire and train staff
- operation
  - ongoing training and quality management
  - ongoing business development
  - maintenance and process improvements
- decommissioning

Once the Technical Concept Guidelines for Bioenergy Projects are released, they will be presented to potential bioenergy project developers to help them develop bankable bioenergy projects and secure funding with International Financial Institutions as well as linking them with other IRENA platforms such as IRENA/ADFD Facility and Sustainable Energy Marketplace.

Successful Strategies for Bioenergy Scale-up: Project 3.2

Forestry Biorefineries with High-Value Co-Products

Background

The global pulp and paper industry is one of the leading users of biomass from forests. Pulp and paper mills around the world generate significant amounts of electricity for their own process use and external sales. The fuel source is the residues from the wood that is used as feedstock for pulp and paper production. Pulp and paper production represents over 5% of economic output in Scandinavia, Canada and Russia.

Substantial potential exists in the pulp and paper industry to increase the electric energy yield without affecting the pulp production process. This can take place by minimizing steam use in the chemical processes and optimizing temperature and pressure with a view to maximizing energy output. With growing use of electronic media, paper making has been declining while pulp production is steady due to strong markets for building materials, packaging and consumer products like tissues and diapers. Surplus steam from pulp production could be used to generate extra electricity for the grid at low cost.

But regulatory and financial factors have inhibited investment in the new condensing turbines that would be required to take advantage of this opportunity. In Scandinavia, the power pool price has dropped to such low levels that such investment cannot earn an attractive return through electricity sales. More generally, most countries do not allow electricity from pulp and paper mills to qualify for feed-in-tariffs. Regulatory changes and financial incentives could help to unlock the latent potential.

Moreover, the forest feedstocks on which the pulp and paper industry runs can be used in biorefineries to generate a variety of high-value chemicals and materials in addition to energy. These can reduce the net effective cost of producing advanced biofuels from lignocellulosic feedstocks and help them compete with and displace petroleum-based transport fuels which contribute to carbon emissions and global warming. Pulp and paper mill managers are also largely unaware of the potential that may exist for high-value co-products. By identifying this potential, interest and investment in biorefineries may be activated.

Objectives and Approach

The project would survey potential for increased electricity generation from the pulp and paper industry. For each country and region with substantial pulp and paper production, the project would assess the extent to which paper production has declined is expected to decline over time, the amount of electricity generating capacity and output that could be made available by installing new equipment to convert surplus steam to power, the amount of investment that would be required to install such equipment. It would then examine the regulatory and economic factors affecting the incentives for this investment, with a particular focus on grid access and feed-in tariffs for the electricity generated by pulp and paper plants, and suggest measures that might be implemented to encourage extra power production at such plants. Cooperation with pulp and paper industry associations and research organizations in key countries would be sought to help evaluate the potential, technical requirements for realizing the potential, and costs.

The project would also assess the potential for producing advanced biofuels along with high-value co-products from wood raised in sustainably planted forests. The amounts of sustainable wood potential in each country would be assessed, taking account of planted forest area and annual wood increment of different species within this area. The range of high-value chemicals, materials, and other co-products would be catalogued, the current and projected market values of each co-product estimated, and the combined effect of co-products on the net cost of advanced drop-in biojet fuel for air transport evaluated.

The initial analysis would be carried out for Finland, subsequent analysis for other countries with expanding planted forests, sustainable production practices in place, substantial forest industries and jet fuel demand. The analysis would be carried out in cooperation with VTT Technical Research Centre of Finland.

Successful Strategies for Bioenergy Scale-up: Project 3.3

Renewable Energy Approaches to Reducing Food Waste

Background

FAO, the United Nations Food and Agricultural Organisation, has found that one-third of food produced for human consumption is lost or wasted globally, 1.3 billion tonnes yearly. Production and distribution losses are similar in developed and developing countries, ranging from 26% to 37% in different regions. But consumer food waste is much higher in developed countries (11%-13%) than developing ones (1%-2%). For each major region and food group, FAO data show percentage losses in agricultural production, postharvest handling and storage, processing and packaging, retail distribution, and consumption.[18]

Using the available data it is possible to calculate the total percentage and tonnage lost or wasted for each food group. For crops directly consumed, the tonnes lost or wasted can be divided by the average yield in tonnes per ha to calculate the number of ha that could be liberated by eliminating the losses and waste. For meat and dairy products, the amounts of different kinds of feed to produce each tonne must first be calculated; then the area used to produce the feed can be found; finally this area can be multiplied by share of product lost to derive potential land saved. By this calculus, 442 M ha of land could be freed up in 2050 by eliminating losses and waste from crops directly consumed as food, and another 340 M ha could be made available by eliminating losses and waste of meat and dairy products; 782M ha could be freed up in all. Even if agricultural yields reached their theoretical maximum, so that each reduction of food waste led to less land savings, land released by eliminating waste and losses would still amount to a very substantial 553 M ha.

It is interesting to consider the portion of this potential that might be obtained through international best practice. At the consumption stage, the region with the lowest share of food waste is Sub-Saharan Africa. Production losses are generally lowest in the industrialised countries of Asia. Post-harvest storage losses are most often lowest in North America. At the processing and distribution stages, industrialised regions achieve the lowest losses for three food groups and developing regions for three others.

Best Practice Losses and Waste by Food Type and Stage of Food Chain

Food Type	Agricultural Production	Postharvest Handling & Storage	Processing and Packaging	Distribution: Supermarket Retail	Consumption
Cereals	2%	2%	3.5%	2%	1%
Roots & Tubers	6%	7%	10%	3%	2%
Oilseeds & Pulses	6%	0%	5%	1%	1%
Fruits & Vegetables	10%	4%	2%	8%	5%
Meat	2.9%	0.2%	5%	4%	2%
Milk	3.5%	0.5%	0.1%	0.5%	0.1%

With best practice reducing the levels of waste and losses, potentially available land is roughly half of the theoretical potential. This equates to the total land encumbered by waste and losses less the land still encumbered by waste and losses if best practice for waste and loss reduction were implemented everywhere. The 269 M ha of land made available could provide 16 EJ of advanced biofuel. Of this, about 40% is lost in postharvest handling and storage, processing and packaging, or retail distribution. Food losses at these stages could be reduced through renewable food drying from solar and geothermal resources. [19]

[18] FAO (2011), *Global food losses and food waste - Extent, causes and prevention.* Rome.
[19] IRENA (2016), *Boosting Bioenergy: Sustainable Paths to Greater Energy Security.*

Objectives and Approach

The project would examine survey countries in regions with a high share of food losses in transportation and distribution to find examples of renewable food drying and refrigeration which have been successfully applied to reduce food losses. For each example, the survey would document capital and operating costs, estimated food savings, and implied cost per unit of food loss averted. It would also detail the approaches used to obtain the active endorsement and participation of local stakeholders. Based on the examples documented, recommendations of best practices would be made for others.

Successful Strategies for Bioenergy Scale-up: Project 3.4

Turning Biomass to Bioenergy on Islands

Background

Many islands have a significant bioenergy potential in relation to their overall energy needs. Sources of indigenous biomass on islands include sugarcane, rapidly growing grasses, and municipal waste. Owing in part to the high cost of energy on islands, use of these resources to produce a combination of heat and power can often be a cost-effective alternative to production of heat and power from imported oil.

IRENA serves the needs of island states through the SIDS Islands Lighthouses Initiative and the Global Renewable Energy Islands Network (GREIN). In response to islands' expressions of interest, IRENA organized a meeting in June 2015 which developed a Martinique Action Plan (MAP) of steps to move forward. With respect to sustainable biomass energy development, the MAP calls for action to:

- Derive a replicable methodology for biomass resource assessment on islands, building upon work by IRENA and others on sustainable biomass resource development, including assessment of biomass/waste quantities, qualities, seasonality and long term development.
- Identify islands which would be suitable candidates for detailed evaluation of biomass resources.
- Share basic and advance knowledge on technology options and pathways including costs, capacities, maturity, resilience, feedstock requirements and products.
- Share best practices and blueprints on cascading use and combining biomass and waste-to-energy systems with heat processes and desalination to maximize use of energy potential.
- Develop replicable island value chains considering the various biomass feedstocks, different conversion technologies and possible (combined) outputs according to island needs.
- Share information on islands with sufficient potential to cultivate rapidly growing grasses or other energy or short rotation crops on idle/marginal land or on land that is ill-suited to food production.
- Share best practices for the logistical management of biomass resources to produce electric power on a reliable basis, including production, trade and transportation strategies to bring together a variety of complementary feedstocks that grow at different times of year.

Further, the MAP calls for specific actions around biomass and waste to energy systems for islands:

- Identify islands which are in most urgent need of waste-to-energy systems in view of the limits on land available for waste disposal and the current and anticipated volume of waste streams.
- Perform pre-feasibility studies on a number of such islands to identify suitable technology options for waste-to-energy conversion in view of the organic waste streams present…
- Fund pilot projects on these islands to establish the optimal value chains identified.
- Exchange of experiences and best practice including through the waste-to-energy interest cluster of the Global Renewable Energy Islands Network (GREIN)
- Share best practices on regulatory issues around biomass and waste-to-energy systems…
- Support decision makers in defining the role of biomass and waste-to-energy systems in broader energy systems, considering issues that cut across different sectors … and products….
- Share available methodologies and tools for evaluating the added value of biomass and waste-to-energy pathways … and sustainability of such pathways ….

Objectives and Approach

In response to the very broad and comprehensive set of recommendations made in Martinique, IRENA proposes two initial areas of focus to promote bioenergy on islands. The first would be to screen islands for availability of sustainable biomass feedstock for heat and power production. The second would be to elaborate practical roadmaps for development of bioenergy potential on selected islands.

In screening islands for sustainable feedstock, IRENA would consider all islands which have expressed an interest in biomass and waste-to-energy systems through the SIDS Islands Lighthouses and GREIN.[20] It would evaluate resources such as crop residues, sugar cane bagasse, municipal waste and food waste. It would focus particularly on resources which can be developed for cost-effective heat and electricity applications in harmony with food production, carbon sequestration, and social advancement.

Among those islands with substantial sustainable bioenergy potential in relation to their energy needs, three islands would initially be chosen for elaboration of practical roadmaps to develop this potential. These roadmaps would provide more detailed assessments of cost-effectiveness analysis, access to infrastructure such as roads and power lines, and which energy projects are most urgently needed. They would highlight specific steps needed to develop the potential, including project identification, screening, assessment, selection, pre-development (including analysis of stakeholders, political framework, success factors, monitoring mechanisms, and business viability), development and financing. The hope would be to choose a mix of islands among the Pacific Ocean, Indian Ocean and Caribbean.

[20] As of the launch of the waste-to-energy interest cluster during IRENA's Fifth Assembly on 18 January 2015, these included Bangladesh, Barbados, Cabo Verde, Cuba, Cyprus, Fiji, France, Germany, Greece, Japan, Kiribati, Mauritius, Nauru, Netherlands, New Zealand, Palau, Philippines, Saint Vincent and the Grenadines, Samoa, Thailand, Tonga, United Arab Emirates, United Kingdom, United States and Vanuatu. Additional islands may express interest over time.

Successful Strategies for Bioenergy Scale-up: Project 3.5

Expanding Global Bioenergy Markets and Trade

Background

The cost of producing biofuels and biofuel feedstocks varies significantly from one place to another. To ensure that the feedstocks are obtained and the biofuels produced in the most cost-effective manner, it is therefore essential to promote the trade in sustainable biofuels and feedstocks globally. But this, in turn, requires technical standards to ensure that the traded commodities are of acceptable quality, as well as environmental standards to ensure they are produced sustainably.

Trade in biofuels has arisen to take advantage of the cost differentials. Wood pellets are imported by Europe from the Southeastern United States and by Japan from Vietnam, for example. Such trade can reduce both costs and carbon emissions even over long distances for fuels with high energy density, as marine and rail freight transport have relatively modest carbon emissions per tonne-kilometre shipped. Improved understanding of the logistics involved in assembling suitable quantities of feedstock to supply bioenergy facilities, including the geographical range of feedstock collection required and the associated transportation costs, can shed light on the practicality of trading biomass feedstocks over long distances.

The technical quality of biofuels and feedstocks may vary considerably. For heating and power applications, there are different grades of wood pellets, wood chips, straw-manure briquettes, and other feedstocks, with different shapes, fineness of grind, and types and degrees of impurity. Different types of boilers have different degrees of tolerance for lower-quality feedstock, so standardised information on the quality can be extremely helpful in choosing the lowest-cost feedstock whose quality is acceptable. For production of biodiesel fuel for transport, there are a number of different properties based upon the feedstock of origin and the degree of refinement that has been undertaken, perhaps most noticeably related to performance of the fuel in cold weather. For other liquid fuels, as well, including diesel variants such as jet fuel, gasoline (petrol) variants known as ”drop-in” fuels because they can use existing fuel distribution infrastructure (gas/petrol stations), and even bioethanol, there are differences in quality and performance for which technical standards are vital to making a choice.

The International Organization for Standardization (ISO) has been working in the development of international standards for biofuels. Two technical committees (TC) are established: ISO/TC 238 Solid biofuels, and ISO/TC 28/SC 7 Liquid Biofuels. TC 238 has focused its work on terminology, fuel specifications and classes, physical and mechanical test methods, chemical test methods, sampling, and sample preparation, and safety of solid biofuels. TC 28 looks into ethanol test methods and biodiesel test methods. Concerning sustainability aspects, among the different initiatives, the Global Bioenergy Partnership (GBEP) has developed a set of sustainability Indicators, aiming at an international consensus on the methods to assess the sustainability of bioenergy resources.

A number of schemes have evolved for evaluating the sustainability of biofuels and biomass feedstocks, based upon their origin. Some of the most elaborate schemes attempt to trace each liter of biofuel or each tonne of feedstock on a systematic basis from its point of origin through its point of use, based on certification of the entire chain of custody. But chain of custody approaches are costly and impractical where multiple countries, regulatory agencies and actors are involved. Other schemes attempt to evaluate sustainability based upon the risk factors associated with the country of origin. Imports from countries with strong internal sustainability criteria are deemed of sufficiently low risk to be acceptable.

Objectives and Approach

IRENA has taken an initial step towards assessing global bioenergy markets and trade opportunities by cooperating with the IEA Energy Technology System Analysis Program (ETSAP) to craft a technology brief on biomass production and logistics. Harvesting, collection, treatment, storage and transportation options for different tradeable bioenergy feedstocks are detailed, along with their associated costs.

IRENA could undertake a number of additional activities to promote expansion of bioenergy trade:

- **Develop improved statistics** on biofuels production and trade
- **Promote biofuel quality standards**, in cooperation with standards bodies and trade organizations
- **Disseminate best practices for sustainability certification** of biofuel feedstocks
- **Develop recommendations for free and fair biofuels trade**, including small-suppliers and users

In terms of **statistics**, an overview of existing data on biofuels production and trade could be undertaken, with a view to identifying important up-and-coming categories of biofuel and biomass feedstocks for which data may not yet be collected in sufficient detail or with the most useful specifications. Particular attention would be paid to categories and subcategories of feedstock. For wood-based feedstock, it could be interesting to understand in greater detail, for each country, the amounts of different wood species whose residues are used for bioenergy, the types of solid biofuels that are being produced (such as wood pellets, wood chips, among others), and the quality distribution of each type (in terms of impurities, fineness or other characteristics related to cost and performance). For agricultural feedstock, it could be interesting to understand in greater detail the amounts of different crops and crop residues of each species that are used for bioenergy purposes, how much of each is traded, and in what forms. Is there significant trade in residues such as bagasse, for example, despite the relatively low energy density as compared with bioethanol or biodiesel?

With respect to **quality standards**, IRENA could review the full range of standards in place for the full range of solid and liquid biofuels that are produced and traded, in cooperation with international trade bodies and bioenergy associations. The initial focus could be on identifying key points in common with a view to recommending the best standards that have been developed, supporting recommendations that partners may already have made, and highlighting needed areas of improvement. We might then work with partners to develop improved quality standards for the feedstocks, fuels and regions with gaps.

In terms of **sustainability certification**, a similar review could be undertaken of the various schemes that have been proposed and implemented. Both extremely demanding chain-of-custody schemes and risk assessment approaches would be evaluated, along with others that might be identified. Which are most likely to be effective under what circumstances in ensuring the sustainability of traded biofuels and biomass feedstocks would be evaluated, based upon theoretical considerations for those that have been proposed and the record of performance for those that have been implemented.

As a start for **supporting free and fair trade**, IRENA could perform an economic assessment of the potential for trade, in terms of the **economic and environmental cost of transport** by different modes over different distances. This would help to identify the geographic scope of likely trade opportunities in different biofuels and biomass feedstocks. For example, would trade in sugarcane bagasse be expected logically to be circumscribed by a certain radius of overlapping points of production? By the zone of a river running through a country? By a specific radius of seagoing traffic (e.g. the Caribbean or Pacific)? Would the importation of wood pellets to Europe suffer a significant economic or environmental penalty owing to the likely distance of certain wood supply sources overseas? Or not?

An important point of departure for analysis of trade opportunities would likely be the assessments of bioenergy production potential and bioenergy demand for different countries under REmap. Countries with projected supply in excess of demand could well export bioenergy to others. Countries with projected demand in excess of supply could meanwhile welcome bioenergy imports.

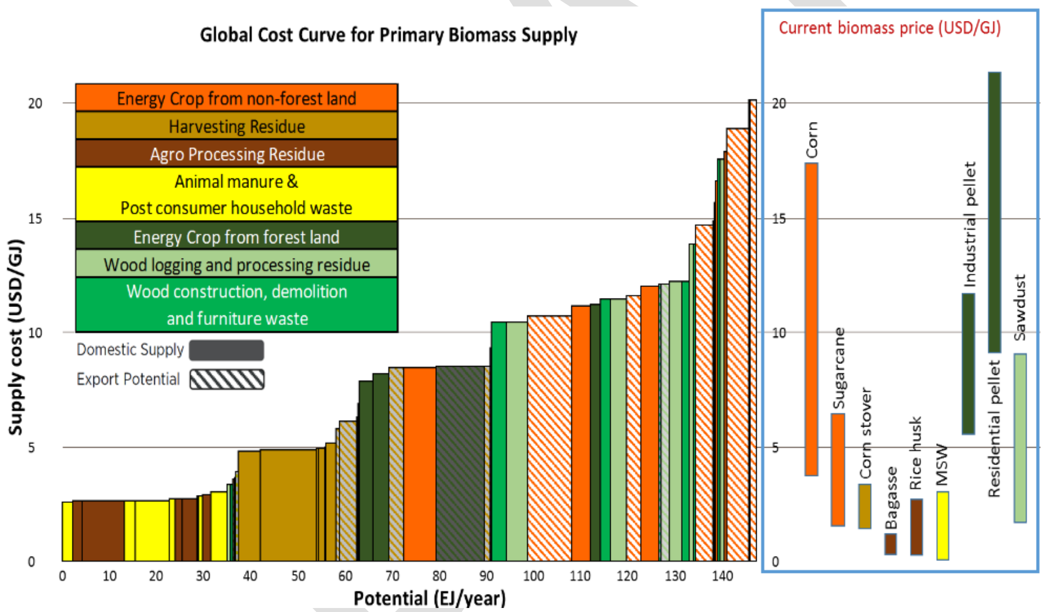
Successful Strategies for Bioenergy Scale-up: Project 3.6

Country Advisory Services for Expanding Bioenergy Supply and Use

Background

IRENA has a number of activities to help countries make informed choices about which renewable energy technologies could be beneficial and practical policies for putting these technologies in place. The Renewable Readiness Assessment (RRA) programme sends teams of experts to help local stakeholders agree on a specific set of policies that they will work together to implement. A grid assessment programme helps island nations to understand how much electric generating capacity from locally available wind, solar and other renewable resources can be installed over what period of time as power grids are reinforced to allow for a growing share of variable renewable generation. Activities like these could in principle include a more intensive bioenergy component than they do now.

The REmap programme, which focuses on practical options for doubling the share of renewable energy in the overall energy mix by 2030, as well as boosting the role of renewables in 2050, has generated supply curves of how much different bioenergy and other renewable energy options cost, both with and without consideration of health and environmental benefits, and how much of each option could be put in place. The REmap activity could also be fortified by a more intense examination with countries of how much bioenergy they might sustainably extract from agricultural residues, wood crops, restoration of degraded lands, and land freed by more efficient farming and reduced waste in the food chain.



Objectives and Approach

IRENA member countries that wish to consider their sustainable bioenergy options in greater depth may request the Agency to include more detailed examination of bioenergy options in REmap strategies, grid expansion strategies with a higher share of renewables, and Renewable Readiness Assessments.

Some of the types of advice that might be provided are suggested by a 2016 IRENA working paper on *Bioethanol in Africa: The Case for Technology Transfer and South-South Co-operation*. This paper notes the importance of building institutional capacity to design suitable bioenergy promotion policies, develop market conditions for bankable investments, and encourage feedstock production.

One focus of country advice could thus be evaluation of specific market opportunities such as:

- Surplus or underutilized feedstocks that could be used for heat, power or fuel;
- Transport market prospects for liquid biofuels to compete with gasoline or conventional diesel;
- Power market prospects for biomass to compete with other sources of electricity generation;
- International market prospects for exporting wood pellets, bioethanol and biodiesel.

With respect to encouraging feedstock production, country advice might focus on aspects such as:

- Evaluation of the most promising feedstocks, from a technical and economic perspective (what mix of crops could have the highest yields and highest profits under current conditions);
- Agricultural extension services to spread knowledge on how best to maximise feedstock yield;
- Processes for involving local stakeholders in the choice of food and fuel crops to grow;
- Governance structures to ensure secure land tenure and reward investment in the land;
- Logistical analysis of the geographic range over which feedstock will need to be collected for different scales of use (such as cooking, combined heat and power or biofuel refining);
- Renewable refrigeration and food drying to reduce waste and loss in the food chain (which may help to free up land for bioenergy crops alongside food crops for which less land is needed).

With regard to broader policy direction, advice might be offered to countries on:

- Setting ambitious but realistic targets for expanding bioenergy use in different sectors;
- Putting in place regulations and financial incentives to help meet the targets;
- Providing market access and fair tariffs for heat and electricity generated from biomass;
- Establishing land use planning and agro-ecological zoning to expand food and fuel production.

The specific focus of advice to be provided would be agreed with each country in advance.