IRENA
International Renewable Energy Agency

IRENA Work on Bioenergy for Sustainable Development:

Accomplishments and Findings 2014-2017

Introduction: Meeting the Need for More Bioenergy

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.

IRENA's REmap work in 2017 has found a major scale-up of bioenergy is needed through 2050. REmap envisions 235 EJ of renewable energy use by then, with 44% for heat and other direct uses, 40% for power, and 16% for transport. Roughly three-eighths of the 2050 renewable energy supply (37%) would be some form of bioenergy: 10% for buildings, 13% for industrial process heat, 11% for liquid transport fuels, and 3% for power. So we need to understand how the bioenergy could be supplied, what technology could be used, and how it could be scaled up. IRENA's work on bioenergy therefore has 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.***

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.

3. Successful Strategies for Bioenergy Scale-up

Even with abundant feedstocks and cost-effective technologies, focused strategies will be needed for scaleup. ***There are strategies that work, with a mix of public incentives to attract private investment***, but they have so far been limited in scope and impact. We need to draw out the best elements and spread them more widely.

Sustainable Supply of Bioenergy Feedstock

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.

Global Biomass Supply and Demand Projections – A Working Paper for Remap 2030

One of IRENA's first forays into assessment of biomass potential, this paper examines potential bioenergy supply from bioenergy crops, agricultural residues, post-consumer and animal waste, and forest products. It further reviews the supply cost of different forms of biomass and markets for bioenergy in the power, building, industry and transport sectors. It concludes that there is substantial bioenergy potential in every end-use energy sector, and that international trade may meet one-fifth to two-fifths of bioenergy needs.

http://biomasspower.gov.in/document/Reports/IRENA_REmap_2030_Biomass_paper_2014.pdf

Boosting Biofuels: Sustainable Paths to Greater Energy Security

IRENA's brochure on *Boosting Biofuels* documents very substantial sustainable bioenergy potential:

- ***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.
- ***Land 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. Including agricultural residues and wood from forests, the potential would be even greater.

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 extension services to promote modern farming techniques and enhance access to seed, water and fertilizer in developing countries.
- Improve ***logistical approaches*** for cost-effective harvesting of farm and forest residues.
- Collect ***comprehensive data*** on land that could be used for sustainable biofuel crops.

- 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 to avoid discarding good food 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 promote sustainable feedstock sourcing and 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.

http://www.irena.org/publications/2016/Apr/Boosting-Biofuels-Sustainable-Paths-to-Greater-Energy-Security

Regional Supply Potential Studies

As a follow-up to the *Boosting Biofuels* study, a report was prepared on *Biofuel Potential in Southeast Asia: Raising food yields, reducing food waste and utilizing residues.* 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 highlights the potential for developing these resources in five countries of Southeast Asia (Indonesia, Malaysia, Philippines, Thailand, Vietnam) which are members of both the Association of South East Asian Nations (ASEAN) and the Asia Pacific Economic Cooperation (APEC). In the agricultural sector, detailed information is 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.

http://irena.org/publications/2017/Jun/Biofuel-potential-in-Southeast-Asia-Raising-food-yields-reducing-food-waste-and-utilising-residues

A companion follow-up study on *Biofuel Potential in Sub-Saharan Africa* focuses on five countries which may be taken as broadly representative: Ghana, Nigeria, Mozambique, South Africa and Uganda. It shows major potential to displace fossil fuels through production of liquid biofuels in the longer term and use of solid biofuels for heat and power as advanced technologies for liquid biofuels mature.

https://www.irena.org/publications/2017/Nov/Biofuel-potential-in-Sub-Saharan-Africa

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.

http://www.irena.org/eventdocs/QUANTITATIVE_HIGHLIGHTS_Sustainable_Bioenergy_Supply_Workshop_Berlin.pdf

Briefing Paper on Bioenergy for Sustainable Development with IEA Bioenergy and FAO

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 *Bioenergy for Sustainable Development* to explain how bioenergy can be expanded to help achieve the goal of Sustainable Energy for All (SEforAll) while also contributing to food security and environmental protection. The paper was finalized following review by IRENA members at the bioenergy event during Assembly in January 2017.

http://www.irena.org/eventdocs/Bioenergy%20Side%20Event%20-%20Brief%20on%20BIOENERGY%20AND%20SUSTAINABLE%20DEVELOPMENT%2020170105.pdf

Working Paper on Energy and Land Use for UNCCD Global Land Outlook

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."

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 on Energy and Land Use was prepared, as part of UNCCD (2017) *Global Land Outlook First Edition*. It notes that bioenergy from farm and forest residues has particularly modest land requirements.

http://www.globalbioenergy.org/uploads/media/1709__UNCCD_IRENA__Energ__and_Land_Use..pdf

Report on Bioenergy from Degraded Land in Africa

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. Within this framework the AFR100 initiative aims to restore 100 M ha, most of which has been pledged.

In collaboration with the University of Utrecht in the Netherlands, IRENA has evaluated the sustainable bioenergy extraction from AFR100 pledges, utilizing data from the World Resources Institute and IUCN. It was found that up to 6 EJ of bioenergy could be supplied from land restoration under the pledges, if the highest yielding degraded lands were used. More detailed analysis is included for Rwanda and Kenya, which have applied the in-depth Restoration Opportunities Assessment Methodology (ROAM).

http://www.irena.org/publications/2017/Dec/Bioenergy-from-degraded-land-in-Africa

Cost-Effective Technology for Bioenergy Conversion

Technology for Advanced Liquid Biofuels in Transport

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 (like 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, thereby avoiding carbon-releasing land use change and leaving more land for food crops.

IRENA’s ***Innovation Outlook: Advanced Liquid Biofuels*** provides a comprehensive view of advanced biofuel potential and steps to achieve this potential. It examines the practical and economic potential for advanced liquid biofuels, biofuel technology pathways and innovation opportunities, trends in advanced biofuel technology deployment, and 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.

The study identifies opportunities for innovation across a wide spectrum of advanced biofuel conversion pathways, with a 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, but requires more effective catalytic upgrading processes. Gasification needs to prove reliable long-term operation in view of feedstock contaminants, Fischer-Tropsch processes need proof at commercial scale. Ethanol and methanol fermentation from syngas could benefit from modification of fermentation organisms to improve tolerance to contaminants and raise yields.

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.

http://www.irena.org/publications/2016/Oct/Innovation-Outlook-Advanced-Liquid-Biofuels

IRENA's REmap working paper on ***The Renewable Route to Sustainable Transport*** reviews advanced biofuel options in terms of feedstock availability, climate change impacts, technology costs and trade. It finds that "advanced biofuels will be key if the share of renewables in transport is to increase."

http://www.irena.org/publications/2016/Aug/The-Renewable-Route-to-Sustainable-Transport-A-working-paper-based-on-REmap

Bioenergy Technology Briefs for Different End Use Sectors

IRENA has prepared technology briefs on the use of biomass in various energy sectors, some 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. Briefs have been completed on biofuels for aviation, biomass for heat and power, biogas for road vehicles, and biogas for domestic cooking.

Several of the briefs focus on biogas, a modern form of bioenergy produced through anaerobic digestion of food waste, agricultural residues, manure, and sewage, or collected from landfills. Biogas 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 major potential.

Biofuels for Aviation: As a sequel to the *Innovation Outlook: Advanced Liquid Biofuels*, IRENA has prepared a brief on biofuels for aviation. Many airlines and aircraft manufacturers have committed to voluntarily reduce greenhouse gas emissions by half by 2050. Biojet fuels, which do not require modifications to existing jet engines, are the only real option to achieve such reductions on schedule. While biojet can be produced from conventional sources like vegetable oils and tree-derived tall oil, advanced biojet from lignocellulosic feedstocks such as residues from agriculture and forestry will be required to reach the scale desired. The brief outlines the main features, status and prospects of four different biojet technology pathways. A particular focus is on the economic challenge of producing biojet in the face of competition from fossil jet fuel and the policy incentives that may be needed.

http://www.irena.org/publications/2017/Feb/Biofuels-for-aviation-Technology-brief

Biomass for Heat and Power: Several countries have used biogas from agricultural residues for heat or combined heat and power (CHP) 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. The brief describes different CHP processes that use biomass feedstocks, their technology status, their current and prospective costs, and policy options that may help to expand their market potential.

http://www.irena.org/publications/2015/Jan/Biomass-for-Heat-and-Power

Biogas for Road Vehicles: 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. The methane can also be converted to compressed natural gas (CNG) for use in freight trucks and marine shipping. Reviewing the features of large-scale biogas technologies for road transport, the brief points out that the main challenge for biogas as a fuel is cost, but suggests that the combined costs of production, purification and upgrading could be reduced by 30 to 40% through improvements in process efficiency.

http://www.irena.org/publications/2017/Mar/Biogas-for-road-vehicles-Technology-brief

Biogas for Domestic 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, so their fuel costs a lot to buy in urban areas, takes a lot of time to collect in rural areas, and puts pressure 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. The brief describes the range of modern biodigester and cookstove technologies, their environmental, economic and social benefits, barriers to their deployment, and policy options to overcome the barriers.

https://irena.org/publications/2017/Dec/Biogas-for-domestic-cooking-Technology-brief

Measuring Small-Scale Biogas Capacity and Production

Since many governments have launched programmes to promote the use of household biogas digesters for cooking and lighting, IRENA has developed a field guide which presents methods for estimating biogas capacity and production. Relevant operational features of different biogas technologies are highlighted.

http://www.irena.org/publications/2016/Dec/Measuring-small-scale-biogas-capacity-and-production

Bioenergy in IRENA Database of INformation on Standards and Patents In Renewable Energy (INSPIRE)

IRENA collects comprehensive information on renewable energy patents, available through the INSPIRE platform. The number of bioenergy patents has quadrupled in the last decade, reaching some 85 000 in 2016. More than half of these (50 000) are for biofuels, and more than a third (33 000) for fuel from waste. Many of the remaining patents pertain to biomass for end-use applications, such as efficient cook stoves for homes, heating systems for buildings, and processes used in the chemical and cement industries.

http://inspire.irena.org/

Successful Strategies for Bioenergy Scale-up

With abundant bioenergy potential and a widening array of technologies for bioenergy production, it is important to provide advice on successful strategies for bioenergy scale-up. IRENA has developed a Bioenergy Simulator to help farmers think about the best mix of crops to consider planting, in terms of food and energy yields and returns on investment. IRENA has also developed a module of the Project Navigator to help design bankable projects for scale-up of modern wood energy. Finally, IRENA collects data which can be used to track member country progress in scaling up different bioenergy forms.

Bioenergy Data Collection to Track Scale-up Progress

IRENA collects data on amounts of bioenergy supplied from different feedstocks and provided to help meet renewable energy demand in the in transport, power, industrial and buildings sectors. These data 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 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).

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.

http://resourceirena.irena.org/gateway/dashboard/?topic=18&subTopic=50

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 bioenergy sources, technologies and end-uses in a user-friendly way. The simulator includes options spanning 4 categories of feedstock (14 bioenergy crops, 30 types of agricultural residues, 9 types of livestock waste, 52 species for forest plantations), 25 bioenergy production processes, and 3 bioenergy 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. It aims to help users explore initial options, but not to make final technology choices or investment decisions.

While the FAO programme on Global Agricultural Economic Zones (GAEZ) has developed yield data for food and grass crop yields at high levels of resolution, it has not done so for wood crops, for which the simulator is therefore obliged to use global average data. IRENA is working on an algorithm to estimate local wood yields from available land and satellite data on soil conditions, climate and rainfall. The focus is especially on nitrogen-fixing wood species that can be planted together with food crops to boost their output. Better wood yield estimates should improve the advice the bioenergy simulator can provide.

http://www.irena.org/eventdocs/Bioenergy%20Side%20Event%20-%20Presentation%20on%20Bioenergy%20Simulator%2020170113.pdf

https://irenanewsroom.org/2016/12/12/simulating-bioenergy-potential/

IRENA Project Navigator Development Guidelines for Bioenergy Projects

IRENA's Project Navigator aims to guide potential investors through all the steps needed to put a renewable energy project in place. Its Project Development Guidelines cover 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 initial *Technical Concept Guidelines for Bioenergy Projects*, completed in 2017, focus on biomass fuel from woody feedstocks. They support projects for conversion of woody feedstocks (such as farm and forest residues, food and wood processing waste, and demolition wood) into wood-based solid biofuel (like logs, chips, briquettes, pellets, torrefied wood, and charcoal) suitable for use in combined heat and power (CHP) or district heating (DH) systems. They 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. Work has started on similar guidelines for biogas projects.

CHP projects face a dual challenge: 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 the local or regional electrical power grid). The *Technical Concept Guidelines for Bioenergy Projects* are designed to help project proponents gain assured inputs and outputs to persuade investors.

https://irenanewsroom.org/2017/03/01/developing-bankable-woody-biomass-projects/

https://www.youtube.com/watch?v=advjZ9QWqFw

https://navigator.irena.org/index.html