chapter 6

Sustainable Development and Innovation

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Highlights

- Sustainable bioenergy has an important role to play in the future energy mix that provides access to modern energy services for all.
- Sustainable bioenergy can increase the share of renewables in view of using the variety of locally available energy sources and needs to mitigate climate change.
- Integrated assessments of bioenergy systems are essential.
- Monitoring of bioenergy systems needs to be improved.
- The public perception can impede or accelerate realization of sustainability objectives via bioenergy.
- Institutional and policy frameworks as well as capacity building are critical for sustainable bioenergy.

Summary

Bioenergy can play an important role in facilitating the attainment of sustainable development but this requires innovation and enlightened public policies that effectively respond to economic, social and environmental considerations. To promote beneficial and efficient use of natural resources via bioenergy deployment, this chapter emphasizes the need for integrated analysis and assessment of production chains, under a landscape approach to natural resources management (land, water, biodiversity) encompassing enhanced and sustained productivity (bioenergy, food, feed, feedstocks, timber), environmental services (hydrology, biodiversity, carbon) and economic value. Key needs for advancing sustainable development using bioenergy include: a) improved data gathering and analysis to support the development of appropriate public policies and governance systems in bioenergy R&D and operations, b) enhanced monitoring and evaluation of the economic, social, and ecological costs and benefits of bioenergy systems, c) enhanced institutional and human resource capacity in both public and private sectors for improved governance, knowledge generation and extension services in bioenergy systems; d) the development and promotion of innovative financing schemes for business models, especially to enable communities to benefit from small scale bioenergy projects; and e) innovative communication tools to foster enhanced participation by bioenergy stakeholders and civil society in developing integrated and state of the art bioenergy investments and operations.

Examples of Innovative and Integrated Bioenergy Systems

In order to achieve sustainable development goals, modern, efficient and well designed bioenergy systems can facilitate an effective transition towards sustainable and renewable energy systems. This is most productively approached by local natural resource management that closely matches the supply opportunities with local demands operating at an integrated landscape scale.

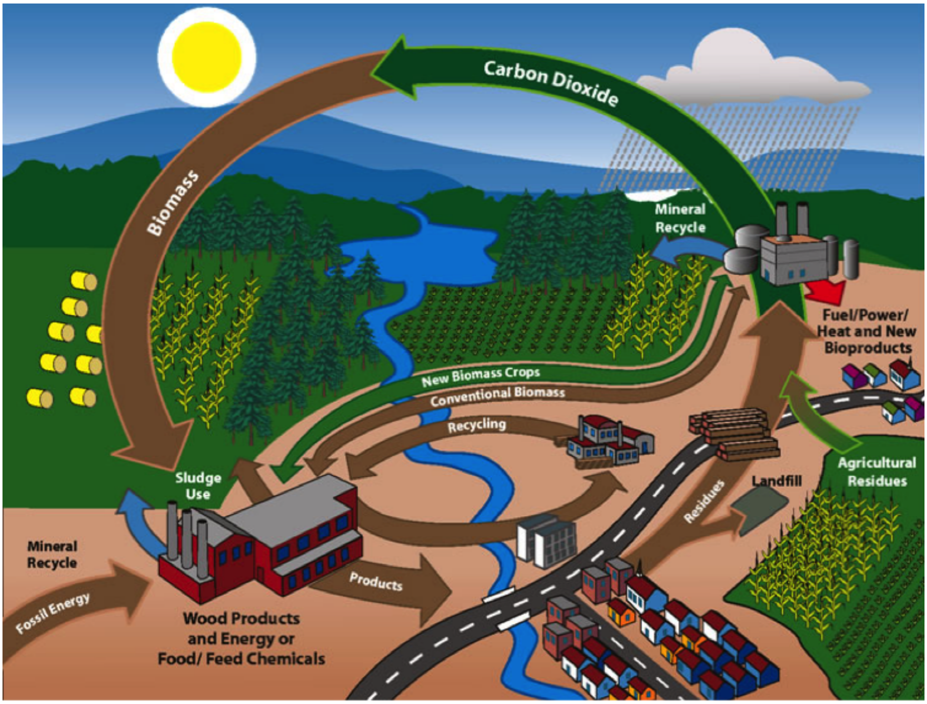

Figure 6.1. illustrates a large bioenergy system showing many of the key material and energy flows, as incorporated into the Biomass Site Assessment Tool (BioSAT 2014). The US Forest Service and University of Tennessee in the United States developed BioSAT, with the goal of assessing the potential for bioenergy from biomass produced from planted forests and biomass residues. This tool includes a natural resource geo-referenced database, physical (soil, slope, hydrology, biomass) and economic data, which are used to objectively identify suitable sites for woody and agricultural residue biomass collection and processing centers (biorefineries). Using tools such as this, it is possible to achieve integrated production of food and multiple energy products while simultaneously optimizing societal demand and local landscape potential and constraints.

6.1 Introduction

Sustainable and equitable development involves meeting the needs (including basic needs for food, energy, clothing, shelter, decent jobs) of human society within the sustainable carrying capacity of natural systems (Box 6.1).

Box 6.1. Sustainable Development definition

Sustainable Development has been defined in many ways, but the most frequently quoted definition is from *Our Common Future* (WCED 1987), also known as the Brundtland Report: "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". All definitions require systems thinking – connecting space and time. The concept of sustainable development has in the past most often been broken out into three constituent domains: environmental sustainability, economic sustainability and social sustainability. A fourth domain often added is that of institutions and good governance.

Sustainable energy is a key enabler for sustainable development. As pointed out in different studies using various integrated economic, social, environmental models (WWF 2012; Greenpeace 2008, GEA 2012; IEA 2013) bioenergy has important roles to play in the future sustainable energy mix. Presently, bioenergy accounts for about 10% of the global primary energy mix, with most of it being inefficient and harmful use of traditional biomass for home cooking and heating. The actual energy mix and potential for sustainable bioenergy development, however, will depend on the conditions and needs of particular countries and regions. The scale of deployment of bioenergy and the realization of benefits therefrom will be maximized by innovation in science, technology, business models, and policies that enable them, as well as continuous improvement and extension services based on learning from experience involving all these aspects.

It is important to recognize the potential role of bioenergy in the framework of Sustainable Development Goals (SDGs), established in 2012 at the United Nations Rio+20 summit in Brazil, integrated into the follow-up to the Millennium Development Goals (MDGs) after their 2015 deadline and introducing explicitly as the Goal 4: improve universal, affordable access to clean energy that minimizes local pollution and health impacts and mitigates global warming (Griggs et al. 2013). Reinforcing this nexus of energy and sustainable development, as well as proposing an active commitment of the national governments, connected to SDGs, the UN Secretary-General's Sustainable Energy for All initiative (SE4All) put forward a global platform "to ensure universal access to modern energy services, to double the global rate of improvement in energy efficiency, and to double the share of renewable energy in the global energy system (all by 2030)" (UN 2014). These targets are relevant for all countries, but depending on the national conditions different priorities and emphasis can be adopted to implement actions towards the desirable development of the energy sector, necessarily interacting with other national strategies and policies (Nilsson et al. 2013). Under such integrating concept, bioenergy is a prime example of how energy interlinks with other areas, including water, ecosystems, health, food security, education and livelihoods, and can harness multiple benefits, if properly planned and managed. This desirable development of sustainable and modern bioenergy can be promoted from small-scale local use in stand-alone applications or mini-grids as well as large-scale production and commoditization of bioenergy, through automotive biofuels and bioelectricity. On the other hand, modern bioenergy can replace predatory and inefficient bioenergy systems.

To live up to its potential to contribute to sustainable development, bioenergy deployment needs to be planned and implemented well. A number of environmental and social risks have been highlighted in chapters 9 to 21, this volume, and appropriate environmental and social safeguards need to be put into place and effectively implemented. Yet, beyond risk mitigation, bioenergy can generate substantial sustainable development benefits and concretely contribute to many of the following policy objectives:

Diversity and security of energy supplies: Many nations have the ability to produce their own bioenergy from agriculture, forestry and urban wastes. Produced locally, bioenergy can reduce the need for imported fossil fuels – often a serious drain on a community or developing country's finances. By diversifying energy sources, bioenergy can also increase a country or region's energy security.

Equitable energy access: Currently more than 1.4 billion people have no access to electricity and the access of an additional 1 billion is unreliable. Bioenergy can help provide access to energy for energy-deprived and off-grid communities, thereby contributing to the goal of universal access to modern energy services by 2030. Modern bioenergy technology can improve living conditions for 2.4 billion people relying on biomass and traditional fuels for cooking and heating.

Rural development: With 75% of the world's poor depending on agriculture for their livelihoods, producing bioenergy locally can harness the growth of the agricultural sector for broader rural development. Availability of bioelectricity or biodiesel allows productive services such as irrigation, food and medicine preservation, communication, and lighting for students. Transitioning from traditional biomass use to modern bioenergy can reduce the time needed to collect water and firewood, which means that many women and children have more time to study or to dedicate to income generating activities. Care is needed not to compromise local food production and water access systems.

Employment: Agriculture is labor-intensive, and job opportunities can be found throughout the bioenergy value chain. With increasing scale and sophistication, the bioenergy value chain can be the driver of industrial development and create a more skilled labor force over time.

Health benefits: When modern bioenergy replaces the traditional inefficient combustion of biomass, indoor pollution is reduced along with subsequent health impacts. The health of women and children who spend time around cooking fires, is disproportionately impacted by inefficient biomass cooking systems.

Food security: Bioenergy can increase food security when investment and technology improve the overall agricultural productivity and food availability. While higher food prices can reduce food accessibility, bioenergy can improve family incomes and hence improve the ability to purchase food. New infrastructure built to support a developing bioenergy sector, can improve access to markets in various industry sectors, thereby increasing overall accessibility. Stability as well as food utilization can be improved through increased access to locally produced bioenergy that, for instance, enables crop drying, cooking and purification of drinking water.

Greenhouse gas emission reduction: Bioenergy that replaces fossil fuels or traditional use of biomass for energy can reduce GHG emissions as well as carbon black emissions, a short-lived climate pollutant. However, the potential to live up to this promise depends on the GHG balance during production and conversion of bioenergy across the feedstock supply chain to energy production and use.

Climate change adaptation: Although directly dependent on rainfall regime and climate conditions and thus potentially affected by climate change, bioenergy production involving improved and adapted germplasm can result in enhanced resilience to climate change. In some cases, increased atmospheric CO_2 concentrations could result in increased productivity of bioenergy feedstock via a CO_2 fertilization effect. Alongside adaptation of agriculture at the landscape level, bioenergy crops may increase system resilience.

Biodiversity and land cover: In order to reduce impacts on biodiversity, bioenergy systems should not be promoted in forested and environmentally sensitive areas, and adequate measures must always be taken to preserve the natural landscape as much as possible, for instance adopting biological controls of pests (instead of pesticides), creating and/or preserving wildlife corridors and maintaining riparian forests. Beneficial effects for biodiversity can be expected when abandoned, formerly intensively used farmland or moderately degraded land is used and rehabilitated via a systemic approach.

Deforestation: Sustainable bioenergy production avoids deforestation, by replacing natural forest firewood, a key source of deforestation today. In some contexts, forest management and afforestation should be promoted to increase the availability of woody biomass. The REDD (United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) (UN 2013) guidelines must be considered.

Although bioenergy is not in all cases the best-suited option to achieve any one sustainable development objective, it has the capacity to deliver benefits with respect to several sustainable development objectives simultaneously. Furthermore, modern bioenergy systems are able to utilize a large variety of feedstocks including feedstocks and agricultural residues from a variety of agroclimatic regions. In addition, flexibility of bioenergy systems is derived from feedstocks processed through different conversion routes, serving different end uses, and being produced at different scales, and catering for local and export markets. Thus, while inherently complex, involving several actors and interests, properly designed and well implemented bioenergy systems are able to serve diverse objectives, covering social, environmental and economic aims.

In this chapter the innovation perspective is discussed initially, as an essential element of sustainable bioenergy schemes, focusing more closely on liquid biofuels production chains, exploring new methodologies required to assess and follow-up bioenergy programs and systems, and commenting, under this innovation standpoint, the relevant nexus food security and bioenergy. In the following sections, the need for improved data gathering and analysis, capacity building and new financing schemes is presented, as well as the crucial role of consultation and communication in this context.

6.2 Bioenergy Systems: the Innovation Perspective

Bioenergy production is being practiced in different regions and is contributing not only to energy diversity but also to a significant part of the energy needs, locally or globally, while concurrently addressing pressing environmental concerns and promoting development goals. In attempting to reap all these cross-cutting benefits, the bioenergy sector has become complex because of the variety of feedstocks and producing conditions used, which make it difficult to share learning experiences and scale up and out such systems. More recently, however, there are a range of emerging and proven bioenergy production systems from which replication and adaptation experiences are starting to be derived.

The underlying requirements for bioenergy development involve the identification of a reliable supply of suitable feedstock for various locations and agroecozones. In addition, there is a need for sustainable feedstock supply chains and properly designed conversion systems (conventional and emerging) at appropriate scales, while sustainably managing the natural resource endowments (land, soil, water, waste, etc.). The whole chain requires optimization in terms of agricultural and industrial productivity, logistics management, optimum resource use, and integrated management to meet with the main socio-economic and environmental aspects as far as practically possible. All products, by-products and waste products should be valued in the production chain under a multi-functional landscape approach that involves food, feed, fiber and energy production in balance with the environment, ecosystems services, and social development. It is interesting to observe that innovation acts independently in the elements of biofuel value chain, but improves the overall production system, as depicted in Figure 6.2.

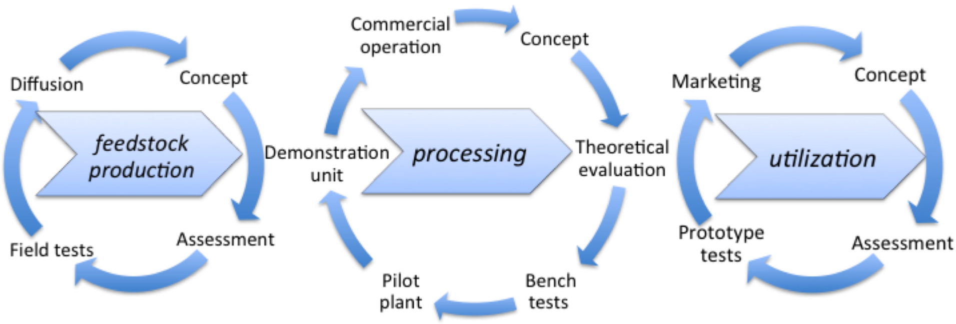

Figure 6.2. Innovation cycles in biofuel value chain.

In each element of this chain innovation can play a decisive role, and some areas are more promising, as depicted in Table 6.1, but there are three main areas where bioenergy and development can intersect: 1) Industrial-scale production of biofuels from agricultural land, 2) Village-scale production and utilization of bioenergy (e.g. methane digesters, biofuel-powered cooking stoves) from any plant feedstock on any kind of land, and 3) Industrial-scale use of forest products. In this chapter, we will focus on the first area to explore the perspectives of sustainable development and innovation. In fact, the production of ethanol from sugarcane and corn (maize) provides significant and tested examples of mature industries for the concurrent production of food (sugar/starch and feed products), energy (bioelectricity and bioethanol) and multiple co-products (chemicals and allied products).

Table 6.1. Areas and topics of more interest for innovation in bioenergy.

Innovation applied to feedstock production	Innovation applied to processing	Innovation applied to utilization
Forestry Agricultural land Urban residues Particular issues of Developing Countries (scale, appropriated technology)	Transport fuels Heat and cooking fuels Industrial and village models Biorefinery, other products (e.g. aviation biofuels)	Combined heat and power Innovative uses of biofuels (e.g. ethanol in Diesel engines) Developing Countries context (e.g. cooking stoves, niche biofuels production and use)

To foster innovation in bioenergy is more than just promoting R&D in agriculture and conversion technology. Significant improvement can be done also in logistics, management, environmental impacts mitigation and byproducts development, among other areas. In any case, a significant effort is required in terms of planning, sourcing, human resources preparation, co-operation with more advanced centers, etc. The results of innovative bioenergy systems will strongly depend on the suitability of a given technology in a given context and human resources. Skilled and motivated professionals are absolutely essential for effective stage-skipping and leapfrogging processes (Lee and Mathews, 2013).

6.2.1 Innovation and Biofuels

Today, significant amounts of biofuels are produced for direct use as automotive fuel or blended with conventional fossil fuels in several countries, as presented in Chapter 8, this volume. The use of ethanol as a transportation fuel is currently concentrated in the USA (Box 6.2) and Brazil (Box 6.3), but blends of 10-20% ethanol in gasoline have proven feasible in many countries and the automotive technology has expanded the conditions for using ethanol. The flex-fuel engine technology no longer requires dedicated cars that only run on alcohol and compression-ignited engines have been shown to run well on 95% ethanol (E95), as demonstrated in a thousand busses abroad (Scania 2007). Looking toward the future, the prospect of fueling agricultural machinery and trucks with locally-produced ethanol could be highly advantageous for developing countries, for many of which fuel for light duty vehicles is not the highest priority energy need.

6.2.2 Innovative Tools and Methodology Issues

Adequate policies are generally required to reduce business risks by providing clear strategic long-term demand targets and insertion in the country´s energy mix, price structure and incentives, infrastructure development and expansion. At the same time, policies must aim at avoiding the negative impacts on the landscape and local community and take into consideration the existing and future environmental protection regulations and land use planning. All these requirements demand new analytic tools and methodologies (Box 6.4).

To consider bioenergy development integrated with other aims, such as agricultural development, environmental protection, and energy planning, the whole landscape including agriculture, forestry, livestock, recreation and infrastructure components need to be included in the analysis to optimize synergies. A key aspect of the landscape approach is the possibility to conserve and harness ecosystem services (biodiversity, hydrology, carbon sequestration) that are essential for long-term sustainability of feedstock production. The production model should be evaluated, involving the way the feedstock is produced (small grower, outgrower or extensive crop), scale, technology (mechanization and automation levels) and land tenure, interactions among growers, processing plant and local community in terms of services exchanged, infrastructure and labor use. Given the complexity of a multisector approach at a landscape scale, it is essential to have a good system of monitoring and evaluation with respect to targets, incentives, pricing policy, impacts on resources, public acceptance, etc.).

Box 6.2. Ethanol from corn: impact on rural development and sustainability

Corn ethanol in the United States has several interesting characteristics that have contributed to improving rural activities. For example: 1) local policies and fiscal incentives in support of corn ethanol resulted in attractive ethanol prices and not only provided a more secure income for rural communities, but also encouraged innovation and investment into farm infra-structure; 2) R&D boosted maize yields by 30% per hectare over the past decade, cancelling out the grain that is diverted from food and feed systems into ethanol production, while increasing sales to domestic and international markets; 3) statistical evidence shows that the introduction of GM[1] traits accounts for 1/3 of this increase in yield because of the technical innovation; 4) nitrogen pollution remains a problem, but improved agronomy and genetics have resulted in a 30% decrease in the amount of nitrogen used per metric ton of grain produced; 5) stover production increased 30%, improving the potential resource for lignocellulosic biofuels, with lower impacts on soil carbon because more stover could be returned to the soil; 6) increased productivity and no-till cropping has resulted in corn ethanol systems changing from net loss of soil carbon to a gain under maize; 7) in the dominant ethanol from corn dry milling process responsible for 90% of the production mills, in 10 years, innovation in maize production and processing improved ethanol GHG benefits versus fossil fuels by 35%, reduced the fossil energy use by 30%, and process water use by a factor of 2 (Chum et al. 2013); 8) systems approaches to improve agricultural lands and reduce non-point pollution emissions to watersheds, remediate nitrogen run off, and increase overall ecosystems' health (Gopalakrishnan et al. 2011; Gopalakrishnan et al. 2009) are being tested that could release significant amount of land to even more efficient lignocellulosic feedstock production. In fact advanced technologies to produce ethanol from lignocellulosic materials have recently been commercialized and are expected to create new opportunities to utilize currently underutilized biomass.

[1] All GM development should comply with the Biosafety Protocol, in the framework of the Cartagena Protocol on Biosafety (CBD, 2000), that seeks to protect biological diversity from the potential risks posed by genetically modified organisms resulting from modern biotechnology.

Box 6.3. Sugarcane ethanol: innovation in a mature agroindustry

Many sugarcane producing countries can become cost-competitive ethanol producers, due to the lower cost of cane compared to other ethanol feedstocks and the fact that two-thirds of ethanol production cost is from feedstocks. Sugarcane is widely recognized as an efficient alternative among first generation biofuel feedstocks, because of its high productivity, high yield per hectare, potential for expansion, a very positive energy balance, its potential for producing surplus electricity, and the avoided lifecycle GHG emissions (Leal et al. 2013). Sugar factories are being transformed into "bio-refineries" with multiple energy and non-energy products, which can be extended further in the future by second generation biofuels technology based on cane fibers.

Experience with the global sugarcane industry (involving more than 100 countries) provides a wealth of lessons that could, with appropriate adaptation, be applied to other biomass crops in terms of breeding and agronomy, supply chains, industry operations and optimization, co-product utilization, optimum resource use, and market development, as well as the institutional and regulatory framework required to foster innovation in bioenergy. Innovations in terms of product development, technologies, policies and strategies undertaken over the past decades with respect to large scale commercial bioethanol production (e.g. the Brazil case, Chapter 8, this volume), electricity production (e.g. the Mauritius case, Chapter 14, this volume) and alternative products utilization at smaller scales, have paved the way towards sustainable production which deserves to be seriously considered to be undertaken in most cane producing countries.

The process of sugar manufacture from cane is mature and fairly standardized worldwide, with limited opportunities for improvements in efficiency and productivity. However, as widely demonstrated, sugarcane can sustain a far more diverse and multifunctional role beyond sugar production. The flexibility of sugarcane as a feedstock is derived from its significant biomass potential and product portfolio, especially bioethanol from molasses/juice and electricity from bagasse, all of which can improve profitability and competitiveness. For example, although distillery effluents have a high polluting potential, they can be recycled to cane fields thereby replacing part of the chemical fertilizer requirement. Improvement in using solid residues has increased substantially the electricity production in sugar mills. Modern bagasse cogeneration plants operating at high pressure of 82-87 bars can export 130-140 kWh of electricity per metric ton of cane processed, which can be increased through further system optimization and improvement in energy efficiency (Seabra and Macedo, 2011). The use of cane agricultural residues (equivalent in volume to bagasse generated in factories but usually left in fields) can double the electricity production potential. In order to facilitate carbon and nutrient cycling in sugarcane systems, however, only part of these residues are collected and used to generate electricity.

Box 6.4. Agroecological zoning: a tool for landscape approach

One tool to help address cumulative impacts on a landscape level is agroecological zoning for the different bioenergy feedstocks. Brazil has extensive experience, as illustrated in Figure 6.3 for sugarcane in Brazil (MAPA 2009). Macedo, Nassar et al. in Chapter 17, this volume discuss this aspect. In addition, complementarity of energy resources, even spatially separated, can provide valuable seasonal resilience to a country´s energy mix as in the case of the seasonal low hydropower production in Northern Brazil which is compensated by the bagasse-based electricity production (Seabra et al. 2011).

Figure 6.3. Agroecological zoning for sugarcane in Brazil (MAPA 2009).

The assessment of the maximum practical biomass energy potential through agricultural productivity and industrial efficiency improvements provide innovation opportunities. For example, first generation energy production technologies are mature while second generation technologies are being demonstrated, applied, optimized and deployed in a range of small to commercial scales. Continued support for research and development, capacity building, innovation attempts and absorption is urgently needed for continuous innovation and improvements to the current state of the art bioenergy process. However, the limits of optimum resource use and efficiency improvement need to be recognized in forecasting analysis and policy and strategy development.

To be able to have a clear view of future potential improvements it is important to make an assessment of the full potential of the selected feedstock in terms of limits for yield gains and trait improvements (metric tons/ha of dry biomass and sugar/starch/oil content). This process should take into consideration the yield gaps compared to other locations, the theoretical potential of the crop, possibility to introduce irrigation and other agriculture management practices (no tillage, precision agriculture, GMO varieties, low impact mechanization, nutrient use and application techniques).

On the processing side, it is important to evaluate the overall conversion efficiency of the primary energy content of the biomass in the field as a crop to the total useful energy of main product and co-products. Such information provides opportunities for integrating and optimizing the different steps involved in the combined agro-industrial processes for desired improvements. One important point to consider is that if the feedstock in question is not part of the traditional agriculture of the region, or if crop diversification and integration is planned, the anticipated potential is unlikely to be achieved due to the inherent conservative nature of farmers and the resistance to accept new or different practices and crops.

6.2.3 Bioenergy and Food Security: an Innovative Approach

Food and bioenergy production can coexist positively. Some approaches to develop synergies between both products are:

- integrating bioenergy production into existing activities and land use in ways that do not displace food production and in some cases improve the food production (forest products, buffer strips, perennial rotations, resilience, agricultural development);
- producing bioenergy in land that makes a small contribution to food production, which includes the huge quantity of global pasture land;
- using excess agricultural capacity to bring additional value and resilience into agricultural economies and the human communities that depend on them.

To access the effective impacts of bioenergy on the food availability and prices it is very important to visualize and deploy techniques for the joint or integrated production of food with bioenergy. Many examples involving use of agricultural residues as feedstock in bioenergy processes, as well as corn, wheat, soybeans and rapeseed meal production as co-products of the ethanol and biodiesel production already exist and must be harnessed more systematically. For example, (a) corn-soybean rotation on the same land in alternate years, (b) the sugar/ethanol integrated production where the full use of the sugars in the cane juice is made and no molasses need to be produced, (c) peanuts and soybean rotated with sugarcane in the area that is going to be renewed with new cane planting, (d) the use of cane irrigation system to provide water for food crop production, (e) greenhouse food production using utilities from the cane processing plant. It is also worth evaluating the fungibility effect of biomass, which can be generally used as food, feed and feedstock for bioenergy, ultimately providing resilience and greater food security in cases of droughts or other severe weather events, for example.

Globally, pasture and grazing land occupied an area estimated as 3,500 Mha (million hectares) in 2000, which is more than two times the global agricultural land (FAOSTAT 2013) and there is an interesting potential for integrating bioenergy feedstock and food production. In Brazil, where pasture occupies around 200 Mha and cattle is raised in a low density system (about one live unit per hectare) a small improvement in cattle stocking rates can liberate a few million hectares for agriculture and biofuels; the federal government program called Low Carbon Agriculture (ABC in Portuguese) has provisions for soft loans sufficient to release 4 Mha of current pasture to other land uses in agriculture (BNDES 2012).

The use of agricultural residues (straw) for soil protection, nutrient recycling and soil carbon increase and the use of factory wastes (vinasse, filter mud and boiler ashes) as fertilizers, displacing some of the chemical fertilizer use is a traditional practice in the sugarcane sector (Costa et al. 2013). Especially, vinasse could be used for the production of liquid fertilizer through concentration and blending with other nutrients for direct application in the field, when soil conditions permit, or after anaerobic digestion. The residues from the sugarcane production and processing (bagasse and straw) and the ethanol itself can be used to replace traditional cooking fuels (e.g. collected firewood, and dung or charcoal) in the forms of pellets, briquettes and alcohol or gels, used efficiently in modern cooking stoves. More information about this is available in Chapter 14, this volume.

6.3 Need for Increased Capacity in Data Gathering and Analysis

Bioenergy has been in the spotlight for some time, some claiming the virtues of bioenergy for energy supply and climate change mitigation, and others pointing to environmental and social impacts. Bioenergy's future greatly depends on verifying these claims through scientific assessment, analysis, objective evidence and feedback loops into decision-making processes that are integrated and complex. This approach will allow taking corrective actions to maximize benefits and minimize risks. Chapters 9 to 21, this volume, identify multiple areas where clear gaps exist in data and analysis of bioenergy potentials, and many call for the systems-level data gathering and synthesis approach that we similarly advocate here from an innovation perspective.

In Chapter 9, this volume, Woods et al. point to some critical data and knowledge gaps such as (a) a lack of data and models, and coordination, (b) competing demands for food, feed and fiber; agricultural and forestry management practices; (c) marginal lands; (d) water availability and use; (e) ecosystem protection; (f) climate change; (g) choice of energy crops; (h) economic market development; and (i) costs associated with biomass production. According to the authors, "the inherent complexity of biomass resources makes the assessment of their combined technical potential controversial and difficult to characterize." They further identify key uncertainties associated with assessment of bioenergy potential, such as population growth and demand for land-based products, climate change impacts, and the extent of land degradation, water scarcity, and nature conservation requirements. They recommend that major policy efforts, such as land use zoning, will need to occur despite the uncertainties and shortcomings of zoning. A similar perspective also emerged from a recent analysis of 90 published studies on the potential for bioenergy production in which estimates varied by several orders of magnitude (Slade et al. 2014). The authors concluded that it was necessary to pursue ground-up empirical studies to obtain reliable estimates of bioenergy potential for purposes of policy formulation.

Macedo, Nassar et al. in Chapter 17, this volume, highlight success stories in agro-ecological zoning, but note that new governance systems (also an innovation) must be put in place to deal with increased complexity of land use regulation, as well as to engage stakeholders properly. Richard and El-Lakany in Chapter 13, this volume, advocate for government strategies that encourage multi-functional landscapes, integrated landscape design, and landscapes that are resilient to climate change. For this to occur, bioenergy stakeholders must facilitate innovation in complex environmental assessment and analysis, as well as communication.

Such a landscape approach could hardly be achieved through sustainability certification (Chapter 19, this volume). As the authors caution: "...if standards are to be the most credible measurement of environmental, social and economic performance, they must translate their paper aspirations into frameworks that: (1) assess baseline conditions; (2) collect data and measurements; and, (3) analyze those results to the baseline at the appropriate landscape level". From their collective experience in sustainability policy and certification, they contend that such capabilities are only in their infancy and still must be reconciled with emerging environmental and social principles negotiated in certification standards.

The examples elaborated in Chapter 14, this volume, demonstrate that integrated assessment is being attempted in some cases, such as the development of the LEAF tool in the U.S. that measures impacts on water, soils and climate from corn stover removal. Assessment outcomes, however, cannot remain static; instead, public and private sustainability policies must take information acquired and use that information to adjust mandates if necessary. Alongside the technical complexity, there are the multiple policy objectives related to bioenergy deployment: socio-economic and environmental benefits, which depend on the context. As identified by Diaz-Chavez et al. in Chapter 15, this volume, relevant drivers for developing countries include poverty alleviation, job creation, access to food and health care, energy access, maintenance of land rights, and protecting women and other vulnerable groups from exploitation.

In chapters 3 to 6, this volume, the fundamental need to approach bioenergy policy development from a systems perspective to overcome "siloed" or segregated approaches was clearly identified. For example, some media focus has fanned pushback to biofuels' mandates because of their possible conflict with food security, although the actual impact of bioenergy production is not clearly assessed and in some cases improves food production and access. It goes beyond what biofuels policy can legislate separately or biofuels research alone can solve, while recognizing the need for safeguards in bioenergy development as well as for approaches that deliver on both food and energy security. It should be acknowledged that biofuels policies have already spurred innovative assessments of impacts beyond the capabilities of other sectors similarly affecting land use. Still, the bioenergy field has yet to pull together multiple data points and analytical tools that would give society a more informed perspective on the *systemic* impacts bioenergy can have on the environment and society. In this context, the Bioenergy Decision Support Tool is a relevant reference, which offers support for both the strategy and the investment decision-making processes, under the concept of identification and mitigation of risks and a longer-term perspective of sustainable use of resources, key elements to maximize the potential benefits from bioenergy (UN Energy 2010).

Moving forward, innovations must occur across the spectrum to generate data where it is missing, and build meta-analyses with the capability of applying multi-criteria analysis to harness and integrate multiple, diverse data sets and analytical tools at the proper spatial and longitudinal scales. Further, equally dynamic policies must be in place both to incentivize additional data collection and building complex analytics, as well as on the receiving end to properly put these to use. Currently, no such policy regime successfully achieves this goal. As the authors of Chapter 19, this volume, note, for example, the U.S. Renewable Fuel Standard triennial assessment about its environmental effects clearly acknowledges that assessment of environmental baselines in many cases does not exist. Furthermore, the Standard creates no channel to incorporate what is being learned about biofuels' sustainability back into the Standard. Similarly, while the EU has received reports back from member states on the results of sustainability certification, the EU summary of the results is quite conclusory and it is not transparent as to what type of data and analysis regimes are applied, nor the baselines to which continuous improvement is being used. Based on the data and analytical gaps identified above, it is unlikely that such a summary can be achieved at this time, even though the chapters of this volume clearly expect this type of environmental analysis to occur. As the complexity of data and analytical tools increase, which must occur in order to gauge systems-level achievements, those responsible for incorporating outcomes into policy must ensure transparency and build capacity for all stakeholders to participate meaningfully in complex decisions.

Certification regimes can play a leading role in identifying missing data and analytical tools. Many principles of sustainability certification theoretically require that biorefineries and farmers conduct assessments of baseline conditions, and where practices do not maintain or improve those conditions, they should adjust management practices accordingly. Even in the US, with advanced technological capabilities and policies, this type of assessment is extremely difficult. If a farmer were directed not to contribute to water pollution in a sustainability certification, that farmer would have to know first what waters fall under the prescription. Within the farmer's control are waters that physically are present on or under the property; however, multiple landowners upstream can affect water quality conditions. With the exception of the Chesapeake Bay, which has been led by US EPA, many states have not completed studies of water quality conditions of receiving waters, nor have they mapped agricultural contributions to nutrient pollution that could guide more targeted producer-by-producer goals. Standards would be confronted, then, with having to impose blindly practice-based requirements that prevent water pollution (e.g., no-till, reduced fertilizer use), without knowing the exact contribution of that farmer to baseline conditions. Chesapeake Bay modeling of water quality conditions and agricultural contributions to nutrient pollution has been a decades-long process, and is being challenged in federal court by farm groups as not based on accurate field-level data (ironically, however, agriculture has lobbied successfully not to be required to report such data), and too uncertain to base nutrient prescriptions on. The same models are being applied in other watersheds such as the Mississippi, to develop state non-point source pollution policy. Ideally, for certification to most accurately and economically apply a water quality principle to an individual producer, tools such as LEAF, which incorporate tools such as RUSLE2 (which gauges soil loss), would also tie into water quality models being developed for nutrient-stressed watersheds. Further, data on economic profitability at the micro-grid level could be incorporated into such models to identify those ecologically sensitive lands where perennial biomass cropping would make more sense economically and environmentally over corn production. At this time, no such capability exists.

Even if water, soil, climate and economic analytical tools could be tied together, the issue for certification regimes, too, is to construct an interface between the information required from the farmer for certification and these models. That is, the most convenient way to conduct assessments for certification is for the farmer to enter information through a web-based interface. This interface must 'communicate with' analytical tools by providing the necessary information in a format that software applications can use. Farmers must understand how to use the interface, why such information is needed, and how the information is analyzed to reach conclusions about the sustainability of the operation. This is onerous for farmers, and arguably only gauges one economic actor's effects on the system. Current thinking is that that these types of analytics would likely be more useful, from the perspective of gauging systems-level sustainability, at the biorefinery level. Biorefineries have greater economic capacity to take in information from the farmers they purchase biomass from and apply "shed" level analytics to that data, whether watershed, biodiversity shed, or socio-economic shed. Gauging biomass' overall effect within a watershed or species habitat is much more valuable information to a policymaker concerned about advancing sustainability than individual, field-by-field certifications. Biorefineries, too, typically are the economic actors responsible for sustainability accounting in bioenergy policies.

Closing this section on data needs, it is worth stressing that although bioenergy is inherently complex and site-specific solutions should be evaluated, several analytic tools and cases studies are already available to support decisions and put forward plans to implement sound bioenergy programs.

6.4 Capacity Building and Sustainable Bioenergy

Proper institutional framework and skilled human resources are essential for promoting sustainable bioenergy, at several levels. At the level of governmental agencies, trained personnel is required to plan, design, implement, follow-up and oversee national and regional bioenergy programs, defining consistent objectives, establishing budgets and financing schemes, indicators and assessment activities. At operational level, professionals are needed to design, build, commission and start-up, operate, maintain and assess bioenergy systems.

Thus, training programs, at different levels should be developed, and some should consider international and horizontal co-operation. Some countries have relatively mature bioenergy programs and can help train and mentor teams. In order to provide support to farmers, considering the adoption of new cultures for feedstock production, as well as the introduction of new practices and technologies, it will be critical to strengthen the extension services, and to scale out and scale up the application of innovative ideas.

There is also an urgent need to train personnel for developing Research & Development activities in the field of bioenergy, including for planning, designing and assessing programs and projects. Regional and international co-operation and the financial support of multilateral agencies can be relevant, although the national perspective on bioenergy priorities, domestic demands and resources should be kept. It is also important to observe that time and resources are needed to prepare and train skilled personnel and it thus requires long-term and stable programs. At a more general level, it is advisable to consider introducing curricula that cover bioenergy concepts, potentials, perspectives and constraints to inform students and future professionals on the fundaments and applications. This aspect is discussed below, in the context of promoting public awareness and participation in the process of implementation and evaluation of bioenergy programs.

Sustainable bioenergy programs will benefit from appropriate and nationally relevant institutional, legal, and regulatory frameworks, involving governmental, private agencies, and other institutions able to develop and execute policies in bioenergy. Some important characteristics include:

- Bioenergy necessarily involves multi-sectorial or multi-ministerial management, co-operation and coordination, to harmonize the perspectives of agriculture, energy, social affairs, the environment, and industry, among other agencies and institutions. To implement this approach requires sometimes a learning phase, but the results are rewarding, as observed in the application of UN Energy in the Decision Support Tool for Sustainable Bioenergy in some African countries (UN Energy 2010).
- An essential corollary of a good institutional framework is a comprehensive legal framework that provides the necessary governance and enforcement conditions

to propose and develop bioenergy programs. A good indicator of the level of government commitment to promote and support bioenergy is the existence of clear legislation, defining responsibilities, setting general and specific objectives and defining elements of control.

- Although stable and foreseeable legislation is important to reduce the risk perception about bioenergy and to stimulate actors to develop bioenergy projects, it is also important to maintain a level of flexibility to adjust targets and programs according to local conditions. In this regard, permanent follow-up and monitoring of results are good resources to guide the Administration facing changing contexts and perspectives.

The relevance of capacity building cannot be overlooked. In all the cases where a bioenergy program developed successfully, it is relatively easy to find the existence of trained people, with good institutions and proper legislation in place, as well as with enough and updated information available. Studies evaluating different situations, from Europe (McCormick and Kaberger 2007) to India (Ravindranath and Balachandra 2009), confirm that the lack of know-how and weak institutional capacity are barriers obstructing the expansion of bioenergy. Recognizing this demand, the Global Bioenergy Partnership launched the Working Group on Capacity Building for Sustainable Bioenergy in 2011 (GBEP 2011a).

6.5 Need for Flexible Financial Models

While promoting sustainable bioenergy projects in developing countries demands usually relatively modest investment compared to conventional energy systems, the majority of bioenergy systems in developed economies require massive capital requirements, not only for the development phase but also for their implementation and operation. As a reference, to absorb the average growth in transportation fuels (currently 2 billion tons worldwide), which seems coupled to economic growth (1.5% annually or 30 million tons), one needs to annually mobilize 120 million tons of extra biomass, with scales comparable to rebuilding the world's largest port (Shanghai) every 5 years.

When implemented in 150 kton/year production facilities (typical scale of today's 1st generation liquid biofuel plants), this translates into an estimated annual increase in capital requirement of 50 billion dollars for the approximately 200 plants that cost USD 250 million each. To meet the RFS2 targets by 2022, USDA estimated that USD 168 billion would be required to finance about 500 biorefineries (USDA 2010). Clearly this level of investment requires cumulative development, testing and implementation times of 20 years or more, given the average rate of innovation in process industries as shown in Figure 6.4. Change in conventional logistic systems to accommodate this increase in biomass transport and use (road, train, ship/port) will require comparable huge investment and lead times. For example, a change in agro/forestry system depends on the sort of biomass equivalent to annually replanting grains, 5-7 cycles of sugarcane, and 10-20 years for forestry and (palm) plantation replantings), at somewhat more modest investment, but still needing relatively large amount of capital.

Capitalizing the bioenergy sector is now a major priority and a massive opportunity for private and public investors (agro-banks, pension funds and other institutional investors, insurance companies, national development banks, and private equity funds. There is still a high level of risk for investors because:

- there are – with the exception of conventional agro-food/fuel processors such as sugarcane and corn ethanol – no clear mature and demonstrated winning technologies yet and there may be a need for multiple energy products;
- no guarantee of biomass supply since – again with the exception of conventional commodity agro/forestry products for food and paper industry – there are no established biomass markets with clear specifications and pricing mechanisms. An exception is the APX/ENDEX (Amsterdam Power Exchange) wood pellet trading, based on a weekly updated traders index.
- few companies are vertically integrated in bioenergy (or biorenewables) technology portfolio and biomass value chain yet, whereas many, if not most, traditional (fossil) fuels and power companies have a well integrated well-to-wheel or power-to-plug model. This implies that most (commercial) bioenergy developments, especially for 2nd generation biomass utilization, require forms of open innovation such as ranging from public-private partnerships (BE-Basic, CLIB2021, EBI) to joint ventures (Shell-Cosan, DSM-POET, DuPont-Genencor etc.). The open-innovation format has substantial financial benefits due to sharing risk, capabilities and costs.
- most bioenergy industries suffer from the relatively low added value of energy products, which is augmented by the inherently low mass yield of energy densified products (energy carriers) from biomass. This is obviously related to the relatively high state of oxidation of biomass: 23% (lignin) to 53 % (cellulosics) of the dry biomass is oxygen atoms, with an average of 40-43% of whole biomass.

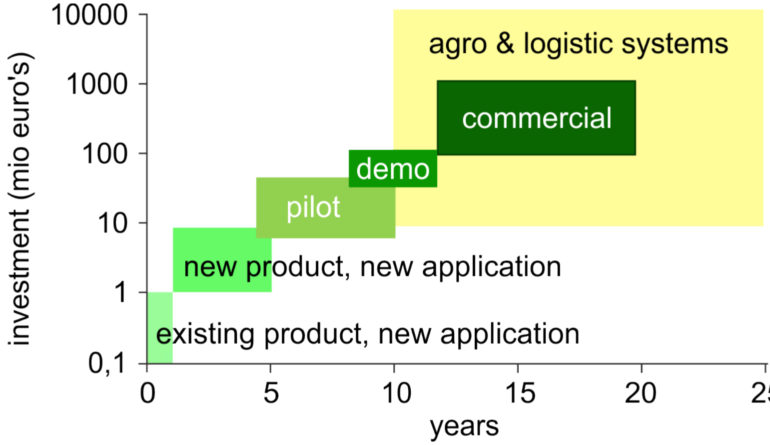

Figure 6.4. Time and investment scale estimates (van der Wielen and van Breugel 2013).

- whereas the fossil energy world has been successful to add value to nearly all of its feedstock, the biorenewables industry is still struggling to implement the full biorefinery model, including higher added value product portfolio with biochemical and biobased materials.
- hence, co-products are generally beneficial for closing the gap between revenues and production costs (and prevent emissions), but unfortunately most current co-products such as power/heat from CHP-installations, and biogas from wastewater treatment have relatively low added values. Further technology and market development for full biomass utilization is urgent. This financial situation affects the competitiveness of bioenergy systems negatively, and renewables based electricity production and biofuels are heavily subsidized at a global level. Global subsidies had a value of more than $ 60 billion in 2010 and –without additional measures - are expected to raise to almost $ 250 billion in 2035, of which roughly 25% for liquid biofuels and 25% for power (co-firing) (IEA 2013). In many countries, governments strive to reduce subsidies or phase them out.

Considering the different categories of risks, in Table 6.2 some mitigation strategies are suggested, to accelerat implementation of innovative biofuels projects (Koonin and Gopstein 2011). It is worth to observe that the technology risk should be the first to mitigate, since robust and well tested bioenergy paths are possibly the most important feature of really feasible bioenergy projects.

Table 6.2. Risk mitigation strategies to develop bioenergy projects.

Risk	Mitigation Strategy
Technology	Validation of R&D at pilot and demonstration scales
Construction	Engineering, procurement and construction performance guarantees at demonstration scale
Operations	Validate operations performance at pilot and demo scales
Finance	Competitive awards, loan guarantees, IPOs, debt finance
Feedstock supply	Develop harvest and logistics operation at pioneer scale
Product off-take	Advocate long-term purchase agreements

Source: Koonin and Gopstein (2011)

The development of bioenergy (or more generalized biorenewable) production systems will likely follow two parallel pathways:

1. **large-scale:** continue the trend of ever larger scale biorefineries such as those for sugarcane in Brazil and elsewhere, corn (USA and France), wood pellets (Canada, USA, Baltic) or palm oil (Malaysia, Indonesia, Colombia, elsewhere) serving national and export markets, or;

2. **distributed manufacturing:** based on smallholder models ranging from individual farmers to small and medium sized producers with mostly regional markets. In addition, rapid development in internet technologies also allow small businesses to have global costumers, although transportation costs rapidly increase with distance (up to 10% for sugarcane based production, and up to 40-50% for more difficult terrains) (Palmeros-Parada et al. 2014, Pantaleo and Shah 2013).

With respect to financial aspects and especially financial innovation (innovation in financing models), we need to distinguish between the development stage (Research, Development and Demonstration, R&D&D), the demonstration (1^{st}) plant and the n^{th} plant (mature technology and supply/value chain), for each of those pathways, as indicated in Table 6.3. Government support is required for bioenergy particularly at the development stage: R&D expenses in biofuels in 2012 was about $1.7 billion ($1.2 billion from governments), much of it going on next-generation technologies like cellulosic ethanol, Fischer-Tropsch biodiesel and algal oil from a total USD 4.8 billion governments RD&D and total $9.6 billion on all renewables (BNEF 2013).

Table 6.3. Financing models for promoting bioenergy.

Financial models	Large scale	Distributed manufacturing
Development stage (R&D&D)	National science and technology foundations and internal private resources Public private partnerships, and publicly (co)subsidized pilot facilities	National science and technology foundations and internal private resources Co-operatives such as in dairy, sugarcane, potato, beet, grains and other commodity (including co-operative agro-banks) Public private partnerships Venture capital including business angels
1^{st} Plant	Loans and guarantees by national development banks, regional development funds and other government linked financials, joint ventures and public-private partnerships (often also Joint Ventures), excise tax credits and feed-in tariffs	Loans and guarantees by regional development banks and regular financing agents Various (regional) governmental including fiscal holidays / exemptions Crowd or cloud funding Micro-credits
n^{th} Plant	Senior debt (secured (priority) loans mostly on company assets) from financials, investment funds, institutional and other equity investors governmental/fiscal stimuli such as excise tax credits and feed-in tariffs	Regular (regional) financing agents with various loans/debt structures, usually too small for investment funds and institutional and other equity investors

In the case of small-scale projects, at farm level and bioenergy programs in developing countries, innovative finance and insurance schemes must be considered, in order to reduce risk and improve attractiveness in context of lower resources available. In these cases, to connect projects and programs with extension services and operational support is advisable, since it requires more attention to reinforce entrepreneurship and local capacity, particularly in the design and deployment of bioenergy systems, as already mentioned.

6.6 Relevance of Consultation and Communication

Due to various strong relationships with other sectors, which create conditions for multiple benefits and impacts, bioenergy requires a clear strategy of stakeholder involvement aiming to build and support the development of sustainable bioenergy programs. The different voices of those who may benefit and those who may run risks need to be heard, and engagement in the identification of pathways that balance impacts needs to be ensured. Thus, proper consultation and communication strategies are crucial aspects to take into account. We categorized them below as follows: public participation overview, stakeholder engagement, public participation and bioenergy; and public perception and communicating good practices.

6.6.1 Public Participation - An Overview

The term participation is often used interchangeably with involvement, consultation, and engagement. Public participation is used as a general term to cover the range of approaches involving members of the public. Guidelines on public participation and stakeholder involvement are provided by various organizations including the International Association of Public Participation (IAP2), the International Association of Impact Assessment (IAIA), the ISEAL Alliance, which is the global membership association for sustainability standards, the Roundtable for Sustainable Biomaterials (RSB), the United Nations Environment Programme (UNEP) and the Global Bioenergy Partnership (GBEP).

The ladder of participation introduced by Arnstein (1969) was one of the first attempts to articulate the range of approaches explaining how much power was given to the public from the lowest side (manipulation) to the highest side (citizen control). Public participation therefore needs to be considered at the highest level including citizens in the decision-making process. This public participation has been used systematically in environmental management tools including Environmental and Social Impact assessments and Strategic Environmental assessments.

For the last 20 years, public participation has been a key issue in environmental assessment and decision-making processes. In Principle 10 of the Rio Declaration, Earth Summit (UNCED 1992), public participation was considered a main issue for sustainable development and this was reaffirmed at the World Summit on Sustainable Development (WSSD 2002). A further key driver for public participation in environmental decision-making has been the Convention on Access to Information, Public Participation in Decision making and Access to justice in environmental matters (UNECE 1998) known as the Aarhus convention.

6.6.2 Key Principles of Stakeholder Engagement

The basic rationale underlying public participation is the public's 'right' to be informed and consulted, and to express its opinion on matters that affect them (Sheate 2011). Out of distrust on governments and experts, the public has been demanding to have a more influencing role in the decision-making process. As a process, public participation should lead to better decisions being made and can lead to improved relations between developers and local people. Early stage dialogue may contribute to provide clarifications and reduce misunderstandings. Table 6.4 summarizes the principles for good practice on stakeholder engagement presented by UNEP (2012).

Table 6.4. Principles for stakeholder engagement.

Principle	Process
Integrated	The process should be able to integrate the contributions of very different groups of stakeholders from government to international organizations to local communities. This principle ensures inclusive and fair representation
Adaptive	The process should be flexible and also engage a range of stakeholders through different methods
Transparent	The process should have clear, easily identified requirements. It should ensure that there is public access to information. Limitations and difficulties should be acknowledged and the reasons why particular decisions were taken should follow a trail that is accountable
Credible	The stakeholder engagement process is the only way in which affected stakeholders may have an influence on the decision-making process. It is important that the process be conducted by professionals to ensure faith in the process and those facilitating it
Rigorous	The process should apply "best practices", using methodologies and techniques appropriate to the scale and phase of the stakeholder engagement process, specifically when it comes to stakeholder consultation and record-keeping
Practical	The process should result in information and outputs which assist with problem solving and are acceptable to and implementable by proponents
Purposive	The process should aid in decision-making by taking into account the concerns of all stakeholders

Source: UNEP (2012)

According to the UN Commission on Human Rights principle “Free prior and informed consent (FPIC) (Tamang 2005), is the principle that a community has the right to give or withhold its consent to proposed projects that may affect the lands they customarily own, occupy or otherwise use”. Such principle is even considered “a key principle in international law and jurisprudence related to indigenous peoples” (Forest People 2013).

The Forest People Organisation (2013) considers FPIC necessary to ensure a level playing field between communities and the government or companies and it helps to reduce risks in investments. FPIC also implies careful and participatory impact assessments, project design and benefit-sharing agreements. FPIC has been widely accepted in the ‘corporate social responsibility’ policies of private companies working in sectors such as dam building, extractive industries, forestry, plantations, conservation, bio-prospecting and environmental impact assessment.

6.6.3 Stakeholder Participation in the Bioenergy Sector

Bioenergy initiatives have been implemented under different business models in developed and developing countries, reinforcing in all cases the need for properly considering the public’s participation, identifying and engaging stakeholders in the project conception and implementation, mainly due to land use and food security concerns. This participation has been recommended by good practice guidelines, including the Roundtable for Sustainable Development, the United Nations Environment Programme and some research projects such as the EU COMPETE project and the Global-Bio-Pact project.

Mapping stakeholders for bioenergy initiatives should include national level policy and institutions as well as stakeholders at the productive level including NGOs, farmers, other civil organizations and the industry sector (including also farmers with different forms of participation (e.g. outgrowers). A simple tool could be to use a quadrate to represent them and identify the links between these different bodies and stakeholders (Diaz-Chavez et al. 2010), as shown in Figure 6.5. Several sustainability standards for bioenergy crops have included in their criteria issues related to FPIC such as the Roundtable for Sustainable Palm Oil, the Roundtable for Sustainable Biomaterials, and BONSUCRO. Figure 6.6 depicts the Credibility Principles of the ISEAL Alliance.

Some developing countries have engaged local communities in a participatory approach. An example is the Task Force on Biofuels in Tanzania, which involved different stakeholders. The Ministry of Energy in Tanzania started in collaboration with the Swedish Development Agency (SIDA) the consultation with different villages as part of the Strategic Environmental Assessment for the biofuels policy.

The private sector has also complied with this participatory process as demonstrated in the certification of biofuels initiatives by the Roundtable on Sustainable Biomaterials (RSB).

Figure 6.5. Mapping stakeholders for bioenergy initiatives (Diaz-Chavez et al. 2010).

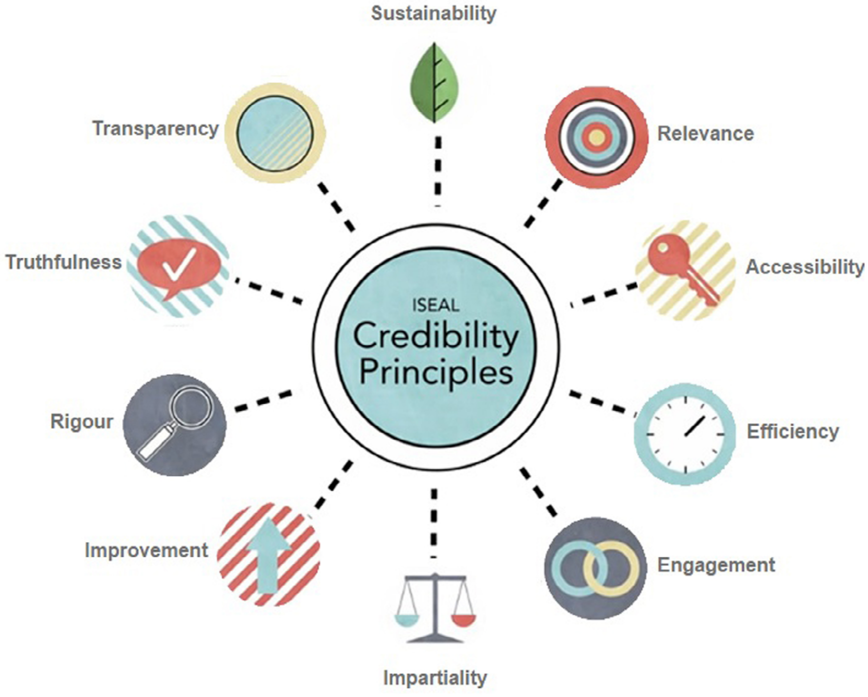

Figure 6.6. Example of the Credibility Principles (ISEAL 2013).

6.6.4 Public Perception and Communicating Good Practices

The analysis of public perception (PP) should be a prerequisite for future development of the Bioenergy initiatives since PP determines the public acceptance, and thus the demand of biofuels/bioproducts as well as the possibility to develop their supply (Fallot et al. 2011).

It is important to recognize that there are significant differences in the way experts and the public perceive risks associated with environmental and social issues. Decision makers legitimately consider the public's opinions when making decisions but it is their duty to inform the public timely and clearly about benefits and possible drawbacks associated to bioenergy projects. Although public perception is recognized as an important determinant of success of renewable energy programs, there are few studies analyzing its real impact and how those perceptions are formed. Fallot et al. (2011) reported this lack of analysis to assess the relationship between public's acceptance of biofuels and the sector's development (Rohracher 2010; Devine-Wright, 2010).

There is a difference between perception and belief. Perception is the result of current experiences and information and adapt over time while beliefs are formed based on past experiences (Bleda and Shackley 2008). Public perception also depends on cultural aspects, history and economy of the producing countries, objectives of importing countries, environmental and social targets, as well as on the positive or negative impacts on individuals and communities (Fallot et al. 2011). Public perception of Bioenergy (particularly biofuels) is often tackled in a rather informal way ("people say …"). A proper methodology for assessing public perception comprises statistically sound methods including representative samples (Fallot et al. 2011).

Analyzing public perception will help the government and private sector to better understand how to orient policies and initiatives. This should also be the result on how to communicate the findings, proposals and benefits of bioenergy projects including employment generation and jobs quality; energy security; food security; positive impacts on climate change mitigation and adaptation.

Communication with the media and opponents of bioenergy should also be promoted. Six case studies analyzed on public perception within the Global-Bio-Pact EU funded project demonstrated that the public gets most of the information on bioenergy initiatives through the media (mainly newspapers, TV, radio and internet) (Global-Bio-Pact 2010). Cultural aspects were one of the key issues addressed in countries where NGOS have dominated the media, people were more informed about the negative issues rather than the positive aspects of biofuels demonstrating the need to find better forms of communicating with stakeholders including the media. Different methods for engaging with stakeholders and the public have been developed that contribute for better communication. In Table 6.5 are presented some alternatives for promoting stakeholder engagement, public participation and forms of communication that can be employed.

Table 6.5. Tools and forms of communication for stakeholder engagement.

Tools for stakeholder engagement and public participation	Forms of communication
Stakeholder mapping	Visual aids (posters, leaflets, photos, diagrams)
Participatory rural appraisal	Software images including GIS
Stakeholder forum groups	Focus groups
Participatory ecological land use management	Experts and general public meetings
	Stakeholders dialogue meetings
	Media communication reports

Source: UNEP 2012

6.7 Final Remarks

Making bioenergy an integral part of sustainable development requires a systems approach and integration on different levels: assessment, policies and strategies, and business models. Political leadership, providing long-term, consistent policy legal, and institutional frameworks are necessary to leverage the necessary investment in innovation and scale up of the existing good practice examples.

Bioenergy cannot be looked at in isolation, but as part of a wider energy system in the context of wider resource use for different end uses. At the heart of any decision making process is integrated resource assessment, particularly: integrated water management and land use planning. Methodologies have been developed for both and are ready for implementation. Furthermore, projected energy, food and materials needs should be accounted for as part of the assessment.

Policies need to be long-term, providing investors' security, and consistent with policies for climate, rural and industrial development, and energy and food security. Targets and mandates as well as feed-in tariffs for bio-electricity have proven useful tools spurring market development – if derived based on integrated assessments, taking into consideration the different pressure points, and flanked by sustainability standards on the project level.

Monitoring and verification of policies' effectiveness is important. Capacities for data collection and analysis need to be strengthened. The Global Bioenergy Partnership (Box 6.5) has developed 24 indicators agreed upon by a wide network of governments and intergovernmental organizations, which can provide useful guidance for such a monitoring process (GBEP 2011b). Analysis of progress towards or away from previously set national objectives allows for effective corrective action. Sustainability standards, developed in multi-stakeholder processes, which reflect the social, economic and environmental pillars are a tool that can be used to improve project level planning and management.

A number of examples exist, where innovation has given rise to new business models. The use of co- or by-products is one, where different business opportunities have been combined. Similarly, for integrated food-energy systems, which cater for different end uses by making the most of resource inputs. It is also interesting to consider that new technologies for biomass processing aiming at energy products are posed to produce high value chemicals, which can justify the implementation of demonstration plants.

Innovation and scale up of sustainable, modern bioenergy can contribute simultaneously towards the achievement of the three objectives of the Sustainable Energy for All initiative: universal access to modern energy services; doubling the share of renewable in the global energy mix, and doubling the rate of energy efficiency improvements globally by 2030. To achieve the renewable objective, the share of traditional biomass needs to be decreased dramatically and modern bioenergy can be a key stepping stone in this transition. Local production in remote, energy poor areas improves access. Both a transition from inefficient firewood and dung use to modern bioenergy, as well as use of co-/and by-products, residues and waste, and technology advances allowing the use of highly efficient feedstocks, contributes to the efficiency objective. This last aspect is essential: innovation could lead to much better feedstocks and much better processes, essential to feasibility of bioenergy systems.

6.8 Recommendations

1. To promote cross-sector data and information gathering, for informing innovative design and continuous monitoring of bioenergy systems.
2. To promote integrated assessment of social, economic, environmental aspects of bioenergy systems, adopting a landscape approach of natural resources management (land, water, etc.) to enhance productivity (bioenergy, food, feed, feedstocks, timber), environmental services (hydrology, biodiversity, carbon) and economic value, as a key reference framework informing innovation.
3. To promote innovative bioenergy technologies, considering the whole production chain: feedstock production, conversion and final use, in different scales and contexts.
4. Policies need to consider short- and long-term costs and benefits to avoid negative social and environmental impacts, while offering safe investment conditions.
5. To develop financing schemes and business models, especially to enable communities to benefit from small-scale bioenergy projects.
6. To enhance institutional frameworks and capacity building for improved governance, human resources, knowledge generation, innovation and extension in bioenergy systems.

Box 6.5. The Global Bioenergy Partnership (a summary from GBEP 2014)

The Global Bioenergy Partnership (GBEP) was launched in May 2006, resulting from a consultation process among developing and developed countries, international agencies and the private sector interested in bioenergy. GBEP aims to organize, coordinate and implement targeted international research, development, demonstration and commercial activities related to production, delivery, conversion and use of biomass for energy, with a focus on developing countries. GBEP and its Partners comprise 23 countries (Argentina, Brazil, Canada, China, Colombia, Fiji Islands, France, Germany, Ghana, Italy, Japan, Mauritania, Mexico, Netherlands, Paraguay, Russian Federation, Spain, Sudan, Sweden, Switzerland, Tanzania, United Kingdom, United States of America) and 14 international organizations and institutions, such as the Economic Community of West African States, European Commission, Food and Agriculture Organization of the United Nations, Inter-American Development Bank, International Energy Agency, International Renewable Energy Agency, United Nations Conference on Trade and Development (UNCTAD), United Nations Department of Economic and Social Affairs, United Nations Development Programme, United Nations Environment Programme, United Nations Industrial Development Organization and United Nations Foundation. A further 27 countries and 12 International Organizations and institutions are participating as Observers.

GBEP provides also a forum to develop effective policy frameworks to suggest rules and tools to promote sustainable biomass and bioenergy development, facilitate investments in bioenergy, promote project development and implementation and foster R&D and commercial bioenergy activities. GBEP's main functions are to:

1. promote global high-level policy dialogue on bioenergy and facilitate international cooperation;
2. support national and regional bioenergy policy-making and market development;
3. favor the transformation of biomass use towards more efficient and sustainable practices;
4. foster exchange of information, skills and technologies through bilateral and multilateral collaboration;
5. facilitate bioenergy integration into energy markets by tackling specific barriers in the supply chain;
6. act as a cross-cutting initiative, working in synergy with other relevant activities, avoiding duplications.

6.9 The Much Needed Science

1. Develop integrated assessment of social, environmental, economic aspects of bioenergy systems, adopting landscape approach of natural resources management.
2. Develop conceptually and implement bioenergy systems models proper to integrated analysis of impacts, risks and benefits, in a broad sense.
3. Develop bioenergy technologies considering the “new” opportunities of feedstock supply (such as urban residues, agricultural residues) and innovative processes, aiming at different markets (domestic, national, local).

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