Mitigation Strategies: Biofuel Development Considerations to Minimize Impacts on the Socio-Environmental System

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Introduction

Expanding the production of biofuels is a priority for many nations seeking to offset climate forcing from fossil fuel use, enhance rural development, and improve national or local energy security. Development of biofuel systems, though, vary from region to region depending on the different priorities nations and local communities assign to the motivations and implementation strategies selected within their regional context. There are also numerous risks associated with expansion of biofuels including unacceptable impacts on a suite of critical socio-environmental issues related to food security, human well-being, and the function and integrity of ecosystems.

Deriving maximum benefit from expanding biofuel production while minimizing adverse impacts will require careful attention. Figure 17.1 illustrates the general gradient of benefits and impacts for a suite of goods and services related to biofuel systems. Development strategies will need to adjust for regional heterogeneities and scale projects so that the collective extent of biofuels does not outstrip potential socio-environmental benefits (region C of Figure 17.1). Strategies for protecting food security, human well-being, and the functioning and integrity of ecosystems need to combine specific criteria relative to performance goals, a strong commitment to best practices, and the recognition that expanding biofuels beyond some level will, even with best practices, lead to an unacceptable level of impacts.

Similarly, designing effective biofuels policies will require a combination of global- and local-scale policy tools and ways to evaluate trade-offs that include the impact of the aggregate application of these policies. Policy tools consist of incentives that link biofuel

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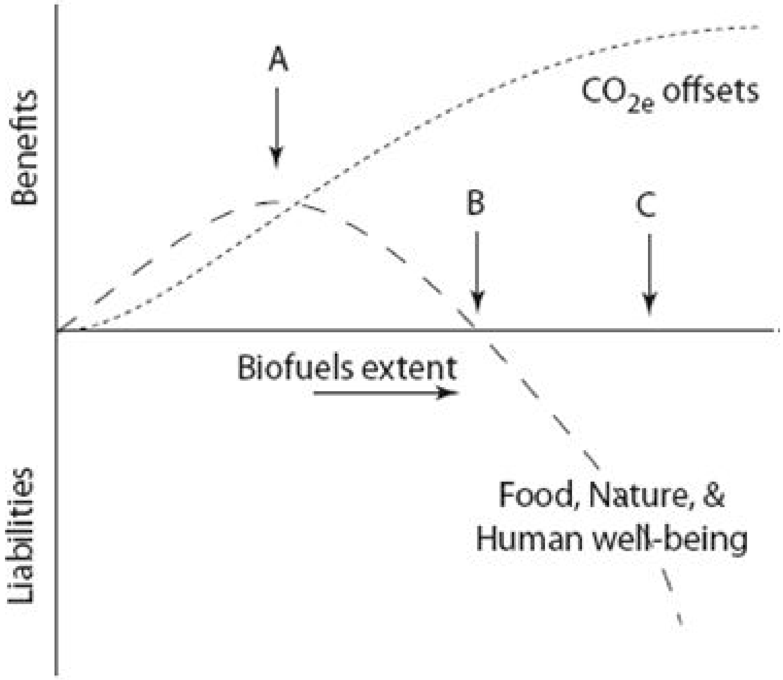

Figure 17.1 Conceptual model illustrating the likely scaling of the net benefits and net liabilities of biofuels expansion, as a function of the spatial extent of the deployment in a region or country. The offset of fossil CO2 equivalents increases gradually with the extent of the deployment, accelerating with economies of scale and the technology improvements that come with increased scale. At high levels of deployment, the growth in fossil offsets grows, as the biofuels developments move onto less appropriate land or as the inputs of fossil energy for fertilizer or the releases of N2O from fertilization increase. The net of the benefits and liabilities for food security, nature, and human well being is likely positive for small deployments, when the biofuels occupy appropriate lands and have little impact on other land-based activities. The net benefits increase initially as more people are able to take advantage of employment opportunities. But the net benefits likely reach a maximum at a modest extent of deployment, as liabilities related to competition with food, stresses on biodiversity, and environmental pollution increase. Further increases in the extent of the biofuels deployment leads to rapidly increasing net liabilities for food, nature, and human well being, as food security and ecosystem services face increasing risks of large-scale failure and as rural people are displaced. The point labeled A represents the deployment extent at which the net benefits for food, nature, and human well being are maximized. B represents the point of transition from net benefits to net liabilities. And C represents an extent of biofuels deployment well beyond the level consistent with the protection of food security, ecosystem integrity, and human well being. The shape of the responses and the physical dimensions of the extent axis will vary with the ecological, economic, and cultural setting.

mandates and standards to CO2e savings, relate fuel tax systems to the CO2e savings benchmarked against conventional gasoline or diesel, and provide tax breaks for biofuel research and development investments. In addition, policy interventions can be implemented to reduce international trade barriers and provide for technologically sound interventions that reduce the risk of implementing biofuel mandates which are not compatible with current engine tolerances and other aspects of the fuel system. Policies can also be implemented that safeguard various aspects of environmental and social-well being, such as reinforcing the protection of internationally designated protected environments; requiring application of global standards for human rights, labor conditions, and child labor; and providing appropriate valuation to other natural resources such as water, fertilizer, and land resources utilized for biofuels production.

At the local scale, addressing the goals for protecting socio-environmental conditions will require approaches for balancing sometimes competing priorities which lack universally agreed common currencies. Careful analyses of trade-offs among these priorities and development of socio-environmental criteria are necessary to allow for transparent ways to evaluate impacts. Moreover, strategies for developing biofuels are often formulated at international or national scales, and may conflict with local scale preferences which represent specific socio-environmental goals, benefits, and constraints of the particular situation under consideration. Evaluation of strategies indicates that there are many ways for bio fuel development to take, but few ways for development to maximize net benefits.

This chapter provides a series of principles, as well as local and global considerations of socio-environmental criteria, for enabling production of biofuels to offset climate forcing from fossil fuel use, improve national or local energy security, and enhance rural development while protecting food security, human well-being, and the functioning and integrity of ecosystems and still recognizing that individuals or societies can differ on their relative valuation of these factors. The maximum extent of biofuels production consistent with protecting these values is almost certainly less than the levels advocated in some national plans.

Assessing Trade-offs

In the development of biofuel systems, there are a number of considerations which are associated with current societal goals (i.e. food security, human well-being, and the functioning and integrity of ecosystems). Recently, concerns have been raised regarding some of the potential impacts of bioenergy development which might compromise the achievement of such goals including enhanced net CO_2e emissions, adverse effects on food security, increased land-use conversions, increased pollution, loss of biodiversity, and disruption of rural livelihoods. Thus, biofuel development strategies must address a set of multiple criteria across multiple spatial scales (i.e. from local to global) and across development and deployment time scales. Recognition of this has led to efforts to account for trade-offs of various biofuel strategies. Assessing such strategies and the policy interventions that support them will require development and implementation of an evaluation framework that incorporates the multiple socio-environmental constraints in order to assess how different biofuel strategies may minimize the negative effects while providing socio-environmental benefits.

The challenge of integrating across these impacts is increased by the fact that they are not easily expressed in common units and different groups or societies might assign a particular impact a very different level of importance. In addition, local impacts may appear beneficial, but, with large geographic deployment, may have a negative effect at an aggregated scale (Figure 17.1). Finally, the relative importance of each factor will likely depend on the local environmental, economic, and social conditions, as well as on the scale of the existing biomass energy industry. As part of the evaluation of biofuel systems, criteria are needed to assess the collective impact on socio-environmental dimensions. The criteria include consideration for climate protection, food security, human well-being and economic development, and the functioning and integrity of ecosystems.

Climate protection

Some biofuel systems may contribute to climate protection by substitution of fossil fuels and an associated reduction of net CO_2e emissions, but the selection of one or more biofuel pathways needs to clearly demonstrate reductions of net emissions to the atmosphere relative to fossil fuel sources. In addition, biofuel production systems need to develop land management practices and land conversion techniques that minimize emissions of GHG and other aerosols. Conversion of lands containing large carbon stocks accumulated over centuries must be avoided so that carbon emissions from these reservoirs do not occur at a rate that affects the net rate of net losses of CO_2e. Development of biofuel feedstock systems may also affect the biophysical feedbacks of the land surface, resulting in additional climate change effects, and should be avoided. Therefore, analyses of net emissions of CO_2e and changes in biophysical factors of the entire biofuel system needs to be evaluated.

Food security

It is recognized that biofuel feedstock production can directly compete with food production. All of the current feedstock systems for liquid biofuel conversion are also used as food stocks for human or livestock consumption. The use of food crops for biofuels has affected both the availability and the price of crop commodities. This competition is most acute among disadvantaged communities which are often associated with rural regions of the world. These communities will be impacted by increased food prices resulting from greater diversion of food crops into the biofuel market. So it is important to set criteria that reduce the impact of biofuel feedstock production on food security and the agricultural land systems in the different regions of the world (Biofuels Roundtable Sustainability Criteria). As biofuel systems develop to utilize increasingly more diverse feedstocks, additional consideration for potential competition with fiber crops and wood products is needed.

Human well-being

Benefits to human well-being from expanded biofuel production include potential climate mitigation and enhanced income and rural development. Indirect benefits may also accrue as improved social services arise from economic development of the local biofuel industry. Current strategies among development agencies and cooperative international efforts to expand biofuel production are exploring these potential benefits; however, it is important to note that not everyone has equal access to these benefits and that expansion of biofuel production systems may only favor a select group of producers (Chapter 12, Vanwey 2009). The type of biofuel systems deployed and the economic feasibility of the development strategy within a specific region will impact how local communities are affected. The accessibility of benefits and the share of socio-environmental impacts taken on by different groups needs to be evaluated to better understand the differential allocation of such benefits and impacts.

The development of biofuel systems will require adequate infrastructure to support production, conversion, and transportation of feedstock and biofuels to meet bioenergy needs in a region. This development of infrastructure may contribute to human and social well-being by providing jobs, access to technologies not yet available, and access to other social services not able to be supported under more rural conditions (e.g. hospitals, schools, stores). However, experience with similar windfall revenues accruing to oil-producing countries suggests that such infrastructure will only be developed if appropriate policies or incentives are implemented to support the equitable development practices.

Biofuel development may also exacerbate existing inequalities, as gains from the production of biofuels are most likely to go to richer individuals and communities. Government policies have the potential to reduce such inequality if such policies ensure that equal access is available and that gains are shared among communities and individuals who are at the bottom of income and wealth distributions. Additionally, **b**iofuels production on large farms often displace small farmers without providing employment or adequate compensation. Without complementary investments in education or employment provisions, these displaced farmers will lose their livelihoods and possibly be forced to move to already overcrowded cities.

Biofuels production may also negatively impact communities through environmental degradation. Environmental impacts of intensive agricultural systems and the fate of biofuel waste/ co-products often have negative health impacts for people living near farms and processing facilities. For example, runoff from fields and effluents from biofuels processing may contaminate drinking water or food (Martinelli and Filoso 2008).

Functioning and Integrity of Ecosystems.

Biofuel systems are dependent on the functioning and integrity of ecosystems and particularly ecosystem services related to soil, air, water, and biodiversity. The following sections present considerations for evaluating these components in the development of biofuel systems.

Soil. Biofuels can alter soil quality by modifying soil erosion, compaction, organic matter, soil biota, pH, nutrient leaching and gaseous losses of nutrients (e.g. denitrification). Conservation tillage, maintenance of year-round plant cover, minimizing heavy vehicle traffic, avoiding steep slopes, and integrated fertilizer management reduce the risks to soil quality. Some biofuel crops, such as sugar beets which greatly increase the risk of soil erosion and compaction, have inherently negative effects on soils. Other crops, such as perennial grasses, are generally positive for soil quality if belowground organic matter inputs are maintained and other soil aspects are managed properly. Woody systems need to be evaluated to assess long-term implications of aboveground harvesting of biomass on soil quality issues.

Air. Current biofuel systems sometimes use fire in land conversion (e.g. palm oil) or pre-harvest (e.g. sugarcane). These practices can substantially degrade air quality through the production of fine particulate matter and the emission of ozone precursors (e.g. NOx). A particularly acute example of the degradation of air quality related to biofuels production is the burning of sugarcane in the Sao Paulo region of Brazil despite government bans on the practice (Martinelli and Filoso 2008).

Field soil emissions are another potential source of ozone precursors, but can be reduced with best management practices. Biofuels options should avoid crops or management options that include burning or have high biogenic trace gas emissions.

Water. Biofuel production can affect water availability, particularly through water use for irrigation or through modifications of evapotranspiration (Chapter 8, de Fraiture and Berndes 2009), and water quality, particularly through the contamination of surface and groundwater with fertilizer derived nutrients, pesticides and herbicides (Chapter 9, Simpson et al. 2009). For example, large-scale corn cultivation is often associated with ground-water contamination with nitrates and herbicides and, if irrigated, with substantial water use. Crops, such as switchgrass, which require low fertilizer, herbicide and pesticide inputs, retain most of added fertilizers, and do not require irrigation are ideal candidates for maintaining or even improving water availability and quality. Water resources can also be negatively affected if biofuels lead to the degradation of riparian areas, so biofuel production should be avoided in these areas. Additionally, feedstock processing can impact water quality and quantity. Development of biofuel systems needs to consider water resource availability and impacts to water quality in the evaluation of biomass cultivation and conversion systems.

Biodiversity. The major concern for biodiversity is the replacement of highly diverse natural and semi-natural ecosystems with biofuel crops which are currently dominated by intensively managed monocultures of very low plant and animal diversity (Chapter 7, Sala et al. 2009). Land-use change impacts can be minimized by avoiding the replacement of natural and semi-natural systems with high conservation value and by using crops and management practices that maximize diversity within biofuel productions systems. Crop choice and management practices that favor diversity include minimum tillage (favors soil diversity), low pesticide and herbicide use, and the promotion of landscape structural heterogeneity (green-veining, hedgerows, etc). In some cases, such as the use of hay from semi-natural grasslands for biogas production, biofuel production could actually promote biodiversity (see box 17.1). Additional concerns include the potential for the introduction of invasive species (Raghu et al. 2006), the change in soil biota under altered organic matter quality, and the displacement of non-biofuel agricultural land use into natural and semi-natural ecosystems.

Economic Considerations

Development of biofuels, like other technological advances, will be determined in part by the economic feasibility and available technological capacity. These considerations need to be evaluated in the context of where and when decisions are being made on biofuel development. Economic viability is contingent on a number of factors including costs associated with feedstock production, bio-refinery, and supporting infrastructure. These costs incorporate labor, building materials, type of biofuel, techniques of energy conversion and delivery, waste facility systems, market demands, and availability of resources such as water in the location under consideration. The aggregate costs of biofuel development must be competitive relative to the cost of producing and using fuels from fossil sources. Where biofuels provide a public good, public support of the primary costs associated with the production of biofuels can be justified. Public investment should favor the types of biofuels that provide the greatest good.

Costs will vary over time as biofuel development evolves and matures; for example some costs may decline as the technologies are advanced, others may increase, and some costs will be less dynamic due to more stable fixed costs across technological advances. Market competition with low cost fossil fuels has limited the adoption of biofuels, particularly in the transportation market. Advanced biofuel technologies incorporate multiple conversion pathways that generate not just liquid fuels, but also a variety of products targeting multiple markets. Currently, most biofuel production units are more or less single purpose plants focused on either bioethanol or biodiesel production. Future generations of bio-refineries will combine food and fuel production, chemicals/materials and fuels production, or production of all three with higher feedstock conversion efficiencies, higher economy viabilities, and improved product portfolio flexibilities. Careful selection of advanced bio-refinery technology is therefore important to derive the most benefit at the lowest cost, and incentives need to carefully consider the target benefits before favoring any one technology over another by lowering its cost.

The time and initial cost needed to develop the technological and infrastructure capacity to bring various biofuel strategies to maturation can be considerable; however, selection of new biofuel strategies will also depend on other energy developments in both consumption and production areas. For

box 17.1. Feedstock Options to Increase Socio-Environmental Benefits

The practical use of grass biomass for biogas production at the economic scale is already implemented in a number of European regions (Erdmanski-Sasse, 2007). Several research projects have looked into options for the energetic use of grass biomass from semi-natural grasslands. These aim to combine nature management objectives with the utilization of biomass for energy production. These options include several thermal conversion options such gasification, pyrolysis, hydro-thermal-upgrading (HTU) or biogas production. Another option is the biorefinery concept, which can generate a variety of products including transportation fuels.

Agricultural biomass residues, such as straw or rice husks, offer a source of bioenergy that is not directly in competition with food production and can lead to strong GHG savings. With an increased utilization of biomass for energy production, crop residues will become economically more valuable, in particular with the advent of 2nd generation technology. Straw is already being used in Europe as a bio-energy resource and a study by the JRC its future potential is considered significant (Edwards *et al.*, 2005).

The use of residues for bioenergy does generally not increase environmental pressures. However, these materials play important agri-environmental functions. Leaving crop residue, such as wheat straw, olive husk, sunflower stalk, rice straw or tobacco stalk, on the soil surface reduces runoff and soil erosion, through sheltering the soil with a non-erodible material (cover), conserves soil moisture, helps keep nutrients and pesticides on the field, and improves soil, water, and air quality (Steiner, 1994). Excessive harvesting of residues can also reduce the ability of rainfall to infiltrate the soil and replenish groundwater supplies (Kartha, 2006). Consequently, the level of co-harvesting strongly influences soil quality and soil erosion, leading to negative effects on water quality. Sustainable removal rates will vary by region and sometimes with fields as well as between management systems, depending on the climatic conditions and the specific crop rotations (FAO, 2005).

example, new breakthroughs in the energy technology fields may provide the economic boost to biofuels or lead to other developments which may prove less expensive to produce, but offer equivalent energy and climate regulation effects. These considerations will affect the economic feasibility, as well as related factors associated with other socio-environmental considerations such as increased demand for food and fodder, expanding markets for biomass-derived products, and land constraints.

Currently, biofuel strategies are progressing along several approaches which include expansion of "first-generation" production of ethanol and biodiesel; technological development in support of "second-generation" advances to enable cellulosic and new biofeedstocks; and, lastly, development of multiple capacity bio-refining and bioenergy systems for generation of electricity and other products. Development and investment in these strategies are occurring simultaneously, but the ultimate mix of strategies is uncertain. This uncertainty affects the analysis of economic feasibility of biofuel systems, especially in light of energy strategies that include electrification of the transport sector. However, technological advancements along all three lines of development are taking place and agility in the financing of these development strategies will be critical. Actual deployment will be determined by economic and socio-environmental considerations within a geographical context and the temporal availability of relevant technology and infrastructure to support the development. Certain policy and market incentives will also influence both the development timeline and the placement of these biofuel systems.

Toward Developing Better Biofuel Strategies

How can the scientific community help decision makers guide biofuels policy? One key to answering this question involves establishing the right boundaries to the problem. Specifically, good decisions about the expansion of a biofuels industry should address not only the motivations, but the potential socio-environmental impacts as well. However, the motivations and impacts are not easily expressed in a common currency and people or societies with different priorities might assign very different weights to a single factor. The relative importance of each factor will likely depend on the local environmental, economic, and social conditions, as well as on the scale of the existing biomass energy industry.

This section combines two approaches to integrating these issues to better assess if a biofuel strategy is environmentally sound, socially acceptable, and economically viable. One approach defines a set of global principles that can be used under any setting and across multiple scales. The second approach deals more with local scale trade-offs . This approach addresses issues that depend on the local ecological, economic, or social setting; and on the relative emphasis assigned each impacted area. Together, the two approaches define a decision support framework for biofuels developments with guidance on the best suited regions, approaches, and the most appropriate spatial extent. A multi-pronged approach, combining global principles with additional criteria tuned to local conditions, can ensure that biomass energy developments meet these standards.

Global Guiding Principles. The following criteria can be formulated to provide a means to evaluate practices which avoid negative impacts on food supply, greenhouse gas emissions, biodiversity and global equity due to land-use change.

• Food and Fiber - It is not acceptable that the deployment of biofuels leads to global food shortages. Several studies have indicated that increased biofuel production will require a substantial expansion of agricultural land for intensive cultivation, and still likely meet only a small fraction of the world's future energy needs (MNP 2006; 2008; Santi 2008; Campbell et al. 2008; Gallagher et al. 2008; Fangione et al. 2008; Searchinger et al. 2008; Chapter 6, Ravindranath et al. 2009; Chapter 16, Bustamante et al. 2009). These estimates of land use conversion are generally based on assumptions about historically reasonable yield increases that and little change in the complementarity between food and biofuel production (but see Gallagher et al. 2008) There are, however, opportunities to improve the complementarity between food and biofuel production through the use of crop refuse (see box 17.1), although this would require the development and deployment of methods to improve the exploitation of crop and other refuse (see example below). The expansion of biofuel production could also potentially lead to substantial increases in crop and biofuel productivity in developing countries through improvements in agricultural infrastructure (Chapter 15, Bekunda et al. 2009).

• Greenhouse gas emissions - The conversion of natural and semi-natural ecosystems to biofuels or crops cause significant greenhouse gas emissions (Chapter 6, Ravindranath et al. 2009; Chapter 16, Bustamante et al. 2009). This criterion generally calls for avoidance of conversion of old forest stands and other ecosystems on soils rich in organic material (i.e. peatlands, tropical rain forests), as well as avoidance of biofuel feedstocks requiring large amounts of N fertilizer. Abandoned, under-exploited, and degraded "marginal" lands appear to provide good opportunities for conversion to biofuel crops with minimal land-use related greenhouse gas emissions. Unfortunately, "marginal" lands are poorly defined, so there are widely varying estimates of their extent and viability of exploiting them (Chapter 15, Bekunda et al.2009; Chapter 6, Ravindranath et al. 2009 ; Campbell et al. 2008; Searchinger et al. 2008; Gallagher et al. 2008). Given their importance it is vital to reach agreement on their potential for biofuel production.

• Biodiversity - The conversion of many natural or semi-natural ecosystems to biofuel monocultures will result in the substantial loss of local biodiversity and to a decline in global biodiversity if deployed over large areas. It is generally accepted that biofuels crops should not replace natural or semi-natural ecosystems in areas that are currently protected. This constraint leaves room for substantial debate over the extent to which non-protected ecosystems should be converted to biofuels since they may also harbor substantial biodiversity. In addition, the use of grasslands and forests for advanced biofuel production could serve as a biodiversity management tool in some ecosystems, even in protected areas (see grassland example below) (EEA 2008; Tilman et al. 2006)

• Global equity -- Global agreements on climate change mitigation policy have been difficult to reach in part because of current inequities in the global political economy. It is essential that any global biofuels programs not perpetuate such inequities and it would be ideal if they moved us towards decreasing such inequities. In doing this, we must protect against providing an unfair advantage to producers in more developed countries, such as that gained through subsidies or trade barriers. We must also dissuade multinational corporations from using their higher levels of capital and greater ability to invest in research and development to produce biofuels in developing countries without investing in public goods (physical infrastructure and human capital development) in those countries.

Taken as a whole, these global constraints suggest that biofuels will not be a panacea for environmental or energy problems, and that any benefits need to be carefully balanced against other environmental and social impacts. Mandates for liquid biofuels must not get ahead of a consideration of the potential negative impacts associated with biofuel production and processing. In particular, we must guard against biofuels presenting another instance of externalizing the environmental and social costs of energy and fuel production. This requires combining these global constraints with a clear consideration of localized criteria for production and processing of biofuels.

Local Socio-Environmental Principles - We propose a framework for a bottom-up assessment of biofuels that would help to treat the full set of environmental, social, and economic criteria outlined above. In combination with the global criteria previously examined, local scale criteria can provide a clear evaluation of the tradeoffs between biofuel production systems and socio-environmental impact. A scientific assessment of best practice should then be coupled to an analysis of governance tools that would provide the incentives to put in place "best practices" at these scales. Inappropriate choice of crops, poor crop management, non-optimal processing, poor local governance, and the co-opting of benefits by local or global elites can off-set benefits that accrue from optimizing and limiting land-use change at larger scales. We focus here on the criteria for minimizing the local or national social and environmental impacts of biofuels.

• Social Impacts - Biofuels production is best pursued in local areas and countries in which it can provide meaningful increases in energy security without compromising other criteria. For some countries, this can lower the amount of scarce foreign exchange that must be devoted to the purchase of fuels while meeting increasing demands for energy over the course of development. For individual communities, positive impacts are potentially much greater. Communities with no access to a national energy grid can bring electricity to their residents using biofuels and complementary generators with a dramatically smaller investment relative to the cost associated with unreliable connections to an also unreliable national grid. This is analogous to how cell phone technology has bypassed traditional land lines to bring the communication infrastructure to many rural communities.

Any implementation of biofuels production that displaces farmers or agricultural workers must be accompanied by an investment in the creation of new jobs and the training of displaced workers (whether local or migrant workers) for gainful employment. In addition, policies should encourage collective local ownership of small-scale biofuels production facilities to ensure that benefits reach the most in need. Particularly in developing countries, biofuels producers and refiners should employ local workers at all levels. When large-scale biofuel production displaces small farmers or puts agricultural laborers out of work, the biofuels producer should provide support for skills development among displaced farmers and workers to qualify them for jobs in the biofuels industry or elsewhere.

Large-scale biofuels production should promote income growth and economic development by combining employment of local workers at all levels with skills training in order to develop a workforce able to move freely in a modernizing economy. Small-scale biofuels production for local energy generation and potentially for sale on the domestic market would ideally contribute to average incomes through production being organized in cooperatives or collective ownership leading to an equitable distribution of profits.

Use of profits for investment in public goods should also be encouraged. In communities with either small or large scale biofuels production, producers should contribute to the development of appropriate public goods, including transportation, utility, education or health care infrastructure.

• Environment - The broad range of local-scale environmental constraints are often overlooked in global analyses of biofuels. Most annual crops currently used have negative impacts on several of the environmental criteria that we have outlined above, which can be improved only to a limited extent by better management. Perennial species, when properly managed, often allow lower vehicle traffic, reduce soil erosion, minimize nutrient leaching, improve local bird and insect diversity, etc. Policy-makers and the biofuels industry must recognize that many crops currently used for liquid biofuel production (e.g., corn and rapeseed) have intrinsically poor environmental profiles and that even crops with potentially lower environmental impact (e.g., sugarcane) are often poorly managed (see Chapter 15, Bekunda et al. 2009). It is incumbent on the scientific community to identify alternative crops and management practices that minimize a broad range of environmental impacts (see EEA 2008, Santi 2008).

• Economic viability – Economic considerations are an important element of selection criteria for any biofuel development. Deployment of biofuel systems should not lead to further economic inequities nor lead to disproportionate economic burden on any one class of stakeholders. Various economic mechanisms should be incorporated to enhance the development of appropriate technologies which enables the multiple goals of the communities involved. These considerations include job creation, production and distribution systems, marketing of production and finished products, con-version and waste processing, and energy products.

Incentives for Best Practices: Global- to the Local-Scale

At the global level, if a coalition of governments or an international governmental organization (IGO) supports the development of biofuels, the following policies would help promote biofuels that address the above criteria through a combination of taxes or import tariffs on biofuels with certain characteristics, in order both to create a disincentive for undesirable practices and to raise money for positive incentives.

Positive incentives include tax incentives (lower rates) and direct subsidies or public investments. Combining these with absolute rules prohibiting certain practices will encourage practices desirable based on the criteria presented above. A set of policy instruments is presented in box 17.2. We primarily recommend market-based policies rather than regulation requiring an extensive monitoring and enforcement structure in order to avoid the location of biofuels production in countries with few resources for such enforcement.

Direct regulation should prohibit the growing of biofuels feedstocks in biodiversity hotspots, or in areas of severe water stress. Regulations should also prohibit cross-border trade in biofuels that are not demonstrated through life cycle analysis to be carbon positive. The onus must be on the producer to show through solid scientific methods that the net impact of the biofuel, including indirect land use impacts, is a reduction in carbon emissions. It is the responsibility of the scientific community to do more extensive research to provide an appropriate method for determining these impacts, allowing regulators to avoid the multiplying of standards-setting organizations as we have seen in the certification of sustainable forestry.

Tax Mechanisms. At the national or international level, appropriate behavior should be encouraged through market mechanisms, particularly through differential taxes on cross-border trade and on profits. The level of tariff on the import of biofuels to countries that are net consumers should be tied to the net carbon impact of the biofuels, effectively a carbon tax. Thus, producers would pay the lowest taxes on the most carbon reducing biofuels, encouraging them to move production for international markets to the location in which such fuels can be produced to have the highest climate change mitigation impact.

Within countries, tax rates for biofuels producers should be tied to the congruence of the company's activities with best practices for minimizing adverse (or maximizing positive) social and environmental impacts laid out above. In particular, tax rates should be tied to the proportion of employees from local areas, the investment in local infrastructure (around production and processing areas), sustainable use of water, water quality, and impacts on local biodiversity. It is again incumbent upon the scientific community to be a full partner with industry in developing universally recognized methods for measuring such criteria while allowing legislative bodies to determine the exact tax impacts of each criterion.

Direct subsidies should be provided for research and development of improved biofuel and bioenergy technology, with larger subsidies to those developing technology appropriate for use in disadvantaged regions. Direct subsidies should also promote small-scale production of biofuels with limited environmental impacts (positive or negative) but large social impacts through promoting local energy security or development. These subsidies should include domestic investment and international investment through overseas development assistance or tax credits in developed countries to companies that implement such programs in developing countries or in disadvantaged regions of their own countries. These policies would encourage public-private partnerships in the development of locally appropriate and locally desired biofuels programs in disadvantaged rural communities, modeled on programs such as the Mexican state and federal governments' matching programs which match public investment with remittances from migrants to finance development projects and build capacity in traditional migrant-sending regions.

Considerable scientific analysis must be done before we are in the position to make quantitative assessments of the full set of tradeoffs, and the absence of widely accepted box 17.2

Possible top-down policy instruments to promote sound biofuel development

1. Link biofuel mandates, incentives, and standards to CO_{2e} saving. At the global level, the primary reason for doing biofuel is to limit CO_2 production from fossil fuel

2. Link fuel tax system to the CO_{2e} saving benchmarked against conventional gasoline or diesel. Biofuel has differential impacts on CO_2 and sustainability (ranging from energy balance, energy density, land use, fertilizer use and water use, etc) depending on the production process. A mechanism is needed to reward the better biofuel. A fuel duty is a typical tax levied on fossil fuel, this kind of levy could be used to enhance the production of low carbon fuel, proportionate to the CO_2 saving.

3. Grant tax breaks for bio-fuel research and development investment. To promote investment in improving biofuel technologies, granting corporation tax credits on biofuel R&D investment could be used.

4. Align biofuel blending thresholds with drive-train acceptance and sustainability. There are limits to how much bio-fuel conventional engines can accept and the planet can produce biofuels. Production needs to be constrained within these limits to avoid adverse impacts to society and the environment. Through fuel specification standards, it is possible to define the maximum blending percentage of bio-fuel to match the technological and environment limits.

5. End bio-fuel trade barriers. The climate doesn't care where the bio-fuel is produced, but some regions are much more efficient at producing biofuel than others. To even the playing field and to allow for sustainable biofuel developments to grow, worldwide (i.e. UN sponsored) ban on biofuel import and export tariffs should be instigated.

6. Reinforce protection of internationally designated protected environments. Biodiversity and net carbon sinks need to be protected. Increase penalties on destruction of protected environments through international courts. And pay host governments income to protect these environments (paying from a fund based on carbon production per capita).

7. Require application of global standards for human rights, labor, child labor, so that equitable participation in economic development of biofuels can be attained. By requiring these standards as a condition of import approval and compliance with fuel standards, better safeguards on the socially acceptable production of these products can be enhanced.

8. Rationalize prices of the water, fertilizer, and land resources utilized for biofuels production, this will ensure appropriate use of resources. In addition, the alignment of tax rates to price elasticity in order to encourage resource conservation can be promoted.

quantitative analysis has led and will continue to lead to substantial disagreements over the potential for biofuel production without significant environmental, social, or economic damage. We urge the scientific community to develop several quantitative assessments of this type, so that we can begin to estimate uncertainties in the spirit of the IPCC assessments of climate change. We also urge policy makers and the biofuels industry to take a multi-factor, multi-scale view of biofuels as outlined above.

At the local level, issues of human well-being, food and other natural resources (particularly water quality and quantity) become salient to decision-makers because losses in these domains in one location cannot be balanced by gains in another location in the calculus of local decision-makers. In economic terms, at the global level, given appropriate pricing, there are no externalities; at local levels, climate change mitigation is virtually always an externality. For example, displacement of small farmers can destroy a rural community while it is part of the larger process of economic transformation for countries and the globe. Similarly, community and national income gains due to employment in the harvest of biofuel feedstocks are more salient than potential climate impacts of inefficient feedstocks or the global importance of local forests. In communities with poor connection to markets, and in countries facing high import costs, food security similarly becomes more salient than any potential benefits to be reaped from mitigation. Distant impacts of feedstock cultivation through nitrogen runoff (causing eutrophication downstream) or greenhouse gas emissions in the production of such fertilizer have little impact on the decisions of local planners unless appropriate pricing brings these impacts into the calculus of the planners. On the positive side, the use of biogas capture technology to process waste products from confined animal feed operations (CAFOs) is likely to appeal to local communities primarily because of the adverse human health impacts of such wastes rather than the climate change mitigation impacts. Examples of possible biofuel strategies for local development are presented in box 17.1.

Biodiversity is itself multidimensional and different aspects are salient to different levels of decision-makers. The preservation of biodiversity for the ecosystems services it enables is salient at local levels. For example, the loss of traditional medicines collected in forests cleared to make way for the cultivation of biofuels feedstocks has substantial local impacts. Similarly, the water filtration services provided by wetlands are important at a community and national level. Biodiversity preservation for the future potential contained in such diversity, however, appeals more at a global level. Such genetic diversity and diversity in the functioning of ecosystems is a global resource on which groups from any region might draw, while the more specific ecosystems services of biodiversity serve local communities.

Implicit in this discussion of local and national decision-making is the assumption that such units plan on a shorter time horizon than would a global decision-maker. Individuals may plan on the scale of the remainder of their lives, or potentially a portion of their children's lives, but communities tend to plan shorter futures. Communities and nations cannot be sure of their continued existence on a century time scale, and their governments cannot be sure of their continued existence on a decadal time scale. This is not to say that communities and nations will not act to mitigate climate change, but that shorter term issues that might not enter into a global calculus are more salient at the local and national levels.

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