chapter 20

Bioenergy Economics and Policies

Hans van Meijl[*a†], Edward Smeets[a], and David Zilberman[b]

[*]Lead Author
Responsible SAC: Helena L. Chum
Associate Editor: André M. Nassar
Contact: [†]hans.vanmeijl@wur.nl

[a] LEI Wageningen University and Research Centre, The Netherlands;
[b]University of California Berkeley, USA

Highlights

- Policies and energy prices are key drivers for current bioenergy and the emergent bioeconomy;
- Bioenergy is part of a larger transition to a bioeconomy;
- Technological change and full biomass utilization might create a competitive industry;
- A coherent policy package can temporarily stimulate an immature industry and regulation can deal with indirect effects of the bioeconomy.

Summary

This chapter describes developments in the bioenergy market and related policies. Recent bioenergy developments, often induced by policies, lead to a greater interconnectedness between energy and agricultural markets and influenced relative food and feed prices and land-use changes. An analytical framework is presented that places bioenergy within the bioeconomy. The impacts of supply push and demand pull polices are analyzed, and the reasons for policy interventions are introduced. The effectiveness of policy intervention is likely to increase if they are directly connected to a target such as the reduction of emissions or the stimulation of economic growth. Because the bioeconomy is an immature or infant industry, policies that temporarily stimulate its development might be justified. Technological change and full biomass utilization for food, feed, energy, materials and chemicals may lead to a competitive bioeconomy sector. Regulation could potentially deal with indirect effects of bioenergy such as social (land grabbing) and environmental effects (land, water, biodiversity). Given the importance of private sector investments in the development of biotechnologies, excessive regulation might create a disincentive to innovation.

20.1 Introduction

Currently, more than fifty countries have adopted biofuel blending targets or mandates and many others are implementing or considering biofuel quotas (REN21 2013). Also, the use of biomass for heat and power is increasing rapidly, mainly as a result of policies aimed at, among others, reducing greenhouse gas (GHG) emissions, improving energy security and enhancing rural economic development especially in industrialized countries. The global demand for bioenergy in 2010 was 1277 Mtoe, which is expected to increase to 1881 Mtoe in 2035 according to the New Policies scenario or 2235 Mtoe in case of the 450 Scenario that is aimed at limiting climate change to an average long-term increase in average global temperature of 2°C (IEA 2012a).

In a wider context, these developments are part of a transition from an economy that is based on non-renewable resources (especially for energy production) to a biobased economy based on the use of biomass residues from multiple sources and farming renewable resources (Zilberman et al. 2013a). This transition is partly policy and partly market driven, as non-renewable resources such as oil and minerals, are finite and will become increasingly scarce (new sources such as shale gas and oil may temporarily increase in the short run). Another driver is the potential emergence of new technologies that can convert biomass into a wide array of products (WEF 2010). Within the development of the bioeconomy, this chapter focuses on the economic aspects and policies related to bioenergy.

Biomass has been a traditional source of energy in the form of wood or dung. The modern biofuel industry aims to harness advances in biology and engineering to produce fuels for transportation and energy. The competitiveness of biomass based energy systems compared to conventional energy depends on the price of fossil energy feedstock and biomass, and the conversion efficiency and costs. Given the current market conditions, it is unlikely that the industry of ethanol and biodiesel would survive in the absence of tax credits and blending mandates (IEA 2011). The world ethanol price was about USD 1.20/ liter gasoline equivalent in 2012 and biodiesel was around USD 1.55/liter (REN21 2013). Biodiesel prices are higher than in 2006 - 2011, when prices varied between USD 0.90 and USD 1.50 per liter. However, the price of conventional gasoline was “only” USD 0.78/ liter. Few biofuel systems are currently economically viable. The Brazilian sugarcane based system has in recent years been the most competitive biofuel industry. However, this biofuel industry is currently struggling because of recent costs increases (e.g., land and labor), as well as the appreciation of the Brazilian Real versus the US dollar which affects export markets, decrease of oil prices, and the government’s induced cap-price on gas which keeps gas and therefore domestic biofuel prices and demand low. Corn based ethanol in the US is now competitive with oil in various states and the US is exporting it to the rest of the world. In contrast, biofuel use in the EU and most other countries is quite costly, mainly because of higher feedstock costs and the use of biodiesel in the EU. More efficient technologies might be emerging, such as the production of biofuels and biochemicals from cheap lignocellulose biomass through biochemical or thermo-chemical conversion (see Chapter 12, this volume), which may increase the economic competitiveness of the liquid biofuel industry (Kamm 2004; WEF 2010; OECD and IEA 2013). However, Smolker (2008), and Latham and Wilson (2013) challenge this optimistic view and wonder if the prospects of the bioeconomy are realistic.

The economic viability of bioenergy derived electricity and/or heat depends on the feedstock, conversion technology, scale of operation and the availability of heat sinks in the case of

Combined Heat and Power (CHP) (IEA 2012b). Electricity generation can be competitive today if wastes or residues are used, in case of large-scale operation or if heat from CHP systems can be used. The IEA (2012b) states that as long as the external costs of fossil fuel based generation are not fully taken into account, power generation from biomass will require some level of financial support. An example of economically profitable biobased heat and electricity production and use is the use of bagasse from sugarcane in Brazil.

The increasing production of biomass feedstock and conversion to energy has important economic consequences, which, directly and indirectly, influence the environmental and socio-economic performance of bioenergy systems and policies. The increased use of conventional agricultural crops and wood pellets increases the correlation between energy markets and conventional markets for agricultural commodities and forestry production (Du and McPhail 2012). In 2022, biofuel production is projected to consume a significant share of the world's total production of sugarcane (28%), vegetable oils (15%) and coarse grains (12%) (OECD-FAO 2013). Energy prices increasingly drive long-run agricultural price levels and energy market fluctuations are increasingly transferred to agricultural markets (Baffes and Dennis 2013). The tighter market integration is perhaps the most fundamentally important change to occur in agriculture in decades. The impacts of the increased integration and correlation are transmitted to other parts of the world through the trade of feedstock used for bioenergy production and through the trade of biofuels (Banse et al. 2008; Hertel et al. 2010; Laborde 2011). These indirect effects are key to the issue of indirect land use change (iLUC) and the resulting impact on GHG savings from first-generation biofuel policies. iLUC issues have received widespread attention, but economic mechanisms and correlations are also potentially crucial for many other social, economic and environmental issues, such as the impact on biodiversity, food prices and food security, fresh water resources, employment, economic competitiveness, and growth. To ensure that bioenergy policies truly contribute to sustainable development, it is crucial to gain insight on the economic impacts of bioenergy systems and the resulting direct and indirect effects.

In this chapter, we first describe the developments in the bioenergy market and its policies. Second, we provide an analytical framework that places bioenergy within the larger picture of the bioeconomy and its direct and indirect effects. Third, we discuss in more depth the arguments for policy intervention and we discuss the impacts of demand pull and supply push policies used to achieve the policy targets. The chapter ends with conclusions and recommendations.

20.2 Key Findings

20.2.1 Economic Developments in the Bioenergy Market

World bioenergy use in 2010 was 1277 Mtoe, which is about 10% of the total global primary energy use (IEA 2012a). About 60% concerned the traditional use of biomass for cooking and heating. Traditional use of bioenergy is the combustion of solid fuels such as firewood, charcoal and agricultural residues for cooking, heating and lighting. The remaining 40% is used in modern bioenergy systems. Modern bioenergy involves the use of biomass in producing higher value energy carriers, such as electricity and liquid and gaseous fuels, or heat and power in modern installations.

The industry and power sectors use more than half biomass in modern energy systems (Figure 20.1). Non- traditional biomass is expected to grow from 526 Mtoe in 2010

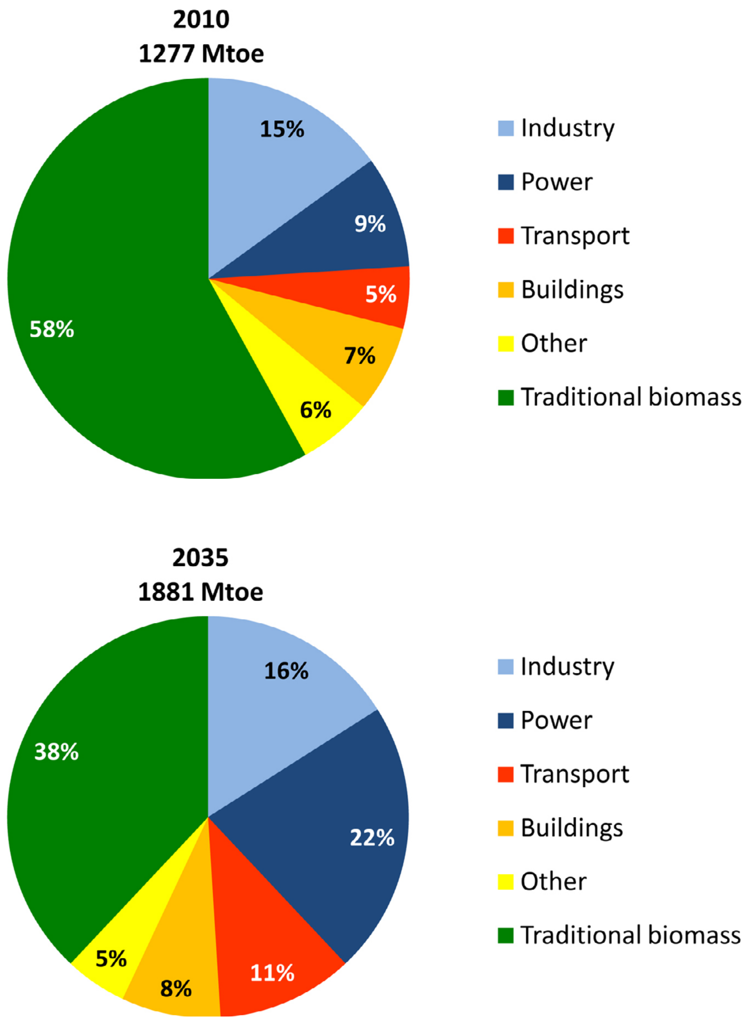

Figure 20.1. World Bioenergy use by sector and use of traditional biomass in 2010 and 2035. Source: IEA, World Energy Outlook, 2012a. Figures are based on the *New Policies Scenario* that takes account of broad policy commitments and plans that have been announced by countries.

to nearly 1200 Mtoe by 2035, growing at a rate of 3.3% per year (IEA 2012a). Both biofuels and power more than double their share in world energy use and are expected to reach 210 Mtoe and 420 Mtoe by 2035, respectively. Biomass for heat and power and industrial applications has traditionally been locally sourced, but trade is increasingly becoming important (e.g., pellets).

International trade grows quickly to complement local supply due to the growing demand of biomass for electricity, heat, and transport fuels. Wood pellets, biodiesel, and ethanol are now traded internationally (HLPE 2013). Others include methane, fuel wood, charcoal, and agricultural residues. The global biomass energy markets are diverse, volatile and vary according to the fuel type (see Figure 20.2). Figure 20.2 shows, among others, ethanol trade flows for Brazil and the US in 2011. Shortages of sugar have lead to sugar price peak due to bad weather and low sugar stocks caused an increase of the use of cane to sugar instead of ethanol. The US had been an importer of sugarcane ethanol for many years until about 2010 when imports fell close to zero as the costs of sugarcane ethanol increased relative to corn ethanol (see Crago et al. 2010). In the last 2-3 years, imports from Brazil have resumed, but mainly to meet the low carbon fuel standard in California.

Ethanol and biodiesel based on agricultural crops are the most commonly produced biofuels for transport. Among the two, bioethanol is far more important than biodiesel: in 2012, the production of bioethanol reached over 87 billion liters, while biodiesel was only

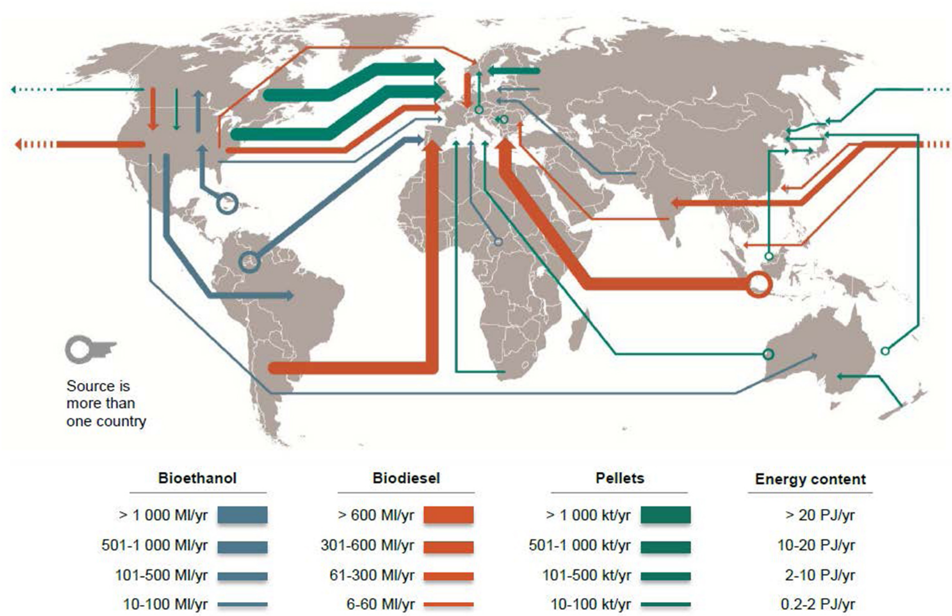

Figure 20.2. Net trade streams of wood pellets, biodiesel, and ethanol in the year 2011 (HLPE 2011).

roughly 18 billion liters (FAO-OECD 2013). The leading producer in 2012 was the US, which produced 45 billion liters of bioethanol, followed by Brazil (24 billion liters), China (9 billion liters), the EU (7 billion liters) and Canada (1.7 billion liters). Biodiesel production is heavily focused in the EU. Almost 11 billion liters of biodiesel were produced in the EU, which represents almost 60% of the total biodiesel production in 2012. The other biodiesel producers are the USA (4.2 billion liters) and Brazil (2.7 billion liters).

The main feedstock for biofuel production is maize in terms of production of biofuels on energy basis (Figure 20.3). To a large degree, this can be attributed to the use of corn for bioethanol production in the US. The second most important crop is sugarcane. Molasses, wheat, and vegetable oils played a smaller role in terms of quantity, though it should be noted that, especially for vegetable oils, direct comparison of the quantities is misleading as the oil represents only a fraction of the oilseed.

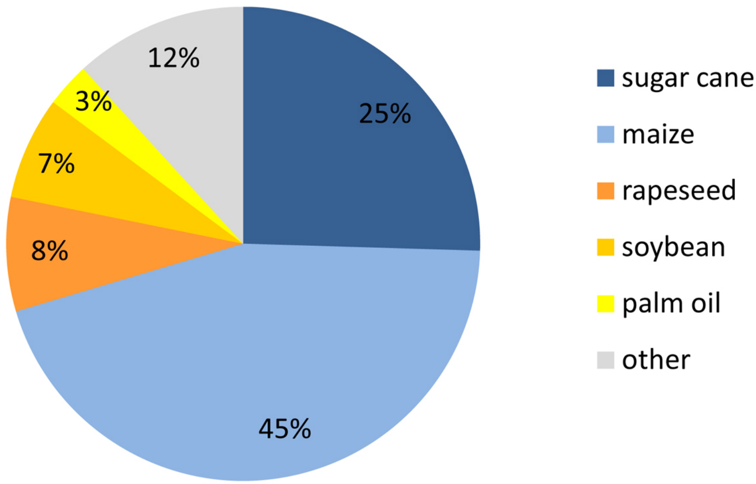

Figure 20.3. Feedstock use for biofuels production (% of total biofuels on energy basis), 2010. Source: New Climate Economy (2014).

20.2.2 Bioenergy Policies are a Key Driver

Policy support for the production and use of bioenergy is provided in virtually all countries. Biofuels policies consist primarily of biofuel blend mandates and subsidies, and also sustainability certification schemes. Subsidies are given mainly as fuel tax exemptions, but partially also as R&D grants. Table 20.1 shows the biofuel mandates in the world.

Table 20.1. Overview of national and state level biofuel blend mandates.

Country	Mandate
Angola	E10
Argentina	E5 and B7
Australia	Provincial: E4 and B2 in New South Wales; E5 in Queensland
Belgium	E4 and B4
Brazil	E18–25 and B5
Canada	National: E5 and B2. Provincial: E5 and B4 in British Columbia; E5 and B2 in Alberta; E7.5 and B2 in Saskatchewan; E8.5 and B2 in Manitoba; E5 in Ontario
China	E10 in nine provinces
Colombia	E8
Cost Rica	E7 and B20
Ethiopia	E5
Guatemala	E5
India	E5
Indonesia	B2.5 and E3
Jamaica	E10
Malawi	E10
Malaysia	B5
Mozambique	E10 in 2012-2015;E15 in 2016-2020; E20 from 2021
Paraguay	E24 and B1
Peru	B2 and E7.8
Philippines	E10 and B2
South Africa	E10
South Korea	B2.5
Sudan	E5
Thailand	E5 and B5
Turkey	E2

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Country	Mandate
United States	National: The Renewable Fuels Standard 2 (RFS2) requires 136 billion liters (36 billion gallons) of renewable fuel to be blended annually with transport fuel by 2022. State: E10 in Missouri and Montana; E9–10 in Florida; E10 in Hawaii; E2 and B2 in Louisiana; B4 by 2012, and B5 by 2013 (all by July 1 of the given year) in Massachusetts; E10 and B5, B10 by 2013, and E20 by 2015 in Minnesota; B5 after 1 July 2012 in New Mexico; E10 and B5 in Oregon; B2 one year after in-state production of biodiesel reaches 40 million gallons, B5 one year after 100 million gallons, B10 one year after 200 million gallons, and B20 one year after 400 million gallons in Pennsylvania; E2 and B2, increasing to B5 180 days after in-state feedstock and oil-seed crushing capacity can meet 3% requirement in Washington
Uruguay	B5; E5 by 2015
Vietnam	E5
Zambia	E10 and B5
Zimbabwe	E5, to be raised to E10 and E15

Source: REN21 2013

All stages in the chain for biobased heat and power systems are supported by government policies (Bahar et al. 2013). This ranges from production to conversion of biomass, distribution of bioenergy, and support to final consumers of bioenergy. Policies might be directed to all forms of renewable energy or bioenergy, or may focus on certain production chains such as biomass-powered combined heat and power (CHP) plants or biogas. Examples of support at various levels of the production chains are listed by Bahar et al. (2013).

Renewable energy targets, tax exemptions, and feed-in tariffs for renewable electricity, public investment, loans or grants, are the most common support measures, provided both by a large number of high income countries and elsewhere (Figure 20.4).

Figure 20.5 shows estimates of the global level of subsidies for renewables based electricity production and biofuels in the New Policy scenario that takes broad policy commitments and plans that have been announced by countries into account (IEA 2012). Global subsidies reached more than 60 billion USD in 2010 and are anticipated to increase to almost 250 billion USD in 2035 should these policies be maintained at the level of the conducted analyses.

20.2.3 Analyses Framework of Bioenergy within the Emerging Bioeconomy

The increasing production of biomass feedstock and conversion to energy has important direct and indirect economic consequences which influence the environmental and socio-economic performance of bioenergy systems and policies. In the past, agricultural markets and energy markets were not closely correlated. The higher energy prices and the use of conventional agricultural crops and wood pellets for bioenergy increased

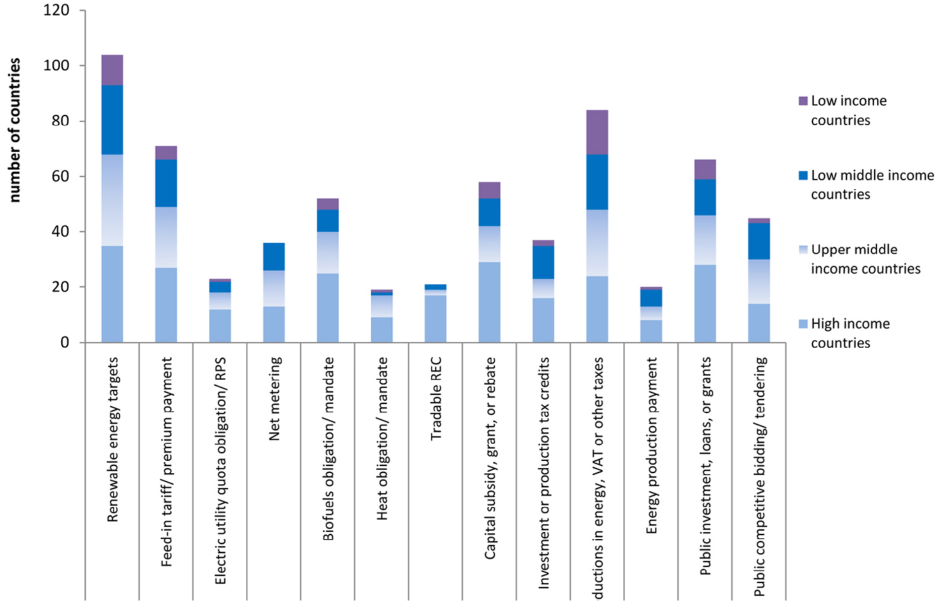

Figure 20.4. Frequency of policy measures to promote renewable power energy. Source: REN 21 (2013).

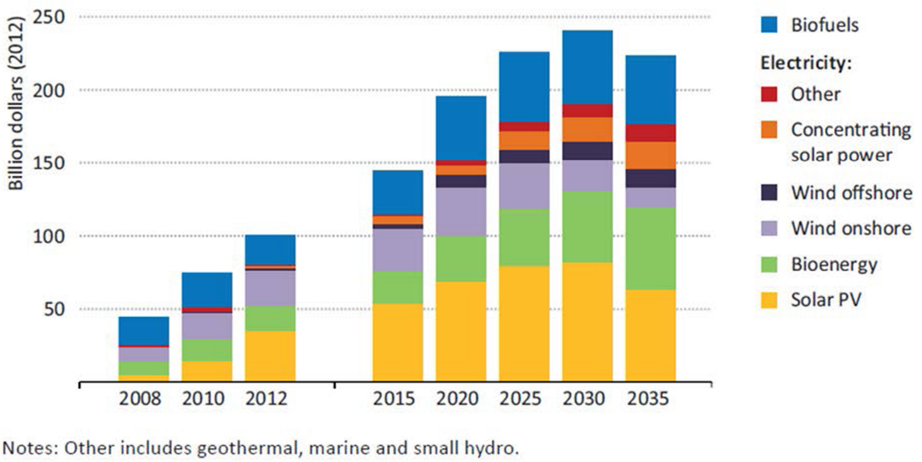

Figure 20.5. Global subsidies to renewables-based electricity and biofuels by technology and fuel. Source: IEA, World Energy Outlook (2012a). Figures are based on the *New Policies Scenario* that takes broad policy commitments and plans that have been announced by countries into account.

the correlation between energy markets and conventional markets for agricultural commodities and forestry production (Du and McPhail 2012; Baffes and Dennis 2013). Figure 20.6 shows that ethanol, gasoline, and corn prices are correlated.

In order to encompass a comprehensive overview for the complex economic analyses of the bioeconomy in general and bioenergy specifically, we use a supply-demand

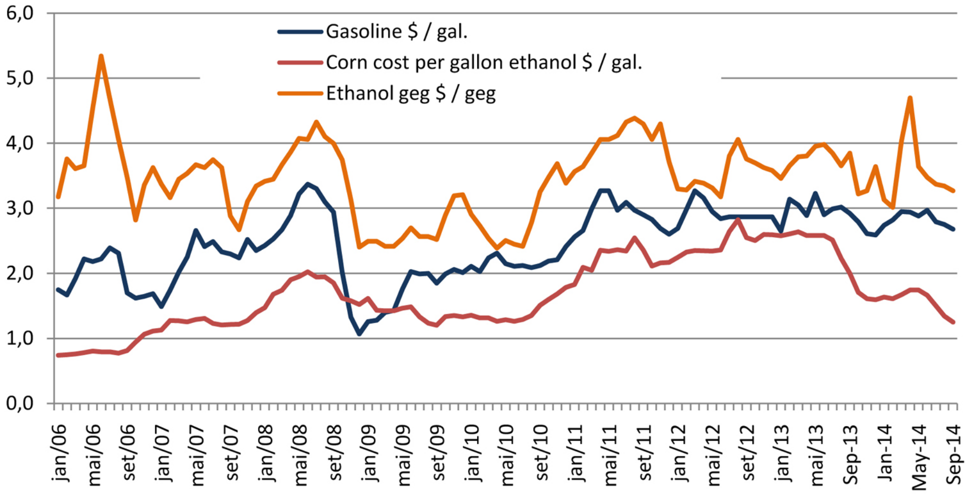

Figure 20.6. Fuel ethanol, corn and gasoline prices, by month. Source: USDA, Economic Research Service, US Bioenergy statistics (USDA 2014).

framework that connects the building blocks (drivers, impact, response) for our analyses (see Figure 20.7). The current fossil-based economy is the starting point, whereby the pathway of transition to a sustainable bioeconomy (including bioenergy) is influenced by system and policy drivers. The demand for the bioeconomy is coming from a linked system of food, wood, energy, chemicals and non-market services. The supply of biomass uses land, water, waste and human capital resources and these are linked to the demand system. The broader policy objectives or policy targets for establishing a sustainable bioeconomy are:

- reducing dependence on non-renewable resources;
- adapting to and mitigating climate change;
- enhancing economic growth and creating jobs;
- improving trade balance in various countries[1]
- ensuring food security; and
- managing natural resources sustainably.

[1] It has been a major reason for countries like Brazil, the US and some EU countries. This will be discussed it in more detail later.

The policy objectives provide guidance for the choice of indicators to measure whether a bioeconomy and its policies contributes to these objectives. The bioeconomy is a complex system that encompasses the land based food and forestry sectors and interacts with the fossil based system. Its developments will have many direct and indirect effects and (potential) developments. Policies should be assessed for sustainability and therefore people, planet and profit indicators can be taken into account. Sustainability indicators may include the dependency on non-renewable resources, GHG emissions, biodiversity, jobs and economic growth, trade balance and food security (see red boxes in Figure 20.7).

The system drivers of the bioeconomy (blue boxes in figure 20.7) are related to the supply and demand of the bioeconomy. Demographic growth, consumer preferences and economic growth are identified as key drivers of demand, and technological and climate change as key drivers of supply of biomass (light blue boxes). Natural and human capital resources are also important supply key drivers (dark blue boxes).

The third block includes policy and management initiatives and responses for achieving the policy targets by influencing the demand and supply system drivers. For many applications, the cost of renewable energy is currently higher than technologies that

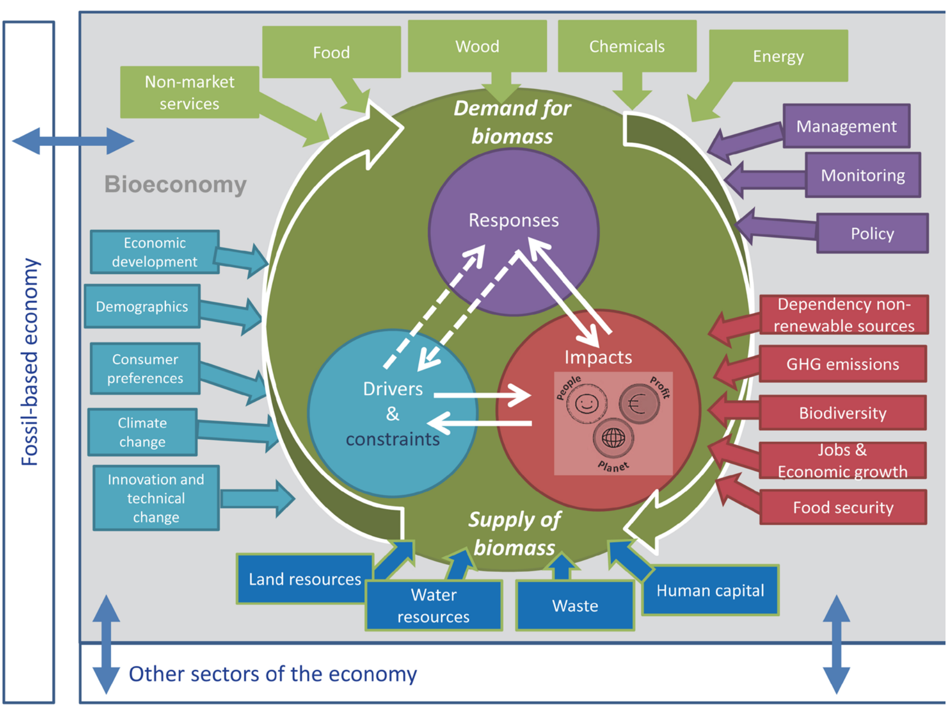

Figure 20.7. Systems analysis framework for the bioeconomy (Van Leeuwen et al. 2013).

produce electricity, heat or fuel from fossil fuels. One assumption behind the current incentives is that they will eventually drive down the cost of these technologies, through economies of scale and learning-by-doing. Indeed, there is evidence of learning-by-doing in the production and processing of biofuels (Chen et al. 2012). In that sense, these incentive policies play a critical role in the innovation process of renewable-energy technologies. According to Bahar et al. (2013), some policies focus on creating demand for these technologies in order to pull them into the market place (market-pull policies), while others focus on production of the technology or fuel itself in order to increase supply or foster innovation (technology-push policies). Section 20.2.5 describes the implications of market-pull and technology-push policies. In general, consumer, agricultural, energy, economic growth, technology and environmental policies can be used to facilitate the transition from a fossil based to a bioeconomy.

Computable general and partial equilibrium (CGE and PE) economic models connect the natural and human resources to the various demand developments in the fossil and bioenergy economy and focus on the interconnectedness of all these markets (e.g. Banse et al. 2008; Hertel et al. 2010; Laborde 2011). Therefore a main contribution is that beyond the direct effects on for example, production, prices, trade, land use and emissions they also take some indirect effects into account. Two important indirect effects are the indirect land use effect (iLUC) and the rebound effect. iLUC is the change in land use outside a feedstock's production area needed to replace the supply of that commodity and that is induced by changing the use or production quantity of that feedstock (see Chapter 17, this volume). A second important effect studied in the field of economics is the effect that substitution of fossil resources by biomass decreases the demand for fossil resources and therefore induces a lower price. A lower price leads to higher fuel consumption in other markets which partly offsets the initial fossil fuel and GHG savings. This is called the rebound effect (Hochman et al. 2010; De Gorter and Just 2009; Rajogopal et al. 2011)[2].The iLUC and rebound effects in the context of mitigating climate change will be discussed in section 20.2.4.

20.2.4 Arguments for Policy Interventions

One of the six key arguments for an active bioenergy policy, mentioned in the previous section, is *reducing dependence on non-renewable resources* and increasing energy security. Most economies rely heavily on fossil resources as carbon and energy sources, making them vulnerable to insecure and dwindling supplies and market volatility. Several countries, in the EU and the US, maintain trade barriers to promote and protect domestic production of biofuels (OECD 2014). Critics argue that many countries are unable to displace a significant share of their oil consumption to bioenergy, and as a result, are unable to control the fluctuation in fuel prices (Bento 2009). Even a limited share in gasoline consumption requires a large share of their land devoted to biofuels, which may be unacceptable from a food security perspective as long as agricultural

[2] The rebound effect of biofuel use is also known as indirect fuel use change, indirect energy use change, indirect output use change or carbon leakage.

productivity is not significantly enhanced. Exceptions might include countries like Brazil where there is a large and underutilized land base (Youngs and Somerville 2012).

A second key argument is the assertion that bioenergy will contribute to an overall reduction in GHG emissions and is therefore important toward *mitigating climate change effects*. The GHG savings from biofuels are heavily debated. There is a consensus based on life cycle assessments (LCA) that ethanol from sugarcane and corn reduce GHG emissions. However, LCA methods do not take market interactions into account and might be misleading when a large amount of biofuel is produced (iLUC and rebound effects). The iLUC effects are usually calculated by economic market equilibrium models. Searchinger, et al. (2008) calculated the initial LUC effect of 104 g CO_2 equivalent (CO_2e) per megajoule (MJ) of US corn ethanol while the emission factor of gasoline is 92 g CO_2e/MJ. Wicke et al. (2011) conclude that due to various model improvements the estimated LUC related GHG emissions decreased to 32 g CO_2e/MJ (CARB 2010) and more recently to 15 g CO_2e/MJ (Hertel et al. 2010; Tyner et al. 2010). Also Al-Riffai et al. (2010) and Laborde (2011) have found significantly lower values for corn ethanol (e.g. 7 g CO_2e/MJ in the latter). Wicke et al. (2011) and Tyner et al. (2010) identified that model improvements consisted of factors such as improved data, increased spatial resolution, including pasture land as an option for conversion to bioenergy production, crop yields on existing agricultural land and newly converted land for agricultural and bioenergy crops, treatment of co-products for animal feed, and the modeling of wood products (including by-products and the fraction of carbon that is stored for a longer period). Furthermore, GHG savings are very dependent on the feedstock used. Khanna and Crago (2012) also show the wide uncertainty in estimates of iLUC in the US and EU. Recently, it has been suggested that the use of residues and waste for bioenergy production also has an iLUC effect, as the use of residues and waste increases the profitability of the sector that produces the biomass (Smeets et al. 2014a).

Rebound effects, caused by increased fuel consumption due to a lower induced oil price, are crucial for the renewable energy policies being effective in reducing GHG emissions, yet they are presently under-researched. The net worldwide rebound effect is usually positive, which means that GHG emissions do not decrease as much as usually assumed. Estimated rebound effects are highly dependent on the applied method, scenario assumptions, the assumed supply and demand elasticities of oil and biofuels and the time frame. With regard to biofuel policies the reviewed studies indicate that biofuel credits and other financial policies promoting biofuels typically lead to higher positive rebound effects compared to biofuel blend mandates. 2010; De Gorter and Just 2009; Rajogopal et al. 2011). Chen and Khanna (2012) show how the rebound effect depends on the implementation of biofuel policies in the US and its implications for greenhouse gas emissions. They state that “The likely range of the change in GHG emissions with the average iLUC effect is (-) 1.2% to 0.4% under the Renewable Fuels Standard, (-)1.9% to (-)3.3% under the proposed national Low Carbon Fuel Standard, and (-)3% to (-)5.3% under a $60 per-metric-ton carbon tax policy relative to US GHG emissions under the BAU scenario over the 2007-2030 period”. Estimations with the CGE model MAGNET indicate a (positive) global rebound effect of the biofuel blend mandate in the EU in the year 2020 of 22% to 34%, i.e. the use of 1 energy unit of biofuel reduces global oil consumption from 78% to 66% (Smeets et al. 2014b). A complicating issue for direct and indirect GHG emission effects is that the fossil system is evolving as well and therefore analyses should be temporal (dynamic).

Enhancing economic growth and creating jobs is a third key argument for promoting bioenergy. The macro-economic impacts of a biobased economy in general and bioenergy in particular are not well known. A key result is that as long as bioenergy needs policies or subsidies to exist, its contribution to the macro-economic GDP growth is almost always negative (Meijl et al. 2012). From a job perspective, bioenergy might be beneficial, because in general, bioenergy is more labor intensive than its fuel equivalent. Advanced applications of biomass require large investments in research and development, production plants, logistics and human capacity. Existing sectors may potentially benefit, directly or indirectly, from the emergence of a green, bio-based economy, although there will also be threads for immobile factors in other sectors. There will also be opportunity costs involved in replacing existing production systems and in shifting resources that are being used in existing sectors to the biobased economy.

A CGE model framework is designed to identify and quantify these types of economic trade-offs. Two developments are critical to making biomass a profitable venture from a macro-economic point of view. The first is the efficiency of technologies to produce and collect biomass in a sustainable manner, and convert it into final products relative to fossil based technologies. The second is the (development) price of fossil based substitutes. The difference between the costs of production of the biobased product and the fossil-based substitute is an important determinant of the economic viability. These developments are (obviously) partially uncertain. To emphasize these uncertainties, as well as other risks and trade-offs involved in producing various biomass products. Meijl et al. (2012) calculated a series of possible effects on Malaysia's GDP of using palm biomass substitutes based on a range of technological and fossil fuel price scenarios. At an oil price of US$125, the predicted net contribution to GDP per ton biomass is three times as high for biobased chemicals as for pellets and bioethanol. Electricity from palm biomass has a negative contribution to GDP as it is not competitive with electricity from coal, although small-scale production might be economically viable under conditions that were not investigated in this study (such as remote, non-grid connected locations). The fact that Malaysia enjoys full employment limits the economic benefits of the use of biomass for energy and other applications. Also, the availability of capital is a constraint, as the development of a bioeconomy requires huge capital investments (e.g., logistics).

The prospects of increased farm income and rural economic development, primarily in less developed countries, can justify some degree of government intervention to promote the increase of biofuels production. Many studies show the positive impact on farm prices and income (Banse et al. 2008; Hertel et al. 2010; Laborde 2011). The crop sectors especially benefit from biofuel production and studies show some mixed results for the livestock sectors. On the one hand, traditional feed costs (e.g., corn and soy) for livestock farmers increase due to increasing feedstock prices resulting from a higher bioenergy demand; on the other, cheap co-products of biofuels (e.g., Distillers Dried Grains and Solubles, DDGS) can be used to feed animals and this reduces their costs. Biofuel production might increase the price of some crucial inputs such as land and fertilizer, which might harm non-biomass for energy sectors. According to IFPRI (2005), there is a potential for developing countries to specialize in bio-energy crops, especially crops that can be produced in poorer soils and adverse climatic conditions. Due to the substantial yield gaps to be explored in these countries, increased biofuels production can be partially achieved through intensification of existing cultivated areas. Cash from bioenergy crops enables farmers to buy better seeds and fertilizer to improve their yields. In turn, this will represent increases in farm income. The use of marginal lands in developing countries for second-generation biofuels production could also translate into an increase in rural income. In general, land abundant developing countries might have a comparative advantage in biomass for bioenergy, but potential trade barriers from developed countries could prevent developing countries from using this advantage. This might result in outside groups acquiring larger areas of farmland in developing countries where safeguards against exploitation are weak. Therefore, traditional market-based instruments may have to be complemented with regulatory schemes that characterize land based on its social and ecological potential, so as to prevent the conversion of land that can have adverse consequences that exceed the benefits from its use.

Improving the balance of trade has been a fourth major reason for investment in biofuel. It was the major driver for the introduction of the biofuel program in Brazil. In the 1970s, Brazil could not afford importation costs of fuel to meet local needs (Azanha and Zilberman 2014). Zilberman et al. (2014) argue that balance of trade considerations are a major driver of current US biofuel and energy policies.

To achieve social acceptance of bioenergy *ensuring food security and the sustainable management of natural resources* are the fifth and sixth important objectives to take into account, respectively. Managing natural resources in a sustainable manner requires conservation of biodiversity, water and other ecosystem land services. This section focuses, however, on whether and how bioenergy can be produced within the context of food insecurity. The food crisis of 2007-08 led to the re-emergence of the old food-versus-fuel debate, raising concerns about biofuels increasing food insecurity (Sagar and Kartha 2007). Biofuel and bioenergy use has in the past and is expected to in the future, induce higher pressure on the global demand for biomass unless a commensurate supply response is initiated. A clear distinction has been noted, however, between highly productive crops and applications, particularly sugarcane ethanol in Brazil, versus the relatively lower yielding production of biodiesel from soya and rapeseed (Rosillo-Calle and Johnson 2010). Some empirical studies suggest that biofuels contributed to 10-15% of food prices increases (see Figure 20.8). This is in direct contrast to previous studies (Mitchell 2008; NPR 2008; Rosegrant et al, 2006) which had stated a much higher impact on food prices arising from the conventional biofuel programs of Brazil, USA, EU and others, e.g. up to 75% of the 2008 increase in food prices. Analysis of observed data has not identified an impact at these higher levels.Recent econometric evidence by Baffes and Dennis (2013) found that oil prices were the main driver of the higher food prices.

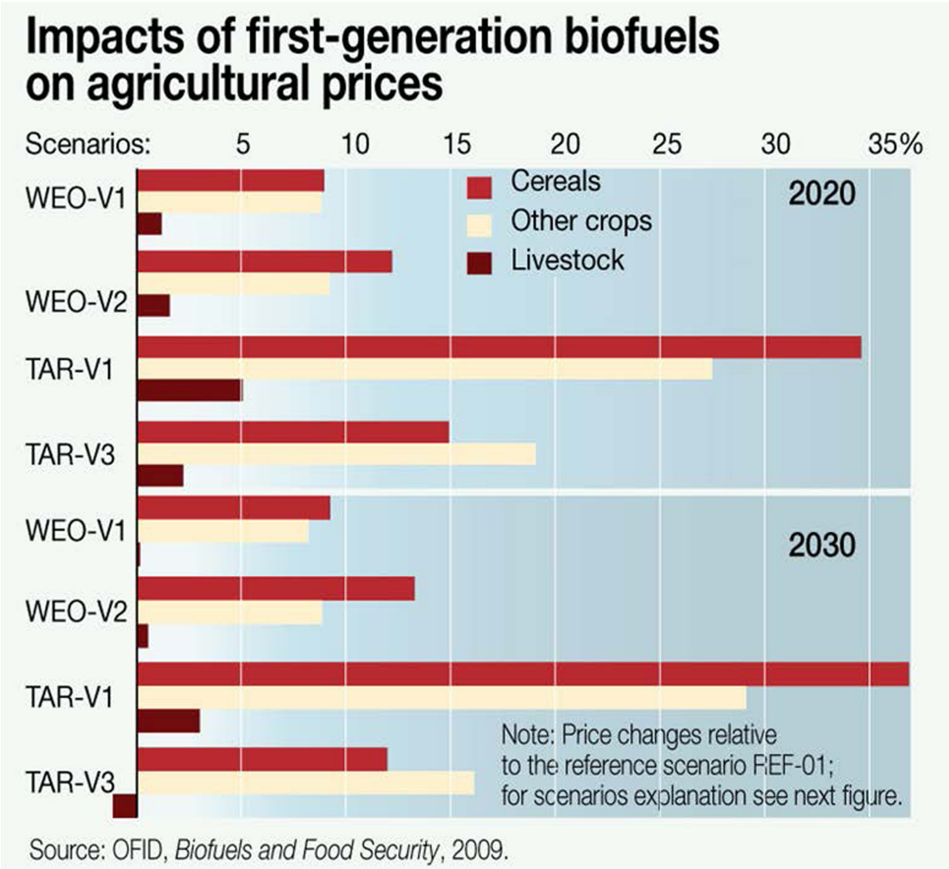

Figure 20.8. Impacts of conventional biofuel production on agricultural prices (UNEP, GRID Arendal 2011).

Van Ittersum (2011) suggests that agricultural output will need to triple between 2010 and 2050, if global agricultural biomass is to deliver 10 per cent of global energy use by 2050. More fundamental objections to increased demand for biomass for energy are voiced by Krausmann et al. (2013) who estimated that a 250 EJ/y bioenergy scenario by 2050 would increase the human appropriation of net primary production (HANPP) from 27-29% to 44%, and caution against a further increase. The HANPP provides a useful measure of human intervention in the biosphere. However, the analysis is not so simple, for example higher food prices might also lead to higher farm income in poor rural areas, with subsequent investments in the agricultural system leading to higher food security over the long run (Achterbosch et al. 2013). Direct and indirect or more dynamic effects may have different impacts on food security over various time-scales.

Food security according to the frequently cited FAO (2006) definition takes availability, access, utilization and stability into account. The effect of bioenergy production on food security through these variables is sometimes positive (e.g. improving access to food through higher producer prices and more secure household income based on sales to markets for bioenergy), sometimes negative (on food availability through food production, food trade or food access through consumer prices) and sometimes goes either way (on utilization and stability dimensions through macro-economic variables, see Figure 20.9 for an illustration in the case of biofuels). As a result, simple assertions that bioenergy production is a risk to food security or benefits food security should be treated with caution. Such claims often reflect a partial view on the issues at hand.

Public policy intervention in bioenergy is motivated by diverse concerns and objectives that vary in scale. While rural economic development can be considered a local concern, energy security is a national concern and reducing GHG emissions is a global one. Depending on how different governments weigh each concern, some policy interventions will make more sense than others. For example, if the chief goal of biofuels expansion is the reduction of GHG emissions, then it is important to learn "where", "how much", and "what type" of biofuels to produce.

20.2.5 Economic Impact of Government Policies

In this section we discuss the implications of some key market-pull and technology push policies for bioenergy. We focus on government incentives, first from a more static perspective and then from a more dynamic or innovation imperative.

Many countries have established national targets for renewable energy, typically to be achieved by 2020 (demand pull). Most of these targets are only aspirational, but

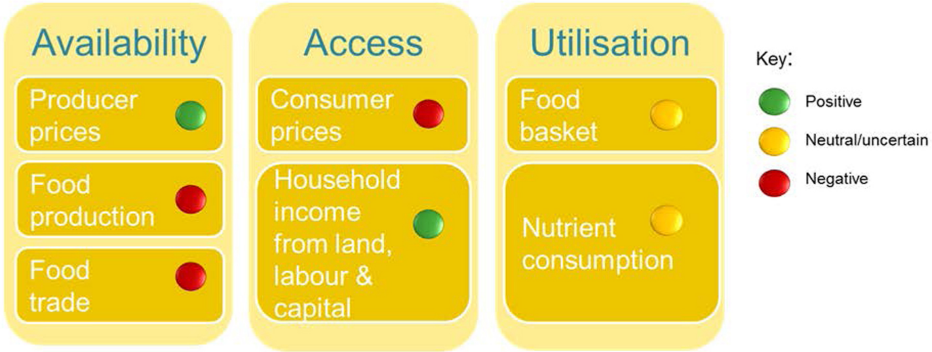

Figure 20.9. The impact of increased biofuel production on three dimensions of food security. Source: Shutes et al. (2013).

some - like those established by the European Union's Renewable Energy Directive (RED) - are legally binding. Where the targets are binding, systems for crediting renewable-energy production or sales (green certificates) are usually created. With respect to electricity, the most common policies are special feed-in tariffs (FITs) that either guarantee a fixed price for electricity sold to the electricity grid, usually for at least a decade, or a fixed premium per kilowatt-hour sold (REN 21 2013). The extra costs of these FITs and premiums are usually passed on to electricity consumers, but in a few countries they are paid out of government funds (which comes from taxpayers). Excise tax credits are often used in transport to make biofuels competitive against fossil fuels. Fuel excise tax credits are the most direct and widely used instrument. Because most countries tax the consumption of gasoline, the excise tax credit effectively lowers the cost of biofuel relative to gasoline, and thus promotes its expansion up to the point where the blender is indifferent between using gasoline and biofuels (Bento and Landry 2008). The FIT paid by government funds and tax credits reduces the price of fuel and therefore increases the rebound effect as consumption of fuels increases. The increase in fuel consumption increases externalities associated with GHG emissions and other factors such as congestion and accidents. Tax credits generally favor current (first generation) technologies and might delay better technologies as the former reduce costs by learning effects. There could be exceptions when there are synergy effects between first and second generation technologies such as the use of sugarcane bagasse for cellulosic ethanol.

Mandatory blendings, such as the Renewable Energy Directive in the EU and the Fuel Standard and renewable portfolio standards at the state level (RFSs) in the USA are a kind of command and control regulation (quota) which, from an economic point of view, are more costly than an incentive based approach such as subsidies as the costs of achieving the same outcomes are substantially higher (e.g. Markusen and Melvin, 1988). There are economic costs associated as a mandate creates an (sub-optimal) excessive production of biofuels\bioenergy. A difference with all kind of subsidies is that mandates are government budget neutral and the costs are paid directly by fuel consumers (i.e. higher fuel prices) and not by all taxpayers. Another crucial difference of mandates with subsidies is that the indirect rebound effect is reversed, as mandates lead to higher instead of lower fuel prices and therefore lead to less fuel consumption and related negative externalities (e.g. Khanna et al. 2008). If the policies strive to reduce GHG emissions, then GHG related taxes are most effective from an economic point of view. From a dynamic point of view they stimulate GHG friendly technologies and this induces learning effects. Large additional subsidies for renewable energy may not be necessary; instead, getting the price right on GHG emissions that raise fossil based prices and improving the competitiveness of renewable energy is more critical. The welfare impacts at national level in an open economy of a mandate and a subsidy are not straightforward and dependent on, for example, initial level of policy distortions and the ability of a country to influence (world) market prices. Lapan and Moschini (2012) and Cui et al. (2011) show, for example, that for the US, a mandate might lead to higher social welfare than a subsidy. Chen et al. (2014) show that the cost-effectiveness of a carbon tax relative to a biofuel mandate in an open economy is not necessarily the case. It depends on the relative impact of the two policies on the terms of trade. Since a biofuel mandate (e.g. in the US) raises the price of corn exports and can lower the price of fuel imports, it improves the terms of the trade and can provide positive economic benefits for the US. This chapter also compares the cost effectiveness of a biofuel mandate in the US to a carbon tax for achieving a reduction in GHG emissions and shows that while both policies lead to positive economic benefits for the US, the biofuel mandate in the US can have a large negative economic impact on the rest of the world. Trade policies such as import tariffs on ethanol in the USA and the EU favor domestic producers and can be justified from a domestic energy security perspective. However, from an economic point of view they generally lead to lower welfare, as countries do no exploit their comparative advantage.

Technological push policies, which support invention and innovation through R&D, production and sales, have been forwarded by the work of the economist Joseph Schumpeter (1934) who regarded innovative technologies as the essential forces behind social and economic changes. In Schumpeter‘s view, though process innovations are vital, only product innovations can give rise to new industries. The knowledge market is characterized by market failures that may take the form of knowledge spillovers from learning-by-doing, or R&D spillovers. Because the value of these positive externalities is not fully captured by the firms that generate them, they may undertake less of the activities that generate them than would be socially optimal. To correct for these market failures, extensive research, development and demonstration (RD&D) programs relating to renewable energy are present in rich countries. According to the IEA these countries spent at least USD 4.1 billion on RD&D related to renewable energy in 2011 (www.iea.org/stats/rd.asp).

With regard to agriculture, genetic improvement and improved fertilizer use have been major contributors to the Green Revolution. Qaim and Zilberman (2003) state that “the introduction of new biotechnologies that are based on a better understanding of the principles of molecular and cell biology are also major contributors to further increases in agricultural productivity and, in particular, increases in yield per acre and reductions in the use of inputs”. Barrows et al. (2014) argue that the use of genetically modified (GM) varieties in soybean and corn enabled societies in Asia to meet the high increase demand by enhancing their production. Qaim and Zilberman (2003) state, furthermore, that “these technologies may further reduce the environmental footprint of agriculture and increase the amount of land available for biomass and biofuels”. However, the public (especially in Europe) is concerned about the social and environmental sustainability of these new technologies and also about other environmental aspects, such as soil fertility and carbon stock maintenance. Regulation has banned these technologies in Europe and Africa, or made them very expensive. Zilberman et al. (2013a) stress that “while regulation is important both for the protection of society as well as for the development of goodwill toward the technology, excessive regulation may be harmful to technological innovation, especially given the importance of private sector investment in the development of new biotechnologies”.

The emergence of the bioeconomy in the EU and the USA is criticized for its heavy focus on technology and economics and for not placing ethical questions and risk first (Hilgartner 2013; Birch 2012). Birch et al. (2012) argue that these techno-knowledge fix visions of the bioeconomy might create "the conditions for what they seek to promote," in other words are self-fulfilling. McCormick and Kautto (2013) argue that "policy making should include a wide range of perspectives – also critical – to enable innovation and not restrict societal development only to one perspective". Additional visions for a bioeconomy should be developed such as agro-ecological food chains (Levidow et al. 2012a, 2012b, Levidow, 2013) and a "glocal" (both global and local) distributed bioeconomy that focuses on the nearness and interconnectivity of biomass locations and locations where products and energy are consumed and produced (Luoma et al. 2011). This later vision would seem to support local bioenergy production.

20.3 Conclusion

Bioenergy has grown rapidly due to high oil prices and especially a variety of government policies, such as feed-in-tariffs, tax exemptions and biofuel mandates. This increase led to more interconnectedness between energy and agricultural markets and influenced relative food and feed prices and land-use changes. In turn, this resulted in concerns from a food security and environmental perspective. Whether the policies are justified depends on their goal or vision. There is much optimism about the benefits of developing a bioeconomy, but considerable trade-offs and risks are also expressed. The bioeconomy has been criticized for stressing a technology-fix vision and neglecting incorporation of additional ones. To achieve broad public support, the general public and key stakeholders should be involved in an open and informed participatory dialogue. Commitments for a *sustainable* development of a bioeconomy by government and industry is another key condition.

Justification of bioenergy policies depends on its goals and the various goals can be in conflict with each other. Different goals have different scales and this creates conflicts. While rural economic development can be considered as a local concern, energy security is a national concern and reducing GHG emissions is a global one. The goal of reducing dependence on non-renewable resources has to be viewed critically, as a significant reduction in the use of non-renewable resources requires large amounts of land, which may cause problems from a biodiversity and food security point of view. The mitigation of climate change is heavily debated. While LCA studies show GHG savings, they do not take indirect effects such as iLUC and rebound effects into account. These indirect effects might limit or change GHG savings. Multisectoral economic models are naturally equipped to assess these indirect effects although this requires major data and model improvements.

As long as an economy is not at full employment the bioeconomy can create jobs as it is a more labor intensive technology than a fossil based one. A bioeconomy can contribute to economic growth if biobased technologies are competitive with fossil based technologies. On one hand, it depends on the efficiency of biobased and fossil based technologies and on the other on the volatile price level of biomass versus fossil energy prices. The bioeconomy can contribute to increased farm and rural economic development but regulatory schemes are necessary to deal with social and environmental adverse consequences. Stimulating a bioeconomy improves trade balance if one exports biomass (including agriculture) and imports energy.

To achieve social acceptance of bioenergy while ensuring food security and managing natural resources is key. Managing natural resources in a sustainable manner requires conservation of biodiversity, water and other ecosystem services of land. The effect of bioenergy production on food security is sometimes positive (e.g. improving access to food through higher producer prices and more secure household income based on sales to markets for bioenergy), sometimes negative (on food availability through food production, food trade or food access through consumer prices) and sometimes goes either way (on utilization and stability dimensions through macro-economic variables). As a result, simple assertions that bioenergy production is a risk to food security or benefits food security should be treated with caution.

In general, policies could be much more directly connected to their targets. If policies strive to reduce GHG emissions then GHG related taxes are most effective from an economic point of view. If policies should contribute to a higher economic growth than productivity enhancing policies are most desired.

As the bioeconomy is an immature or an infant industry it is in general not competitive with the fossil-based economy. Policies might be justified to temporarily stimulate its development. Technological change that reduces costs and full biomass utilization for food, feed, energy, materials and chemicals might create a competitive industry. The development of more efficient biomass conversion routes, especially those that can convert lignocellulose biomass into biofuel and biochemical, can potentially contribute to a transition towards a competitive biobased economy.

Regulation could deal with the indirect effects of bioenergy such as social and environmental effects (land, water, biodiversity). However, given the importance of private sector investments in the development of biotechnologies, excessive regulation might create a disincentive to innovation. One of the biggest challenges is the development of a regulatory framework that limits externalities from new bioenergy and, at the same time, does not curb innovation.

20.4 Recommendations (Policy)

- Policies could be much more effective if they are directly connected to a target. E.g. CO_2 taxes to reduce emissions.
- The bioeconomy is an immature industry which may justify temporary policies to stimulate its development. Policies directed at technological change and full biomass

utilization for food, feed, energy, materials and chemicals may create a competitive industry focused on reduction of emissions and stimulate economic growth.

- Regulation could potentially deal with the indirect effects of bioenergy such as social and environmental effects (land, water, biodiversity). One of the biggest challenges is the development of a regulatory framework that limits social and environmental externalities from new bioenergy and, at the same time, does not curb innovation.
- To achieve broad public support the general public and key stakeholders should be involved in an open and informed participatory dialogue. Commitment from government and industry toward the sustainable development of a bioeconomy is a key condition.

20.5 The Much Needed Science

- Integrative approaches addressing the emerging bioeconomy within society are essential.
- System analyses tools of the bioeconomy are necessary to assess the impact of technology, demand, and policy drivers on sustainability.
- Economic models should be enhanced to better quantify the indirect land use and rebound effects of the bioeconomy, better understand the impact of bioenergy on the various dimensions of food security, and improve the modeling of technological change.
- Evidence is needed on the effectiveness of policies with regard to the various sustainability dimensions (people, profit, and planet).
- Data collection, harmonization of concepts and monitoring is needed for the development of the bioeconomy. What part of the economy is biobased?
- Additional visions for a bioeconomy should be developed and integrated into policy. For example, in addition to a focus on promoting technologies (including biorefineries) and fixing all undesired side effects with regulation and other policies visions, agro-ecological food chains and “glocal” (both global and local) distributions systems could be developed.

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