Chapter 14
A Regional Perspective on Biofuels in Asia

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14.1 Introduction

In the beginning of the biofuel boom in the late 2000s, there were high expectations in many Asian countries that biofuels could enhance energy security, provide jobs, and reduce greenhouse gas (GHG) emissions. There were hopes that biofuels could be produced and consumed on a large scale and high expectations of significant biofuel trade. Some countries – particularly developing countries – hoped for biofuels to become a new major source of exports. For example, many in Indonesia hoped that their country could become the "Middle East of biofuels." Likewise, some developed countries, including Japan and some EU countries, hoped that significant biofuel imports, particularly from Southeast Asia, could diversity their energy sources. Thus, at that time, a regional perspective or strategy might have expected some countries (especially developing countries) to become major biofuel exporters and others (especially developed countries) to become major biofuel importers, with some potential interregional trade as well. Sustainability issues might be solved through a mechanism to apply sustainability standards.

This vision of a regional strategy or perspective assumed that significant land and other resources would be available to produce biofuel feedstocks on a reasonably large scale and in a sustainable manner. However, it generally has been very difficult to concretely identify large amounts of specific available land and assess whether adequate water is available, even before addressing sustainability issues. This chapter does not undertake a comprehensive study of available land and other resources, but rather reviews some existing efforts. It also considers the prospects for large-scale trade in biofuels to contribute to a major expansion of biofuel use.

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Overall, this chapter concludes that large-scale increases in production are probably not realistic without large-scale diversion of land from other uses such as food production and without further pressure on the environment and other resources necessary for production, particularly water. To put it in more concrete terms, the current level of production of biofuels is generally modest, generally accounting for less than 5% of transport fuel in Asian biofuel-producing countries. Already at this level, the sustainability of biofuels has been questioned, although in some areas outside the region, such as the USA and Brazil, the share of transport fuel accounted for by biofuels is higher. While it could be conceivable to expand current levels to some extent, it seems clear that it is very difficult to expect biofuels to replace a large share of transport fuel such as 50% or even 30% or 20%.

Encouragement of smaller-scale production tailored to local conditions as a way to promote rural development and poverty reduction or as a way to address waste management issues may be more realistic. However, without large economies of scale of production, it will be difficult to reduce costs. In addition, there are various other challenges to the promotion of small-scale biofuels such as capacity of farmers; availability and cost of land, water, labor, and other inputs; and availability of markets for final outputs. If the main goal is to increase rural employment rather than energy security or GHG emissions reduction, then there may be other ways to accomplish this rather than through biofuels.

Sustainability standards and certification systems are one possible way to encourage the development of biofuels in a positive direction. However, while they may enable sustainable incremental production, they cannot create new land for biofuels; moreover, if they are to be effective, they should restrain the availability of new land by preventing excessive land use change from forests or food crops. The main efforts to implement sustainability standards have been taking place in Europe, where they will be required as part of the Renewable Energy Directive (RED), and they will apply to biofuel imports (Spiegel 2011). At the time of writing, there was no comparable initiative in East Asia, although a global voluntary initiative, the Roundtable on Sustainable Biofuels (RSB), has been developed with the participation of stakeholders from Asia and elsewhere, which could serve as the basis for an initiative in the region, and producers in the region could adopt the standards voluntarily. The RSB standard is still in the early stages of implementation, so it remains to be seen how effective it will be.

The rest of this chapter is organized as follows. First, the global feedstock requirements for biofuel production are examined. Second, the potential to expand biofuel production in East Asia is considered. Third, the limitations of second-generation biofuels are discussed. The fourth section explores the potential for trade to expand biofuel use in the Asian region. The fifth section considers the potential of sustainability standards, and the sixth section concludes.

14.2 Global Feedstock Requirements for Biofuel Production

This section discusses the global feedstock requirements for current biofuel production and uses them to estimate the potential for significantly expanded production. Already, globally, a significant share of the world's grain and vegetable oil production is being used to produce biofuel. However, this has only succeeded in replacing a small amount of liquid transport fuel.

Table 14.1 shows that overall, 11% of coarse grains and vegetable oils and 21% of sugarcane were used to produce bioethanol and biodiesel on average in 2008–2010. In 2020, this is expected to increase to 12–16% for grains and oils and 33% for sugarcane. Biofuels produced by these feedstocks accounted for 2.0% and 5.3% of diesel and gasoline use, respectively, on average in 2008–2010, and this amount is expected to increase to 3.8% and 8.8%, respectively, by 2020 according to Table 14.2.

Table 14.1 Present and future share of global coarse grains, vegetable oil, and sugarcane production used to produce biofuel

	2008–2010 average	2020 projection
Share of global production of coarse grains used to produce ethanol	11.0%	12.0%
Share of global production of vegetable oils used to produce biodiesel	11.0%	16.0%
Share of global production of sugarcane used to produce ethanol	21%	33%

Source: Calculated based on OECD-FAO Agricultural Outlook 2011–2020 (2011)

Table 14.2 Estimated share of global coarse grains, vegetable oil, and sugarcane production needed to significantly expand biofuel production

	2008–2010 average	2020 projection
Share of ethanol in global gasoline use (%) (energy shares)	5.3%	8.8%
Share of biodiesel in global diesel use (%) (energy shares)	2.0%	3.8%
Estimated share of global production of coarse grains needed for ethanol to replace 20% of global gasoline use	41.5%	27.3%
Estimated share of global production of vegetable oils needed for biodiesel to replace 20% of global diesel use	110.0%	84.2%
Estimated share of global production of coarse grains needed for ethanol to replace 50% of global gasoline use	103.8%	68.2%
Estimated share of global production of vegetable oils needed for biodiesel to replace 50% of global diesel use	275.0%	210.5%
Share of sugarcane in gasoline use	21%	33%
Estimated share of global production of sugar cane needed for ethanol to replace 20% of gasoline use	79%	75%
Estimated share of global production of sugarcane needed for ethanol to replace 50% of gasoline use	525%	434%

Source: Calculated based on OECD-FAO Agricultural Outlook 2011–2020 (2011)

Based on this, the amount of feedstock that would be needed to expand biofuels to account for 20% or 50% of gasoline and diesel use can be calculated. The result is that in order to offset 20% of gasoline and diesel use in 2008–2010, 41.5% of global coarse grain, 110% of vegetable oil, and 79% of sugarcane production would have been needed. To offset 50% of gasoline and diesel use, 103.8% of coarse grain, 275% of vegetable oil, and 500% of sugarcane production would have been needed.

Thus, the level of biofuel feedstock production and technology in 2008-2010 was not sufficient to replace 50% of either diesel or gasoline, since more than the entire amount of global feedstock production would have been required. Even to replace 20% of diesel or gasoline would have required much larger amounts of feedstock.

By 2020, it is projected that both feedstock production and the share of biofuel in gasoline and diesel will increase, because of increased productivity and stronger biofuel mandates. It appears that the percentage of biofuel feedstocks needed to replace 20% or 50% of gasoline and diesel would decrease to some extent. Nevertheless, a very large amount of feedstock would still be necessary to replace 20% of gasoline and diesel. To replace 50% of gasoline would still require more than half of the total production of coarse grains, and to replace 50% of diesel, even double the 2020 global vegetable oil production would not be enough. To be sure, technological advances and increases in yields may improve this situation to some extent, but the bigger picture is that there is a fundamental limit to how much biofuels can replace gasoline and diesel, considering that expansion of global biofuel production is constrained by a scarcity of farmland which will be needed to feed an increasing global population.

According to the FAO, to meet the needs of an expanding global population and adapt to changing consumption patterns, the world's food production will need to increase considerably over the coming decades, growing 70% above the level of 2009 by 2050 to feed an estimated additional two billion people. Much of this will need to be met by rising yields, although one study found that many biofuel feedstock crop yields have been overestimated, so that there might not be much room to increase them, and also rising yields may lead to environmental pressures (Johnston et al. 2009). The FAO says there is some room to expand biofuel feedstock production, but many of these potential new production areas are far from areas where biofuels would be consumed and not necessarily suited for the crops in the highest demand. Thus, most production growth would probably have to occur on existing agricultural land (FAO 2011).

Water shortages will also be a concern, and this issue was examined by FAO (2011). FAO's report carefully avoided concluding that there is not enough water for biofuels, but rather explained that there will be increased competition for water, as well as land, among different uses including food and fuel. A study by SEI examining the water energy and food nexus calculated that completely replacing fossil transport fuels would require 30 million barrels of ethanol and 23 million barrels of biodiesel per day, and only 10% of the required ethanol would require an additional 600 km^3 of water per year, which is much more than the global consumptive combined municipal and industrial water use (Hoff 2011, 19). Water is needed not only for the additional feedstock production but also for the fuel refining process. Thus, biofuels will compete for water as well as land. Water availability is a key global challenge (UNEP 2007) which is particularly severe for Asia (Kataoka and Shrestha 2010; de Fraiture et al. 2008). So future biofuel plans and targets will need to clearly indicate where the water will come from.

Therefore, it might be manageable to replace up to 10% of gasoline and diesel, although even this may be limited by sustainability constraints. However, there appear to be strong physical limitations to going much beyond this.

Of course, this calculation assumes the extrapolation of current technologies and production methods and does not take into account the possibility of yield or other productivity increases, so it may overestimate the amount of feedstock needed. Nevertheless, it is clear that productivity increases would have to be very substantial in order to make much of a difference. It may not be very realistic to expect this. The FAO cautions that while there is some room to increase crop yields, this involves certain environmental risks which would involve some difficulties in managing (FAO 2011).

14.3 Potential to Expand Biofuel Production in East Asia

In recent years, a number of Asian countries have established mandates or targets for biofuel use, as well as corresponding promotion policies. These targets have ranged from modest to ambitious as can be seen from Tables 14.3 and 14.4. China and India (bioethanol) and Indonesia and Malaysia (biodiesel) have been producing a significant amount of biofuels. Other countries in East Asia such as the Philippines (biodiesel), Thailand, and Vietnam (ethanol) also have been increasing their biofuel production, although the scale still remains modest. Most countries have found it very difficult to meet their targets due to difficulties in expanding production.

To what extent is it realistic to expect that countries might be able to meet their targets or otherwise significantly expand biofuel production, even aside from sustainability criteria? Assessing the physical potential for expansion of biofuel production is a very difficult exercise, since there is insufficient data in many cases. In particular, the reliability of land availability data is often questionable.

In most Asian countries, most land is already being used, or is a forest, or may not be very productive. Strong demand for biofuels will likely cause a shift in land use from food energy crops and may eventually cause deforestation. Although feedstock production technologies are advancing, there is limit to how much yields can increase. The use of agricultural waste has been suggested as a source of additional biofuel production, but this is sometimes already being used for other purposes or is providing ecosystem services. Collection of these wastes may be difficult or uneconomic. The use of marginal lands to grow nonfood crops that need little water such as *Jatropha* and others has also been suggested. However, while it is possible to grow crops such as *Jatropha* on wastelands with little water, yields will be low, and costs will be high if they are not irrigated or provided with fertilizer or planted on more fertile land. Moreover, marginal lands, sometimes called "wastelands," actually often are used by poor people with insecure land use rights.

Table 14.3 Future demand and production of bioethanol in the case study countries

Country	Target year	Scenario	Blending mandate/target	Gasoline demand in target year	Ethanol required	Production in target year				Total ethanol production	Target achieved?
						Current production	Ethanol from waste	From new land	From residue		
China	2020	Medium	10MMT	113,072	12,700	6686	5309	5905	10,778	28,678	Yes
India	2017	Low	20%	15,312	3062	2562	2690	215	4350	9817	Yes
Indonesia	2015	Low	10%	22,269	2227	212	856	563	660	2291	Y/N
Philippines	2011	Low	10%	4660	466	105	279	0	0	384	No
Thailand	2011	Low	10%	4893	489	408	434	330	0	1172	Yes
Vietnam	2020	Medium	500ML	6592	500	164	482	355	729	1730	Yes

Unit: million liters. *Source:* modified from USAID (2009)

Table 14.4 Future demand and production of biodiesel in the case study countries

Country	Target year	Scenario	Blending mandate/target	Diesel demand in target year	Biodiesel required	Production in target year		Total biodiesel production	Target achieved?
						Current production	From new land		
China	2020	Medium	2MMT	225,134	2400	355	224	579	No
India	2017	Low	20%	64,706	12,941	317	33	350	No
Indonesia	2010	Low	10%	11,593	1159	753	144	897	No
Malaysia	2010	Low	5%	6466	323	443	–	443	Yes
Philippines	2009	Low	2%	5967	119	211	–	211	Yes
Thailand	2012	Low	10%	17,338	1,734	48	236	284	No
Vietnam	2020	Medium	50ML	11,541	50	–	34	34	No

Unit: Million liters. *Source:* modified from USAID (2009)

The potential of several Asian countries to expand biofuel production to reach these targets has been analyzed by USAID (2009) which analyzed different possible scenarios for expanding their biofuel production, taking into account requirements for land and water. The study considered the options of shifting some land use from forest and food crop uses, increasing crop yields through the use of new technologies, use of crop residues, and use of marginal lands. The study considered both first-generation feedstocks, whose production increase may need to focus on underutilized land, and second-generation biofuel technologies using waste and residues from existing agricultural lands. Two scenarios considering crop mix, land use, and increasing yields were provided. The first scenario assumed expanding production of six crops using underutilized land, taking into account each country's specific resources. The second scenario assumed the use of five crops (maize, rice, sorghum, sugarcane, and wheat) to produce feedstock for second-generation bioethanol. Then, the scenarios were considered with each country's strategy for future biofuel production for approximately the next 10 years. The results of this study are summarized in Tables 14.3 and 14.4 above.

The USAID report optimistically concluded that for ethanol, around the year 2020, four of the six case study countries can probably meet their targets; one is borderline, and the other will fall somewhat short. However, for biodiesel, meeting the targets may be much more difficult, and only two of the seven countries are expected to do so. Moreover, the main reason why Malaysia and the Philippines are expected to meet their biodiesel production targets is because the targets are low.

The conditions necessary to reach the optimistic conclusion in the case of ethanol can be clearly seen from USAID's analysis. In all six case study countries, current production is less than the target, in some cases considerably less. Reaching the targets could be accomplished by significant expanded use of waste or residues and would not necessarily require new land.

Although the USAID study was able to identify some potential new land that could be converted to produce ethanol in each case study country except for the Philippines, the amount of land was not large. Presumably, this was the amount of land that USAID believed could be diverted without significant impact on food production or forests. Any significant increase in the amount of land used for biofuel feedstock production would cause concerns about land being converted from food production or forests.

In the case of biodiesel, the current production levels of the countries which are unable to meet their targets are generally significantly below the targets. To be sure, the USAID study did not consider the potential for waste to biodiesel or crop residues, so there could be some future potential for this. Nevertheless, the USAID study also did not identify significant new land that might be available for biodiesel production, at least not enough to enable these countries to meet their targets. The case of Indonesia is particularly important, since it was initially hoped that it could be a major exporter of biodiesel. In Indonesia, the main existing crop suitable for biodiesel is palm oil, for which Indonesia is one of the world's largest producers. However, palm oil is the main source of cooking oil in Indonesia, so its price and availability are very politically sensitive. Palm oil is also a major ingredient in many other products – including packaged foods – and India is a significant importer of palm oil for cooking. Therefore, any significant expansion of the use of palm oil for biodiesel would negatively impact its use as cooking oil, or in other products, or could encourage deforestation to make way for new palm oil plantations.

Table 14.5 presents a hypothetical scenario showing how much gasoline and diesel could be replaced if the entire production of selected feedstock crops in selected countries were to be entirely used for biofuels. For example, in the case of Indonesia, in 2008–2010, the country produced 272 million liters of biodiesel which accounted for 1.3% of diesel use (by energy share). Indonesia also produced 64 million tons of palm oil in 2005. USAID calculated that about 230 l of biodiesel can be produced from one ton of palm oil feedstock. Therefore, if Indonesia's entire production of 64 million tons of palm oil hypothetically could be converted to 14.7 billion liters of biodiesel, extrapolating from the share of diesel accounted by current biodiesel production, and assuming that all of the current biodiesel production is based on palm oil, the result is that converting all of Indonesia's palm oil to biodiesel would replace only about 70% of diesel fuel. This is admittedly a very rough, back of the envelope calculation. A number of factors could increase the potential replacement ratio, for example, if more crops were included or land productivity was higher. But the calculation is also conservative, in that it double counts the existing feedstock use, thereby overestimating the potential replacement ratio (possibly to a significant extent).[1] Overall, it gives an indication of the potential scale of biofuels in comparison to the use of liquid fossil fuels. It suggests that it may be quite difficult to expand crop-based biofuels to much more than 10% of liquid fossil fuels.

Tharakan et al. (2012) include an estimate of the potential for biofuels in the countries in the Greater Mekong Subregion (GMS). They note that available statistics optimistically suggest the potential to produce large amounts of biofuels. However, they conclude that the actual potential is much more modest if social and environmental risks are taken into account; moreover, land availability statistics typically are not very accurate in these countries. They note that while land availability currently is not a serious concern, expected increases in population and corresponding demand for food could generate increasing competition for land, and increasing risks of climate change and extreme weather are likely to adversely affect agricultural productivity.

Even in the more optimistic case, the ability of the GMS countries to generate significant exports is limited (see Table 14.6). In 2009, under the assumption that 10% of arable land could be used for biofuels, only Myanmar and Laos could have

[1] For example, in the case of Indonesia, all of the palm oil is assumed to be used to achieve the 70% replacement of biodiesel. However, some of the palm oil was already used to achieve the existing 1.3% replacement ratio, which was the basis for the extrapolation. This double counting is thus not very significant in the case of Indonesian biodiesel, but it might make more difference in the case of ethanol in Brazil. This is because a significant part of the sugar crop is already included in the current replacement ratio, which is already high at 47%. This calculation implies that about two thirds of the sugar crop is already used for ethanol, and converting the other one third would only push the replacement ratio up to 70%.

Table 14.5 Potential for biodiesel and ethanol to replace diesel and gasoline in selected countries

	Biofuel production	Domestic use	Fuel use	Share in fuel use (energy Sh.)	Share in fuel use (volume)	Net trade	Feedstock and date of data[a]	Total prod. feedstock[a]	Biofuel from feedstock[b]	Biofuel produced if 100% feedstock is used	Share of fuel use if 100% feedstock used
	Av 2008–2010 MN L	Av 2008–2010 MN L	Av 2008–2010 MN L	Av 2008–2010	Av 2008–2010	Av 2008–2010 MN L		MT	L of biofuel/ton of feedstock	MN L	Share of domestic fuel use
				%	%						%
Biodiesel				(Share of diesel)							
Indonesia	369	272		1.3	1.7	98	Oil palm 2005	64	230	14,720	70.3
Malaysia	765	206		1.6	2.0	559	Oil palm 2005	76	230	17,480	135.8
USA	1658	909		0.3	0.4	748	Soybeans 2005	83	183	15,189	5.0
Brazil	1550	1550		2.7	3.4	0	Soybeans 2005	50	183	9150	15.9
Ethanol				(Share of gasoline)							
China	7189	7041	2024	1.8	2.6	148	Maize 2005	133	400	53,200	47.3
India	1892	2109	183	0.9	1.4	−217	Sugarcane 2005	232	70	16,240	79.9
US	42,857	44,663	42,338	5.3	7.7	−1806	Maize 2005	280	400	112,000	14.0
Brazil	26,091	22,589	21,061	47	57	3502	Sugarcane 2005	420	70	29,400	66.0

Calculated based upon OECD-FAO Agricultural Outlook 2011–2020 (2011)
[a]Rosamond et al. (2007)
[b]USAID (2009)

Table 14.6 Hypothetical share of domestic transport fuel demand that could be met through biofuels in GMS countries

	Bioethanol[a]		Biodiesel[b]	
	2009	2020	2009	2020
Cambodia	44	23	8	4
China (Yunnan and Guangxi)	73	40	4	3
Lao PDR	104	40	27	10
Myanmar	269	96	34	28
Thailand	13	3	1	0
Viet Nam	20	10	0	0

Source: Tharakan et al. (2012, 8)
Unit: percent
[a]Assumes bioethanol is produced from converting 10% of available land from wasted grain/crops
[b]Assumes biodiesel produced from converting 10% of available land

met all of their gasoline demand with bioethanol and have some leftover for exports. For Myanmar, this might be significant, as it would have been able to export ethanol equivalent to 169% of its gasoline consumption. However, the total quantity would not have been very significant in terms of total gasoline consumption of potential developed country importers. Moreover, by 2020, due to expected rising fuel consumption in the GMS countries, only 3–40% of gasoline demand might be able to be met by domestic production and 96% in the case of Myanmar. For biodiesel, the potential to replace diesel fuel is much less (Tharakan et al. 2012). Thus, while the authors find that biofuels could make some contribution to domestic transport fuel in GMS countries, it seems clear that there will not be sufficient capacity for any of these countries to become leading suppliers to developed countries. Like Indonesia, the GMS countries have no prospect of becoming the Middle East of biofuels.

Even in the case of production for domestic use, Tharakan et al. (2012) observe that the extent to which this potential can be realized depends on various factors, including the type of production system that is used. GMS countries are subject to similar environmental and social constraints as in other areas, in particular potential food-fuel conflicts. They note that large-scale industrial plantations – which would be necessary for large-scale exports – would be particularly problematic. They conclude that smaller-scale production based on surplus land, nonfood crops, and smallholder-based production is more realistic (Tharakan et al. 2012, 413).

14.4 Limitations of Second-Generation Biofuels

It has been hoped that so-called second-generation or advanced biofuels can overcome the limitations of first-generation biofuels based on conventional agricultural feedstocks. However, in practice, these are also subject to a variety of physical limitations limiting the scope of their potential, besides waiting for technical advances. For example, the IEA has estimated that 10% or 25% of the global forestry and agricultural residues in 2007 could have produced enough biodiesel and ethanol to provide 4.2–6.0 to 10.5% of current transport fuel demand, respectively (IEA 2010, 9). To be sure, this could be an important partial contribution, but it is still not enough to serve as the main source for transport fuel.

Many second-generation biofuels – including switchgrass, algae, etc. – require land and water, just as first-generation ones do. In many cases, waste from forests and agriculture perform ecosystem services such as returning nutrients to the soil, so there is a fundamental limitation on how much these resources can be exploited. In particular, this "waste" is often used by small-scale farmers in the region for fertilizer, so if it is used to produce biofuel, then farmers may be forced to use more conventional fertilizers (Elder et al. 2008, 13).

14.5 Biofuel Trade: A Scramble for Biofuels?

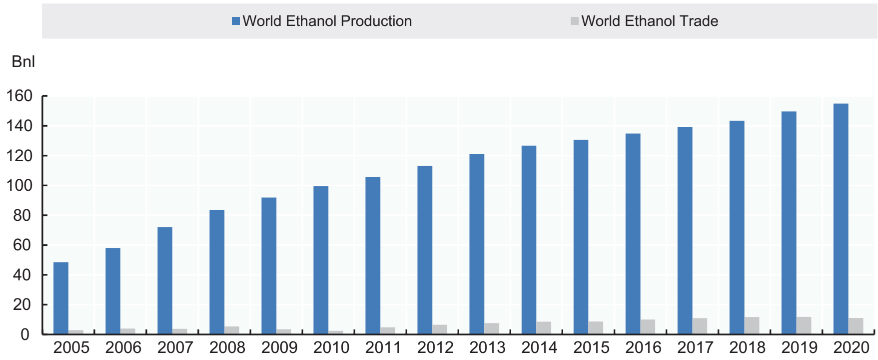
Much of the existing discussion on biofuel trade has focused on criticizing the common practice of using protectionist policies to provide advantages to domestic biofuel producers and estimating the resulting economic inefficiencies and costs. Much less attention has been paid to the underlying logic of biofuel trade and its connection to sustainability issues.

At the beginning of the biofuel movement, most interested countries aimed to nurture domestic producers. However, while some intended to be mainly self-sufficient, others, particularly in Europe and Japan, realized the impossibility of self-sufficiency, and intended to supplement domestic production with imports, partly to enhance energy security, but also partly as a way to reduce greenhouse gas emissions. Soon, it became apparent that some countries which intended to be self-sufficient could not, and overambitious targets would need to be met through imports. Still others had ambitions to be major biofuel exporters. For example, some in Indonesia hoped for their country to become the "Middle East of biofuels," and indeed, at one time, the EU had hoped to import significant quantities of biofuels from Indonesia or other Southeast Asian countries.

Now, it has become apparent that many or most countries will not be able to achieve their targets, even relatively modest ones, and few countries will be able to develop large-scale exportable surpluses beyond their domestic requirements. There is not likely to be any "Middle East of biofuels," in East Asia, not even Indonesia.

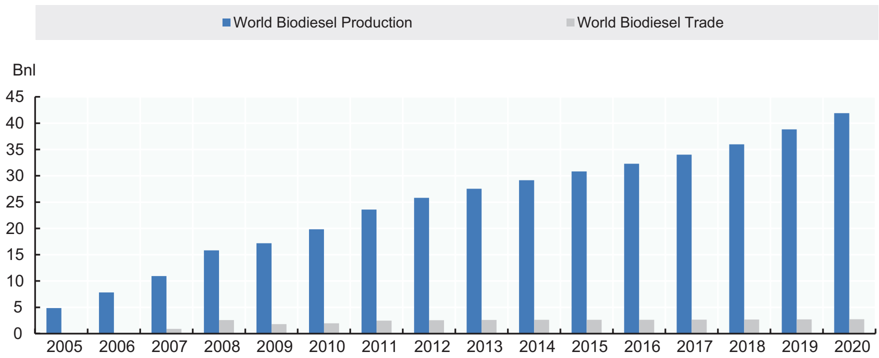
In fact, only a small share of biofuel production has been traded globally, about one-tenth, as can be seen from Figs. 14.1 and 14.2. Moreover, an OECD-FAO study suggested that increasing global biofuel production will not necessarily lead to increased global biofuel trade in the future either.

Of course, biofuel trade exists and will continue, but it will ebb and flow based on marginal supply and demand differences and price fluctuations among feedstocks and between biofuels and fossil fuels, etc. Differences in biofuel and feedstock trade protection policies, biofuel and fossil fuel promotion policies and subsidies, and blending mandates will also induce trade. In particular, countries



Source: OECD and FAO Secretariats

Fig. 14.1 Development of the world ethanol market



Source: OECD and FAO Secretariats

Fig. 14.2 Development of the world biodiesel market

with strong biofuel mandates but inadequate domestic production are likely to attract imports unless domestic producers are granted trade protection. Conversely, in this situation, if trade protection for domestic producers is strong enough, then the biofuel mandate would remain unmet if the domestic producers can or will not increase production.

Some countries, such as the USA or Brazil, may at times export some biofuels which cannot be absorbed into their domestic markets, but the available quantities are not likely to be enough to enable major increases in biofuel utilization mandates in many countries simultaneously. Moreover, the US could alternate from being a net exporter to a net importer, so export volumes could be unstable. The EU and USA are particularly significant, since they account for a majority of the world's biodiesel production, and the USA and Brazil account for 89% of global bioethanol production, although the amount exported is much smaller. Their policy decisions on biofuel trade have a large influence on global markets for biofuels and other related products.

In sum, it is not hard to imagine a global “scramble” for biofuels, if many countries, especially those with large markets, set aggressive blending mandates and generate significantly more demand than can be met by domestic production. The largest producing countries also have large domestic markets. While they may at times have some room for exports, their ability to consistently export on a scale needed to help many other countries to meet ambitious mandates is questionable.

14.5.1 EU

The EU’s share of global biodiesel production in 2009–2010 was approximately 65% (European Biodiesel Board). The production of biodiesel has been heavily subsidized because its production cost has been higher than that of fossil fuels. Consequently, EU’s biodiesel has been consumed and traded internally. Like most of the rest of the world, the EU has focused on promoting internal production for internal consumption through various industrial policy and trade protection measures (Kutas et al. 2007). Historically, the EU has used high import tariffs to protect agriculture; this also has protected biofuel feedstock producers. Recently, the EU shifted to direct payments to biofuel feedstock farmers rather than import tariffs or quotas. According to Swinbank (2009), “the EU maintains a tariff on ethanol of 10.2 euros per hectoliter (about 45 percent at current prices) and a somewhat lower tariff on biodiesel of 6.5 percent.” Although the EU was considering to expand its use of biofuels, it still provided trade protection to domestic biofuel feedstock producers.

Despite its high tariff and focus on protecting domestic producers, the EU also set a high biodiesel blending mandate. This implied that imports would also be required since EU production would not be able to produce enough to meet the mandate (and/or that some EU land would have to be diverted from food to fuel crops). This strict blending mandate reflected not only a desire for cleaner energy but was also intended to enhance energy security and supply diversification.

The European Commission’s strategy, “An EU Strategy for Biofuels,” was published in 2006 (EU 2006). It stated that stimulating trade opportunities and supporting biofuel producers in developing countries were key elements of the strategy. The strategy aimed to secure biofuel supplies from developing countries and to facilitate the production of crude vegetable oil for bioenergy. The EU intended that the biofuels from the high blending mandate would be complemented with imports from countries like Malaysia and Indonesia. The EU’s main environmental concern at that time was unilateral reduction of greenhouse gasses, and it had not considered the potential for sustainability issues arising from production in the expected exporting countries (Jank et al. 2007). In fact, the Netherlands was the biggest market for refining and combustion of palm oil at the time (Greenpalm.org 2011). The production of “green electricity” had the potential to boost demand for palm oil by more than 1,000,000 MT annually; nevertheless, the Dutch government stopped its subsidy for using palm oil for electricity, because of negative publicity regarding the sustainability of palm oil production in Malaysia and Indonesia. EU leaders became sensitive to criticism that their biofuel promotion policy might be leading to deforestation and higher food prices (Harrison 2008). In the response to this, the EU considered revising or reinterpreting the standard (Euractiv.com 2008; Reuters 2010). The EU relaxed the biofuel blending mandate and started working on a possible biofuel certification considering environmental impacts (Al-Riffai et al. 2010).

In 2009, the EU adopted the Renewable Energy Directive (2009/28/EC) which established a target of 10% of the energy used for transport within the EU to come from renewable sources. It was understood that a significant portion of this would come from biofuels. However, the Directive also imposed sustainability requirements (Spiegel 2011). In order to count toward the target, biofuels must not be produced at the expense of primary forests or carbon-rich soils such as peatlands and must demonstrate a savings of greenhouse gasses of at least 35% compared to fossil fuels (RSB 2011, 3). Therefore, while the risk of large-scale imports of unsustainably produced biofuels was reduced, the EU will probably remain a major importer. It is not likely to become a major exporter of biofuels and instead will compete for imports with other countries with high blending mandates.

As of 2012, the biofuel share of transport fuel reached only 4.65%, far short of the 10% target, and much of that had to be imported (USDA 2011). The EU probably will not have sufficient feedstock production capability by 2020 to reach its expected 6.6%, biodiesel target blend, so net biodiesel imports are expected to be more than 2 billion liters, and about 2.3 billion liters of net ethanol imports will be needed to reach the expected level of 8.2%, ethanol blend. Between 2008 and 2010, the EU imported on average 1.5 billion liters of ethanol and 1.6 billion liters of biodiesel (OECD/FAO 2011). In the meantime, vegetable oils for human consumption and industrial use (e.g., cosmetics) have to be imported, so imports of biofuels or vegetable oils for use as biodiesel will compete with these uses (Jank et al. 2007).

14.5.2 USA

In the USA, approximately 95% of bioethanol is made from maize, and 90% of biodiesel is made from soybeans. Although ethanol from maize in the USA is generally more costly to produce than sugarcane used for ethanol in Brazil, it was cheaper in 2000 when sugar prices in Brazil hit their peak, while US maize prices dropped. US production and consumption of ethanol have accelerated in recent years. In 2008, nearly 30% of maize produced in the USA was used for ethanol, and 20% of soybean production was used for biodiesel. High blending targets made the USA the world's largest ethanol importer, since it was not able to meet these targets solely through domestic production. In 2006, the USA accounted for more than half of global ethanol imports, and Brazil accounted for more than half of US imports.

The USA also has imported ethanol from Caribbean Basin Initiative (CBI) countries which can enter duty-free. Although the USA has adopted policy measures to increase biofuel production, it has not been able to keep pace with the rapid increase in biofuel consumption (Jank et al. 2007). Therefore, if the USA maintains its current blending mandate, it might be sufficient to increase imports of ethanol gradually from the small CBI countries. However, if the mandate increases further, it would be necessary to import larger quantities of ethanol from countries such as Brazil with larger production capacities.

Elobeid and Tokgoz (2006) conducted a study simulating the removal of US import tariffs on ethanol. This study estimated that removing the tariff would increase world's ethanol prices by 24% and sugar prices by 1.8%, and it would decrease maize prices by 1.5%. In the USA, ethanol prices would fall by 14%, since cheap imports from Brazil would displace imports from Caribbean countries, and US consumption would increase by 4%. In Brazil, ethanol consumption would drop by 3%, and ethanol exports would increase by 64%.

The USA has been a major importer of biofuels in the past, and imports could potentially increase if the US consumption continues to outpace production, and the blending mandate becomes more aggressive. However, this potential may be moderated by increasing the productivity of maize production and continued political pressure to maintain trade protection for domestic producers. Although the USA also exports some biofuels, it seems unlikely that it could become a major consistent supplier to many other countries, at least not without significantly diverting more of its food crops to use for biofuel production.

14.5.3 Brazil

At the time of writing, Brazil was the world's largest bioethanol consumer, as well as one of the most efficient and low-cost producers. Brazil had neither production subsidies nor import tariffs on ethanol. Compared to corn-based ethanol produced by the USA, Brazil's sugarcane-based ethanol production had a much higher productivity, and Brazil's cheap labor was suitable for labor-intensive sugarcane production. Brazil also had abundant water, which is essential for large-scale production.

With these advantages, Brazil has been the world's most competitive producer of bioethanol. Brazil produced 22,100 million liters of bioethanol in 2008. According to the OECD-FAO Agricultural Outlook (2008), projected bioethanol production in 2017 will increase 83.3% from 2008 to a total of 40,500 million liters. Overall, Brazil is the sole country with the ability to potentially export a large amount of bioethanol in 2017 according to projections by OECD-FAO and FAPRI (2010).

Nevertheless, there are limits to Brazil's ability to export biofuels to the world. On one hand, from 2008/2010 to 2020, Brazil's production of ethanol is expected to rise from 26 to 50 billion liters. On the other hand, much of the projected increase in production is expected to be consumed domestically, as the replacement of gasoline increases from 47% to 75%. So only about 9.6 billion liters would be exported in 2020, although Brazil still would be the world's largest exporter by far. This represents about one fifth of Brazil's total production and 6.2% of expected global production of 155 billion liters. Incidentally, the USA is expected to be by far the largest importer, and the expected amount of 9.5 billion liters is nearly equal to Brazil's entire export amount. The EU is expected to import another 2.4 billion liters (Table 14.7).

14.5.4 Possibility of Large-Scale Trade

The fundamental limitations of large-scale trade are illustrated by the OECD/FAO projections (OECD/FAO 2011, 92). Out of the total global production of 91.6 billion liters of ethanol in 2008–2010, only about 3.8 billion liters were exported, and of this amount, about 3.3 billion liters were imported by the USA and the EU, leaving little available for other areas. In 2020, global ethanol production is expected to grow significantly to about 155 billion liters, but only 11 billion liters are expected to be exported, mostly by Brazil (9.7 billion liters) and mostly to the USA (9.5 billion liters). In Asia, the largest ethanol exporters in 2020 are expected to be China (1,200 million liters), Thailand (509 million liters), and the Philippines (153 million liters), while the major importers are expected to be Japan (769 million liters), India (614 million liters), and Malaysia (11 million liters) (OECD/FAO 2011, 92) (See Table 14.7).

For biodiesel, the scale of expected trade is even smaller. Total global biodiesel production in 2008–2010 of 17.6 billion liters was dominated by the EU (9.2 billion liters), the USA (1.7 billion liters), Argentina (1.6 billion liters), and Brazil (1.6 billion liters). Total global exports accounted for only 2.5% of total production; the main exporters were Argentina (1329 million liters), the USA (748 million liters), and Malaysia (559 million liters), with the EU being the largest importer (1.6 billion liters) (OECD/FAO 2011, 93).

In sum, there is no clear potential source of large-scale exports that would be needed if all Asian countries were to simultaneously increase their blending mandates significantly beyond domestic production capabilities. The world cannot rely on Brazil alone. If a sufficient number of countries in East Asia or elsewhere were to significantly increase biofuel blending mandates, it would likely cause a global biofuel supply shortage. Globally there would be pressure to shift more land to fuel crops and increase the risk of non-sustainable production practices.

It is worth mentioning the various barriers to biofuel trade (see Table 14.8). One of the main determinants of biofuel trade is the relative prices of inputs such as feedstocks and competing fossil fuels. These relative prices fluctuate considerably and contribute to the volatile nature of biofuel trade. Trade protection tends to be high, as countries want to promote their domestic industries. Biofuels also suffer from high transportation and insurance costs. All of these factors tend to discourage biofuel trade.

Generally, trade is considered to increase efficiency. However, this may not necessarily always be the case for biofuels, if the trade is motivated by strong blending

Table 14.7 Biofuel projections (ethanol)

	Production (MN L)		Growth (%)[a]	Domestic use (MN L)		Growth (%)[a]	Fuel use (MN L)		Growth (%)[a]	Share in gasoline-type fuel use (%)				Net trade (MN L)[b]	
										Energy shares		Volume shares			
	Average 2008–2010 est.	2020	2011–2020	Average 2008–2010 est.	2020	2011–2020	Average 2008–2010 est.	2020	2011–2020	Average 2008–2010 est.	2020	Average 2008–2010 est.	2020	Average 2008–2010 est.	2020
North America															
Canada	1493	2359	3.08	1530	2408	0.57	1324	2202	0.66	2.2	3.4	3.3	5.0	−48	−49
USA of	42,857	63,961	1.89	44,663	73,474	3.32	42,338	70,484	4.13	5.3	8.4	7.7	12.1	−1806	−9514
which second generation	3	4368	–	–	–	–	–	–	–	–	–	–	–	–	–
Western Europe															
EU(27) of	5651	16,316	10.50	7186	18,690	7.31	4687	16,173	8.09	2.3	8.2	3.4	11.8	−1536	−2374
which second generation	0	1626	–	–	–	–	–	–	–	–	–	–	–	–	
Oceania developed															
Australia	299	492	0.75	299	492	0.75	299	492	0.75	1.0	1.6	1.5	2.3	0	0
Other developed															
Japan of	307	946	13.28	704	1715	5.81	90	1687	18.26	0.0	0.0	0.0	0.0	−398	−769
which second generation	0	593	–	–	–	–	–	–	–	–	–	–	–	–	–
South Africa	384	421	0.44	93	47	0.07	0	0	4.62	0.0	0.0	0.0	0.0	291	374
Sub-Saharan Africa															
Mozambique	25	59	6.17	21	29	0.56	0	9	1.48	0.0	3.3	0.0	4.8	4	29
Tanzania	29	55	7.14	33	52	5.97	1	19	37.15	0.1	2.7	0.2	4.0	−4	3

Latin America and Caribbean															
Argentina	303	470	2.20	240	402	0.97	110	272	1.47	1.6	3.4	2.3	5.0	63	68
Brazil	26,091	50,393	5.93	22,589	40,695	5.15	21,061	38,383	7.28	47.3	67.1	57.2	75.3	3502	9698
Columbia	310	587	5.63	353	385	−1.20	315	347	−1.33	4.5	5.6	6.6	8.1	−44	202
Mexico	64	90	2.29	168	275	2.29	0	0	–	0.0	0.0	0.0	0.0	−104	−184
Peru	71	217	2.55	25	175	1.47	20	174	1.48	1.1	8.2	1.7	11.7	46	41
Asia and Pacific															
China	7189	7930	0.71	7041	6685	0.18	2024	2975	4.34	1.8	1.5	2.6	2.3	148	1,246
India	1892	2204	1.78	2109	2818	1.48	183	800	1.48	0.9	3.0	1.4	4.5	−217	−614
Indonesia	210	248	0.99	169	168	0.15	0	0	6.77	0.0	0.0	0.0	0.0	41	80
Malaysia	66	74	0.80	87	85	0.09	0	0	5.38	0.0	0.0	0.0	0.0	−21	−11
Philippines	118	603	12.74	263	450	3.49	193	350	−0.30	2.1	3.0	3.1	4.4	−144	153
Thailand	672	2111	9.32	599	1602	8.72	424	1389	4.54	3.8	11.2	5.6	15.9	73	509
Turkey	64	88	0.98	108	142	3.43	50	87	5.23	0.6	0.9	1.3	−44	−54	
Viet Nam	150	423	4.75	95	334	14.84	8	255	25.87	0.1	3.5	0.2	5.1	55	90
Total	*91,657*	*154,962*	*3.98*	*91,821*	*155,983*	*3.95*	*73,742*	*136,123*	*4.45*	*5.3*	*8.8*	*7.7*	*12.6*	*3,792*	*11,012*

Source: OECD and FAO Secretariats
– Data not available
[a]Least-squares growth rate
[b]For total net trade exports are shown

Table 14.8 Bioethanol and biodiesel import tariffs

Country	Ethanol ($/L)[a]	Biodiesel ($/L)[b]
Australia	$0.24	na
Brazil	$0.70	na
Canada	$0.50	na
EU	$0.10	Ad valorem duty of 6.5%
Japan	$0	na
USA	$0.14	$ 0.26

[a]IEA
[b]Swinbank (2009)

mandates or subsidies, which may instead worsen market imbalances caused by highly distortionary biofuel promotion policies.

Expanded trade, including through liberalization of trade restrictions, does not necessarily enhance sustainability either. Particularly in most Asian countries, there appears to be little room to increase land devoted to biofuel production without deforestation or shifting from the production of food crops, so a significant increase in production may be associated with significant risks of reduced sustainability. Therefore, from the standpoint of biofuel-producing countries, to increase exports significantly would risk reducing sustainability of biofuel production by stimulating it beyond the limits of sustainability. Likewise, if the sustainability of production in an exporting country were to decline, the sustainability of the energy use of the importing country would also worsen rather than increase. This problem was illustrated in the debate over the EU's blending mandate in the 2000s. At that time, it was expected that imports from Indonesia and other places would help it to meet ambitious mandates, but as an increasing number of studies raised serious doubts about the policy's likely impacts on sustainability, particularly the risk of deforestation, the EU suspended and finally canceled the policy's implementation and shifted to a more modest mandate combined with sustainability standards. By the same token, trade protection for domestic biofuel producers might enhance sustainability by restraining the scale of production to more sustainable levels.

14.6 Sustainability Standards

Various efforts have been made to develop sustainability standards and certification systems for biofuels in order to enhance their sustainability (Dam et al. 2008). They give producers a chance to demonstrate it on a case-by-case basis. However, by themselves, they cannot create new land or other resources such as water. Moreover, it is too early to assess their potential effectiveness, as they have not been extensively implemented.

At the time of writing, there were no officially recognized global or regional biofuel sustainability standards. An international dialogue on sustainability criteria and the development of transparent and harmonized standards and certification schemes was held through various frameworks. The Roundtable on Sustainable Palm Oil (RSPO) and Roundtable on Responsible Soy (RTRS) are commodity-based initiatives with criteria for certification. The Better Sugarcane Initiative is another roundtable initiative focusing on biofuel feedstocks (Elder et al. 2008). The Roundtable on Sustainable Biofuels has developed a global comprehensive, voluntary, multi-stakeholder initiative including standards as well as a certification system. At the same time, the G8 countries created the Global Bioenergy Partnership (GBEP) which also consisted of public, private, and civil society stakeholders in a joint commitment to promote bioenergy for sustainable development. GBEP is potentially the most important one, since it includes governments as members, but it was "not willing to develop an additional standard and certification scheme" (Scarlat and Dallemand 2011); therefore, GBEP was expected to reach consensus on biofuel sustainability as a meta-standard. The UK has established its own Renewable Transport Fuel Obligation (RTFO).

The "roundtable approach" provides opportunities to develop certification systems supported by a wide range of stakeholders. Nonetheless, as the criteria developed by those roundtables are only voluntary commitments, this approach will be effective only if all stakeholders actually follow the criteria. Another concern is the motivation of the participants. Some NGOs argued that the roundtables provide some governments an excuse not to take stronger, more direct measures to protect the environment and vulnerable populations (Reuters 2007).

There are two main motivations for sustainability standards. The first is sustainability concerns, which might lead countries to develop their own standards, partly aimed at avoiding imports of unsustainably produced biofuels. The second is for export promotion, to make domestically produced biofuels more attractive to customers who are concerned about sustainability. For developing countries, the main concern may be standards in advanced countries that imports are required to meet. Establishing a reliable and robust but low-cost certification system is a major challenge. Other constraints for certificate and standard systems include implementation costs, physical and human capacity, and monitoring costs. Standards and certification systems may be particularly challenging for small producers, who may need assistance to be able to comply with these schemes.

One key issue for implementing biofuel sustainability standards/certificates is how to attract the participation of producers. Some producers may adopt the standard hoping to charge a higher price to environmentally conscious consumers, but many will adopt it only if it is required by government regulations or by customers.

However, there is no recognized global or regional standard. The EU has adopted a requirement for certification, but it has also encouraged competition among certification systems. The Roundtable on Sustainable Biofuels (RSB) has developed a global standard through multi-stakeholder dialogue, but it is voluntary. More time is needed to see how it will develop.

There are currently no efforts to develop regional sustainability standards in East Asia. The RSB standard could serve as a basis for one, as it was developed with input from Asian stakeholders, and producers have the option of adopting it voluntarily.

14.7 Conclusion

Overall, current modest levels of biofuel use in Asian countries may be feasible, but it is likely to be practically quite difficult for biofuels to account for a large share of transport fuel use of 20% or more. Some Asian countries established blending mandates of 5–10% of transport fuel, but even these levels will be very difficult to meet with domestic production.

It is not clear where new large-scale production can come from. Waste or agricultural residue may be potential sources, but there are various problems in accessing them. Some new land may be available, but it is not always clear where, and even if land can be found, it is not likely to be on a very large scale. In order to devote large-scale additional land to biofuel production, it would probably be necessary to divert food production or convert forestland. Productivity gains may help some, but many Asian countries may still experience population increases in the coming years, and some land and agricultural productivity increase will need to be devoted to increasing food crops and living space.

Some countries may need to meet their targets through imports, if the targets are strictly enforced. But it is not necessarily clear where large-scale imports could come from. The major global producers, the USA and Brazil, also reserve the bulk of their production for domestic use, and export volumes are unstable. Brazil's export potential is not necessarily enough to meet every country's blending mandate shortfall. Most countries are not strictly enforcing their blending mandates, so a "scramble" for imports has not occurred. But if many countries were to simultaneously enforce strict mandates, a scramble for imports could result.

Sustainability standards could be useful to discourage unsustainable production practices. The standards would be more effective if they are mandated by governments and need a robust certification system. However, standards themselves cannot create additional land or other resources.

Smaller-scale production based on individual local circumstances to promote rural development or address waste problems may be more realistic. However, without scale economies, the costs will be relatively high, and the contribution to energy security and GHG reduction will be modest. In any case, it seems better for each country to pursue its own strategy tailored to its individual circumstances and local conditions.

References

Al-Riffai P et al (2010) European Union and United States biofuel mandates: impacts on world markets. Inter-American Development Bank, Washington, DC

Dam JV et al (2008) Overview of recent developments in sustainable biomass certification. Biomass Bioenergy 32:749–780, IEA Bioenergy Task 40 special issue

de Fraiture C, Giordano M, Liao Y (2008) Biofuels and implications for agricultural water use: blue impacts of green energy. Water Policy 10(Supplement 1):67–81

Elder M et al (2008) Prospects and challenges of biofuels in Asia: policy implications. In: Climate change policies in the Asia-Pacific: re-uniting climate change and sustainable development. Institute for Global Environmental Strategies (IGES), Hayama, pp 105–131

Elobeid A, Tokgoz S (2006) Removal of U.S. ethanol domestic and trade distortions: impact on U.S. and Brazilian ethanol markets. Working Paper 06-WP 427. Center for Agricultural and Rural Development Iowa State University

EU (2006) An EU strategy for biofuels

Euractiv.com (2008) Biofuels for transport, 11 April. http://www.euractiv.com/transport/biofuels-transport-linksdossier-188374 . Accessed 14 May 2012

FAO (2011) The state of the world's land and water resources for food and agriculture (SOLAW): managing systems at risk, summary report. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London. http://www.fao.org/docrep/015/i1688e/i1688e00.pdf (Accessed May 14, 2012)

Food and Agricultural Policy Research Institute. FAPRI (2010) U.S. and world agricultural outlook. Iowa State University 2010. http://www.fapri.iastate.edu/outlook/2010/. Accessed 12 July 2011

Greenpalm.org (2011) RSPO supports Dutch industry's call on the EU to abolish import duty on sustainable palm oil. http://www.greenpalm.org/en/blog-press/blog/rspo-supports-dutch-industrys-call-on-the-eu-to-abolish-import-duty-on-sustainable-palm-oil. Accessed 12 May 2012

Harrison P (2008) EU backs away from biofuel goal. Reuters, 5 July. http://uk.reuters.com/article/2008/07/05/us-eu-energyidUKL0542894820080705? sp=true. Accessed 14 May 2012

Hecht AD et al (2009) Good policy follows good science: using criteria and indicators for assessing sustainable biofuel production. Ecotoxicology 18:1–4

Hoff H (2011) Understanding the nexus. Background paper for the Bonn 2011 conference: the water, energy, and food security nexus. Stockholm Environment Institute, Stockholm. http://www.water-energy-food.org/documents/understanding_the_nexus.pdf. Accessed 25 May 2012

International Energy Agency (IEA) (2010, February) Sustainable production of second-generation biofuels: potential and perspectives in major economies and developing countries. Information Paper

Jank MJ et al (2007) EU and U.S. policies on biofuels: potential impacts on developing countries. The German Marshall Fund, Washington, DC

Johnston M et al (2009) Resetting global expectations from agricultural biofuels. Environ Res Lett 4(014004):1–10

Kataoka Y, Shrestha S (2010) Promoting wise use of water: application of economic instruments. In: Institute for Global Environmental Strategies (IGES), White Paper III. Hayama, pp 149–170

Kojima M, Mitchell D, Ward W (2007) Considering trade policies for liquid biofuels. World Bank, Energy Sector Management Assistance Program (ESMAP), Washington, DC, p 141

Kutas G et al (2007) Biofuels—at what cost? Government support for ethanol and biodiesel in selected OECD countries. The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD), Geneva

OECD/FAO (2008) OECD-FAO agricultural outlook 2008–2017. OECD Publishing and FAO

OECD/FAO (2011) OECD-FAO agricultural outlook 2011–2020. OECD Publishing and FAO

Reuters (2007) Corrected: green group wary of plans for "eco-friendly" palm

Reuters (2010) EU report signals U-turn on biofuels target

Roundtable on Sustainable Biofuels (RSB) (2011) Biofuel for thought. 2(3) September. http://rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Newsletters/RSB_Newsletter-September%202011.pdf. Accessed 5 Apr 2012

Scarlat N, Dallemand JF (2011) Recent developments of biofuels/bioenergy sustainability certification: a global overview. Energy Policy 39(3):1630–1646. https://doi.org/10.1016/j.enpol.2010.12.039

Spiegel (2011) Chaos at the pumps: German consumers are wary of new E10 biofuel

Swinbank A (2009) EU support for biofuels and bioenergy. 'Environmental sustainability' criteria, and trade policy. International Centre for Trade and Sustainable Development. Issue paper No. 17

Pradeep Tharakan, Naeeda Crishna, Jane Romero, and David Morgado. Biofuels in the Greater Mekong Subregion: Energy Sufficiency, Food Security, and Environmental Management. Asian Development Bank. ADB Southeast Asia Working Paper Series. No. 8. January.

UNEP (2007) Global environment outlook GEO4: environment for development

USAID (2009) Biofuels in Asia: an analysis of sustainability options

USDA Foreign Agricultural Service (2011) GAINS report. EU-27 annual biofuels report, no. NL1013, June 24