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Biofuels in the Greater Mekong Subregion: Energy Sufficiency, Food Security, and Environmental Management

Pradeep Tharakan, Naeeda Crishna, Jane Romero,
and David Morgado

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ABSTRACT

Global production and trade of biofuels have expanded rapidly in the last decade, spurred on by the adoption of policies and incentives to support their increased use in the European Union and the United States. In the Greater Mekong Subregion (GMS), growing demand for biofuels could help support the agriculture sector and provide an alternative source of energy. However, experience from the subregion and elsewhere has shown that if deployed unsustainably, biofuel development can be associated with numerous risks, particularly in terms of food security, impacts on soil and water quality, and biodiversity, which in turn have negative ramifications for human development. This paper draws extensively on existing literature and integrates various themes to provide an overview of four main issues related to biofuels deployment in the GMS: the need for alternative energy sources, risks to food security, considerations for environmental management, and opportunities for rural development. The paper finds that with increasing fuel demand projected for the GMS, biofuels could make a significant contribution to offsetting oil demand and to increased agricultural and rural incomes, though the overall benefits to the region's population depends largely on how risks to food security are managed and on the production system that is adopted. Using examples from within the GMS, the paper illustrates that expansion involving smallholder-based production on surplus land, and an emphasis on non-food crops and second-generation biofuels, could pave the way for sustainable utilization of biofuels in the GMS.

1. INTRODUCTION

Biofuels have been the focus of intense interest, discussion, and debate in recent years. Spurred on by the adoption of policies and incentives to support their increased use in the European Union (EU) and the United States (US), both global production and trade of biofuels have expanded rapidly in the last decade (IEA 2010a). In response, several Asian governments announced ambitious plans to promote biofuels production for both domestic consumption and export (Zhou and Thomson 2009) and, as a result, the total production of biofuels in Asia increased from just over 5 billion liters in 2002 to almost 11 billion liters in 2010 (OECD-FAO 2011).

For decision makers in the Greater Mekong Subregion (GMS),[1] growing global demand, particularly for first-generation biofuels,[2] could provide a new market for existing agricultural products, and help support the agriculture sector, which sustains the majority of the region's population. It has been argued that due to the availability of farm land, abundant labor, and favorable weather conditions in the subregion, biofuel expansion could help farmers diversify their activities and earn additional income (Malik et al. 2009). Conversely, experience from the subregion and elsewhere has shown that, if deployed unsustainably, biofuels development can be associated with numerous risks, particularly in terms of food security, impacts on soil and water quality, and biodiversity, which in turn have negative ramifications for human development (USAID 2009).

Much work has been done on the regional impacts of biofuel deployment in Southeast Asia (Elder et al. 2008, USAID 2009, Zhou and Thomson 2009). Much of the work considering the GMS, however, has either focused on an individual aspect of biofuel deployment, such as impacts on trade (Yang et al. 2009) and employment (Malik et al. 2009), or has presented results of case studies from individual countries (ERIA 2009, Shepley et al. 2009). This paper draws extensively on existing literature and integrates various themes to provide an overview of three main issues related to biofuels deployment within the overall context of energy demand and environmental trends in the GMS. The initial sections of the paper describe the energy utilization context and biofuels industry in the subregion, and analyze the extent to which biofuels development in the GMS could offset fossil fuel demand under different scenarios. Subsequent sections of the paper discuss three major issues related to biofuels development in the GMS—food security, environmental management, and rural development. Finally, recommendations are made on how policies need to be designed and implemented to ensure that the production and utilization of biofuels in the GMS may be sustainable.

2. ENERGY DEMAND, SUPPLY, AND SECURITY IN THE GREATER MEKONG SUBREGION—THE NEED FOR ALTERNATIVES

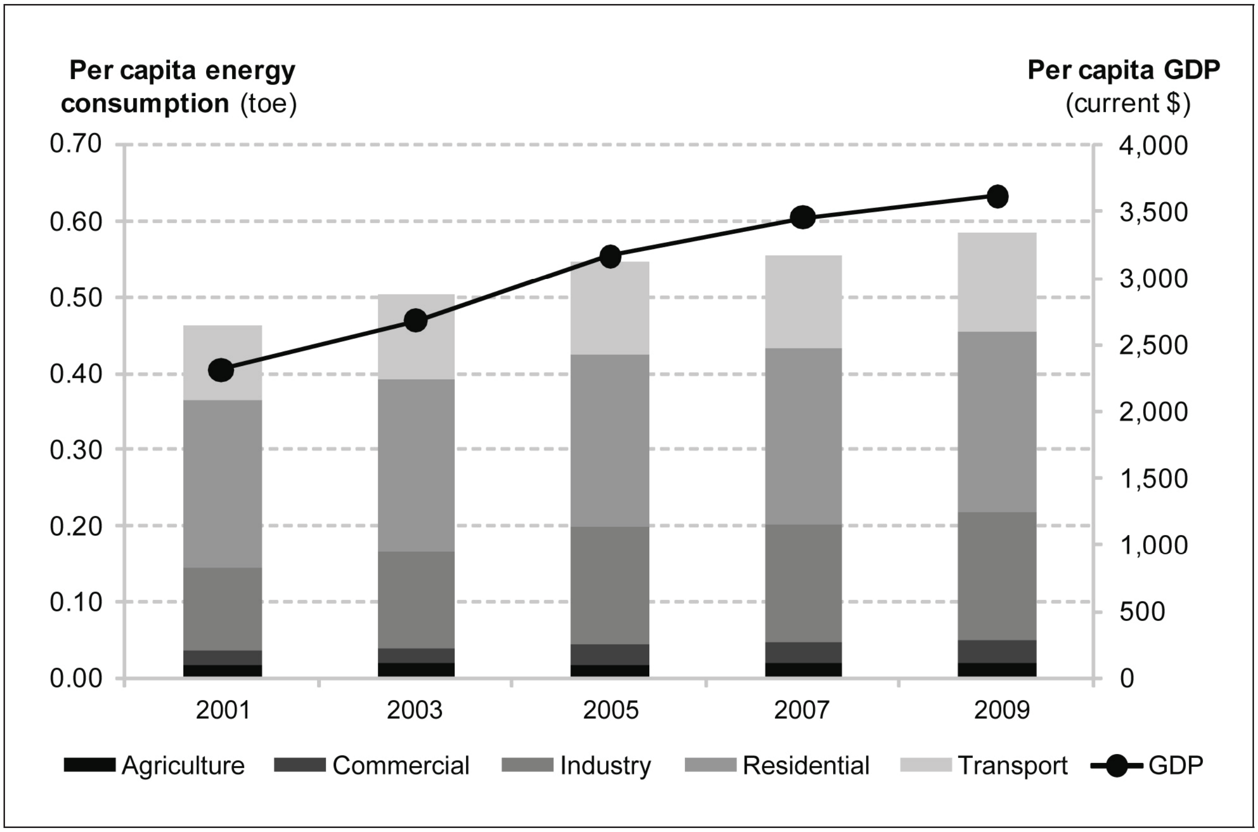
GMS countries have experienced a rapid growth in their gross domestic product over the last two decades. Concomitantly, energy demand has risen as well (Figure 1). Across the region, while electricity demands are met through coal and hydropower, the transport and industry sectors are primarily dependent on diesel and gasoline, and therefore account for the largest

[1] The Greater Mekong Subregion (GMS) is a natural economic area bound together by the Mekong River, covering 2.6 million square kilometers and a combined population of approximately 326 million. The GMS countries are Cambodia, the People's Republic of China (PRC, specifically Yunnan Province and Guangxi Zhuang Autonomous Region), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam.

[2] First-generation biofuels are primarily derived from food crops, such as grain (corn, wheat, etc.), sugarcane for bio-ethanol, and oil seeds (such as palm oil) for biodiesel production.

share of energy demand from fossil fuels. These sectors are constantly growing—for example, transport energy demand in the GMS (excluding the People's Republic of China [PRC]) increased 50% between 2000 and 2009, from 20 million to 30 million tons oil equivalent (IEA 2011). Throughout GMS countries, the consumption of energy outstrips production, which indicates a heavy dependence on fossil fuel and other energy imports. Larger energy consumers such as Thailand imported over 60% of its domestic energy needs between 2002 and 2006 (Chirapanda et al. 2009), while Cambodia and the Lao People's Democratic Republic (Lao PDR) imported all their commercial fossil fuels in 2006.

Figure 1: Gross Domestic Product and Energy Consumption in the Greater Mekong Subregion, excluding the People's Republic of China



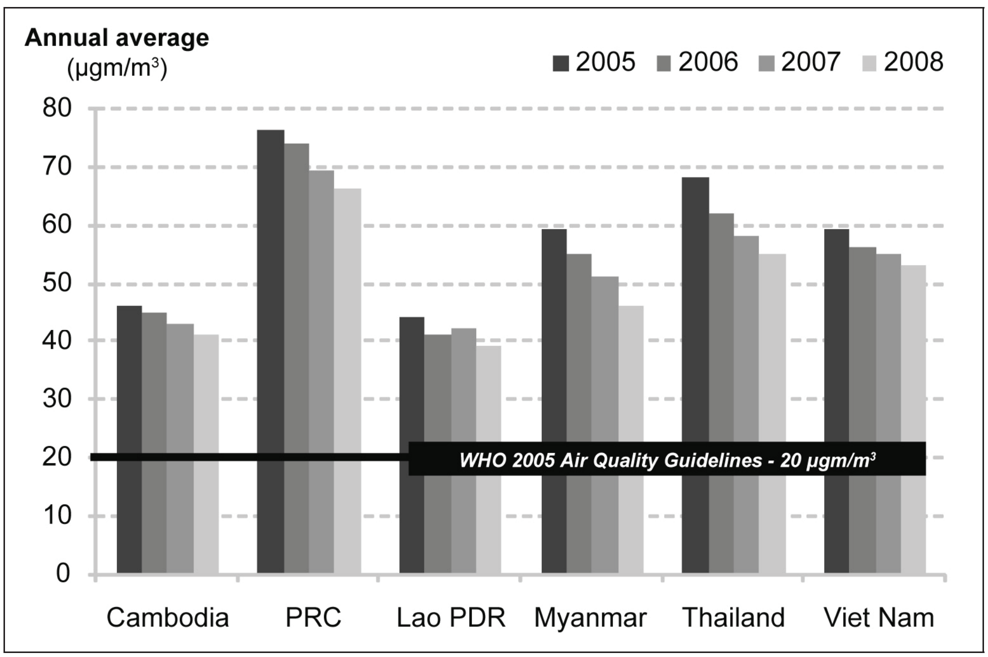
GDP = gross domestic product, GMS = Greater Mekong Subregion. PRC = People's Republic of China, toe = ton of oil equivalent.
Note: These figures exclude the People's Republic of China.
Sources: GDP data from ADB (2011); energy data from IEA (2011) and national ministries.

Under a business-as-usual (BAU) scenario over the next decade, energy consumption in the subregion is expected to increase between 7% and 16% per annum, at rates much higher than that of increases in economic growth (ADB 2006). Within the transport sector, gasoline and diesel consumption over the next decade is also expected to increase as illustrated by current trends in vehicle sales and registration. In Myanmar, for example, the number of vehicles registered is increasing at 19% per year, and in Cambodia, the energy demand from transport is expected to grow four- to fivefold by 2030 (Kyaw et al. 2009; Luyna, Chetra, and Vulthea 2009).

The consumption of petroleum and dependence on imports impact national budgets, trade balances, and household incomes. Most countries have to subsidize fuel costs in order to protect their populations and industries from fluctuating fuel prices. Even so, changes in fuel subsidies and increasing fuel prices do affect consumers and can cause significant civil unrest.[3] Diversifying sources of energy, and in particular identifying new indigenous sources for the transport and industry sectors, is important if GMS countries want to increase their energy security.

The use of fossil fuels in the subregion is also associated with environmental and health impacts. Over 21% of energy-related greenhouse gas (GHG) emissions in the GMS (excluding the PRC) in 2007 were from the transport sector, which highlights the significant role that transport plays in driving climate change (WRI 2010). These emissions are a direct result of the current modal split in GMS countries that favors road transport systems, and the dependence of road transport on fossil fuels. Other air pollutants associated with fossil fuels, particularly from the road sector, include emissions of particulates, and nitrogen and sulfur oxides, which have significant health impacts, particularly in urban and peri-urban areas. Figure 2 shows particulate emission levels in urban areas in the GMS compared to World Health Organization (WHO) guidelines and illustrates that air pollution in GMS countries is still a concern with serious ramifications for human health.

Figure 2: Particulate Emissions in Urban Areas in the Greater Mekong Subregion Compared with World Health Organization Guidelines



GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, µgm/m^3 = microgram per cubic meter, PRC = People's Republic of China, WHO = World Health Organization.
Note: The data are averaged over all areas within a country with populations of over 100,000 inhabitants.
Source: World Bank Environment and Data Statistics.

In summary, there is a significant need for introducing alternative fuels to the GMS, particularly for the transport sector, including bio-ethanol and biodiesel, to offset projected demand using energy produced from local resources, with fewer environmental impacts.[4]

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[3] Recent examples of fuel price hikes and associated civil riots include riots in Indonesia in 2005 in response to government reduction in fuel subsidies, and protests in Myanmar in 2007 in response to a fuel price increase.

[4] In terms of impact on air pollution, biofuels have been shown to lead to lower volatile organic chemicals (VOCs), sulfur, and carbon monoxide (CO) emissions, but also to potentially increased nitrogen oxide (NOx) emissions and ozone, and in some cases particulates (USAID 2009). Overall, if land clearing and the burning of vegetation burning are avoided, biofuels would have a smaller impact on air pollution than fossil fuels.

3. CURRENT DEVELOPMENT AND POTENTIAL PRODUCTION OF BIOFUELS IN THE GREATER MEKONG SUBREGION

3.1. Current Status

Following the market demand for biofuels, the GMS countries have responded or are responding with strong national biofuel programs to support energy security, renewable energy, and a new attractive growing market for the agriculture sector (Malik et al. 2009, Yang et al. 2009). National biofuel programs, production capacity, and industry development vary greatly across the GMS countries, with the PRC, Thailand, and Viet Nam taking the lead with established policies, targets, and incentives. Table 1 presents a summary of biofuels policies in the GMS. Policy mechanisms include regulatory instruments like blending targets and mandates to create demand coupled with incentives for the private sector to get involved in biofuel development and, finally, provision of subsidies to reduce the cost of production so that biofuels are favorable when compared with fossil fuels. In all countries, the biofuels industry is still dependent on government incentives due to higher production costs when compared with fossil fuels.

Table 1: Summary of Biofuels Policies and Targets in the Greater Mekong Subregion

Country	**Policies/Incentives**	**Policy Targets** (million liter per year)
Cambodia	No policies	n/a
Lao PDR	E10 by 2015 E20 by 2020	Insufficient information
Myanmar	E5 and E15 B5 to B20	Insufficient information
PRC[a]	E10 Subsidies for producers	Bio-ethanol: 12 by 2020 Biodiesel: 6 by 2020
Thailand	E10 and E20 B5 Tax incentives	Bio-ethanol: 3,285 by 2022[b] Biodiesel: 1,643 by 2022[c]
Viet Nam	1% of total fuel demand in the transportation sector in 2015 and 5% by 2025 E5	Bio-ethanol: 684 by 2020 Biodiesel: 128 by 2020

GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, n/a = not available, PRC = People's Republic of China.

Notes: 1. Bio-ethanol and biodiesel density assumed to be 789 tons/million liter and 845 tons/million liter (USAID 2009), respectively.
2. B5 and B20 refer to percentage of biodiesel in diesel fuel.
3. E5, E10, E15, and E20 refer to percentage of bio-ethanol in gasoline.

[a] These policies cover the whole of PRC.
[b] Suryadi (2010).
[c] DEDE (2009).
Source: Authors.

The PRC is the third largest producer of bio-ethanol in the world, producing just over 1.78 million (metric) tons of liquid biofuels in 2008 using mostly maize and wheat (IEA 2011). Biodiesel production is much lower, 0.2 million tons per year based mainly on waste vegetable oil. One of PRC's five main bio-ethanol producing plants is located in Guangxi Zhuang Autonomous Region and had a production of 0.2 million tons in 2007 using only cassava (Malik et al. 2009, Huang et al. 2009a). The government targets for the whole country are to produce 5 million tons per year of bio-ethanol by 2012 and 12 million tons per year by 2020.

The PRC is also the only GMS country with experience in producing second-generation biofuels (IEA 2010b).[5]

The target for biodiesel is to use Jatropha and reach 6 million tons per year in 2020 (Malik et al. 2009). Yunnan province is the national Jatropha demonstration province for the PRC. The provincial government has proposed 14 biodiesel refining plants with a production capacity of 3.2 million tons of biodiesel per year. Table 2 provides an indication of production and yield of different feedstock in the three major biofuel-producing countries in the GMS, and shows that sugarcane is a good potential source for bio-ethanol in Yunnan and Guangxi.

Table 2: Feedstock Production and Yield in the People's Republic of China, Thailand, and Viet Nam

	Yunnan and Guangxi PRC		Thailand		Viet Nam	
	Land used ('000 ha)	**Yield** (t/ha)	**Land used** ('000 ha)	**Yield** (t/ha)	**Land used** ('000 ha)	**Yield** (t/ha)
Bio-ethanol						
Cassava	320	19.8	1,148	21.0	492	16.5
Maize	1,698	3.8	1,021	4.0	1,079	3.9
Rice	3,801	7.2	10,541	2.9	7,343	5.0
Sorghum	5	2.2	36	1.8	–	–
Sugar beet	–	–	–	–	–	–
Sugarcane	1,126	69.7	996	60.8	276	58.3
Sweet potato	23	20.0	–	–	170	8.1
Wheat	1,102	6.0	–	–	–	–
Biodiesel						
Castor	–	–	13	0.8	7	0.8
Coconuts	–	–	253	6.5	120	8.7
Jatropha	40	0.0	–	–	30	0.0
Oil palm	–	–	420	16.8	–	–
Rapeseed	226	1.5	–	–	–	–
Soybean	–	–	131	1.7	183	1.4

ha = hectare, PRC = People's Republic of China, t = metric ton.
Source: FAO (2011).

Thailand is one of the top eight global biofuel producers and has sufficient feedstock for both biofuel and other uses as illustrated by the country reporting a net surplus of bio-ethanol feedstock production in recent years (Chirapanda et al. 2009). The government has established a biofuels program whereby bio-ethanol has been introduced for the transport sector in the form of E10[6] gasoline. In 2010, bio-ethanol consumption was approximately 329 kiloton oil equivalent (ktoe) (approximately 648 million liters) and average production of bio-ethanol was estimated at 1.16 million liters per day. Moreover, the government has mandated the use of B5[7] since 2011 and B10 should become available by 2014. The main source for biodiesel has been oil palm while Jatropha is being used for small-scale applications. In 2010, biodiesel consumption was approximately 475 ktoe (589 million liters) (Chirapanda et al. 2009, Malik et al. 2009, USAID 2009, Yang et al. 2009, DEDE 2011a–b).

5 Second-generation biofuel: biofuels produced from cellulose, hemicellulose, or lignin (IEA 2010b).
6 E10: terminology used to indicate the percentage of ethanol in gasoline. In this case, 10% ethanol mixed with 90% gasoline.
7 B5: diesel blended with 5% of biodiesel.

In 2007, the Government of Viet Nam put forward their target for biofuels: 1% of total fuel demand in the transport sector in 2015 and 5% by 2025.[8] The volume of biofuels needed to meet 5% of total petroleum demand by 2020 is estimated to be around 1.6 million tons (540 million tons of bio-ethanol and 1.09 million tons of biodiesel) (Nguyen et al. 2009, Yang et al. 2009). Bio-ethanol is to be sourced from sugarcane, sweet sorghum, and molasses, and biodiesel from catfish oil and Jatropha. Bio-ethanol production capacity from sugar factories is estimated at 53 million liters per year and from cassava 320 million liters per year (Nguyen et al. 2009).

In Cambodia and the Lao PDR, food security is a critical issue for decision makers and the current focus has been on pilot biofuel projects using Jatropha to raise awareness on process and technology. In Cambodia, policies are particularly directed at rural electrification and there are no particular policies and targets regarding biofuels (Luyna, Chetra, and Vulthea 2009). In the Lao PDR, the government is planning to promote biofuels and has stated that it expects E10 to be commercially available by 2015 and E20 by 2020. In terms of biodiesel, the Lao PDR has already been producing biodiesel from Jatropha, coconut, oil palm (low potential), and castor oil plants, although these are currently at a pilot stage (Sanatem et al. 2009).

The Government of Myanmar has tested some programs for biofuel development in parts of the country and plans to replace gasoline with E5 for use at the community level and E15 (using anhydrous bio-ethanol) nationwide (Khaing 2010). Diesel is to be replaced by B5 to B20 at both community and national levels (Suryadi 2010). Biofuel production and commercialization only started in 2008 and, consequently, production is relatively low compared to other GMS countries. In 2009, the production capacity of anhydrous bio-ethanol was estimated at least 659,000 liters per year. Sugarcane is the main source of bio-ethanol followed by maize, cassava, and sweet sorghum. Biodiesel production is still at the demonstration level and the main source is Jatropha (Kyaw et al. 2009, Yang et al. 2009, Khaing 2010). The government initially introduced a 3-year plan for Jatropha for 2006–2008, which raised a lot of interest initially due to the increase in diesel prices at the time. However, plantations were seen to conflict with demand for land for food production in poor areas and proved to be unsuccessful in matching national biofuel demand (Cushion et al. 2010, Suryadi 2010).

3.2. Potential for Expanded Biofuels Production in the Greater Mekong Subregion

An initial analysis of potential production of biofuels in GMS countries is provided in Table 3. The analysis estimates the amount of biofuels that could be produced in each country if

(a) 10% of available land in the countries were converted to biofuel feedstock production,[9]

[8] Target stated under Decision 177/QD-TTG on "Strategy for Developing Biofuel for the Period 2005–2015 and Vision to 2025."

[9] This analysis assumes a production of a certain mix of crops and land intensity per crop on available land in each country. These figures are based on national data and current crop production trends. Land intensity (liter/ha) is taken from USAID (2009) and available land (for crop production) from Malik et al. (2009). The following assumptions have been used. Split of crop types: Cambodia (cassava – 20%, Jatropha – 20%, oil palm – 20%, sugarcane – 20%, maize – 20%); PRC (cassava – 25%, Jatropha – 25%, sugarcane – 25%, sweet sorghum – 25%); Lao PDR (cassava – 25%, coconut – 25%, Jatropha – 25%, sugarcane – 25%); Myanmar (cassava – 8.5%, Jatropha – 33%, sugarcane – 25%, maize – 8.5%, sweet sorghum – 25%); Thailand (cassava – 33%, oil palm – 33%, sugarcane – 33%); and Viet Nam (cassava – 33%, Jatropha – 33%, sugarcane – 33%).

(b) all the crop production that is currently lost on-site postharvest (referred to as “wasted grain or crop”) were converted into bio-ethanol using current technologies,[10] and

(c) crop residues were recovered and converted to bio-ethanol using emerging technologies.[11]

Table 3: Summary of Potential Biofuels Production in the Greater Mekong Subregion

Country	Possible Production of Biofuels from Conversion of 10% Available Land (million liter)		Possible Production of Biofuels from Wasted Crop (million liter)		Lignocellulosic (million liter)	
	Biodiesel	Bio-ethanol	Biodiesel	Bio-ethanol	Biodiesel	Bio-ethanol
Cambodia	182	257		138		845
Lao PDR	87	145		70		504
Myanmar	238	962		626		4,901
Thailand	130	176		773		14,609
Viet Nam	26	142		857		7,803
Yunnan and Guangxi, PRC	219	1,298		873		20,472

GMS = Greater Mekong Subregion, Lao PDR = Lao People’s Democratic Republic, PRC = People’s Republic of China.
Source: Authors.

The analysis in the first case serves to show that due to apparent land availability in the GMS, countries like Myanmar, and Yunnan Province and Guangxi Zhuang Autonomous Region in the PRC have the potential to produce large volumes of biofuels (over 900 million and 1.2 billion liters, respectively), without impinging on current cropland. However, this is based on the assumption that land availability figures used accurately reflect the situation in the countries, which is not always the case as competition for land resources in the GMS is often a serious concern. The second case shows that feedstock of first-generation biofuels in the form of wasted grain/crop, if recovered, could also be converted into considerable amounts of bio-ethanol—ranging from 70 million liters in the Lao PDR to 873 million liters in Yunnan and Guangxi in the PRC annually—depending on the agricultural activity in each country. In the third scenario, potential bio-ethanol production from crop residues is shown to be an order of magnitude higher than the other two scenarios, ranging from 500 million liters in the Lao PDR to 20 billion liters in the PRC. However, these numbers are purely hypothetical as the technologies to produce these biofuels are still under development and are not commercially viable as yet. Additionally, a proportion of biomass residues is currently used to revitalize the soil or as a local fuel source, and an abundance of residues (as is assumed here) may not be available.

The aim of the analysis is to understand the extent of the difference biofuels could make to the overall energy mix of the GMS countries, particularly to diesel and gasoline demand from the transport sector, based on current land and crop production trends. Table 4 compares the potential production of biofuels from the first two cases, i.e., conversion of 10% of available land

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[10] This analysis is based on USAID (2009) and assumes that between 1% and 7% of various crops are wasted due to inefficiencies in collection, processing, and transportation. The estimates of total ethanol volumes that could be produced in each country from wasted crop were developed using data on harvested area, crop production, and yields for various food crops and cereals obtained from FAO’s database and from national ministries in each country.

[11] This analysis is based on crop residue estimates for different crop types and locations from Lal (2005) and Gadde, Menke, and Wassmann (2007). Crop residues are defined as the non-edible plant parts that are left in the field after harvest and can include both above-ground and below-ground biomass.

and wasted grains in the GMS, to current and projected gasoline and diesel demand in 2020. It shows biofuels could offset some of the transport energy demand, though there is considerable variation across GMS countries. In Thailand and Viet Nam, when compared to current demand, bio-ethanol could offset demand up to 13% and 20%, respectively, though these numbers are somewhat more conservative when compared to demand in 2020 (2% and 10%, respectively). Biodiesel using feedstock grown on currently available land is seen to have much less potential in these two countries, partially due to the significant demand for diesel in the future. In the rest of the GMS, biofuels seems to have more potential to offset fossil fuels—bio-ethanol could make up over 40% of gasoline demand in 2010 (Cambodia) and between 20% and 40% of demand in 2020 (in Cambodia, Lao PDR, and Yunnan and Guangxi). Based on this analysis, biofuel potential could overshoot transport demand in Myanmar, though this is largely due to the availability of land in the country and comparatively low demand for transport fuels.

Table 4: Potential Biofuels Production in the Greater Mekong Subregion Compared with Demand

	Transport Demand (million liter)				Share of Transport Demand Met through Biofuels (%)			
	Gasoline		Diesel		Bio-ethanol[a]		Biodiesel[b]	
Country	**2009**	**2020**	**2009**	**2020**	**2009**	**2020**	**2009**	**2020**
Cambodia	903	1,729	2,235	4,396	44	23	8	4
Lao PDR	208	540	323	839	104	40	27	10
Myanmar	590	1,656	702	856	269	96	34	28
Thailand	7,417	27,692	1,8480	64,049	13	3	1	0
Viet Nam	5,095	10,132	8,533	14,667	20	10	0	0
Yunnan and Guangxi, PRC	2,978	5,404	4,970	8,518	73	40	4	3

GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.
Note: For all GMS countries except Cambodia, linear regression analysis was used to forecast the future demand of gasoline and diesel consumption based on the current consumption trends. For Cambodia, International Energy Agency (IEA 2010a) projections for Association of Southeast Asian Nations (ASEAN) countries were used.
[a] This includes bio-ethanol produced from converting 10% of available land and from wasted grain/crops.
[b] This includes biodiesel produced from converting 10% of available land.
Source: Authors.

The assessment provided above is based purely on crop production and land availability data for the GMS countries and considers production of feedstock in isolation. It does not take into account the social ramifications of feedstock production, or the economic feasibility of any of the scenarios. In reality, the feasibility of biofuel production is very much dependent on both these aspects. As a result, the figures shown are an overestimate and provide an upper boundary for production potential. Overall, the analysis serves to show that biofuels (based on current land and crop trends in the GMS) have the potential to offset fossil fuel demand, particularly in countries such as Cambodia and the Lao PDR, and provide an opportunity for GMS countries to diversify the sources of their fuels. Other similar analyses for Asian countries have demonstrated that biofuels will not be able to offset total demand for transport fuels (Elder et al. 2008, USAID 2009), and the estimates developed in this paper echo those as well. In order to meet future demand, the expanded use of biofuels will need to be complemented with energy efficiency improvements, such as improvements in vehicle fuel efficiency and use of electric and/or hybrid vehicles.

4. OVERVIEW OF SUSTAINABILITY ISSUES RELATED TO BIOFUELS DEPLOYMENT

The main drivers for increasing biofuels in the GMS and other Asian economies are the desire to increase energy security, address environmental issues and climate change, and provide income opportunities for the rural population and agriculture sector (Zhou and Thomson 2009). Alternatively, biofuels have also been known to entail significant social and environmental risks by increasing food insecurity, negatively impacting biodiversity, and requiring significant subsidies (USAID 2009). A review of the main issues related to the sustainability of biofuels is presented in the following section.

4.1. Biofuels and Risks to Food Security

Soaring food prices in early 2011 brought into sharp focus the need for countries to increase the security and sustainability of their food supply (FAO 2011). Rising food prices, particularly for commodities like sugarcane and corn, have been attributed to biofuel expansion. However, in the GMS there is still some debate on the extent to which biofuels could impact food prices. Huang et al. (2009b) used a general equilibrium model to assess the impact of increasing global bio-ethanol and biodiesel production on agricultural production, trade, and prices in the GMS and found that although biofuel expansion would significantly increase the prices of agricultural products (Figure 3), this could be beneficial to countries that were increasing their feedstock production. For example, due to increasing prices of biofuel feedstock, the study argues that countries that increase production and exports to the rest of the world would raise the national self-sufficiency of these commodities—a benefit for the agriculture sector. In reality, this is only one side of the equation, because a dramatic increase in biofuel production would have an impact on the structure of agricultural production and trade, potentially at the expense of other crops. Additionally, apart from direct impacts on food prices, increasing biofuel exports could also have an indirect impact by increasing the prices of feedstock for other food commodities. For example, the PRC is currently increasing its bio-ethanol production from cassava and as a result is sourcing this feedstock from neighboring countries like Cambodia, the Lao PDR, and Thailand (Rosenthal 2011). Though not a main component of food commodities in the GMS, cassava has been used for animal feeds, and increasing demand for biofuels in the PRC could lead to an increase in the price of meat or dairy products in other GMS countries.

Additionally, even with current policy responses to this issue in place, an expansion of biofuels would have impacts in terms of competition for resources. As described in Section 3, in response to food security concerns, some GMS countries (e.g., Cambodia and the Lao PDR) are promoting those biofuels that do not directly conflict with food crops, i.e., biofuels based on energy crops like Jatropha. The advantages of such crops are that they could be grown on marginal land or wasteland, and, in the case of Jatropha, may not require as much water as other feedstock. However, in reality, the yields from Jatropha on marginal land have been far less than forecasts predicted 5 years ago, and in order to produce enough biofuel to displace a significant proportion of fossil fuel demand, energy crops will likely need to be cultivated on cropland and would pose a risk as they compete with other agricultural products for land, water, and agrichemicals. Although land availability is not a serious concern in the GMS at the moment, the subregion's population is expected to increase to 340 million by 2050[12] and Johnston et al. (2010) estimate that demand for food, and therefore land, could increase 25% by 2050.

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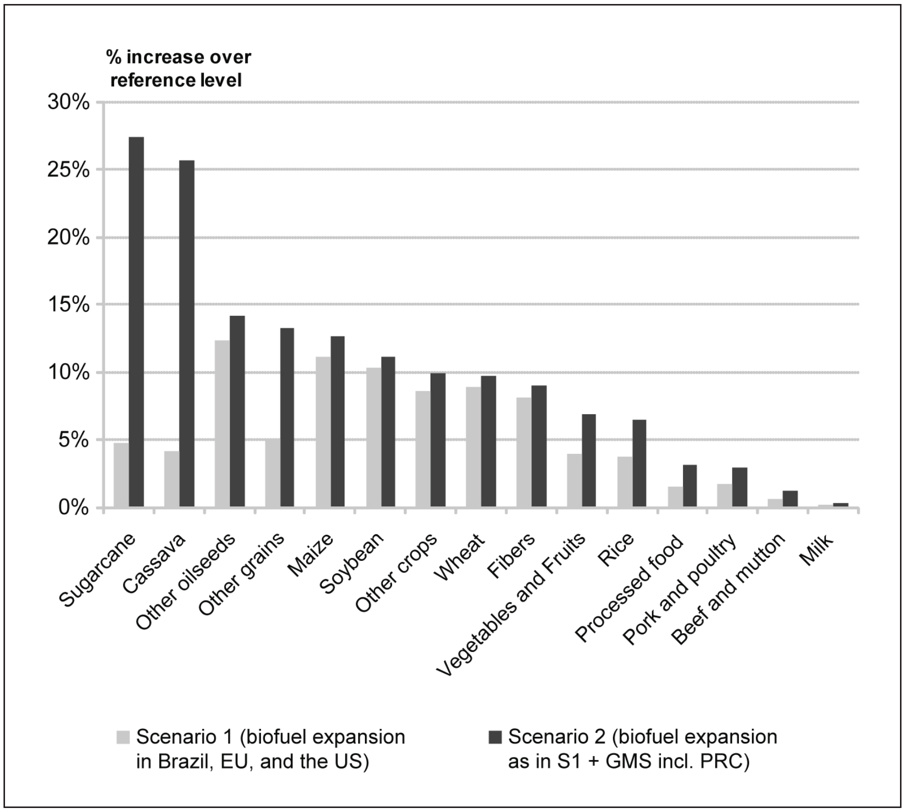
[12] This figure excludes Guangxi Zhuang Autonomous Region.

Figure 3: Increase in Prices of Agricultural Commodities in 2020 against a Reference Level



EU = European Union, GMS = Greater Mekong Subregion, PRC = People's Republic of China, US = United States.
Source: Huang et al. (2009b).

Increasing yields of biofuel feedstock to increase production is another approach to ensure additional volume of feedstock for biofuel use without requiring expansion of cultivation areas. Yields between GMS countries vary, and as shown in Table 5, Cambodia, Lao PDR, and Myanmar could potentially improve their production yields by learning and adopting more advanced farming practices and use of better plant varieties from Thailand, PRC, and Viet Nam. However, it must be noted that increasing the intensity of agricultural production comes with its own impacts, including those on biodiversity (Section 4.2).

It is also important to note that irrespective of biofuels programs, food security is an issue that is increasingly coming to the forefront in the GMS due to a number of external factors. Increasing incidence of extreme weather events and the looming threat of climate change are expected to affect agricultural productivity and the supply of food. Underdeveloped domestic storage and processing systems, deficient distribution, and infrastructure constraints mean that food deficits still occur in countries like Cambodia, the Lao PDR, and Viet Nam, even when the country as a whole records a food surplus (GMS Phnom Penh Plan Secretariat 2008). In Myanmar, over 60% of townships were classified as being vulnerable with respect to food security in 2003 (Kyaw et al. 2009). Food wastage is another key issue to be considered. Gustavsson et al. (2011) estimates that 125 kilograms of food per person are lost every year in Southeast Asian countries, most of which occurs at upstream stages in the food supply chain (i.e., post-harvest, processing, distribution and storage, etc.).

Table 5: Total Production of Selected Energy Feedstock Crops, by Yield and Area Harvested in the Greater Mekong Subregion, 2005–2009

	Production (ton)	Area harvested ('000 ha)	Yield (ton/hectare)
Sugarcane			
Cambodia	245,253	10.21	24.02
Yunnan and Guangxi, PRC	78,487,123	1,125.60	69.73
Lao PDR	322,640	9.15	35.28
Myanmar	8,492,329	157.90	53.78
Thailand	60,595,791	996.10	60.83
Viet Nam	16,083,007	275.80	58.31
Cassava			
Cambodia	2,370,320	114.25	20.75
Yunnan and Guangxi, PRC	6,320,000	320.00	19.75
Lao PDR	171,180	12.01	14.26
Myanmar	275,880	20.87	13.22
Thailand	24,142,055	1,148.20	21.03
Viet Nam	8,112,616	492.10	16.48
Palm Oil			
Cambodia	–	–	–
Yunnan and Guangxi, PRC	–	–	–
Lao PDR	–	–	–
Myanmar	–	–	–
Thailand	7,078,293	420.40	16.84
Viet Nam	–	–	–

GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.
Source: FAO (2011) statistics, data presented are averages of values for 2005–2009.

In summary, biofuels expansion in the GMS will likely impact crop and food prices, both directly and indirectly, and the current biofuels policy framework in countries needs to be strengthened and improved based on regional experiences to take account of this. Additionally, other risks to food security need to also be assessed, and integrated policies that take into account storage and distribution, waste, and climate change and natural disasters need to be defined to reduce the vulnerability of poorer communities.

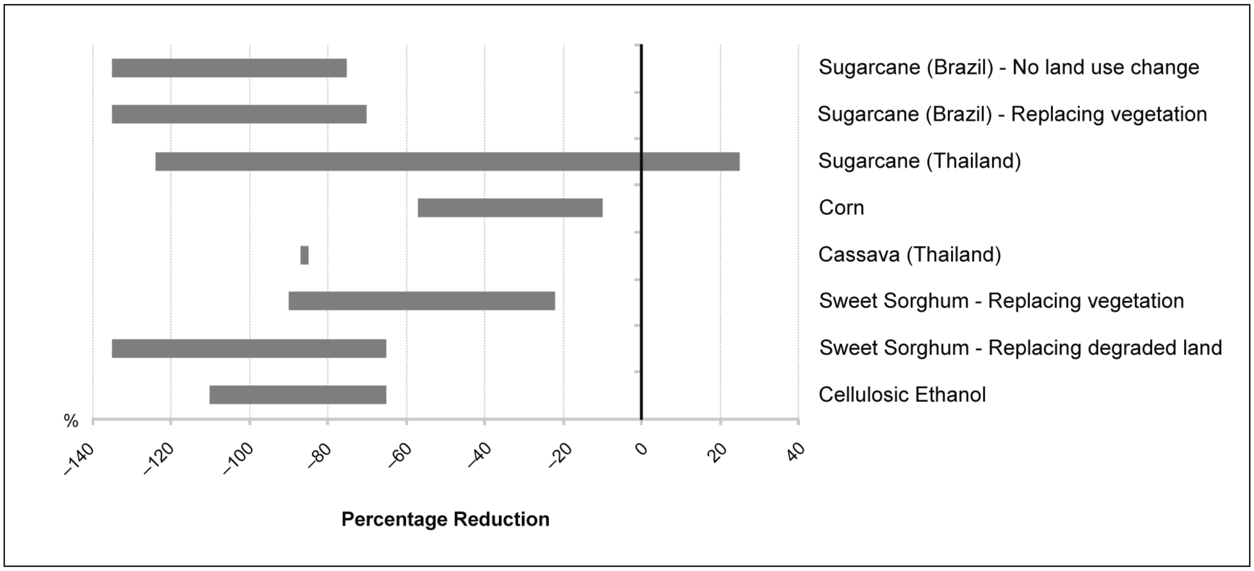
4.2. Biofuels and Reduction in Greenhouse Gases

With the increasing awareness of the risks and impacts of climate change, one main advantage of applying biofuels over fossil fuels is that they can (theoretically) significantly reduce GHG emissions. Life-cycle analyses (LCA)[13] conducted for multiple biofuel feedstock and fuels show a considerable variation in results when compared with fossil fuels, with some studies showing significant positive results and others showing negative results (Elder et al. 2008). One fact that is clear across the literature is that GHG balances produced from LCA studies vary significantly by country and region. USAID (2009) compared GHG balances from bio-ethanol and biodiesel production systems in Asia against a baseline fossil fuel production system, taking into account

[13] Life-cycle analysis is a holistic inventory of the environmental impacts of a given product along its production chain (extraction and processing of raw materials, transport, end use, and disposal) including all resource inputs and discharges to the environment.

a range of production conditions for biofuels.[14] Figure 4 presents the percentage reduction in GHG emissions for bio-ethanol systems based on their study.

Figure 4: Range of Greenhouse Gas Reduction from Biofuels When Compared with Fossil Fuels – Bio-ethanol Systems



Source: USAID (2009).

As demonstrated by USAID (2009), the benefits from greenhouse gas reductions are significant for most different feedstock for bio-ethanol systems, though the production conditions used clearly impact the magnitude of emission reductions. Particularly, plantation on existing crop land or degraded land produces the greatest savings in emissions. Also, although savings can be achieved from all feedstock, some are more favorable than others. For example, in Asia, sugarcane and cassava produce higher savings than corn for bio-ethanol systems (Elder et al. 2008). For biodiesel systems, the analysis shows that where palm is planted on areas of peat, shrub, or existing forest, there are no GHG reductions, and in fact the GHG balances for all feedstock become unfavorable against fossil fuel systems under such conditions (USAID 2009).[15]

Another factor to be considered in relation to GHG emission savings is carbon debt and payback periods. These are affected by the previous use of the land for biofuel development. USAID (2009) shows the carbon payback period when planting on cropland to be around 1 year, whereas when planting on secondary tropical forest, the carbon payback period could range from 10 to 1,000 years, depending on the forest type and location. The analysis demonstrates that there is no justification in terms of GHG savings for planting biofuels on forestland.

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[14] Best-case production conditions assumed low fertilizer and pesticide inputs, plantation on degraded lands, optimal process efficiency, utilization of co-products, and the treatment of wastes. Worst-case production conditions assumed high fertilizer and pesticide inputs, replacement of native vegetation (primarily forests and grasslands), poor process efficiency, poor co-product utilization, and no treatment of wastes (USAID 2009).

[15] Removal of forest and disturbance of peatlands result in reduced carbon sequestration and a net flux of CO_2 from soil reservoirs to the atmosphere. In these situations, the GHG savings attributed to reducing fossil fuel use are negated by these additional emission sources.

4.3. Biofuels Impact on Biodiversity

Within the GMS, biodiversity is a key concern that must be taken into account when developing biofuels policies. The subregion is a biodiversity hotspot and home to a number of globally significant populations of threatened species and new species. Between 1997 and 2008, 1,231 new species were discovered across the GMS, with 308 new species identified in 2008–2009 alone (WWF 2010). Concurrently, forest loss in the subregion has been a serious threat to biodiversity with over 8 million hectares of forest being lost in the last 2 decades (FAO 2010). The primary drivers of forest and biodiversity loss in the subregion are demand for natural resources, particularly expansion of agricultural land. The concern is that biofuel development could exacerbate these trends as has been the case in neighboring countries. In Indonesia and Malaysia, for example, it has been estimated that slightly more than half the oil palm expansion has occurred at the expense of forest area (USAID 2009). Additionally, development of large-scale monoculture plantations for biofuels may have an additional impact in that they could reduce biodiversity within the existing agriculture systems in the GMS.

4.4. Biofuels and Poverty Reduction: Small- vs. Large-Scale Deployment

A main driver for the expansion of biofuels in the GMS is the opportunity to provide access to global markets for agricultural products and increase livelihood opportunities for rural farmers. This opportunity, however, is affected by a number of factors, not least of which is the scale at which biofuels are deployed.

Economies of scale within biofuel production systems may mean that these systems are more suited to large-scale operations. Bio-ethanol production from modern processing plants, for example, has been seen to require a steady input of a large amount of feedstock in order to produce fuels at competitive prices (USAID 2009). However, a biofuel industry dominated by large-scale producers in the GMS may not positively impact rural development and poverty reduction. Larger-scale operations are likely to focus on achieving low costs of production, not on generating rural employment, and may increase income disparity and vulnerability of rural farmers. This is particularly relevant in the GMS, where the agricultural industry has been at the heart of conflicts between large-scale private developers and rural farmers. Economic land concessions in Cambodia, for example, where private companies have been given access to land for agricultural and other development, have faced issues due to a lack of transparency and uncertainties related to consultation with rural users of the land (UN-OHCHR 2007). Attributed to ‘’poor enforcement” of existing legislation, these issues have affected the engagement of development partners in Cambodia. The granting of these concessions highlights the risks to rural development and local livelihoods from developing large-scale agricultural systems.

Many reports on biofuels in GMS countries stress the importance of investing in ”pro-poor” or smallholder-based biofuel systems in order to achieve maximum benefits for rural development (Nivitchanyong et al. 2008, Malik et al. 2009, Shepley et al. 2009). By integrating smallholders in the supply chain of biofuels, additional income for farmers could make a significant difference to their socioeconomic situation. For example, Markandya and Setboonsarng (2008) compared Jatropha development projects involving both concessionaires and smallholders in Cambodia and the Lao PDR and found that the latter had the potential to lift four times as many farmers out of poverty as the former. A series of case studies of biofuel development at the community scale in the lower Mekong countries also revealed that smallholders benefited significantly from community-based biofuel initiatives, particularly in cases where biofuel systems were locally oriented and a proportion of fuel generated was locally used (Shepley et al. 2009).

Even with the potential benefits for smallholder-based biofuels, some significant challenges remain. Small-scale biofuels initiatives require significant support and established market systems in order to succeed. A study of small-scale Jatropha development in Yunnan showed that as there are currently no alternative uses for the plant, farmers engaged in these activities are vulnerable to uncertainties in the currently immature Jatropha market, and that remote villages face reduced revenues from planting Jatropha due to high transportation costs (Sano, Romero, and Elder 2011). In Myanmar, Jatropha expansion by the government has focused on smallholders. However, due to the lack of refineries and processing infrastructure and limited technical support and awareness raising of farmers, benefits from the program have been restricted (ECDF 2008, Cushion et al. 2010).

Current established agri-business models in the GMS which may hinder the development of efficient and profitable smallholder biofuel production pose another challenge. The concession model, as in Cambodia and the Lao PDR, utilizes farmers only as daily wage labor and may not achieve rural development outcomes in the long run (Malik et al. 2009). However, a case study of biofuels initiatives in Tay Ninh province in Viet Nam revealed that biofuel processing enterprises that relied solely on the supply of feedstock from unorganized smallholder farms experienced constraints with raw materials, optimal capacity utilization of their machinery, and difficulty in meeting their profit margins (Shepley et al. 2009).

One community-based business model that has had initial positive results for both rural development and efficiency in the agriculture sector is the cooperative or association model. In Thailand, for example, the government has supported the organization of villagers into community enterprises to enable them to buy and manage their own small-scale biofuel extraction facilities. This has allowed farmers to collect and extract fuel from their crop and sell the finished product blended with diesel as biodiesel (Chirapanda et al. 2009). In this way, smaller communities retain the returns from value-added processing. However, the development of such projects was resource-intensive as skilled management staff were necessary to run the cooperatives and the plant, and a regular supply of feedstock was required to achieve a base level of efficiency.

The final issue that tends to arise out of small-scale biofuel development is the availability of land. In order to counteract issues of food security, some GMS governments are promoting the use of marginal land, i.e., plantations of Jatropha along roads and as hedges between farm properties. In practice, these policies have had mixed results. In Yunnan, the government's prohibition of land clearing and the use of farmland were seen to be followed by villages reviewed in one study (Sano, Romero, and Elder 2011), while in the Lao PDR, in a contract farming system involving smallholders in the production of Jatropha, farmers encroached on forest areas to develop plantations rather than adhere to marginal lands. This was attributed to poor enforcement of the principle by the enterprise hiring the farmers (Shepley et al. 2009).

5. DISCUSSION: HOW CAN BIOFUELS BE SUSTAINABLY DEPLOYED IN THE GREATER MEKONG SUBREGION?

The current energy situation in the GMS is not sustainable. The extensive use of fossil fuels, dependence on oil imports and increasing per capita demand mean that if the GMS is to continue on its current path of economic development and progress, significant changes are necessary within the energy supply and demand dynamics. Some improvement from energy efficiency measures can be expected in terms of reducing energy demand, but alternative sources of supply also need to be identified and developed. In this context, biofuels present an opportunity that GMS countries should take into account.

Currently the production of biofuels varies within the GMS, with the PRC and Thailand, and to a smaller extent, Viet Nam, having well developed biofuels systems in place, and Myanmar, the Lao PDR, and Cambodia currently pilot-testing biofuels production. Based on the assumptions and scenarios in this paper, if biofuels were to be deployed they would be able to meet 3%–40% of the demand for gasoline from the transport sector in 2020, and under 10% of the demand for diesel in 2020 (excluding Myanmar). These figures show that although locally sourced biofuels will probably never be able to fulfill all the demand for transport fuels in GMS countries, they will be able to replace a significant fraction of gasoline and could help countries diversify their current, fossil-fuel heavy, energy mix. Additionally, in countries like the Lao PDR and Cambodia (in which biofuels are seen to have greater potential to replace fossil fuels), as long as countries prioritize the use of biofuels to meet internal demand over export, economic sectors would be less vulnerable to fluctuations in oil prices.

However, biofuels development is associated with significant negative impacts. If the deployment of this source of energy is not planned and implemented with careful consideration of these impacts, current negative trends in countries will have a real chance of being exacerbated rather than improved. In particular, the issues of deforestation and climate change, food security, and rural development are key concerns for GMS countries at the moment, and, as has been demonstrated by a number of local case studies, biofuels have the potential to both negatively and positively impact these issues. Some recommendations relating to these issues emerging from this review paper are below.

Food Security: Even with the wealth of literature focusing on this issue, the links between biofuels and global food prices (and therefore food security) are not clear. Within the GMS, the situation is even more ambiguous and the balance between an opportunity to gain additional revenues for the agriculture sector and potential risks to food prices must be weighed carefully. The current situation of food security in GMS countries is hampered with issues of distribution and storage of food, as well as underlying prevailing conditions of poverty, and GMS countries will need to put in place integrated policies that target the supply of food and risks related to biofuels, climate change, waste, and distribution. In terms of safeguards related to biofuels, some countries are already taking measures to promote energy crops over food crops for biofuels and utilizing marginal rather than core agricultural land, but better enforcement of these regulations will be needed in the future. Additionally, promotion of second-generation biofuels which rely on non-food crops as feedstock could help reduce some direct pressure on food crop production in the near future (though the indirect impact of these would remain), and more investment in developing so-called third-generation biofuel technologies[16] could reduce this further over the long run.

Deforestation and Climate Change: Current trends of deforestation and forest degradation in GMS countries are significantly impacting biodiversity, threatening local communities that are dependent on forest resources, and are a significant source of GHG emissions.[17] For biofuels to have a positive impact in terms of climate change, biofuels policies must include some consideration of current prevailing trends of deforestation and should include measures to discourage biofuels development on forestland. While GMS countries are making efforts to

[16] Third-generation biofuels include biofuels produced from algae.

[17] Land-use change and forestry was responsible for 26% of all GHG emissions in the GMS (excluding the PRC) in 2005 (WRI 2010).

focus biofuel expansion on underutilized and marginal land, the enforcement of regulations protecting forest areas in these countries is weak, and these areas remain vulnerable to both smallholder and large-scale biofuel development. The development of standards for biofuels and certification systems that take into account land-use change and chain of custody may help in checking the replacement of forests with agricultural land for biofuels. Additionally, increasing production yields and efficient collection of waste crops could substantially increase the volume of biofuel feedstock without expanding cultivation into forestlands.

Rural Development Benefits: The opportunities for rural development from smallholder-based biofuel production in the GMS are clearly significant, but the realization of benefits is dependent on the mode of deployment. There are many lessons to be learned from pilot-testing different models in GMS countries, and it is important that future development builds on them and that GMS countries learn from each other's examples. Irrespective of the model chosen, when promoting biofuels from smallholders, GMS countries will need to invest in developing the supply chain for biofuels, and proper research and development should be carried out prior to introduction of new crops for mass propagation, especially in rural areas with subsistence farming. Countries will also need to invest in developing the necessary skills and capacities needed for smallholders to produce and extract biofuels themselves, which would allow them to capture the largest share of the benefits from the production of such fuels. Capacity development will need to be focused at different levels—institutional capacity to develop and support schemes and local capacity to implement successful enterprises.

5.1. Further Issues to Consider

Although this paper considers the potential to produce biofuels from current resources in the GMS, the analysis provided here does not comment on whether GMS countries should allocate these resources to biofuel production. A social cost–benefit analysis which quantifies the trade-off between benefits to the agriculture sector, negative impacts on health and well-being due to changes in food prices and environmental impacts of biofuel production would complement the analysis provided here and may provide more insight into this crucial issue.

6. CONCLUSION

This review demonstrates that biofuels could make a significant contribution to meeting the primary energy demand (especially in the transport sector) in several GMS countries. In doing so, biofuels could also increase agricultural and rural incomes and prospects for regional energy trade, while ameliorating several of the prevailing negative environmental conditions. The extent to which this potential can be realized will depend on the type of production system that is pursued. Expansion in the form of industrial-scale plantations would quickly lead to several of the linked social–environmental–political problems that have been observed elsewhere in Asia and outside Asia, namely food versus fuel conflicts, land grab, destruction of forests, and detrimental impacts on soil and water quality. Expansion involving surplus land, smallholder-based production, and an emphasis on non-food crops and second-generation biofuels could pave the way for sustainable utilization of biofuels in the GMS. However, this latter approach will require significant policy interventions, and dedicated support to the farm sector, much of which is missing currently, and will need to be put in place.

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Biofuels in the Greater Mekong Subregion
Energy Sufficiency, Food Security, and Environmental Management

In the Greater Mekong Subregion (GMS), a growing demand for biofuels could help support the agriculture sector and provide an alternative source of energy. However, if deployed unsustainably, biofuels development can be associated with numerous risks that have negative ramifications for human development. This paper reviews existing literature and integrates various themes to provide an overview of four main issues related to biofuels deployment in the GMS: the need for alternative energy, risks to food security, considerations for environmental management, and opportunities for rural development.

This paper was prepared as a discussion piece for the GMS 2020 International Conference (20–21 February 2012 in Bangkok, Thailand).

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