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Are Biofuels an Environmentally-friendly Choice for Transport? A Study from Vietnam

Strengthening local capacity in the economic analysis of environmental issues

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In Vietnam, the production of biofuels is being promoted as a way to both reduce the country's dependence on fossil fuels and to control its greenhouse gas (GHG) emissions. However, although the government has been working to promote the development of a biofuel industry in the country, there are concerns about whether this approach will be economically viable, actually improve energy efficiency, and help fight climate change.

A new EEPSEA study has looked at the energy efficiency, GHG emissions and cost-effectiveness of using biofuel as an energy source for transportation in Vietnam. The study is the work of Loan T. Le of Nong Lam University. The study shows that energy efficiency and GHG emissions savings can be made by substituting ethanol for gasoline (in a blend of the two fuels) and by substituting biodiesel for diesel (again in a blend of the two fuels). Biodiesel has additional environmental benefits in that its main raw material can be grown on marginal degraded land. However, in comparison with biodiesel, the production and use of bio-ethanol has advantages in terms of its cost-effectiveness and energy efficiency.

The study concludes that the benefits of using biofuels could be increased by adapting vehicle engines so that they use the fuels more effectively and by improving the sustainability of the ethanol and biodiesel production processes. It underlines the potential that biofuels have in Vietnam, with its results being relevant to the development of sustainable biofuel usage in Vietnam, and to the development of biofuels elsewhere in Southeast Asia.

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A summary of EEPSEA Research Report No. 2015-RR6: 'Biofuel Production in Vietnam: Cost-Effectiveness, Energy and GHG Balances', by Loan T. Le, Faculty of Economics, Nong Lam University, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam. Email: loanle124@yahoo.com, ltloan@hcmuaf.edu.vn

Vietnam's energy challenge

Vietnam is facing a significant energy challenge, as the demand for energy in the country is rapidly growing. Like most rapidly developing countries, its transport sector is expanding particularly fast and this sector has become a major source of GHG emissions. Hence, reducing the environmental impact of vehicles is of interest.

Biofuel is already being supported by government legislation as a way of addressing this issue. National policy focuses on two biofuels: cassava-based ethanol and jatropha-based biodiesel. These fuels are currently being blended with fossil fuels and sold to motorists. The government has set a biofuel production goal of 1.8 million tons per year by 2025. This will be equivalent to 5% of Vietnam's projected total fuel demand for that year.

Cassava-based ethanol production has rapidly developed in recent years. By 2010, eight production plants for this fuel were operating. These had a total annual capacity of 680 million liters of ethanol, of which 420 million liters was used for biofuel. Biodiesel production began in 2008 with the start of jatropha cultivation, and processing experiments have been carried out at seven biodiesel plants.

Jatropha-based biodiesel is seen as an especially promising diesel substitute. This is because jatropha is an environment-friendly plant that grows on marginal degraded soil. It can help stop soil erosion as well as help reclaim fallow land by recycling nutrients. As a non-edible feedstock, jatropha has less of an impact on food security than crop-based biofuels. It also helps to create jobs and diversify agricultural production. It could also be a source of potential earnings due to the carbon emission reductions it produces when it is turned into biofuel.

Can biofuels help?

Despite the potential benefits it can bring, there is growing concern about the economic viability of jatropha-based biodiesel. Due to a lack of research, there are also some uncertainties and concerns about the energy efficiency of its production, the GHG emission savings it can deliver, and the economic viability of using it as a fuel. There are similar concerns about the production and use of cassava-based ethanol.

Loan undertook her study to provide information on these issues to policymakers. To do this, she assessed the amount of energy used and the amount of GHGs produced in the production and use of biofuels. She calculated the energy balance and GHG balance for these fuels. This was done by comparing the energy input and GHG emissions for the production and utilization of biofuel with those of fossil fuel for the same functional unit (1 km of transportation by road vehicles). This analysis involved the use of life cycle assessments. It also considered the effects of the land use changes (LUC) that would result from the production of biofuels. To assess the economic viability of biofuel, she considers their cost-effectiveness (i.e., she compared the social costs of biofuels and

Cassava starch processing near Hanoi, Vietnam.
(Photo by Neil Palmer, International Center for Tropical Agriculture (CIAT) under creative commons license at www.flickr.com)

fossil fuels for the same functional unit).

Loan focused on the ethanol/petrol blends E5 and E10 and on the biodiesel/diesel blends B5 and B10, all of which are being promoted by the Government of Vietnam (GoV). Blend E5 is 5% ethanol and 95% gasoline (by volume). Blend B5 is 5% biodiesel and 95% diesel (again, by volume). These blends have been utilized in domestic transportation since 2010. E10 and B10 are two new biofuel blends (with higher percentages of biofuel to fossil fuel than E5 and B5) that are proposed for use after 2015.

Loan then used this assessment to calculate what the overall effect would be if the GoV's 2025 targets for biofuel production and use were met. The GoV's target for ethanol and biodiesel production by 2025 is 600 Tt and 237.5 Tt, respectively.

'Cradle to grave' assessment of biofuel production and use

As said, Loan's study used a wide range of comprehensive "cradle to grave" calculations and assessments to make a comparison between biofuels and fossil fuels. For example, her assessment of the energy needed to make ethanol included evaluations of both direct and indirect energy inputs. The direct inputs included the diesel used operating tractors and transportation, the coal used for ethanol conversion, and the electricity used for ethanol conversion and blending. The indirect energy inputs included the energy embodied in fertilizers, pesticides, labor, chemicals, plant construction, machines and vehicles.

In reality, fuel efficiency is affected not only by fuel properties but also by other factors such as vehicle speed and gear, vehicle model, and road conditions. For this reason, the study conducted a sensitivity analysis to evaluate the effects of different blends and their fuel consumption variation with respect to fossil fuels and to provide a general assessment of the energy and GHG balances of ethanol and biodiesel.

The percentage change in fuel consumption of ethanol blends with respect to gasoline is considered at three levels, formulating six scenarios: S1, S2, and S3 represent E5 with 5% higher, the same, and 5% lower levels of fuel consumption, respectively; and S4, S5, and S6 represent E10 with 5% higher, the same, and 5% lower levels of fuel consumption, respectively.

The percentage change in fuel consumption of biodiesel blends with respect to diesel is considered at two levels, represented by four scenarios: S7 and S8 are B5 with the same and 5% higher levels of fuel consumption, respectively; and S9 and S10 are B10 with the same and 5% higher levels of fuel consumption, respectively.

The information for this study was primarily collected through two surveys that involved cassava and jatropha farmers, stakeholders in the biofuel production supply chain, and managers at processing and blending plants and stations.

Impact on land use

The study found that the level of cassava cultivation needed to meet the GoV's targets for bioethanol production in 2025 would require a total land area of 94,086 ha. This corresponds to 19% of the land area in Vietnam that was under cassava cultivation in 2009 (or 1.5% of Vietnam's arable land at that time). Of this, it is thought that 12% of the necessary land would come forestland, 31% would come from grassland and 57% from other cropland.

To meet the government's targets for biodiesel production in 2025, a total area of 245,859 ha would have to be used for jatropha production. This is equivalent to 5.94% of Vietnam's land area that was unused in 2009. Of this, it is thought that 15.32% would come from forestland, 78.92% would come from grassland and 5.76% would come from other cropland.

Can biofuels save energy?

The study shows that the substitution of ethanol for gasoline would achieve an overall saving in energy, provided that this change did not increase average fuel consumption figures by more than 2.4% (when E5 is used) and 4.5% (for E10). If the government's targets for bioethanol are met, the energy savings would be equivalent to 12.82–42.08 PJ.

The substitution of biodiesel for diesel would also achieve an overall saving in energy, provided that this change did not increase average fuel consumption by more than 3.31% (when B5 is used) and 6.85% (for B10). For example, the substitution of biodiesel for diesel in the form of B5 would save 1.41 MJ (or 64.06% of primary energy input) for every kilometer travelled.

The study also found that there were opportunities to improve the energy efficiency of biofuel processing by finding a more energy-efficient substitute for the coal and chemicals used, by improving feedstock yields, by making the cultivation of the feedstock more sustainable, by reducing the use of chemical fertilizers, and by reducing transportation distances through the development of more blending and gas stations.

The impact of biofuels on GHG emissions

The study found that the substitution of ethanol for gasoline would achieve an overall reduction in GHG emissions, provided that fuel consumption is not increased by more than 3.8% (when E5 is used) and 7.8% (for E10). Overall, every liter of ethanol produced and utilized would result in a GHG emission saving of **675–4,796 g** CO_2e (carbon dioxide equivalent).

The potential GHG savings from the use of bio-ethanol could be increased by: a) increasing the amount of cassava residue that is returned to the soil and not burnt; and b) undertaking intensive cassava cultivation that incorporates sustainable land management and which reduces the amount of nitrogen fertilizer used.

The study also finds that the production and utilization of biodiesel would always achieve a GHG emission saving in all scenarios used in this study. Overall, biodiesel production would result in a GHG emission saving of 2,143 g CO_2e per **liter.**

Biofuels have the potential to make Vietnam's transport sector greener

When it comes to the cost-effectiveness of using biofuels, the study finds that the substitution of bio-ethanol for gasoline would be cost-effective provided that fuel consumption compared to gasoline does not increase by more than 1.72% and 3.51% for E5 and E10, respectively, at 4% discount rate. Every **liter** of ethanol produced and consumed as fuels in the forms of E5 and E10 could save between VND 3,148–15,941.

However, the study finds that, although biodiesel brings some economic benefits due to the positive LUC it causes, it is, on balance, a less cost-effective option than the use of diesel at the current fuel consumption levels of biodiesel blends. Biodiesel substitution for diesel

Table: Summary of the energy input, GHG emission performance, and social cost of fuels

API category	Gasoline	Diesel	Ethanol	Biodiesel
Energy input ($MJ_{input}\ MJ_{output}^{-1}$)	1.1375	1.1368	0.9342	0.4488
Emission performance ($g\ CO_2e\ MJ_{output}^{-1}$)	83.8	83.8	34.95	-65.65
Social cost ($VND\ MJ_{output}^{-1}$)	377–378	363–364	381–427	514–555

To achieve zero energy balance, zero GHG balance, and zero cost difference compared with gasoline (for ethanol) and diesel (for biodiesel), consumption of the biofuel blends should not exceed:

	Energy balance ($MJ\ km^{-1}$)	GHG balance ($g\ CO_2\ km^{-1}$)	Cost difference ($VND\ km^{-1}$)
Ethanol	2.4% for E5, 4.5% for E10	3.8% for E5, 7.8% for E10	1.31–1.72% for E5, 2.66–3.51% for E10
S1 (E5, +5%)	30.07	1,019.60	12,472.76
S2 (E5, 0%)	-1.35	-156.08	-327.70
S3 (E5, -5%)	-2.15	-186.22	-655.92
S4 (E10, +5%)	0.08	-102.64	254.14
S5 (E10, 0%)	-1.35	-156.08	-327.70
S6 (E10, -5%)	-1.89	-176.35	-548.40
Biodiesel	3.31% for B5, 6.85% for B10	negative GHG balance always achieved	-1.4 to -1.9% for B5 -2.8 to -3.7% for B10
S7 (B5, 0%)	-1.41	-278.04	203.5
S8 (B5,+5%)	14.42	-2,592.39	18,329.5
S9 (B10,0%)	-1.41	-278.04	203.5
S10 (B10,+5%)	-0.69	-383.23	1,027.4

Note: A negative figure in: a) column 1 means an energy saving; b) column 2 means a GHG emission saving; and c) column 3 means cost-effectiveness.

would only be cost-effective if fuel consumption of B5 and B10 decreases by more than 1.4% and 2.8%, respectively, at the discount rate of 4%. These fuel consumption levels for biodiesel blends have not been reached in reality.

The results show that the substitution of gasoline for ethanol could bring energy-efficiency savings to Vietnam's transport sector. It could also reduce the amount of GHG emissions that the sector is responsible for. Given the current levels of engine development, the production and utilization of ethanol is more cost-effectiveness and energy efficient than the production and utilization of biodiesel. It also has an acceptable performance in terms of its GHG emissions.

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