Second and third generation of biofuels[i]

1. Introduction

Biofuels can be classified into 3 generations: First, second and third generation The 2nd generation biodiesel includes liquid fuels derived from Jatrapha seed oil and from a catalytic conversion process of synthetic gas from the gasification of biomass. The 2nd generation ethanol is a liquid fuel from non-food bio-materials such as biomass and bio-waste having high cellulose. Fig A 9 summarizes the benefits of biofuels compared to conventional fuel. It was found that the GHG performance of biofuels is the key to achieving a low-carbon transportation sector and meeting this roadmap's vision. However, given the extensive nature of the potential supply and use of biofuels and their interaction with the agricultural and forestry sectors, all three pillars of sustainability; i.e. (i) environment, (ii) economic and (iii) social, need to be fully considered and appropriately addressed on policy level.

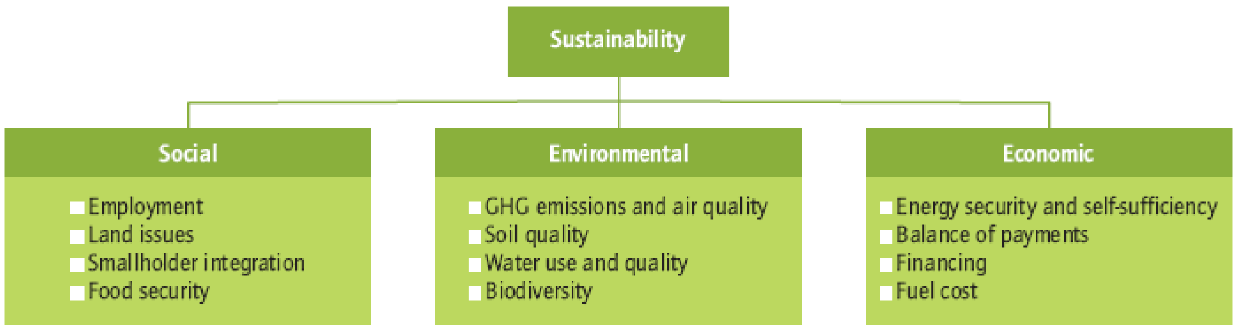

Fig A 9 Environmental, social and economic aspect from biofuels production
Source: IEA (2011)(International Energy Agency, 2011)

2. Second Generation Biodiesel Technology

Biodiesel is fuel derived from biological materials such as vegetable oils, animal fats or oil from algae. Biodiesel usually refers to the products from a chemical reaction of vegetable or waste oil and ethanol and methanol called a Transesterification process. Properties of biodiesel are similar to fossil diesel fuel, which can be used in a standard diesel engine without modification. Biodiesel contains 10% oxygen and zero sulfur, which results in the vehicle engine burning more completely and efficiently. It is credited with reducing 40% of the smog problem and a large percentage of carbon monoxide reduction. Biodiesel can be used 100% or mixed with petro-diesel, called the "B" ratio. B5 to B20 are acceptable levels in several countries.

First generation biodiesel was derived from food bio-feedstocks such as soybeans, palm, canola and rapeseed. Promotion of the first generation biodiesel caused interaction problems with human food-chains, including supply and demand balancing, land use, water management.

Several processes under development aim to produce fuels with properties very similar to diesel and kerosene. These fuels blendable with fossil fuels in any proportion can use the same infrastructure and should be fully compatible with engines in heavy duty vehicles. Advanced biodiesel and bio-kerosene will become increasingly important to reach this roadmap's targets since demand for low-carbon fuels with high energy density is expected to increase significantly in the long term.

Advanced biodiesel includes:

Second generation biodiesel come from non-food bio-feedstocks such as jatropha or the use of technologies such as biomass to liquid (BTL). These feedstocks have the advantage of not affecting the human food chain.

Hydrotreated vegetable oil (HVO) is produced by hydrogenating vegetable oils or animal fats. The first large-scale plants have been opened in Finland and Singapore, but the process has not yet been fully commercialized. Biomass-to-liquid diesel, also referred to as Fischer-Tropsch diesel, is produced by a two-step process in which biomass is converted to a syngas rich in hydrogen and carbon monoxide. After cleaning, the syngas is catalytically converted through the Fischer-Tropsch (FT) synthesis into a broad range of hydrocarbon liquids, including synthetic diesel and bio-kerosene.

Advanced biodiesel is not widely available at present, but could become fully commercialized in the near future, since a number of producers have pilot and demonstration projects underway (IEA, 2011).

3. Second Generation Bio-ethanol Technology

The first generation ethanol feedstocks are corn, sugarcane, maize etc. These feedstocks present the problem of affecting the food price structure. Available land areas for cultivation are also a concerning factor.

Second generation ethanol feedstocks are mainly from agricultural wastes such as corn stover, sugarcane baggase and also from wood, grasses or the non-edible parts of plants. It is produced from lignocelluloses, a structural material that comprises much of the mass of plants. The ethanol is derived not from the starch component like the first generation ethanol, but from the lignocellulosic component of the feedstock. Large sources of lignocellulose are available including non-food wild plants that grow in non-cultivated and non-arable lands. The second generation ethanol feedstocks overcome the two main bottlenecks for the first generation feedstock: adverse effects on food prices and inability to scale.

Cellulosic ethanol is a biofuel produced from wood, grasses or the nonedible parts of plants. It is a type of biofuel produced from lignocellulose, a structural material that comprises much of the mass of plants. Lignocellulose is composed mainly of cellulose, hemicellulose and lignin. Corn stover, switchgrass, miscanthus, woodchips and the byproducts of lawn and tree maintenance are some of the more popular cellulosic materials for ethanol production. Production of ethanol from lignocellulose has the advantage of abundant and diverse raw material compared to sources like corn and cane sugars but requires a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

Lignocellulosic materials, which provide structure to plants, are found in the stems, stalks, and leaves of plants and in the trunks of trees. The abundance of lignocellulosic materials – roughly 60 to 90 percent of terrestrial biomass by weight – along with the fact that they are not used for food and feed (unlike corn and sugarcane), are key reasons why lignocellulosic ethanol and other lignocellulosebased biofuels have attracted scientific and political interest. Lignocellulose and hemicellulose, which are referred to collectively as lignocellulosic materials, can be broken down into sugars, which can then be fermented into ethanol. Lignocellulosic materials being examined for the production of biofuels include those derived from switchgrass, prairie grasses, short rotation woody crops, agricultural residues, and forestry materials and residues.

Ethanol is chemically the same whether it is produced from corn, sugarcane or cellulose. However, the production processes are different and the necessary production technologies are in different stages of development. Corn and sugar based ethanol production technologies have been used at a commercial scale for decades. In contrast, some of the technologies needed to produce cellulosic ethanol, an “advanced biofuel” (broadly defined as a biofuel derived from organic materials other than simple sugars, starches, or oils) are quite new.

The advantage of the use of ethanol as fuel especially in the transportation sector is that ethanol/gasoline mix is an "oxygenate" fuel. It adds oxygen to the fuel mixture so that it burns more completely and reduces polluting emissions such as carbon monoxide.

Any amount of ethanol can be combined with gasoline, but the most common blends are:

- E10 - 10% ethanol and 90% unleaded gasoline.
- Ethanol is a clean-burning, high-octane fuel. Ethanol can be produced domestically in most countries. When ethanol is blended with gasoline, the octane rating of the petrol goes up by three full points, without using harmful additives. The higher the octane rating, the slower the fuel burns and the less likely the engine will knock.

Comparing with corn, cellulosic feedstocks have better energy conversion ratios, reduce CO2 emissions, and create less damaging land and water impact as shown in Table A 8.

Table A 8 Comparison of various ethanol types and gasoline

	Corn ethanol	Cane ethanol	Gasoline	Cellulosic ethanol
Energy output	8	1.3	1	236
CO2 emission	1.94 kg/lit	1.07 kg/lit	2.49 kg/lit	0.22 kg/lit
Ignition temperature	High	High	Lower	High
Water use in production	Growth of corn, refining diesel for tractors	Growth of cane	Refining of crude	Varies greatly
Production per acre	1512 liter	2305 liter	N/A	2780 liter

Source: Worldwatch Institute, US DOE–EIA, US EPA

All existing gasoline-engine vehicles can use E10 with no modifications to the engine. The use of higher mixing percentage needs to tune up and modify the engine, such as E85 is for use in a flexible fuel vehicle.

In terms of the environment and GHG mitigation, cellulosic ethanol has the potential to provide significant lifecycle GHG reductions compared to petroleum based gasoline. In addition, the use of cellulosic materials to produce ethanol may yield a variety of other environmental benefits relative to corn based ethanol. Researchers at the University of California at Berkeley estimated that on a lifecycle basis as shown in Table A 9, cellulosic ethanol could lower GHG emissions by 90 percent relative to petroleum based gasoline. Other analyses have shown that cellulosic ethanol produced using certain feedstocks could be carbon negative, which means that more carbon dioxide (CO_2) is removed from the atmosphere than is emitted into the atmosphere over the entire lifecycle of the product. However, these studies do not include estimates of emissions due to indirect land use change. An analysis undertaken by the California Air Resources Board as it developed the California Low Carbon Fuel Standard found significant lifecycle GHG emission reductions from cellulosic ethanol relative to gasoline.

Table A 9 Lifecycle GHG Intensity for Cellulosic Ethanol, based on the California GREET Model

Fuel	Feedstock	CA GREET GHG (g CO2e/MJ)	GHG reduction compared to gasoline
Cellulosic Ethanol	Farmed trees	1.60	98.3%
Cellulosic Ethanol	Forest residues	21.40	77.7%
California Gasoline (incl. 10% ethanol)		95.9	

A Comparison of first and second generation biofuels shown in Table A 10.
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Table A 10 A Comparison of first and second generation biofuels

First- Vs. Second-Generation Biofuels		
Parameters	1st gen.	2nd gen.
Direct food vs. fuel competition	Yes	No
Feedstock cost per unit of production	High	Low
Land-use efficiency	Low	High
Feasibility of using marginal lands for feedstock production	Poor	Good
Ability to optimize feedstock choice for local conditions	Limited	High
Potential for net reduction in fossil fuel use	Medium	Medium-High
Potential for net reduction in greenhouse gas emissions	Medium	Medium-High
Readiness for use in existing petroleum infrastructure	Yes	Yes
Proven commercial technology available today	Yes	No
Simplicity of processes	Yes	No
Capital costs per unit of production	Low	High
Total cost of production	High	High
Minimum scale for economical production	Medium	High
Direct food vs. fuel competition	Yes	No
Feedstock cost per unit of production	High	Low
Land-use efficiency	Low	High
Feasibility of using marginal lands for feedstock production	Poor	Good
Ability to optimize feedstock choice for local conditions	Limited	High

4. Current situation

A wide variety of conventional and advanced biofuel conversion technologies exists today. The current status of the various technologies and approaches to biofuel production is summarized in Fig A 10 below (IEA, 2011).

Cellulosic Ethanol Production - Current Status

As of March 2010, there are no large-scale commercial cellulosic ethanol refineries producing cellulosic ethanol. There are nearly ten commercial cellulosic ethanol plants worldwide that are either planned or under construction.

Cellulosic Ethanol Production – Future Projections

A study of the future of next-generation biofuels in Europe, by Bloomberg New Energy Finance, estimated that cellulosic ethanol supply could grow from 63bn litres in 2015 to 75bn litres in 2020 (under the base case scenario) and from 73bn litres in 2015 to 90bn litres in 2020 (bull case scenario). The top EU countries for next-generation ethanol supply are identified in order as France, Germany, Spain, United Kingdom, Italy and Poland. Conservatively, France was identified as having the potential to produce 15 billion liters of ethanol from biomass by 2020.

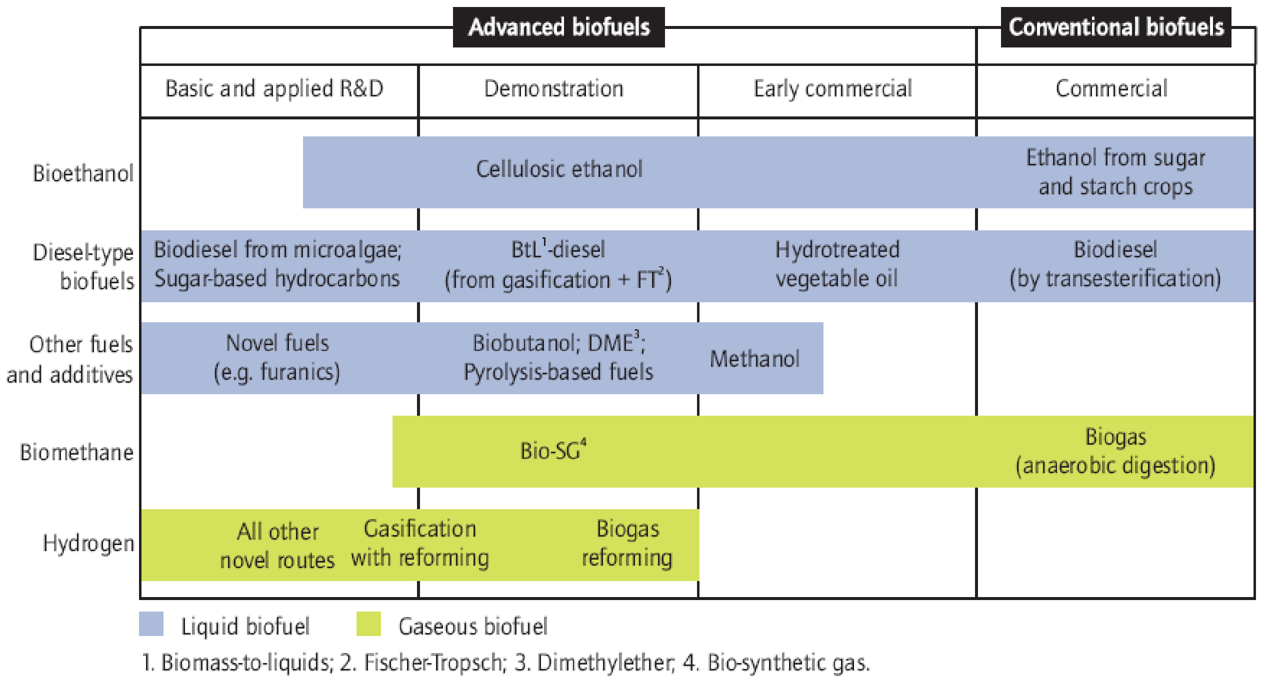

Fig A 10 Current status of the various technologies in biofuels
Source: IEA (2011)(IEA, 2011)

The United States estimated that the cellulosic ethanol production will increase from 3 billion gallons from 2015 to 10.5 billion gallons in 2020. Brazil and China will represent great production and marketable areas for biofuels from nonfood raw materials. India and South Africa are starting to look into ethanol as an option to reduce their energy dependence.

2. Key issues for development

Several advanced biofuels currently in a critical phase of technology development need to reach commercial scale and be widely deployed. As with conventional biofuels, improvements in conversion efficiency are needed, as well as strategies for reducing capital requirements. These strategies have to include integrating the different process steps along the whole supply chain (i.e. from biomass feedstock to the transportation of biofuels) to demonstrate the effective performance and reliability of the process. This should include the use of core technology components such as tar-free syngas production or (hemi-) cellulose to sugar conversion in other industries (*e.g.* the chemical industry).

Specific research and development (R&D) needs will need to be addressed to prove the industrial reliability as well as the technical performance and operability of the conversion routes in order to achieve economically sound production processes, as presented in Table A11. Detailed scientific support, modeling and monitoring of the above fields are required to obtain maximum learning and progress from the current pilot and demonstration activities (IEA, 2011).

Table A 11 Advanced biofuels key research and development issues

Technology	***Key R&D issues***
Cellulosic-ethanol	• Improvement of micro-organisms and enzymes • Use of C5 sugars, either for fermentation or upgrading to valuable co-products • Use of lignin as value-adding energy carrier or material feedstock
HVO	• Feedstock flexibility • Use of renewable hydrogen to improve GHG balance
BTL-diesel	• Catalyst longevity and robustness • Cost reductions for syngas clean-up • Efficient use of low-temperature heat
Other biomass-based diesel/kerosene fuel	• Reliable and robust conversion process in pilot and demonstration plants
Algae-biofuels	• Energy- and cost-efficient cultivation, harvesting and oil extraction • Nutrient and water recycling • Value-adding co-product streams

Source: IEA (2011)(IEA, 2011)

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[i] **This fact sheet has been extracted from TNA Report – TECHNOLOGY NEEDS ASSESSMENTS REPORT FOR CLIMATE CHANGE MITIGATION – Thailand. You can access the complete report from the TNA project website http://tech-action.org/**