Economic & Environmental Aspects of Biofuels

Nihal a g
Dept.of Electrical & electronics
The National Institute Of Engineering
Mysuru ,Karnataka, India
nehalagurdur@gmail.com

Akash
Dept of Electrical and Electronics
The National Institute Of Engineering
Mysuru Karnataka,India
akashgsirolli@gmail.com

Aprameya Karthik s r
Dept.of Electrical & electronics
The National Institute Of Engineering
Mysuru ,Karnataka, India
aprameyakarthiksr@gmail.com

Jeevan Gowda D S
Dept of Electrical and Electronics
The National Institute Of Engineering
Mysuru ,Karnataka,india
Jeevangowda8339@gmail.com

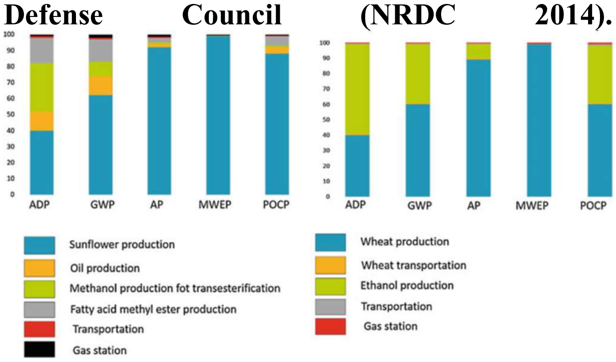
Abstract—

A quadruple transition (demographic, food, energy, and environmental) is required within the framework of sustainable development. The integrated biomass valorization concept, which includes the production of biofuels through the biorefinery concept, is at the crossroads of these global challenges. Biofuel production competes with feed and food production for water and land use. Many countries are concerned about securing these resources in an uncertain geopolitical environment. It also has both positive and negative (climate change mitigation) implications (fertilizers consumption, local pollutions). As a result, the topic sparks massive political and economic debates on a national and international scale. The results of the implementation of supportive strategies for the development of this "new" bioeconomy indicate mixed results in comparison to the objectives that have been set, at least in the near future. This can be explained by the windfall effects created on international markets, which highlight two critical needs. The development and improvement of environmental methods such as life cycle assessment, which are not limited to regional or national economies, will be required in order to instal ambitious and unambiguous agreements for policymakers in future international conferences such as those on climate change.

Introduction

Critical Analysis of the First-Generation Biofuels The first environmental assessment studies of the first-generation biofuels show a positive energy balance (energy produced is about twice as much than the energy consumed) and a potential for reducing the greenhouse gases that is considerable (Ometto et al. 2009). The authors also concluded that the fuel ethanol life cycle is responsible for the consumption of a high quantity and diversity of nonrenewable resources. These resources are linked to the mechanization level of the rural activities, the intensive use of pesticides, fertilizers, and diesel. The ethanol life cycle process is also responsible to negative and adverse impacts at the local and regional scale such as ozone formation, acidification, ecotoxicity, and human tox icity. The main causes for these impacts are the use of fertilizers and the burning after harvest that is in the case of the first-generation ethanol traditionally realized to cogenerate electricity during the process. Similarly, Querini (2012) has found distributed environmental consequences for the first-generation biofuels. These impacts are broken down by their origins in the production cycle of biodiesel from sunflower and first- generation ethanol from wheat. They are presented on Fig. 3 and globally compared to other fuels for the transportation sector in Table 2. In particular, whatever the feedstock being considered, the agricultural practices are responsive for a significant part of

these production impacts. Depending on the good agricultural practices, even the global warming potential is in favor of fossil fuels. Ethanol from sugarcane is confirmed as the most environmental-friendly biofuel for the first-generation. Figure 4 represents the global warming potential for different fuels in a Well-to-Wheel life cycle assessment analysis (Querini 2012). The environmental impacts of fossil fuels occur for a small part during the extraction and refining processes and essentially during the usage phase. Biofuels are characterized by their double distributed environmental impacts: (i) throughout the production chain of the added value, (ii) in most of the environmental compartments considered by the major life cycle assessment methodologies. The question of the good agricultural practices, the sustainable management of land, water, and fertilizers inputs as well as the processing technologies and the final use of the produced resource becomes the central issue. In this context, the economic and ecological performances from one biofuel to another are fundamentally challenged. However, some initiatives are gradually introduced in order to provide sustainability certifications to the most environmentally virtuous biofuels, such as the guideline to evaluate the sustain ability performances of biofuels published by the Natural Resources Defense Council (NRDC 2014).



New Investments in Renewable Energies

The new investments in capacity in renewable energy according to the Renewable Energy Network (REN21 2015) are depicted Fig. 6. Since the economic crisis in 2008, these investments are being reequilibrated between developed, which investments started to stagnate, and developing countries in which the investments remain steadily growing (Fig. 6 left). The sectorial breakdown per sector, as well as the net growth for 2014 in comparison to 2013 [Fig. 6 (right)] clearly show that these redistribution is beneficial for the wind- and solar- electricity sectors but not for the biomass and biofuel sectors. Drivers for these redistributions of funding are to search among the criticism that arise against the first-generation biofuel, and in particular, the fuel versus food debate that reached its paroxysm in 2008. In this context, the biofuel support polices remain under review in the United States and Europe. According to Timilsina and Shresta (2014), the investments for biofuel refineries were approximately 16 billion US$ in 2008 and suffered a threefold drop to 6.8

Fig. 6 Global investments in renewable energy from 2004 to 2014 (left) and sectorial ventilation in 2014. Growth represents the variation in investments from 2013 to 2014. Adapted from REN21 (2015) Economic and Environmental Aspects of Biofuels 537

billion in 2011, and even 5 billion in 2012. In this period, many of the 650-ethanol plants worldwide were operating below their theoretical capacity while others experienced temporary closed down because of the very high volatility of the prices, the fluctuating demand and the many reserves that has been made on first-generation ethanol. Brazil had the capacity to produce approximately 37 billion liters (860 PJ) in more than 440 plants in 2012. However, because of the specificity of the feedstock used, sugarcane that has a short storage life, Brazil has an excess of 30 % in sugarcane milling capacity and the production facilities are generally oversized. In reality, the production reached 26 billion liters (610 PJ). As the United States are primarily using corn, which as a longer shelf-life, the USA with approximately 210 ethanol plants had the capacity to produce 56 billion liters (1310 PJ) in 2012. Therefore, US plants have on average about three times the annual capacity of Brazilian plants. Feedstock differentiation and implementation of integrated first- and second- generation's bioethanol refineries might be an opportunity for the existing Brazilian facilities (Dias et al. 2013). The European Commission has already proposed to limit the proportion of biofuels from the first-generation biofuel used for the transportation sector to 5 % and to remove the subsidies for food crop-based biofuels by 2020 (Timilsina and Shresta 2014). If these commitments are confirmed, the second-generation biofuels are expected to produce the other 5 % in volume within the next five years in the European Union. Thus, once the last technological and economic uncertainties are controlled, investments at the industrial scale should be on the raise again.

Future Challenges to Improve the Environmental Balances of Biofuels

Figure 7 (top) presents the greenhouse gases reduction potential for different feedstock of first-generation. These effects are further amplified with better yields per hectare. In the case of second-generation Miscanthus x giganteus, Arundo donax, and Pennisetum purpureum seem the most promising feedstock for achieving high-energy yields (Laurent et al. 2015). Unfortunately, there is neither ideal feedstock nor universal process for the biofuel production process and the performances are dependent on the good adequacy between the feedstock properties and the whole process. In the case of second-generation fuels, the pretreatment step is of particular importance. For instance, depending on the composition of the plant cell wall and in particular the amount of ramifications on the polysaccharides fractions, either the dilute acidic pretreatment for wheat straw or the ammonia fiber expansion for corn stover (Wyman et al. 2005) will perform best (Fig. 7, bottom). Furthermore, in the situation of intensive farming, a high input of nitrogen fertilizer might lead to adverse effects. In fact, ammonia is produced with the Haber reaction at 200–400 bars and 450 °C in the reaction of the nitrogen from air and natural gas. This is both a high energetic costly process and part of the explanation on the relationship between fossil fuels and food crops prices (Esmaeili and Shokoohi 2011).

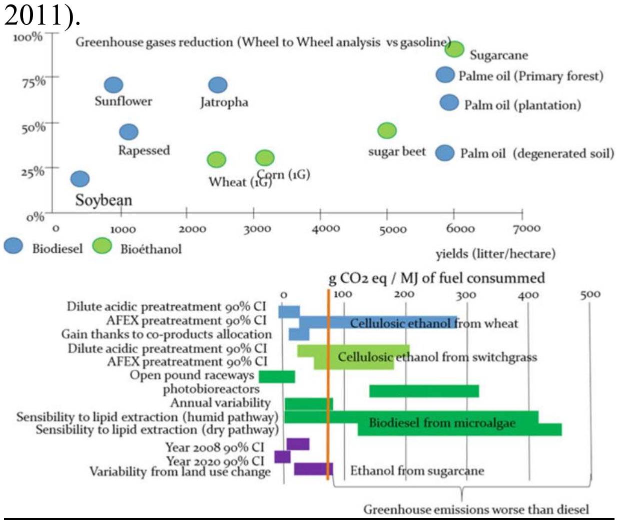


Fig. 7 Comparative assessment of the greenhouse gases reduction potential according to the type of feedstock used (top) and to the type of pretreatment and amelioration potential of the existing technologies. AFEX stands for ammonia fiber expansion. Data compiled from Maurya et al. (2015), Mafe et al. (2015) and Pandey et al. (2014).

Conclusion

Biofuels production processes, whatever the generation, are at the center of industrial ecology principles. In this context, the development of integrated bio refineries combining the best of the first, second, and third-generation processes in one same geographical unit is a promising line to work on. However, even an ideally environmental-friendly energy resource, though large investments and governmental subsidies may have negative indirect effects. This leads to a drop in the prices of fossil resources and makes them even more attractive and used in other parts of the planet. Without any regulation, these financials mechanisms have the side effect of making the efforts obsolete and even counter productive, at least on the global environmental indicators, such as the emissions of greenhouse gases. Therefore, in the absence financial regulatory, the large-scale development of "green fuels" will be just another additional energy to support the global economic activity and never a real alternative associated with the energetic transition. To conclude, the environmental impact of the production of biofuels cannot be tackled without a transparent and standardized collaboration of all stakeholders. They have a common interest to join forces in a holistic research approach that has to be necessarily conducted in a transdisciplinary approach, and not dictated by the sole economic aspects. The development of the biorefinery lies now at a crossroad. It must be refocused on the territorial aspects, especially with the agricultural and forestry sector. It is mandatory to evaluate the actual environmental impacts in terms of waste generation, raw material consumption and regeneration, water availability, and waste recycling processes. This must be done in relation with a geographical context, including all socioeconomic backgrounds, resources avail ability, and short-range markets possibilities. But the virtuous modes of energy generation for the future remain largely to be reinvented.

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