Biofuels for India: what, when and how

Arvind Lali*

DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai 400 019, India

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Introduction

ENERGY requirements of a country fall in two categories: primary and secondary. Primary energy needs of the country imply power requirements to run its industries, and light its houses and offices, while secondary needs imply energy requirements for all the transportation it requires – of its people and goods. In terms of gigawatt equivalents, primary energy needs of India amount to about 250 GW while secondary energy needs amount to about 150 GW. It is also noteworthy that there is an almost 40% slice of total combined need that is met through unorganized renewable resources like burning wood and for heating and cooking purposes. Bulk of India's primary energy needs is met through coal-based thermal power generation, while petro-crude import is required to meet more than 80% of transport fuel requirements. Heavily dependent on import, the transport fuel needs of the country signify its energy insecurity. On the other hand, use of both, coal and petro-oil add to increasing carbon imbalance that the world today struggles to contain.

India has charted for itself an aggressive path towards (a) reducing carbon emissions, and (b) reducing dependency on import of crude oil. The Government has embarked upon an ambitious plan to install 175 GW equivalent of solar power generation by the year 2030. Likewise, wind energy is set for rapid growth. It is argued that with vastly improved batteries for electrical energy storage likely to emerge a reality in the near future, solar electricity may well be used to run vehicles. Nevertheless, while in such a scenario the need for liquid or gaseous transport fuels may decrease and vanish in time, with only half of the primary energy needs being met through solar power by 2030, it seems unlikely that the need for liquid or gaseous fuels is likely to recede within at least the next five decades. Partial or full replacement of petro-derived fuels with renewable fuels must therefore form a priority of the country aiming to reduce carbon emissions as well as ensure some semblance of energy security.

Mandated to blend 5% green biofuels into gasoline (petrol) and diesel by its National Biofuel Policy drafted in 2009, India today has no diesel substitute of note while barely managing to achieve about 3% bioethanol blending in gasoline. Major hurdles have been inadequate manufacturing capacity and non-availability of non-edible vegetable oils and molasses for making biodiesel and bioethanol respectively, the only two renewable fuel alternatives in sight. On the other hand, both molasses-based bioethanol and vegetable or tree-borne oil-based biodiesel though indeed are renewable fuels, fare badly in terms of net energy ratio (NER) and net carbon reduction. Fortunately, use of both these first-generation biofuels is severely limited due to raw material availability, and even at their best both fail to meet the 5% blending requirement of today, let alone the ambitious 20% blending targeted by the Government by the year 2017.

These arguments dictate that India must look towards second-generation advanced biofuels to achieve its target of 10% and beyond in the immediate and near future.

Sufficient waste in India for conversion to 2G-biofuels

USA and Brazil are today the leading countries where renewable fuel programmes have been successful, while Southeast Asia has emerged as a major supplier of palm oil for biodiesel production for use in Europe. Environmentalists and agricultural economists, however, warn that biofuel consumers will need to shift from first generation (1G) biofuels to second generation (2G) advanced

*e-mail: am.lali@ictmumbai.edu.in

biofuels. 2G-Biofuels are defined as those derived from wastes that do not impact the human and animal food chains, and result in more than 60% reduction in fuel carbon emissions compared to equivalent petro-fuel use.

India today can boast of food self-sufficiency alongside a growing young mega-population. Substantial and under-utilized non-fodder surplus agricultural wastes and piling municipal solid waste (MSW) in A-grade to C-grade cities put together have the potential to fully replace petroleum fuel requirements of the country. Rice straw in Punjab and Haryana; cotton and castor stalk in Gujarat and Maharashtra; bagasse and sugar cane trash in Uttar Pradesh, Punjab, Tamil Nadu and Maharashtra; empty fruit bunch in Andhra Pradesh; and bamboo in Assam, Bengal and Odisha all together amount to more than 250 million tonnes of surplus agri-residues. With collection logistics in place, these have the potential to produce more than 75 million tonnes of biofuel equivalent to more than three times the entire petrol consumption of the country. More than 150 million tonnes of MSW already the collected in large to small cities also has the potential to produce more than 40 million tonnes of biofuel. Thus, a 10% target should be quite achievable with these resources. In addition, with cutting-edge technologies under development, biomass generation through algae farming and use of improved marginal-land utilizing energy crops like Napier grass also have significant potential that India must explore to meet its rapidly rising fuel needs. In time, one also expects such technologies to emerge that will derive renewable fuels through direct solar energy utilization to produce hydrogen from water-splitting and hydrocarbons from atmospheric carbondioxide.

There are two aspects that need attention when deciding which renewable fuel product is a preferred option for what end use: (i) the type and availability of a renewable and C-neutral source for conversion to biofuels, and (ii) the type of biofuel product (i.e. partially blendable products or fully fungible fuels). Five ‘renewable resources’ that are abundant in India to meet all our fuel needs are: non-fodder agricultural waste, MSW, forestry waste, carbondioxide from air and power plants, and solar energy (direct or via algae production).

The biofuels of interest can be one or more of the following: (i) Alcohols and others (ethanol, butanol, dimethylether, etc.). (ii) Biodiesel or green diesel (from the above-mentioned feedstocks and not from vegetable fat/oil). (iii) Hydrocarbon/s (biogas methane and higher). and (iv) Hydrogen.

Hurdles to deployment of 2G-biofuel technologies

Technologies needed for the production of second generation and other advanced biofuels have been under development around the world now for over two decades. USA alone has spent several hundred billion dollars since 2000 in promoting development and deployment of 2G-biofuel technologies. Tens of pilot-scale plants were put up and scrapped as improvements are continuously being devised. Three biofuels that have shown potential to find way into markets in the very near future are: 2G-ethanol, 2G-diesel and 2G-bioCNG, all made from biowaste or biomass (i.e. agricultural waste and MSW).

Among these biofuels, 2G-BioCNG or Bio-methane is the one that has taken the fastest strides though using yet sub-optimal technologies. 2G-Ethanol and 2G-diesel can be said to be in a more advanced stage catching up in terms of technology maturity and production cost economics. In USA, according to a report published in *Biofuels Digest* (22 December 2015), the net blended biofuels quantum increased from 4 billion gallons in 2010 to 17 billion gallons in 2015. The share of advanced biofuels also rose from 5% to 20% in 2015, with almost insignificant contributions coming from 2G or cellulosic fuels.

After years of efforts and huge funds spent by both the governments and private industry worldwide, there are eight 2G-ethanol production plants that are in commercial demonstration stages. Based on six different technology platforms, the eight plants, five in USA, two in Brazil and one in Italy, have capacities in the range 250–1500 tonnes biomass/day and with cost ranging from 100 to 450 million USD. However, the technologies deployed in these suffer from three major issues for a country like India: (a) The recommended scales of economy, i.e. biomass processing/day are in excess of 500 tonnes/day and thus are too large for India, where biomass production is mixed and unorganized (due to small farming scales). (b) Most technologies are feedstock-specific and will need pilot trials for varied and different feedstock. (c) The capital costs are too high (Rs 15–20/l ethanol over and above the variable cost of production, which is in the range Rs 30–35/l).

Indian scenario

India has been spending on research in biofuel technologies for more than a decade through CSIR, MNRE, DST and DBT. It was, however, DBT that took a leap in 2007. Shortly after USA set-up its three famous bioenergy research centres (JBEI, BESC and GLBRC), India through DBT set about establishing its own centres for dedicated bioenergy and biofuel-related research and development. Thereafter, MNRE and DST also set up a centre each at Kapurthala and Thiruvananthapuram respectively.

The first DBT bioenergy research centre was set up at the initial cost of Rs 25 crores at the Institute of Chemical Technology (ICT), Mumbai in 2008 with the express mandate to develop, translate and transfer to industry a fully indigenous lignocellulosic ethanol technology. The DBT-ICT Centre for Energy Biosciences today comprises

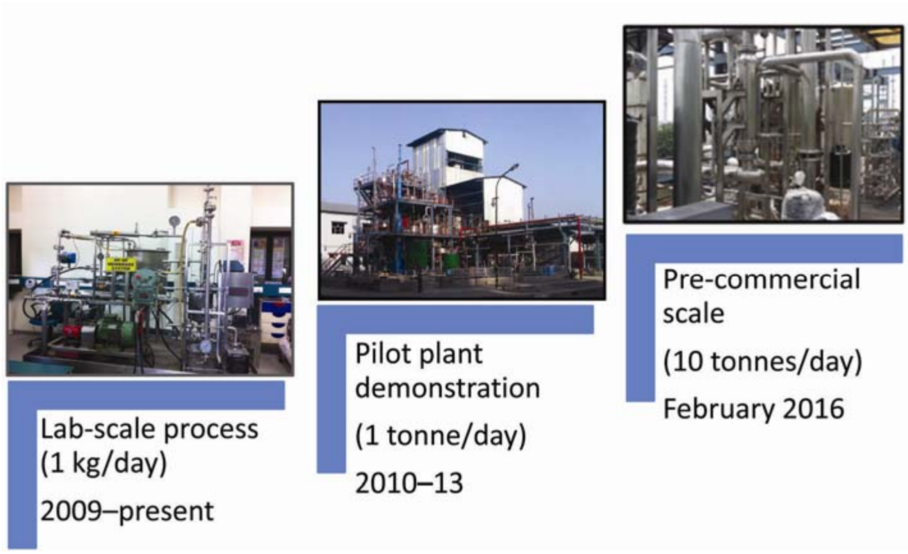

Figure 1. Scaling up the DBT-ICT 2G-bioethanol technology.

a state-of-the-art facility with a work-flow matching the best in the world and more than 100 scientists working on different aspects of bioenergy and bioprocess technologies. The second centre IOC-DBT Centre for Advanced Bioenergy Research was set up in 2012, jointly by DBT and Indian Oil Corporation Ltd (IOCL) at the IOCL Research and Development site at Faridabad, while the third centre, the DBT-ICGEB Centre for Advanced Bioenergy Research, was set up with International Centre of Genetic Engineering and Biotechnology (ICGEB) at their Delhi Campus. The fourth centre, the PAN IIT-DBT Centre for Bioenergy Research was set up in 2014 as a virtual centre involving five Indian Institutes of Technology (IIT-Mumbai; IIT-Kharagpur, IIT-Guwahati, IIT-Roorkee and IIT-Jodhpur). The specific areas of advance biological research deal with enzyme and fermentation technologies utilizing a range of microorganisms, including freshwater and marine algae.

Under a specific mandate and after rigorous efforts, the DBT-ICT Centre at Mumbai has been able to develop an altogether novel 2G-ethanol technology, which after testing at 1 tonne/day scale is now scaled up to a Rs 35 crores demonstration-scale plant of 10 tonnes biomass/day by a private company, India Glycols Ltd at their Kashipur site in Uttarakhand. This plant, built with support from the Biotechnology Industrial Research Assistance Council (BIRAC), is expected to start functioning from February 2016 and will be India's first 2G-biofuel demo plant. The DBT-ICT 2G-ethanol technology has several novel features and is patent-protected worldwide. The technology, devised to overcome all the drawbacks of the contemporary technologies, can produce ethanol from any agricultural residue feedstock, and is relatively low on both CAPEX and OPEX.

Imminently scalable, the globally competitive DBT-ICT technology is ideally suited to Indian conditions as it is feedstock agnostic and can operate well at any scale upwards from 100 tonnes biomass/day. The salient and advantageous features of the DBT-ICT technology compared to the other technologies in the fray are:

(1) The DBT-ICT technology and plant design is feedstock-flexible, i.e. any biomass feedstock from hard wood chips and cotton stalk to soft bagasse and rice straw can be processed.

(2) It is a continuous processing technology and is able to convert any biomass feed to alcohol within a space time of 18 h. All other technologies take 5–7 days.

(3) As a result the capital costs required with the DBT-ICT technology are almost one-third compared to other technologies and the plant becomes a compact one.

(4) The unique enzyme technology developed and deployed here involves an enzyme cost that is one-fifth that incurred by competing technologies.

(5) The DBT-ICT technology does not generate any toxic by-products and hence is safe for the process enzymes and microorganisms used for fermentation to ethanol. Other technologies generate toxic substances and have to design steps to dispose or find uses of by-products.

(6) The DBT-ICT technology recycles all the water in the process and does not generate any effluent unlike sugar distilleries.

The current Government has taken upon itself to give a huge push towards deployment of cutting-edge technologies for 2G-biofuel production. Special support instruments both in terms of capital funding as well as product promotion are being devised to give a boost to biofuel production. Different ministries (MNRE, MoPNG and

MoS&T) are working in close coordination with oil marketing companies and various research centres, universities as well as commercial technology providers to ensure that India is well on the path towards significant biofuel production and use by the year 2020.

Given the complexity of the feedstocks, except for carbon dioxide and solar energy, it is unlikely that the desired biofuels could be produced by any well-defined chemical catalysis. Involvement of one or more biological conversion methods is essential in all cases. India needs to invest heavily and smartly in biofuel technology development and deployment. The technologies that need attention on fast track and mission mode basis are: (i) Ethanol (gas and liquid fermentation from biomass and MSW). (ii) Biodiesel (from algae grown on sunlight and carbon dioxide). (iii) Hydrocarbon/s (including terpenes and methane by fermentation of biomass and MSW). (iv) Hydrogen (solar or fermentation of biomass and MSW; catalytic conversions of biomass and MSW).

Essential features of any sustainable technology suitable to India must be: (i) Fuel production at competitive cost. (ii) Low CAPEX and deployable at medium scale (~100–250 tonne/day). (iii) Feedstock agnostic technology. (iv) Zero waste generation and low water consumption.

DBT can take pride in assuming a leadership role in promoting biosciences so very essential and central to almost all biofuel technologies. The academic and industrial research community is slowly waking up to the rigorous demands of a potentially successful biofuel technology. The industry is also beginning to show signs of willingness to undertake risks with emerging federal financial support. It is hoped that the country will be in a position to develop, deploy and operate indigenous advanced biofuel technologies within the next decade.

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