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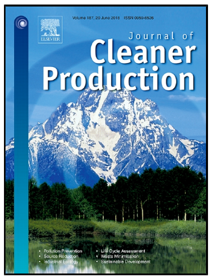

Biofuel policy in India: A review of policy barriers in sustainable marketing of biofuel

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PII: S0959-6526(18)31360-X

DOI: 10.1016/j.jclepro.2018.05.033

Reference: JCLP 12890

To appear in: *Journal of Cleaner Production*

Received Date: 10 October 2017

Revised Date: 02 May 2018

Accepted Date: 03 May 2018

Biofuel policy in India: A review of policy barriers in sustainable marketing of biofuel

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Abstract

Global warming issue due to the combustion of fossil fuel pushes the world to produce renewable and environmental friendly energy from sustainable feedstock. There are several measures on different levels to reduce the global warming including clean energies from wind, solar, and biomass. There are different aspects in bringing these technologies into a reality including development of technology, economic feasibilities, environmental sustainability and finally, support from the government in the form of effective policies and public awareness. Adequate R&D efforts could overcome all the factors but only an effective policy could drive those efforts to reality. Therefore, in this connection this review initially addresses the present state of energy demand, progression of biofuel sources and the bottlenecks in microalgal biofuel production and commercialization. The biofuel policies are essential to change the world's dependence on fossil fuels for a better tomorrow. Hence, this review addresses the salient features of National Biofuel policy of India that helps in regulating the biofuels production and their marketing. As a part of Policy implementation, government of India introduced several schemes and programs in last two-decades, which includes mandate blending of ethanol with gasoline, diesel with biodiesel, for the future clean energy vision, and incentivizing bio-based products/fuels. In addition, participation of both federal and state governments for clean energy initiatives, capital investments and tax credits were described in detail. Many policies lack easy outreach among public and industries, which needs marketing by the government that secures a clean energy future in India. Though India is in the process of evolution, it might be quite difficult to enact a dedicative legislation to deal with the challenges of biofuel marketing. Therefore, recent initiatives and scope were summarized in this review for future endeavors.

Keywords: Biodiesel; Energy demand; India; Microalgae; Biofuel Policy; Policy barriers

1. Introduction

1.1. Rationale of energy demand and green energy projections

The word 'energy' was believed to be derived from the ancient Greek '*energeia*' meaning activity or operation and as the time went by, the definition of energy has been changed according to the field. On the subject of biology, energy can be associated with biological systems, where cells retain energy in the form of tiny molecules like carbohydrates, lipids, and proteins. Energy is conserved in systems, meaning that it can neither be created nor destroyed but it is interconvertible into different forms. Energy can be obtained from many ways but are limited (Fig. 1).

Energy is one of key requirements of modern lifestyle and is currently the most precious commodity required by consumers and various industries worldwide. It is the main component, which directly commands the economic growth of a country (Cleveland et al., 2000). The relation can be understood as higher the energy availability the better the growth of a nation. Energy and per capita gross national product (GNP) has a strong correlation where the country with higher GNP consumes more energy per head (Stern, 2011). Over population and high usage of goods indicated that requirement for energy increases steeply. The exponential escalation of energy was initiated by burning fossil hydrocarbons, with coal supporting the nineteenth century, followed by oil in the twentieth century, and now, sustained by natural gas (Hall, 2016; IEA, 2016; Sayre, 2010). The world total primary energy supply (TPES) from 1973 to 2016 is given in Fig. 2. TPES states that consumption of energy was raised from 6101 Mtoe (Million tons of oil equivalents) in 1973 to 13699 Mtoe in the year 2016 with almost a rise by 124%, indicating the demand for energy. On the social note, energy is essential for economic and sustainable development of any country. Presently, major fraction of energy being used is derived from fossil fuel. Worldwide, dwindling of fossil fuel reserves to fuel price hike (Monari et al., 2016), and rocketed emission of greenhouse gases (GHG) to global warming are the twin threats in the transportation sector (Reyimu and Özçimen, 2017; Hashim et al., 2017; Lecksiwilai et al., 2017). Though fossil fuels are globally valued for power generation, the combustion process of these fuels resulted in various unfavourable consequences like pollution (Liu et al., 2017). Compounds like Sulphur dioxide (SO_2), Nitrogen Oxides (NO_x), ground-level ozone, particulate matter (PM), carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOC) and some other heavy metals are commonly observed the aftermath of fuel consumption (Table 1).

The global emission of CO_2 during the last decade was increased by 2.5% per year resulting in 2 ºC increase in the world's temperature (Friedlingstein et al., 2014). In 2015, around 194 countries signed at the Paris Climate Conference (popularly known Paris Agreement) which aims (a) to bring down the global temperature increase by 2 ºC (b) to limit the greenhouse gaseous emission and (c) explore alternative energy sources. It is also known that the reserves for the fossil fuels are getting depleted and can only cope with few more generations. To protect the environment and to curb the energy demand in the near future, it is imperative to look for renewable, eco-friendly fuel options (Dresselhaus and Thomas, 2001). Due to the energy demand and environmental hitches associated with fossil fuel usage, exploration of alternative and economically feasible sources are being carried out (Rodolfi et al., 2009). In the meadow of renewable energy sources, biofuel – liquid or gaseous non-toxic fuel produced from various biological material gained prominent attention due to reduced emission levels compared to diesel (Tsolcha et al., 2017; Bildirici, 2017). However, sustainable marketing of biofuel into energy market depends on various factors; one of the key elements is policy or legal guidelines and therefore, marketing of algal biofuel would become realistic by establishing transparent policy frameworks, subsidies and mandates. In this juncture, each country has framed its own policies to regulate and improve the penetration of biofuel in the energy market. For instance, the US Government has started its research support for the commercialization of algal-based fuel as the Senate Committee approved a Bill in August 2012 which states tax credit of cellulosic fuel includes algal fuel (Su et al., 2015). Until the Bill is approved, research and development of algae biofuel was benefited from private grants and grants raised through a tie-up with oil companies. Environmental Protection Agency (EPA) and Renewable Fuel Standard (RFS2) established advanced biofuels mandate based Energy Independence and Security Act (EISA) agenda for commercial scale production of algae (Ferrell and Sarisky-Reed, 2010). According to the mandate, by 2022 transportation fuels in the US should contain minimum 36 billion gallons of renewable fuels, and further, at least 21 billion gallons of fuel should be produced from non-corn, cellulose and other biomass sources (Ziolkowska and Simon, 2014). However, any policy might possess certain regulatory gaps that enable political system to endorse contradictory objectives; notably, certain algal enterprises could syndicate biofuels sector with pharmaceuticals production or bioremediation, and thus, it is quite difficult under which category it should be placed (Benson et al., 2014). In concern with the biofuel policies of various countries, the importance of the biofuels has been firstly acknowledged by Brazil, the US, and the European Union, and the situation is now turned towards the Asian countries (Mohan et al., 2006). The success of Brazilian biofuel programs was strongly supported through strict legal mandates and effective implementation (Mohan et al., 2006). In concern with India, National Policy on Biofuel has been adopted in 2008 to regulate the marketing of biofuel in India through firm, transparent and effective manner with standard legal guidelines.

However, Brazil's success cannot be replicated in India due to the seasonal variation and frequent failure of monsoon. Last 15 years, Government of India has adopted number of policy measures to promote the use of biofuels. To achieve the policy targets, the most efficient operative policy strategies need to be ascertained by studying contextual information of the fuel market, dynamics of present-day transport fuel, and policy simulation scenario (Barisa et al., 2015).

Hence, the objectives of this review article aim

(i) To provide insights on the rationale of evolution of biofuel generations and the negative criticism or limitations of various biofuel feedstocks,

(ii) To present microalgae-based biofuel as a paradigm towards next generation sustainable green fuel,

(iii) To summarize the biofuel policy in India including the ethanol blending program, biodiesel program, and policy barriers by endeavoring in-depth analysis of the National Policy on Biofuels, 2008,

(iv) To thoroughly assess the different strategies, interventions and incentive schemes highlighting the key constraints, challenges, and measures that need to be taken to enhance the bioenergy potential in India,

(v) Finally, recent advances, strategic tasks and scope on this front including algal bioenergy were emphasized, which would help the policy makers, industrialists and researchers address the concern that leads to energy security for India in future.

2. Methodology

Commercially viable biofuel production with a better biofuel policy measures are urgent need of this decade and therefore, analysis and review of various policies adopted by different countries including India and its enforcement challenges thereof had been taken as a core discussion for this review. In this connection, high-energy demand and its outlay with inadequate fossil fuel reserves can be traced in past decades, which have comprehensively presented in this review from a plethora of scientific literature by probing global energy projection, energy demand outlook and historical evolution of renewable energy deployment.

Further, emphasis on microalgal biodiesel production and its limitation has been given by reviewing the articles using advantages and constraints of algal biofuel production, policy barriers in biofuel commercialization as keywords. Further, numerous research and review articles were collected and analyzed based on India's stance on biofuel production, biofuel policy in India, policy issues and recent development to draft this state of the art review. To meet and elaborate the core content and objectives of the review, this study employs doctrinal methods. It primarily depends on the text, interpretation and detailed assessment of the primary sources such as Indian Power Alcohol Act, 1948; the Air (Protection and Control of Pollution) Act, 1981; the Environment (Protection) Act, 1986; the Motor Vehicles Act, 1988; Ethanol Blending Programme, 2002; National Biodiesel Mission, 2003. In particular, the review delivers comprehensive analysis of National Policy on Biofuels, 2009 by retrieving and interpreting various official documents and government reports. The observations of other secondary sources such as the Planning Commission Report, 2003; Standing Committee Report, 2015 would also have taken to form the basis of this review. Recent amendments to blending mandate of policy frameworks of India have been summarized by analyzing news reports like the Economic Times, 2017; the Hindu, 2016. By and large, the review and research articles cited in this review manuscript not only cover the span of 2010 to present, but also systematically articulated the developments and key obstacles in the selected topic to convey the provisions for further progress.

3. Evolution of biofuel and its bottlenecks

Biofuel is a nontoxic fuel derived from the various biomass feedstocks, and can be used as a substitute for environmentally unsafe fossil fuels (Voloshin et al., 2016). As shown in Table 2, a variety of biofuels were produced by various countries from biomass such as bio-ethanol, biodiesel, hydrogen and methane. Biofuels have evolved as one of the most important sustainable sources by limiting the emission of GHG and thereby improving the air quality (Huang et al., 2012). The key advantages of biofuels over fossil fuels (i) Biofuels are sustainable and renewable (Razzak et al., 2013); (ii) The toxic compounds or gases released into the atmosphere upon combustion of biofuel are minimum (Surriya et al., 2015); (iii) The CO_2 emission is equilibrated or neutral as the organism produces biomass by sequestering the released CO_2 (Razzak et al., 2013; Surriya et al., 2015).

As shown in Fig. 3, biofuel production is classified into various generations (Hombach et al., 2016; Correa et al., 2017). Sugarcane, molasses, cereal crops, sugar beet, and sweet sorghum are widely used first generation feedstocks for bioethanol production (Hemaiswarya et al., 2012). Furthermore, corn, wheat, and barley are also used to produce bioethanol and biomethanol by fermentation (Voloshin et al., 2016). In concern with second-generation feedstocks, non-edible oils from *Jatropha curcas*, *Pongamia pinnata*, *Hevcca brasiliensis*, *Calophyllum inophyllum* are commonly used for biodiesel production (Hemaiswarya et al., 2012). Oil yield from Jatropha was calculated at about 1,500 L /hectare of rain-fed land with 4,400 plants and therefore, three million hectares Jatropha plantation is needed to replace 10% petro-diesel (Hemaiswarya et al., 2012). As reported by Maity et al. (2014), straw, wood, and grass are also considered as second-generation feedstocks for syndiesel production. In addition to Jatropha, it is estimated that palm and Rapeseed could yield 5950 and 1190 L oil per hectare per year respectively (Trivedi et al., 2015; Ziolkowska and Simon, 2014). With respect to biodiesel yield, soybean oil, Jatropha oil and sunflower oil were able to yield 96, 84.5, and 96 % biodiesel respectively by catalytic transesterification (Sivaramakrishnan and Incharoensakdi, 2017). First generation feedstocks (bioethanol from fermentation of starch or sugar and biodiesel from transesterification of oil from edible crops) and second-generation feedstocks (*Jatropha*, *Cassava*, or lignocellulosic materials) are encumbered with several issues even though blending mandates and tax credit policies have allowed few feedstocks to energy market (Doshi et al., 2016).

The major limitations of first and second generation feedstocks include (i) imperiling food security due to tradeoff between food vs fuel through resource allocation, (ii) surplus land requirement and agricultural inputs, (iii) high capital cost and uncompetitive retail prices (Demirbas, 2008; Hill et al., 2006), (iv) low net energy returns, (v) higher claims over gaseous emission reductions (v) low productivity over seasons (Doshi et al., 2016; Juneja et al., 2013). To overcome the negative consequences of first and second-generation feedstocks, researchers were eyeing for alternate feedstocks, and then identified a third-generation feedstock or next-generation feedstock known as algae, which connotes several pros as it, does not depend on edible crops, does not emit high gaseous pollutant, does not demand surplus fertile land and fertilizer supplements (Mackenzie, 2013; Kim and Lee, 2015).

Various macroalgae feedstocks are used for biofuel production such as *Enteromorpha compressa, Cladophora glomerata, Ulva lactuca, Laminaria* sp., *Macrocystis pyrifera, Durvillea Antarctica* (Chen et al., 2015; Xu et al., 2014). *Laminaria japonica* (sea tangle) is a brown macroalgae that has been used by Xu et al. (2014) to produce biofuel. The macroalgae *Oedogonium* sp. was reported to yi4eld 88% of biodiesel within 2 h reaction time (Sivaramakrishnan and Incharoensakdi, 2017). Third generation feedstocks are mainly used to produce biodiesel - a non-toxic, biodegradable, carbon neutral, long chain alkyl esters, virtually free of Sulphur, aromatics and its properties are close to gasoline and therefore, it can be used in diesel engines with slight or no modifications (Luque, 2010). The biodiesel yield and catalyst used for the production of biofuel from first, second and third generation feedstocks with high free fatty acids content have also been discussed in Table. 3.

3.1 Microalgae - a paradigm to sustainable green fuel

Microalgae offer social, economic and environmental benefits as a conceivable third generation biofuel feedstock over terrestrial oleaginous crops owing to their high areal and volumetric biomass and lipid productivity, ability to acclimatize and grow in all types of water, potential to be cultivated throughout the year irrespective of seasonal variations, non-competence with food production (Ziolkowska and Simon, 2014; Ribeiro et al., 2017).

As presented in Table 4, microalgae possess high lipid content compared to other oleaginous crops on the market till date, i.e., annual production of algal oil can be 300, 130, 50 and 10 times higher than corn, soybean, *Jatropha*, and palm per ha. Also, algae have very fast growth rate, about 20–30 times faster than food crops with short doubling time, which further allows several harvesting cycles in a short span (Chisti, 2007; Schenk et al., 2008; Ziolkowska and Simon, 2014). Microalgal biodiesel fuel is considered to be a potential fuel to avert climatic hitches and is the substitute that can be sustained for an extended period of time to satiate the energy demand of the human population. Further, it is a carbon-neutral fuel, i.e., the amount of CO_2 emitted into the atmosphere upon combustion of biodiesel is assimilated by algae itself- (Ziolkowska and Simon, 2014).

In addition to the advantages of microalgae's innate attributes, implementing and marketing microalgal based biodiesel would deliver various constructive social profits. Positively, a commercial algae-based fuel production system named Algenol, Southwest Florida open up thousands of jobs in 2013, and it further projected the cost of bioethanol production is a dollar per gallon. As environmental benefits, algae will mitigate or sequester 2 g of CO_2 to generate 1 g biomass through its photosynthetic machinery and thus, one ton of CO_2 can be converted into 60–70 gallons biofuel coupled with huge reduction in GHG emission (Hirayama et al., 1998; Hon-Nami, 2006). Generally, algae with 30% lipid can produce 1.6 billion gallons biodiesel (Ziolkowska and Simon, 2014). Further, algal fuel can be implemented as 'drop-in fuels', by which it can be blended with gasoline, jet fuel and diesel.

Regarding economic advantages, algae can be used for the extraction of industrially important co-products through integrated sequential biorefinery process (Fig. 4). Lipid and carbohydrate can be used in fuel production such as gasoline, bioethanol, biodiesel, biogas, jet fuel and hydrocarbon, whereas protein can be used in food, feed and nutraceutical industries, biofertilizers, industrial enzymes, surfactants (Griffiths et al., 2011; Yen et al., 2013). Another economic benefit is algae can grow well in freshwater, seawater, brackish water, sewage water (Cheng and He, 2014; Mata et al., 2010; Mathimani et al., 2017). Microalgae compete neither with portable water nor with arable or fertile land for their cultivation. It is worth mentioning fact that offshore or near-shore cultivation of microalgae for biofuel might avert the land requirement. To replace the fossil fuel by algal fuel, 15,000 (0.42 %) square miles land of total US is required, which is > 1/7th of corn cultivation area (Ziolkowska and Simon, 2014). In this scenario, transparent and easy policies benefitting industries, the public and government are required to regulate and to efficiently use the biofuel. Certain government, has given cost-sharing privileges to decrease the investment risk and also to bring down the subsidies of complete biodiesel production process, i.e., from feedstock experiments to industrialization of biofuel (Su et al., 2015).

As discussed earlier, the biofuels are considered as a panacea for energy insecurity, climate change, and many other complex problems (Pradhan and Ruysenaar, 2014). Therefore, the success of biofuel program has been driven by the effective and efficient biofuel policies. Following the success of Brazil, other developing countries including India also prepared a roadmap to encourage biofuel projects, blending targets and providing subsidies through mandates, missions and biofuel policies. It is in this connection; the next sections will make an in-depth analysis of legal framework governing biofuel in India.

4. The historical perspectives of the biofuel legislation in India

The first legislation on biofuel in India can be traced back to 1948 when the Parliament enacted *Indian Power Alcohol Act,* 1948 (Act No. 22 of 1948). The primary objective of the Act was to provide necessary access for the development of the 'power alcohol' industry in India (Cleveland and Morris, 2013). The Parliament had repealed the Act in 2000 (Indian Power Alcohol (Repeal) Act, 2000). Eventually, the Ministry of Petroleum and Natural Gas (MoPNG) had issued a notification on the *Ethanol Blending Programme* (EBP) in 2002. The notification mandated 5% blending of ethanol with petrol in nine major sugarcane producing States and three Union Territories from January 2003 (Amit Aradhay, 2010). The EBP has been unsuccessful due to the unavailability of sugar molasses, failure to adopt ethanol pricing formula, procedural delays by State agencies, delayed procurement, and various other reasons (Ray et al., 2011). Major developments taken place during the EBP are described in Table 5.

4.1 Biodiesel programme

Given the welfare of rural employment and green energy resources, the government of India is longing to implement biodiesel programme effectively. In order to attain this objective the government had constituted a *Committee on Development of Biofuel* under the leadership of Planning Commission in July 2002, and the Committee submitted a report in July 2003. Based on the report, the government of India has launched *National Biodiesel Mission* (NBM) in 2003, the Mission has a special focus on the cultivation of *Jatropha* on wastelands, and it has identified the Ministry of Rural Development (MoRD) as a nodal ministry. The report also reckoned that around 13.4 million ha of land could be available for

Jatropha cultivation. Various other pertinent developments and implementation of the NBM are discussed in Table 5.

The NBM has to accomplish its goals in two different phases. Phase I consists of experimentation and demonstration, which had to be implemented by 2006-07 (Kumar Biswas et al., 2010). Phase II was proposed for nursery development, seed procurement, and oil extraction plants, installation of transesterification plant, blending and marketing of biodiesel (Bandyopadhyay and Das, 2014; Kumar Biswas et al., 2010). Both public and private sectors, State agencies, domestic and foreign research institutions were encouraged to achieve the targets of the Mission during the second phase.

In 2005, the MoRD prepared a detailed Project Report and submitted it to the government of India for consultation of the pilot phase of biofuel feedstock crops such as *Jatropha*, and *Pongamia* (Mohan et al., 2006; Raju et al., 2012). During the intervening period, the MoPNG (in October 2005) had announced the *Biodiesel Purchase Policy*, which ensures the purchase of biodiesel by oil marketing companies (OMC) at the rate of Rs. 26.50 per litre (inclusive of all taxes), with effect from January 1, 2006. The OMCs shall procure biodiesel that complies the prescribed biofuel standards laid down by Bureau of Indian Standards (BIS), and the purchase shall be done only through the identified (twenty) procurement centres. Howbeit, the cost of biodiesel production was 20% to 50% higher than the price set out in the purchase policy. The current position of biodiesel production is minimum, and thus, the proportion of yield is lower than the production costs.

Law related to Agriculture falls under the Entry 14 of the List-II (State List) in the Schedule Seven of the Constitution of India. It enables only the Legislature of State to enact law relating to Jatropha plantation. Therefore, the central government-owned petroleum companies and private sector firms have to sign memoranda of understanding with respective State government for the promotion of Jatropha plantation on government wastelands or through contract farming with small farmers. However, only a few States such as Rajasthan, Tamil Nadu, Andhra Pradesh, Chhattisgarh, Odisha, Uttarakhand, and Karnataka have been actively taking part in the biodiesel mission to promote Jatropha plantation through various incentives and policies (Venkataraman, 2012). The progress of the NBM was disrupted due to several factors such as unavailability of Jatropha seed production, deficient in seed collection and extraction, and lack of confidence building among farmers and industry players. It is pertinent to note that whatever minuscule biodiesel produced was sold to the unorganized sectors for the purpose of agriculture and irrigation pumps, and to carry out experimental projects by automobile manufacturing companies (Bandyopadhyay and Das, 2014). There has been negligible commercial production and sale of biodiesel across the notified procurement centers. It is estimated that biodiesel production cost is Rs. 13.5/litre, which is higher than the rate notified in the purchase policy *i.e.* Rs. 26.50/litre, therefore the Biodiesel Purchase Policy was unlikely to be implemented (Kumar et al., 2012).

On the other hand, government study proclaimed that farmers had failed to adopt scientific cultivation and maintenance methods for Jatropha plantation, which resulted in a low Jatropha seed yield (Pradhan and Ruysenaar, 2014). It has also revealed that availability of seeds and seed oil content was not properly recorded and maintained. However, most of the biodiesel units were not in function, many others were shut down due to above-said reasons. Therefore, the National Biodiesel Mission had not materialized and finally, put an end. Biodiesel Purchase Policy also seems to be a failure because of 'unrealistic purchase price' and unenthusiastic response from OMCs (Kumar Biswas et al., 2010). The National Mission on Biodiesel was introduced back in 2003, but the government had failed to adopt formal biofuel policy until 2008. As a consequence of these developments, several demands have been raised from all the quarters to revamp the Indian Biofuel Programme. These situations led the Government of India to adopt the 'National Policy on Biofuels' in

September 2008, and the Union Cabinet approved the Policy on 24 December 2009. It is in this connection, the next part endeavours to make a depth analysis of the National Policy on Biofuels, 2008, and also to identify the impediments that policymakers have to address in order to achieve the goal in future.

4.2 Salient features of the National policy on biofuels, 2008

i. The Biofuel Policy achieves at mainstreaming of biofuels, and envisages the main role for energy and transportation sectors in India. The national indicative target of 5% blending by 2012 and 10% by 2017 and 20% after 2017 has been recommended in the Policy. The main objective of the Policy is to cater biofuel demand and to ensure the availability of a minimum level of biofuels across the country (Chandel et al., 2017).

ii. The policy strives to accelerate optimum utilization of non-edible oil feedstocks for production of biofuels in India. To tackle the *fuel v food* controversy, the key feature of the policy is to produce biofuels from non-food feedstocks to be raised on waste, degraded and marginal lands (Murali et al., 2016; Rajagopal, 2008).

iii. Both biodiesel and bioethanol have to be brought under the ambit of 'declared goods', which ensure the unimpeded movement of biofuels across the territory of India. In order to attract foreign direct investment (FDI), the policy allows 100% equity for the development of biofuel technology (Chandel et al., 2017).

iv. National Biofuel Coordination Committee would be constituted under the leadership of the Prime Minister, to provide policy guidance and coordination.

v. To set up Biofuel Steering Committee under the chairmanship of the Cabinet Secretary to oversee the implementation of the Policy. Also, several ministries are involved in the promotion, implementation, and development of the Biofuel Policy-making process, the specific role assigned to the concerned Ministries are discussed in Table 6.

5. In-depth analysis of the National policy on biofuels

5.1 Objectives of the policy

The preamble of the Policy stress upon the negativities of conventional or fossil fuel resources, and the need for an effective use of renewable energy resources. India is considered as one of the mega-biodiversity rich nation, also blessed with abundant renewable energy resources. India's international commitments arising out of International Conventions, such as the United Nations Framework Convention on Climate Change, 1992; the Convention on Biological Diversity, 1992; and also acceded to the Kyoto Protocol, 1997 have legally binding India to limit and reduce the greenhouse gas emissions and to promote sustainable development. In order to address these concerns, biofuels are identified as 'a ray of hope' in fulfilling India's energy security (Preamble of the Biofuel Policy). The key feature of the Policy is to produce biofuels from non-food feedstocks to be raised on waste, degraded and marginal lands, to overcome the debate of food security *v* fuel production (Murali et al., 2016). In this context, Biofuel policy strives to accelerate the selection and utilization of resilient non-edible feedstock for biofuel production in India. Eventually, this Policy has also laid down a roadmap for the medium and long-term goal towards the progression of biofuels, and correspondingly proposes a strategic framework for technological, financial and institutional enabling mechanisms (Sorda et al., 2010; Ravindranath et al., 2011).

5.2 Strategy and approach for the development of biofuels

The scope and objectives of the Policy is restricted to biodiesel, bioethanol, and other biofuels described in Para 3.2 of the National Policy on Biofuels, 2008. Only non-arable lands would be utilized for the cultivation of non-edible oilseeds for production of biodiesel. The bioethanol shall be mainly produced from molasses (Sengupta and Poddar, 2013). Farmers, landless labourers, cultivators, and even companies also encouraged to cultivate feedstock for biofuels. Such plantation would be supported through a Minimum Support Price (MSP) to the growers in the way of financial incentives, subsidies, and such measures would be revised from time to time (Blanchard, 2015; Raju et al., 2012).

5.3 Interventions and enabling mechanism

5.3.1 Plantations

Over 400 species of trees bearing non-edible oilseeds has been identified by the Policy in India, the possibility of all these species will be utilized for production of biofuels. For the use of non-arable land, farmers shall undertake proper permission from the local communities. The provisions of the Panchayats (Extension to Scheduled Areas) Act, 1996 shall be respected in the 'Scheduled Areas', where the majority of the population is tribal communities. These areas are identified in the Fifth Schedule of the Constitution of India. It is pertinent to note that the employment provided in the plantation of non-edible oilseeds would be eligible for coverage under the Mahatma Gandhi National Rural Employment Guarantee (MGNREGA) Act, 2005. The Policy shall ensure the Minimum Purchase Price (MPP) for the purchase of oilseeds and to be implemented with periodic revision (Paras 5.1-5.5 of the National Policy on Biofuels, 2008; Patel et al., 2014).

5.3.2 Processing

The Policy encourages the Government of India to establish a 'National Registry', which is responsible for development and maintenance of necessary data on the availability of biodiesel and bio-ethanol, and the blending levels would be reviewed periodically on the basis of these data. The blending levels have to satisfy the BIS specification requirements and certification standards. Therefore, processing industries and the OMCs have to jointly set up an appropriate mechanism for this purpose. The automobile engine manufacturers are allowed to make necessary modification in the existing engines 'to ensure the compatibility with biofuels', Section 52 of the Motor Vehicles Act, 1988 also allowed such alteration in motor vehicles (Paras 5.6-5.10 of the Policy; Ray et al., 2012).

5.3.3 Marketing and financial incentives

The storage, distribution, and marketing of biofuels are undertaken by OMCs in India; these activities need to be monitored through the existing mechanisms. The MPP for biofuel shall be determined by the Biofuel Steering Committee (BSC) and decided by the National Biofuel Coordination Committee (NBCC). These Committees have to consider the 'entire value chain' while determining the MPP for bio-diesel, and in the case of bio-ethanol, the 'actual cost of production and import price of bio-ethanol' shall be considered (Paras 5.11-5.12 of the Policy). The OMCs would be duly compensated by the Government, in the event of diesel or petrol price shortfall below the MPP for biofuels (Ray et al., 2012).

National Bank of Agriculture and Rural Development (NABARD), Indian Renewable Energy Development Agency (IREDA), Small Industries Development Bank of India (SIDBI) and other financing agencies are required to provide financial assistance for plantation of non-edible oil feedstocks, to set up oil extraction and processing units for production of biofuels. It is significant to note that the Foreign Direct Investment (FDI) up to 100% is allowed under the automatic route for biofuel technologies and projects, provided that the biofuel shall be used for domestic consumption only. However, the FDI participation is strictly prohibited for plantation of non-edible oilseeds (Paras 5.13-5.15 of the Policy). The Policy encourages the Government of India to constitute 'National Biofuel Fund' for providing financial incentives, subsidies, and grants for new and second-generation feedstocks. No Central taxes and duties shall be levied on biodiesel and bio-ethanol, except 16% concessional excise duty for bio-ethanol. Other special concessions also provided for setting up bio-oil extraction plant and processing units. It is pertinent to note that import of biofuels shall be permitted to the certain extent, decided by the NBCC, and the exportation of biofuels can be permitted only after fulfilling the domestic requirements (Paras 8.1-8.2 of the Policy). Unlike in other countries, Indian Policy does not provide any additional incentives for biofuel blenders and retailers (Bandyopadhyay and Das, 2014).

5.3.4 Research and development and quality standards for biofuels

A major shove of the Policy would be given to the innovation, research, and development (R&D) in the field of biofuels. The primacy would be given to the indigenous R&D, and intellectual property would be respected and protected wherever necessary. The educational institutions, research centers, and industries are emboldened to perform collaborative research work, and the necessary grants would be provided in this regard. Transfer of technology and know-how shall be facilitated in order to achieve the global competitiveness (Para 5.19-5.22) The Bureau of Indian Standards (BIS) has laid down the standards, *IS-15607* for bio-diesel and *IS: 2796: 2008* for bio-ethanol, which are adopted from American Standard, *ASTM D-6751* and the European Standard, *EN-14214*. The BIS has to review the existing standards from time to time to develop new standards in compliance with international standards (Paras 6.1-6.2).

5.4 Effective participation of the State Government

The Policy encourages effective participation of the State Government in planning and implementation of Biofuel programmes. The State Governments are required to adopt a biofuel policy and to create a nodal agency for promotion of biofuels (Paras 9.1-9.2 of the Policy). In pursuant to the National Policy on Biofuels, various State governments have been actively involved in the promotion of biofuel programme in India. Various States such as Rajasthan, Tamil Nadu, Andhra Pradesh, Chhattisgarh, Odisha, Uttarakhand, and Karnataka have already drafted biofuel policies and vision statements, and some of them are in the pipeline. The summary of the state-specific policies are discussed in Table 7.

5.5 Institutional mechanism

The National Biofuel Coordination Committee (NBCC) would be constituted under the leadership of the Prime Minister; this committee would provide high-level coordination and policy guidance. The NBCC has to conduct a regular meeting in order to monitor and to implement the biofuel programmes effectively. The NBCC is comprised of the Deputy Chairman of Planning Commission, Ministry of New and Renewable Energy (as coordinating Ministry), Ministry of Rural Development, Ministry of Agriculture, Ministry of Environment and Forests, Ministry of Petroleum and Natural Gas, Ministry of Science and Technology, and Secretary of the Ministry of New and Renewable Energy (Para 11 of the Policy). Biofuel Steering Committee (BSC) would be established under the chairmanship of the Cabinet Secretary to oversee the implementation of the Policy. The BSC comprises of eleven Secretaries from various Ministries and Departments of the government of India. At the national level, several ministries are involved in policy making, promotion and development of biofuels, each Ministry has to coordinate with one another. The specific roles assigned to the concerned Ministries are discussed in Table 7. Quite a lot of programmes were introduced to inspire the cultivation of biofuel crops throughout the India. For instance, the Ministry of Agriculture introduced *Integrated Development of Tree Borne Oilseeds Scheme*, which provides a subsidy to the farmers and Non-governmental organizations for the cultivation of tree- borne oilseeds (Dalemans et al., 2018; Raju et al., 2012).

5.6 Overview of biofuel policies of various countries and key constraints to achieve targets set under the biofuel policy of India

Even after a decade of the efforts in promotion and development of biofuels, India's achievement did not perform well. India has made little progress on this ground while comparing with other countries (Kumar Biswas and Pohit, 2013). For instance, the US has endorsed a sequence of renewable energy legislation entailing tax policies, financial supports and loan assurance for the construction of biofuel plants (Su et al., 2015). The Energy Policy Act, 2005 has enacted to contribute 4 billion gallons biofuels in transport sector by 2006 (Sorda et al. 2010), and Energy Independence and Security Act, 2007 sets a target of 18% renewables in transport fuel consumption by 2022 (Yacobucci and Bracmort, 2010). Further, Biomass Program, 2008 was framed to reduce the gasoline consumption to 30% by 2030 and increase corn based bioethanol production (Sorda et al., 2010).

As a part of the EU Directive 2009/20/EC the European Union has endorsed a renewable fuel requirement of 20% and 10% as gross domestic consumption and transportation sector respectively by 2020 (Czyrnek-Delêtre et al., 2017; Smyth et al., 2010). Further, the EU had laid a roadmap for Competitive Low Carbon Economy on 2011 in which GHG's emission should be decreased to 40%, 60% and 80% by 2030, 2040, and 2050 respectively via low-carbon technologies and robust energy efficiency scheme (Su et al., 2015; Bastos Lima and Gupta, 2014). Rapid progression and awareness of biofuels has begun in Germany at first among the EU Member States. The Biofuel Quota Act, 2007 sets a target of 4.4% biodiesel in diesel by 2010 and further, National Renewable Energy Action Plan, 2010 has mandated 18% renewable energy share in final energy consumption by 2020 (Su et al., 2015). Further, 2% and 5% biofuel blending in conventional diesel is set as target in Canada under the Environmental Protection Act, 1999 (BillC-33), and in Argentina under the Regimen of Regulation and Promotion of the Production and Sustainable Use of Biofuels, 2006 (Sorda et al., 2010). Thailand also targeted to meet 5% blending in Diesel with Palm oil and 10% blending in Ethanol with Cassava. The second Alternative Energy Development Plan of Thailand sets to achieve ambitious targets of 4.1% in the 20% alternative energy mix of the country's total energy demand by 2022 (Kumar et al., 2013). Therefore, in these circumstances, the targets set under the Indian Biofuel Policy seem to be 'unrealistic' due to the following factors (Kumar Biswas et al., 2010).

i) Can India meet the B20 target by 2017?

The blending of bio-ethanol with gasoline was not sustainable due to less cultivation of sugarcane and unavailability of molasses. It is relevant to note that the sugarcane cultivation is cyclical in India, and the availability of molasses varies from season to season. These situations led to gradual shortfall in supply of ethanol in the past, due to the inadequate molasses availability and increased price of molasses (Murali et al., 2016). However, it had not been reached 5% blending requirement as of today, and therefore, achieving ambitious 20% blending mandate by 2017 is a conundrum (UPES Report, 2016; Khanna et al., 2012). Khanna et al. (2012) also confirms that reaching the ethanol-blending mandate as prescribed in the Policy, entirely using molasses would require more than 180% increasing sugarcane production compared to the current observed level, and also diverting entire sugarcane cultivation for ethanol production. As described above, the major hurdles are inadequate manufacturing units, unavailability of non-edible oils, use of first-generation biofuel crops are extremely limited. Further, amendment in the Motor Spirit and High-Speed Diesel Order, 1998 will facilitate the proper issuance, renewal, and cancellation of license for OMCs (Mohan et al., 2006). In other countries, National Biofuel Policy of Malaysia 2006 set initially 5% as a blending mandate and later the amendment has set 7% as blending mandate in diesel by 2015 (Mofijur et al., 2015). Further, policy of Indonesia was framed to substitute 15% gasoline by ethanol and 20% diesel by biodiesel by 2025 (Zhou and Thomson, 2009). Indonesian government also prepared a detailed roadmap to meet targets in biofuel mix of 2%, 3%, and 5% of country's total energy mix in 2010, 2015 and 2025 respectively (Kumar et al., 2013). In this scenario Indian government need to push forward swiftly towards potential biofuel crops or making judicial choice of technologies to achieve ambitious blending targets in near future (Lali, 2016).

i) *Land constraints for the cultivation of biofuel crops:*

Paras 1.5 and 5.1 of the Policy mandates that non-edible oil crops shall be grown only on 'wastelands' in the forest and non-forest areas. It is interesting to note that the Policy did not define the term 'wasteland'. However, the authors could trace the definition of 'wasteland' from the colonial rulers, according to them the term 'wasteland' means 'the land did not pay any revenue because it was uncultivated' *i.e.* from forest to semi-jungle lands, and from drylands to wetlands (Kumar Biswas et al., 2010; James and James, 1999). In 1861, Lord Canning formulated the 'wasteland rules' to administer the revenue generated from the uncultivated lands. Another interesting question arises, whether India has availability of enough wasteland to cultivate biofuel crops to meet the blending mandate, it is significant to note that there is no consensus among Indian policy-makers in this regard. Currently, multiple government classifications on wastelands exist in India those are, two main classifications, nine-fold classifications and Wasteland Atlas (Baka, 2014). Also, a huge part of wasteland had been illegally acquired by poor people, landless labourers; there is no government record available for such encroachment (Kumar Biswas et al., 2010). Para 9.2 of the Policy mandates the State Governments have to decide the land use and government wasteland allotted for such plantations. Notably, finding a suitable land for Jatropha plantation is one of the major concerns in the implementation of the Policy (Goswami and Choudhury, 2015). Baka (2014) and Kumar Biswas et al. (2010) reported that no mandate is available for demarcation of non-cultivable wasteland suitable for biofuel (mainly Jatropha) cultivation in India. Further, grabbing of arable land for the cultivation of biofuel crops has also led to serious socio-economic issues for the successful implementation of the Biofuel Policy (Kumar Biswas et al., 2010; Bastos Lima, 2012).

ii) Practical difficulty in feedstock cultivation:

The government has announced that feedstock cultivation also eligible under the MGNREGA Scheme. The immediate choice of crop endeavour was Jatropha. In order to attain ambitious target of 10% biodiesel-diesel blending mandate the government of India had decided to plant Jatropha on 11.2-13.4 million hectares area by 2012 and the Ministry of Rural Development has been nominated as a nodal agency to launch a demonstration phase for identifying suitable Jatropha growers, nursery development, supplying subsidized Jatropha material (Singh, 2009; Aradhey, 2011). However, in reality it has proven to be blurred from what government has anticipated. The yield of Jatropha plant in suboptimal growing conditions seems to be overestimated by the researchers and policy makers (Sreenivas et al., 2018; Bastos Lima, 2012). It is also learnt that policy makers did not consult the farmers when making such decisions. Generally, Indian farmers grow Jatropha only as a fence crop and most of the farmers unwelcomed the decision of planting Jatropha as monoculture. Meanwhile, the farmers who had agreed to cultivate Jatropha were severely disappointed due to low yields (Bastos Lima, 2012).

iii) *Differential tax structures at State level*:

The Policy had laid down 16% concession duty for bio-ethanol, and no central tax and duty shall be imposed on biodiesel and bio-ethanol. However, State tax policies are not similar, and it may vary from one State to other. The diverse tax structures of some selected States are discussed in Table 7. As reported by Sorda et al. (2010), though states have their own excise tax, biodiesel is exempted from 4% central excise duty as a fiscal incentive. Also, Raju et al. (2012) illustrated that diverse tax structure creates a hurdle for the speedy implementation of the Policy. The rapid and free movement of biofuel across State borders has been limited due to different State policies and restrictive administrative control.

iv) *Different species of non-edible oil feedstock and their suitability*:

Para 5 of the Policy has identified 400 species of non-edible seeds bearing trees in the country, but the practical experiments emphasize only on Jatropha plant. Several research agencies are also involved in the development of genetic improvement or high-yielding varieties of Jatropha plant, but no major success. Also another reason could be, biodiesel production in India mainly relies on Jatropha plant, which is found to be commercially unviable owing to unsustainable seed quality, low yield and marketing challenges (Slette and Aradhey, 2014). Kumar Biswas and Pohit (2013) found that most of the research focuses on plant materials, but it lacks on other factors such as agro-climatic and soil conditions that are necessary to increase the productivity of these crops.

v) *Institutional Constraints*:

The NBM had proposed to establish National Biofuel Development Board but it had later withdrawn due to unknown reasons. As discussed earlier, the National Policy on Biofuels has proposed to establish NBCC, BSC, and the National Registry, but the government has failed to establish it within the stipulated time, and also no institution has been proposed to carry out transferring the benefits directly to farmers and for earning of carbon credits, therefore it is indeed necessary to address these issues through existing institutional mechanism or new mechanism (Kumar Biswas et al., 2010).

5.7 Recent developments

Recently the Ministry of Petroleum and Natural Gas in co-ordination with the Petroleum Conservation Research Association has established a *Working Group* on an industry basis in order to create awareness and promote biofuels in India (PTI, 2015). The central government is also considering the revision to the National Policy on Biofuels, and Motor Spirit and High-Speed Diesel Control Order to facilitate the sale of biofuels (Business Line, 2015). The government of India is expected to unveil a new Policy on 'Flexible-Fuel Cars' that will run on bio-ethanol, petrol, or blend. This 'flex-fuel vehicles' would help in combating pollution and also to increase ethanol consumption. A notable expert on famine and hunger, *P Sainath* broached that 'this is just a magic bullet approach' (The Hindu, 2016).

Due to non-fulfilment of the 2008 Policy, the Petroleum Ministry has recently drafted a new policy on biofuels (it is not yet made available to the public). It has proposed an indicative target of 20% blending of ethanol in petrol and 5% of biodiesel in diesel by 2030. The draft policy envisages the use of other raw materials such as agricultural waste, bamboo, non-edible oil seeds or municipal waste to produce biofuels. The draft policy also allows food grains during surplus production to be used for the production of ethanol, which will effectuate food *vs* fuel debate (Economic Times, 2017).

6. Key legal challenges and a way forward

Considering the slow rate of progress in biofuels development, several bottlenecks presented above are yet to be resolved and the then Planning Commission of India had suggested essential amendments to the existing laws. The term 'biofuels' need to be suitably defined under Section 19 of the Standards of the Weights and Measures Act, 1976, to avoid ambiguities on a certain specification such as measure, performance, materials and physical characteristics of biofuels. The required changes to be incorporated in the Air (Protection and Control of Pollution) Act, 1981, and the Environment (Protection) Act, 1986, in order to maintain the standards for emission or discharge of environmental pollutants. The Ministry of Environment and Forests may notify and list the biofuel under the provision of the Manufacture, Storage and Import of Hazardous Chemical Rules, 1989. To maintain the blending quality and avoid adulteration, it suggested that Union government has to make necessary amendments in the Motor Spirit and High-Speed Diesel (Regulation of Supply and Distribution and Prevention of Malpractice's) Order 1998. Sections 52 and 110 of the Motor Vehicles Act, 1988 may be amended, which will enable the vehicles to run on other fuels like ethanol and biodiesel.

It is also learnt that the OMC's sole dependence on molasses based Ethanol restrict the implementation of Ethanol Blending program. Therefore, as suggested by the Standing Committee on Petroleum & Natural Gas, we have again reiterated that "other than sugarcane, ethanol can be produced from corn, maize, wheat and food grains having high starch content" which has successfully implemented in the USA. Quite a lot of short generation biofuel crops are available, which can grow on rain-fed agricultural lands, this could increase the availability of feedstock as well as to improve farmer's income. Therefore, the Government of India needs to allocate appropriate funds for accelerating up R&D for producing Ethanol from different crops. The Union Government may request all the State governments to prepare a uniform taxation structure in biofuels sector to bring harmonization in levying taxes. The Government of India has to initiate all the Committees proposed under the policy. The Coordinating Ministries may work together to draw comprehensive action plan for the efficient execution of Biofuel program. This action plan might lay down an accurate roadmap for achieving blending targets within a stipulated time. It is indeed necessary for Indian Government to review the Policy and carry out all the possible changes for the successful implementation of Biofuel program.

7. Conclusion

Four components are pertinent for any biofuels to be successfully put into practice namely technology, economics, environmental sustainability and policy support. Challenges in commercially viable biodiesel production had been emphasized in detail by many researchers *i.e.*, cost associated with cultivation, harvesting and production. However, the legal challenges and solutions towards the successful and broad marketing of biofuel in energy market had not been widely discussed especially in developing countries like India. The policy support can only translate a good technology into use and application. In this regard, Indian biofuel policy also adopted mandate in ethanol blending and biodiesel program. However, not much success was reaped out of the biodiesel program mainly due to the food vs. fuel conflict and cost of the biomass cultivation. Hence, this review has undertaken to address the potentials of microalgal feedstock in biofuel production and the policy issues, which hinders its commercialization in India. This review has displayed the significant facts of National Biofuel Policy of India, which had adopted to regulate the legal hurdles in biofuels marketing. The Government of India had taken noticeable efforts on the ethanol blending program, biodiesel program, policies translating to industries has been addressed. The concerns laid down in the biofuel policy had been articulated comprehensively such as procedural and administrative difficulties by State governments, blending mandate, taxation structure, and amendment in existing laws for free movement of biofuel throughout the country. It is pertinent to note that the country has witnessed insignificant success in the implementation of the biodiesel even after ten years of experimentation of biodiesel production; however, the learning experience might govern success in future. In order to achieve India's ambitious biofuel targets, a change should happen across all the grass root levels especially the adequate efforts from both public and government are required for successful and wide marketing of microalgal biofuel. Moreover, the research on energy policy is very primitive where different stakeholders including technical scientist, policy makers, industries, and public need to step-in to develop a framework for policies.

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Figure Legends

Fig. 1. Major forms of energy

Fig. 2. The World total primary energy supply from 1973 to 2016

Fig. 3. Generations of biofuels

Fig. 4. Various products obtained from microalgae

Tables

Table 1 Sources and effects of common pollutants of fossil fuel burning

Table 2 Different feedstock used for biofuel production

Table 3 Biodiesel production feedstock rich in free fatty acids (FFA)

Table 4 Oil yields from various biomass feedstocks and biofuel productivity (Chisti, 2007; Trivedi et al., 2015; Ziolkowska and Simon, 2014)

Table 5 Development and Implementation of Biofuel Policy in India (Planning Commission, 2003; MoP & NG, 2006; National Policy on Biofuels, 2008; USDA GAIN Report, 2010)

Table 6 Involvement of Different Ministries in the Promotion and Development of Biofuels in India (National Policy on Biofuels, 2008; Raju et al., 2012)

Table 7 Analysis of Some Selected State-Specific Biofuel Policies (Raju et al., 2009; Pohit et al., 2010; Raju et al., 2012; Kumar Biswas and Pohit, 2013; Dwivedi et al., 2014; Awalgaonkar et al., 2015)

Fig. 1

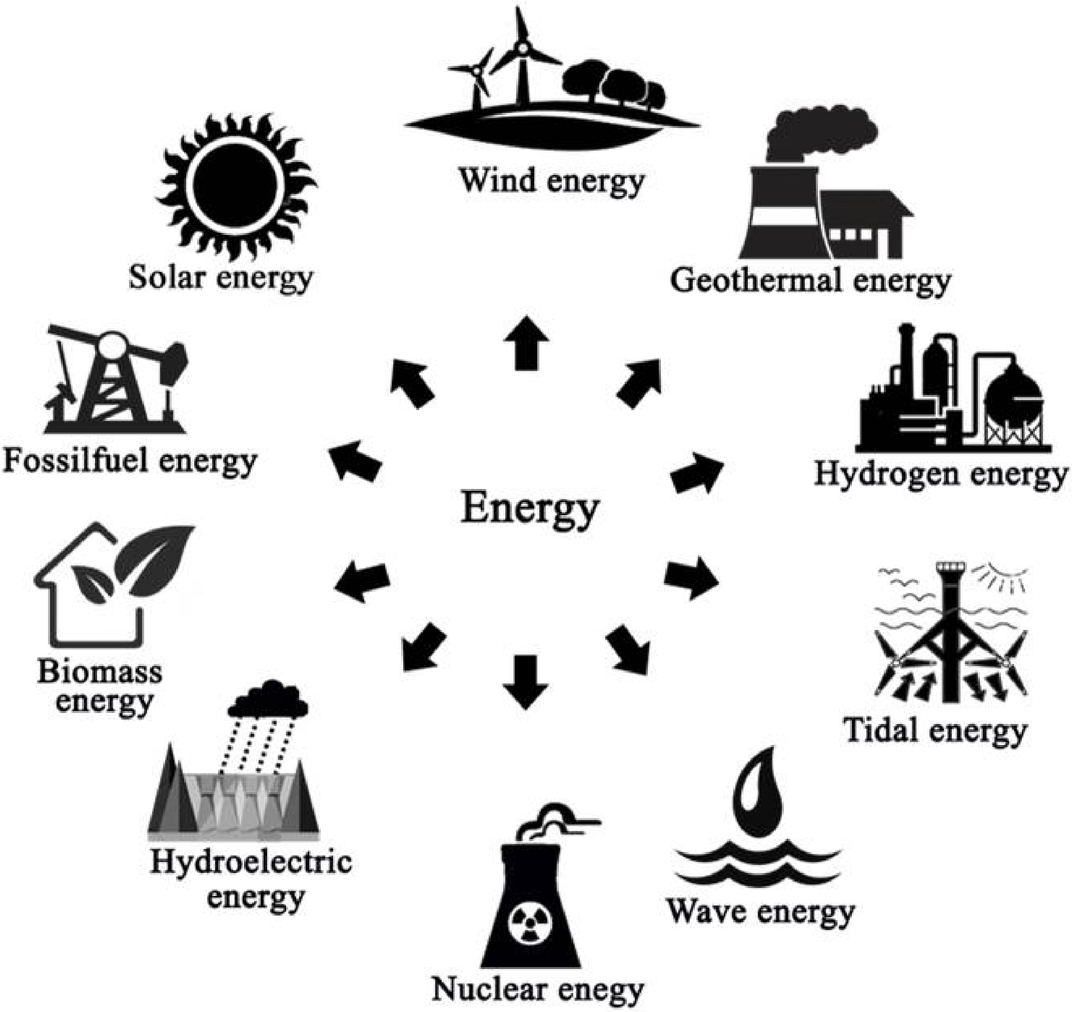

Wind energy
Geothermal energy
Solar energy
Hydrogen energy
Fossilfuel energy
Energy
Biomass energy
Tidal energy
Hydroelectric energy
Wave energy
Nuclear enegy

Fig. 2

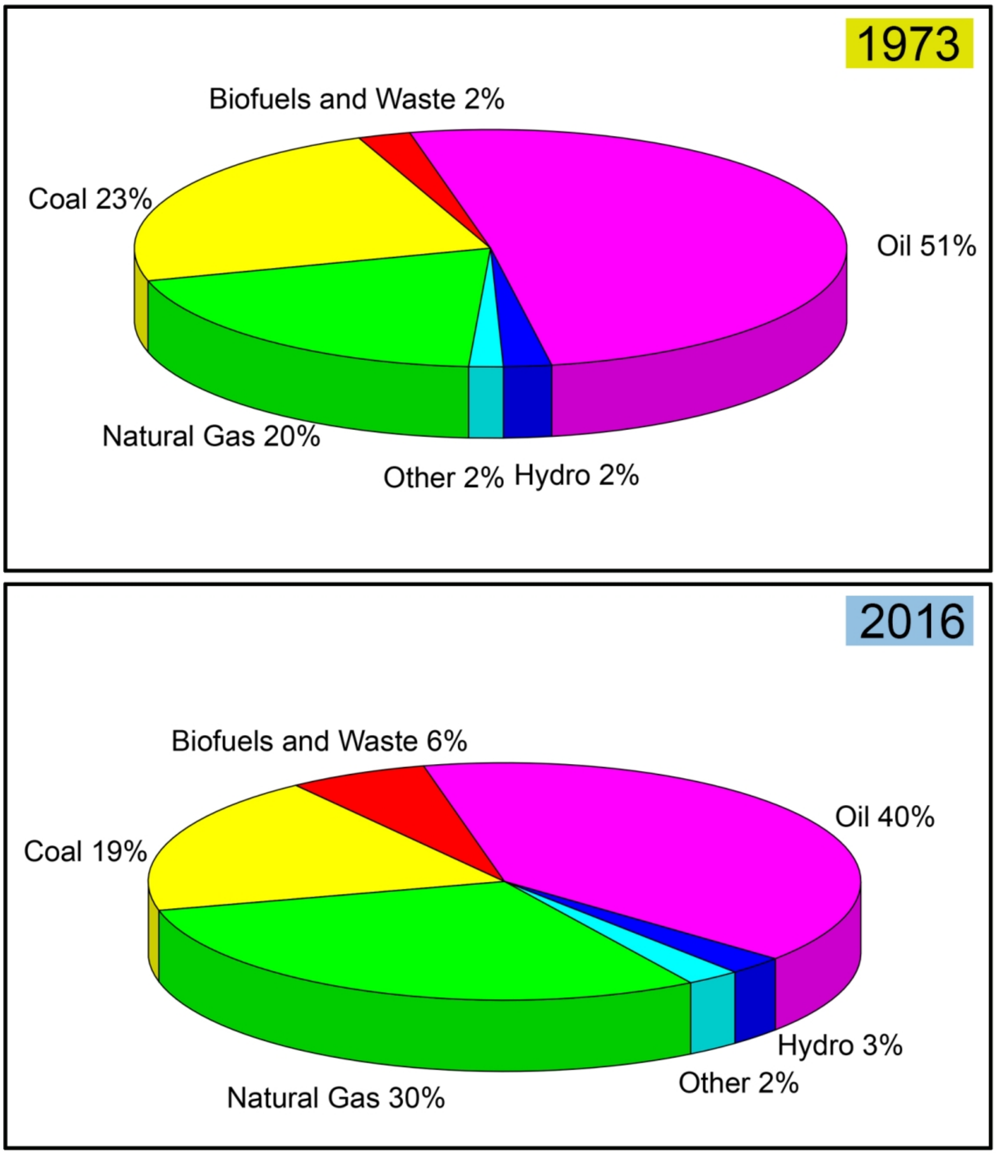

1973
Biofuels and Waste 2%
Coal 23%
Oil 51%
Natural Gas 20%
Other 2%
Hydro 2%
2016
Biofuels and Waste 6%
Oil 40%
Coal 19%
Hydro 3%
Other 2%
Natural Gas 30%

Fig. 3

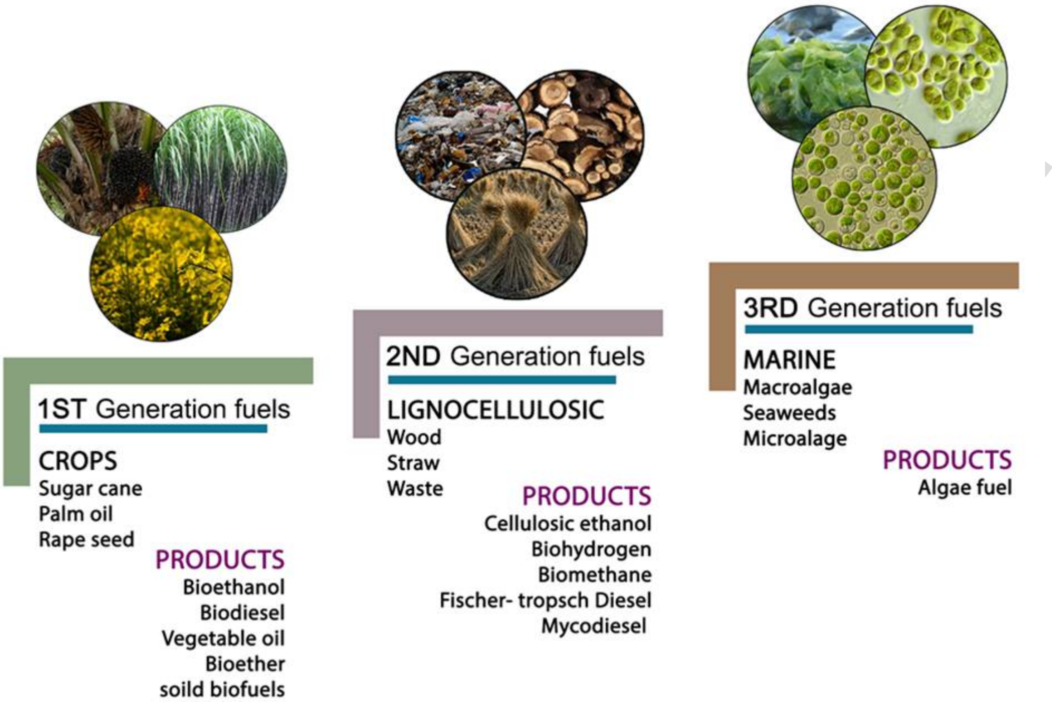
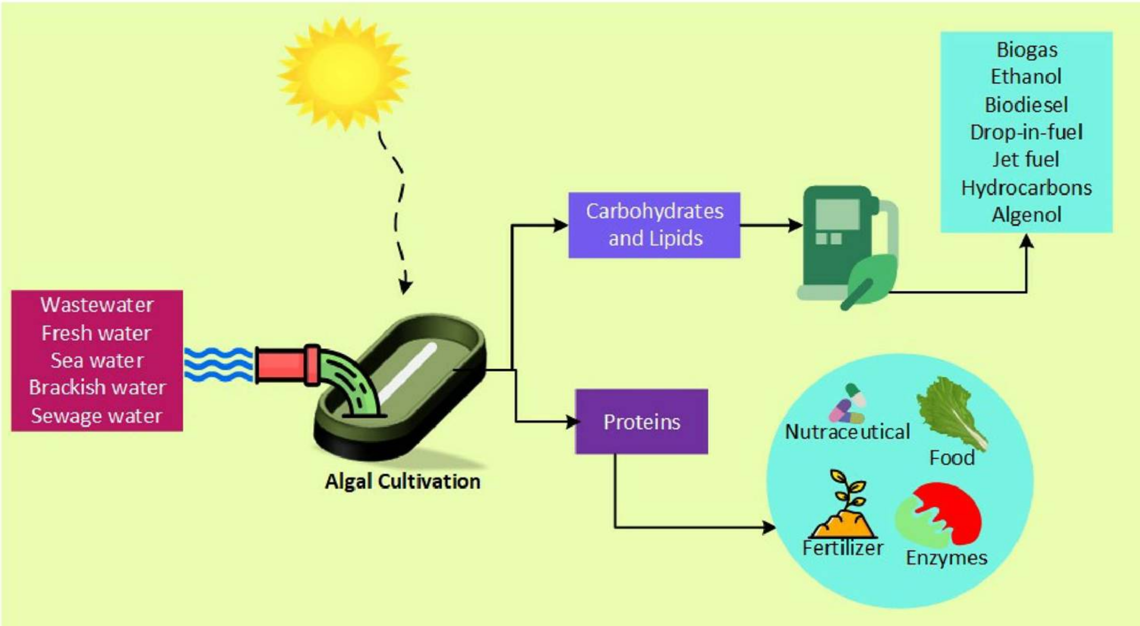

1ST Generation fuels
CROPS
Sugar cane
Palm oil
Rape seed
PRODUCTS
Bioethanol
Biodiesel
Vegetable oil
Bioether
soild biofuels
2ND Generation fuels
LIGNOCELLULOSIC
Wood
Straw
Waste
PRODUCTS
Cellulosic ethanol
Biohydrogen
Biomethane
Fischer- tropsch Diesel
Mycodiesel
3RD Generation fuels
MARINE
Macroalgae
Seaweeds
Microalage
PRODUCTS
Algae fuel

Fig. 4



Biogas
Ethanol
Biodiesel
Drop-in-fuel
Jet fuel
Hydrocarbons
Algenol
Carbohydrates and Lipids
Wastewater
Fresh water
Sea water
Brackish water
Sewage water
Proteins
Algal Cultivation
Nutraceutical
Food
Fertilizer
Enzymes

Highlights

- Microalgal biofuel is a promising substitute for diesel to satiate energy demand
- National Policy on Biofuel adopted by India has been critically addressed
- Blending mandate, Legal challenges, state government participation were discussed
- Effort from government and public are needed for sustainable marketing of biofuel.

Table 1 Sources and effects of common pollutants of fossil fuel burning

Pollutant	**Anthropogenic source**	**Health effects**	**Environmental effects**	**Reference**
Ozone (O_3)	Secondary pollutant formed from chemical reactions of VOCs and NOx	Breathing problems, asthma, eye irritation, reduced resistance to cold	Reduced visibility, damages crops, and other vegetation	(Bell et al., 2014; Tai et al., 2014)
Nitrogen Oxides (NOx)	Burning of Natural oil, coal, gasoline	Respiratory illness and eye related problems, heart diseases	Leads to the formation of smog, acid rains,	(Kampa and Castanas, 2008; Hu et al., 2012)
Sulphur dioxides (SO_2)	Burning of Coal, Oil and high sulfur coal	Permanent damage to lungs, eye vision loss, and other chronic diseases	Precursor for acid rains	(Devalia et al., 1994; Chen et al., 2017)

Table 2 Different feedstock used for biofuel production

Feed Stocks	Biofuel	Country	Reference
Corn, switch grass, Soybean and Sunflower	Ethanol, Biodiesel	USA	(Pimentel and Patzek, 2005; Moser and Vaughn, 2012; Kim et al., 2015)
Sugarcane, soybean, palm oil	Ethanol, biodiesel	Brazil	(Koçar and Civaş, 2013)
Rapeseed, sunflower, wheat sugar beet, barley, sewage, manure, food wastes, landfill	Ethanol, biodiesel, Biogas	EU	(Koçar and Civaş, 2013)
Corn, cassava, sweet potato, rice, Jatropha	Ethanol, biodiesel	China	(Koçar and Civaş, 2013)
Corn, wheat	Ethanol	Canada	(Koçar and Civaş, 2013)
Wheat, sugarcane, molasses, palm oil, cotton oil	Ethanol, biodiesel	Australia	(Koçar and Civaş, 2013)
Vinasse wastewater	Bio hydrogen	Brazil	(Fernandes et al., 2010)
Cheese whey wastewater	Bio hydrogen	Turkey	(Azbar et al., 2009)
Molasses, sugarcane in the future, Jatropha	Bioethanol	India	(Koçar and Civaş, 2013)

Table 3 Biodiesel production feedstock rich in free fatty acids (FFA)

Feedstock	**FFA (wt %)**	**Treatment method**	**Trans esterification catalyst used**	**Ester head group**	**Yield**	**Reference**
Acid Oil	59.3	None	H_2SO_4	Me	95	(Haas et al., 2003)
Brown grease	40	Diarylammonium catalysts	$NaOCH_3$	Me	98	(Ngo et al., 2008)
Calophyllum inophyllum	22	H_2SO_4	KOH	Me	85	(Sahoo et al., 2007)
Fat from meat and bone meal	11	H_2SO_4	KOH	Me	45.7	(Nebel and Mittelbach, 2006)
Hevea brasiliensis	17	H_2SO_4	NaOH	Me	n.r	(Ramadhas et al., 2005)
Heterotrophic Microalga	8.97	None	H_2SO_4	Me	n.r	(Miao and Wu, 2006)
Jatropha curacus	14	H_2SO_4	KOH	Me	99	(Kumar Tiwari et al., 2007)
Moringa oleifera	2.90	H_2SO_4	$NaOCH_3$	Me	n.r	(Rashid and Anwar,

						2008)
Madhuca indica	20	None	*Pseudomonas cepacia*	Et	96	(Kumari et al., 2007)
Nicotiana tobacum	35	H_2SO_4	KOH	Me	91	(Veljković et al., 2006)
Sorghum bug oil	10.5	None	H_2SO_4	Me/Et	77.4	(Mariod et al., 2006)
Tall oil	100	None	HCl	Me	n.r	(Demirbas, 2008)
Tung oil	9.55	Amberlyst-15	KOH	Me	90.2	(Park et al., 2008)
Waste Cooking oil	7.25	H_2SO_4	NaOH	Me	90	(Meng et al., 2009)
Waste fryer grease	5.6	H_2SO_4	KOH	Me/Et	90	(Issariyakul et al., 2007)
Zanthoxylum bungaeanum	45.5	None	H_2SO_4	Me	98	(Zhang and Jiang, 2008)

*n.r Not reported, Me *methyl*, Et *ethyl.*

Table 4 Oil yields from various biomass feedstocks and biofuel productivity (Chisti, 2007; Trivedi et al., 2015; Ziolkowska and Simon, 2014)

S. No	Crop	Oil yield (l/ha)	Biofuel productivity (kg/ha/yr)	Land use (m2/year/kg biodiesel)
1.	Castor	1413	-	-
2.	Camelina	915	-	-
3.	Peanut	1059	-	-
4.	Karanj	2590	-	-
5.	Rubber seed	80-120	-	-
6.	Corn	172	152	66
7.	Soybean	446	562	18
8.	Sunflower	952	946	11
9.	Rapeseed	1190	862	-
10.	Jatropha	1892	656	15
11.	Oil palm	5950	4747	2
12.	Microalgae	58,700	51,927	0.2

Table 5 Development and Implementation of Biofuel Policy in India (Planning Commission, 2003; MoP & NG, 2006; National Policy on Biofuels, 2008; USDA GAIN Report, 2010).

Timeline	Action	Outcome
Ethanol Blending Programme		
January 2003	The Ministry of Petroleum and Natural Gas has made mandatory 5% blending of ethanol with petrol across nine major sugar producing States and five Union Territories in India.	Implemented partially, due to a shortage of blended bio-ethanol and low production of sugarcane.
October 2007	Mandatory 5% blending of ethanol with petrol across 20 States and 7 Union Territories in India.	OMCs contracted for 1.4 billion liters of ethanol for EBP from Nov 2006-Nov 2009. However, only 540 million liters had supplied till April 2009, due to a shortage of molasses. This reason led GoI to delay the implementation of the EBP.
October 2008	The GoI pushed towards 10% blending mandate.	GoI once again deferred the implementation of EBP, due to unavailability of sugar molasses, and delayed procurement.
National Biodiesel Mission		

April 2003	*Phase-I (Experimentation and Demonstration) from 2003 to 2007*: Plantation of Jatropha on wastelands. The NBM proposed to achieve 5% blending mandate of biodiesel in 2007.	The state government, public and private sectors, and research institutions to be involved in achieving the targets.
October 2005	The MoPNG announced bio-diesel purchase policy, OMC shall purchase biodiesel from 20 procurement centers across India at Rs 26.5/litre.	The cost of production is 20% to 50% higher than the purchase price, therefore no sale of bio-diesel during that period.
October 2008	*Phase-II (Self-Execution) from 2008 to 2012*: Blending mandate will be gradually raised to 20% in 2012.	Failed to implement the targets due to lack of large-scale Jatropha plantation, buy-back arrangements, and confidence building among farmers.
National Policy on Biofuels		
December 2009	GoI has proposed to achieve mandatory 20% blending for both biodiesel and bio-ethanol by 2017.	The ambitious targets are unlikely to achieve, though only few months are left.

Table 6 Involvement of Different Ministries in the Promotion and Development of Biofuels in India (National Policy on Biofuels, 2008; Raju et al., 2012)

S. No	Ministries involved	Various responsibility
1	Ministry of New and Renewable Energy (MNRE)	Overall policy-making, and supporting research
2	Ministry of Petroleum and Natural Gas (MoPNG)	Marketing, development of pricing and procurement policy
3	Ministry of Agriculture (MoA)	Research and development on feedstock crops
4	Ministry of Rural Development (MoRD) in coordination with Ministry of Panchayati Raj (MoPR)	Identification of wastelands, and promotion of Jatropha and other feedstock crops plantations
5	Ministry of Tribal Affairs (MoTA)	Identify non-arable land in 'Scheduled Areas'. To activate mechanism for collection of Tree-Borne Oilseeds (TBOs) by tribals
6	Ministry of Science and Technology (MoS&T)	Encourage biotechnological research on non-edible oil feedstock crops
7	Ministry of Environment and Forests (MoEF)	Ensuring implementation of Tree-Borne Oilseeds (TBO) crop plantations in forest wastelands. To monitor the health and environmental impacts on biofuels
8	Ministry of Finance (MoF)	Providing financial assistance and to extend all the benefits such as customs and excise exemptions to the biofuels sector

Table 7 Analysis of Some Selected State-Specific Biofuel Policies (Raju et al., 2009; Pohit et al., 2010; Raju et al., 2012; Kumar Biswas and Pohit, 2013; Dwivedi et al., 2014; Awalgaonkar et al., 2015)

States Involved	Nodal agency involved/proposed	Targeted non-edible oil seed crops	Main actors	Type of land made available	Support provided by Government	Government procurement price	Sales Tax Rate on Diesel (in %)	Sales Tax Rate on Ethanol (in %)
Rajasthan	Biofuel Authority	Jatropha	SHGs, CDOs, Panchayats, and private companies	Wastelands and ravine lands	Subsidized seeds and a 20-year lease of govt. wasteland for plantation	Rs 6/kg	--	--
Gujarat	Agro Industrial Corporation	Jatropha	--	Hilly areas and barren lands	--	--	21	4
Chhattisgarh	Biofuel Development Authority	Jatropha and Pongamia	JFMCs, local farms, and private investors	Wastelands and ravine lands	Free Jatropha seeds for planting, and tax duty exemptions	Jatropha- Rs 6.5/kg Pongamia- Rs 6/kg	25	--
Uttarakhand	Biofuel Board	Jatropha	Van Panchayats (local forest councils), Joint Forest Management Committees,	Wastelands	Genebank for Jatropha to preserve high yielding varieties	Rs 3.5/kg (lower price because of lack of competition)	21	--

			and SHGs					
Odisha	Odisha Renewable Energy Development Agency	Jatropha and Pongamia	Pani Panchayats, and SHGs	Wastelands	Subsidy for seeds and create linkage to MGNREGA	--	--	--
Karnataka	Biofuel Development Board & State task force on biofuel	Jatropha, Pongamia, Simaruba, Mahua, and neem	Traditional communities,	Waste and irrigated lands	Biofuel Park proposed, tax exemptions	--	--	--
Andhra Pradesh	Biodiesel Board	Jatropha, Pongamia, and Simaruba	--	Irrigated and rainfed lands	Systematic R&D support involving ICRISAT and State Agricultural Universities	--	22.25	12.5
Tamil Nadu	Watershed Development Agency and Watershed Development Corporation	Jatropha	D1 Mohan, AGNI NET, AHIMSA	Wastelands and degraded forest lands	Subsidized loans, Tax exemptions, VAT on oil. Several State sponsored programmes linked with biofuel programme	Rs 5-10/kg (with buy-back)	21.43	8+5% Surcharge