

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Sustainability of Bio-Fuel Energy System

Dr. Vidosh Mahate, Anand Bisen*

Head of Department, Department of Mechanical Engineering, SIRTIS, Bhopal, India

Lecturer, Department of Mechanical Engineering, Kalaniketan Polytechnic College, Jabalpur, India

*Corresponding author

ABSTRACT: Different aspects of use bio-fuel are presented to understand the complexity in developing a sustainability model for Bio-fuel energy system. Sustainability is an important issue while examining the feasibility of Bio-fuel use. Issues related to sustainability of Bio-fuels are far more complex than other renewable energy sources. In this paper, we highlight the complexity of the biofuel use and different aspects related to biofuel energy system. Biofuel production in the large scale will be possible if it is technically, economically, socially and environmentally sustainable. Use of Bio-fuel is closely linked with, technical, economic, environment, even the sociality of the region. These aspects are assessed in terms of large number of influencing factors such as modification in engine technology, properties of Bio-fuel, employment, food security, cost of Bio-fuel, profitability, rural economy, pollution, and ecosystem. The interaction between them and their feedback structure is presented using causal loop diagrams. These diagrams help in understanding, how any change in the system through policy interventions has its repercussions in whole of the system.

KEYWORDS: Biofuel, Sustainability, Renewable energy, Causal loop, Food security, Emission

I. INTRODUCTION

World is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. These concerns have motivated the world to search for renewable fuels for ensuring energy security and environmental protection. Biofuel use will decrease the country's dependence on imported petroleum. Bio-fuel technology is regarded as key of energy independence, lowering emissions of greenhouse gases and economic growth of the country. An emphasis on energy security has led to the pursuance for alternative sources of energy that can replace petroleum dependence. Bio fuels are one such alternative that has been identified by various countries and international institutions as fuels for the future. The significance of technical, socio-economic and environmental aspects are assessed in terms of large number of influencing factors: modification in technology, properties of Bio-fuel, employment, food security, cost of Bio-fuel, profitability, rural economy, pollution, and ecosystem.

The transportation sector in fast growing industrialized countries is primarily based on fossil fuels, which are mainly crude oil derivatives. High growth of these developing countries has created the fossil-energy-intensive-approach [11]. Transportation as well as agricultural sectors is the major consumers of fossil fuels and biggest contributor to environmental pollution, which can be reduced by replacing mineral-based fuels by bio origin renewable fuels. Biodiesel has many environmentally beneficial properties. The main benefit of biodiesel is that it can be described as 'carbon neutral'. This means that the fuel produces no net output of carbon in the form of carbon dioxide (CO₂). This effect occurs because when the oil crop grows it absorbs the same amount of CO₂ as is released when the fuel is combusted [21]. Different blending of bio fuel with diesel was used to conduct the test on a twin cylinder air cooled diesel engine. It is observed that all the CO₂ emission of diesel fuels is higher than that of the blended fuels. It shows the variation of HC emission with percentage of load for different fuels, it is observed that HC emission of the various blends was lower in partial load, but increased at higher engine load. It is also observed that NO_x emission from the vegetable oil and the vegetable oil/diesel fuel blends are lower than those of diesel fuel. [1] The smoke density and CO emissions were reduced and the NO_x, HC emissions were slightly increased, with the use of all biodiesel blends with respect to that of the neat diesel fuel, with this reduction/increment being higher the higher the percentage of bio-diesel in the blend. The engine performance with the bio-diesel was similar to that of the neat diesel fuel, with

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

nearly the same brake thermal efficiency and showing higher brake specific fuel consumption [12]. A general conclusion is that all the tested bio-diesel blends can be used safely and advantageously in the present diesel engine, at least in these small blending ratios.

Problems associated with vegetable oils during engine tests can be classified into two broad groups, namely, operational and durability problems. Operational problems are related to starting ability, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injector tip, ring sticking and lubricating oil dilution. [11] Blending, cracking / pyrolysis, emulsification or transesterification of vegetable oils may overcome these problems.

The social aspects of human needs are understood within different contexts for improving the economy of the developing countries. Bio-fuels hold the promise of contributing to rural development by creating jobs in feedstock production, bio-fuel manufacture, and the transport and distribution of feedstock and products. The social benefits are improved health, consumer choice, greater self-reliance work opportunities and technological advances. [18]

Environmental aspects and quality of life indicate that environmental pollution is largely linked to the increasing use of energy, presently the climate changes due to heavy use of fossil fuel with emissions of sulphur dioxide, nitrogen oxide and carbon dioxide become more and more a planetary problem and will influence in the future. Air pollution is one of the aspects of the environmental problems. [6]

Using bio-fuel energy generates a wide variety of economic benefits, many of which are described as job creation is a key part of economic development activity and healthy economies. When more people are working, the benefits extend beyond the income earned from those jobs. Benefits occur when workers spend part of their income in the local economy. This increased spending creates economic activity (jobs and revenues) in other sectors such as retail, restaurant, leisure and entertainment. Bio-fuel energy systems can create more jobs per Rupees invested than conventional energy-supply projects. The number of jobs also depends on how many stages of production are carried out in the region, as more jobs will be created if the materials and technologies are processed and manufactured locally. [12]

II. DRIVING FORCE FOR BIO-FUEL PRODUCTION

Before examining the factors potentially limiting biodiesel production growth, it is essential to better understand of driving force for demand of bio-fuel. The depletion of fossil fuels, Increasing cost of fossil fuels, Environmental concern i.e. supplying clean, environmentally-friendly fuel, Decrease dependency on oil imports, Increase employment, Develop rural economy, and Increase energy security of the nation are the driving forces which create need to increase production of bio-fuel.

Bio-fuel energy use is closely linked with, technical, economic, environment, even the sociality of the region. All these factors interact with each other in a complex manner to generate the dynamics of bio-fuel use and emissions arising thereof.

Technical factors include the link between properties of bio fuel, injection of fuel in the engine cylinder, atomization of fuel, air-fuel ratio, compression ratio, and mean effective pressure. Existing vehicle fleets in developing countries primarily rely on conventional combustion engines, generally with an extraordinarily long service life, resulting in low average efficiencies and a high level of emissions [12]. Emissions are directly related to specific fuel consumption, though technological factors determine the consumption of fuels in the automobiles, but efficiency of engine, air-fuel ratio and atomization of fuel are also equally important. The transport sector is a major consumer of oil and emits atmospheric pollutants therefore requires reevaluations of policies regulatory efforts on a continue basis. Environmental factors influences eco-system of earth, pollution, green house gases, global warming and use of cleaner fuel. Uses of fossil fuel are lead to the increase in atmospheric greenhouse gas levels and also increase in air pollution. Use of bio fuel not only help in mitigation of global warming gases but also lead to creation of new regional

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

employment opportunities which is important for any forward looking transportation system in emerging economies [12].

Economic determinants are cost of bio-fuel, profitability to investors, different incentives to promote bio fuel, rural economy development of nation etc. Economic progress and the resultant increased demand for transportation have been driving the demand for automobiles. A shift in transportation mode also influences the transport energy intensity.

The cost difference in running the vehicles is the single most important factor in switching fuels to cleaner types. The taxation on fuel plays a significant role in this connection. When the incentive is higher, the rate of switching is faster as reflected in the cases of unleaded petrol and LPG [14].

Social factors include employment, the population, health hazards, and food scarcity due to diversion of land under the food grains to bio-fuel. India has approximately 55 million hectares of degraded wasteland that lie outside the areas demarcated as national forests, and another 34 million hectares of protected forest area, in much of which tree cover is severely degraded. A massive programme is needed to develop energy plantations consisting of oil seed species for biodiesel production [11]. The document, India Vision 2020, states that: "The greatest advantage of biomass power and bio fuels is that they can generate tens of millions of rural jobs and stimulate enormous growth of rural incomes, especially among the weaker sections. Therefore, these strategies should not be regarded from the narrow perspective of energy alone, but from the wider perspective of national development". [7] These would also include other benefits, such as creating local employment opportunities; making fuel supply widely available throughout the region; and facilitating easier local redistribution of by-products, particularly the seed cake.

Thus there are many interrelated factors, which determine the bio-fuel demand, and govern the emission pattern from transport sector. It is these interactions among technology, the economy and the choices made by consumers, producers, and policy makers that need to be understood and addressed. Unless this inter-relatedness is explored, understood and put in to a modeling framework, which integrates, relates them dynamically, and explores the sources of policy resistance, the genuine solution to the problem will always elude policy makers. [17]

III. CAUSAL LOOP DIAGRAMS

The causal loop diagram is a visual representation of cause-effect relationships among the elements of the system forming structure of feedback loops. It helps in the process of defining and describing structure of the system and in showing how different parts of the system are interconnected [5]. Since it presents an overall view of the causal structure of the system, it is useful in designing the new policies, in explaining the results of a simulation run as well as in communicating with the person who is not familiar with the system dynamics approach [16]. The policy mechanisms are embedded in the structure of the causal loop itself. For example, the policies related to bio fuel energy system like, emission, land use, changes in engine and properties of fuel etc. form part of the loop. The diagram shown has some of the important links in the causal structure of the bio-fuel energy model.

Different aspects and interactions discussed in previous section are responsible for the dynamics within the bio-fuel energy system. Its clear understanding deserves significant attention to improve the likelihood of successful policy intervention. In any dynamic system there are factors, which vary with time as a result of factors both endogenous and exogenous to the system. At the same time if such systems are modeled to assess long term impact of any policy measure, then there may be many other factors which need to be adopted on a continuous or discrete basis as per the requirement of policy interventions or the changes visualized in the system during the selected time horizon [17]. For the case of bio-fuel energy system, continuous changes include, changes in blending of bio-fuel and vehicle engine technology, changes in land use, introduction of new mode of cultivation program for seeds, new technology for extraction of oil from seeds, implementation of new emission norms etc.

At the same time the success of any policy intervention also depends largely on how the users perceive it and respond to it. It has been observed that amongst energy demand sectors, transport is a crucial sector, first – due to its increasing share in the final consumption mix and second – because it is almost fully dependent on liquid fossil fuels.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Transport sector is therefore a priority area for energy efficiency and particular importance as it accounts for about 84 % of the overall CO₂ emissions. [8]

Use of alternative fuel i.e. bio-fuel is complex and simple assumptions about the expected results may lead to futile and often erroneous understanding of the bio-fuel energy system. To illustrate the process as to how the outcome of any policy measure is dependent on various interrelated factors within and outside the transportation system, a simple cause and effect diagram, called as causal loop in system dynamics parlance is drawn Fig-1. These diagrams help in understanding, how implementing any change in the system through policy interventions has its repercussions in whole of the system. A policy change may trigger series of impacts, which may finally counter the policy itself. Such a phenomenon is observed in bio-fuel energy system when as a pollution reliving measure, the policy of use of alternative fuel (bio-fuel) is adopted. As can be seen from the causal loop diagram in Fig-1, that use of more fossil fuel may induces more pollution leading to rise in environment concern and therefore raising social pressure to reduce the pollution. This requires appropriate government policy to reduce the use of fossil fuel and promote the use of alternative fuel which emits less pollutant. Promoting bio fuel use will requires more land bio fuel plant cultivation, there may reduce land under food cultivation affecting the food security of the country, again forcing the government to review its policies for promotion of bio fuel (Loop A). The policy making process is more discursive than linear and involves a large number of variables that define and successively get affected by the policy process. In simple terms, a policy process is defined as consisting of various stages.

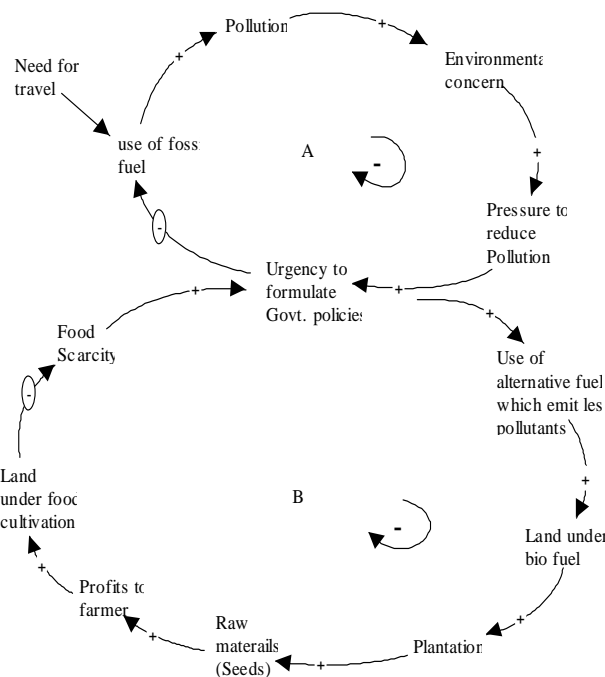


Fig-1.: Causal loop diagram

Various theoretical frameworks have evolved that focus on different variables in the policy process. Models that are used for the purpose of policy evaluation generally ignore this aspect of the social-environmental problem. Such an omission underplays the dynamics of demand of fuel with respect to social-environmental conditions, thus leading to erroneous estimation of demand and therefore the estimation of requirement of bio-fuel.

1. System Dynamics Approach for bio-fuel energy

System dynamics is a methodology to investigate the information-feedback characteristics of complex managerial, economic, or social systems. The goal of system dynamics is to obtain deep understanding of systemic behaviors and to help for the design of improved system structure. The assumption that system behavior results from

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

interacting feedback loops, which force variables to grow or to decline, enables one to understand how unwanted behavior arises and to analyze how a proposed policy design may affect the dynamics of the system. [4] System Dynamics is endowed with certain features which make it very desirable as a methodology for technical, social, economical and environmental impact analysis. Some of these features are following:

- The ability to dynamically model complex, nonlinear relationships of a large number of variables. This enables one to consider many related aspects of the problem, resulting in a holistic approach.
- The ability to explicitly model qualitative factors.
- The ability to experiment with policy alternatives.
- The ability to generate alternative scenarios.
- The ability to incorporate features both the exploratory and normative approaches of impacts analysis. [16]

System dynamics modeling has been used to address practically every sort of feedback system, including business systems, agricultural systems, political decision making systems and environmental systems. [3] Bio-fuel energy system is one such system, which is dynamic, multi-loop, and has non-linear character of feedback system along with flows and stocks of the pollutants and time delays associated with emission and its impact. Finding an effective policy intervention for such system requires a clear understanding of its structure.

The process of creating simulation model helps to clarify the systems structure and makes modelers assumptions of how system works explicit. Once the model is built it can be used to simulate the effect of proposed actions on the problem and the system as a whole [5].

IV. CONCLUSION

From the above analysis, various contextual factors, variables and issues appear to be influencing the emergence of bio fuel policy. Policies are influenced by different factors depending on how powerful these are, not only in terms of what the factors are conveying but also the context and issues these are talking about. This appears to be the case for bio fuel policy. An encouraging trend is that in many countries policy makers are beginning to perceive the potential economic benefits of commercial bio-fuel e.g. employment/earnings, regional economic gain, contribution to security of energy supply and all others. It is requiring attention to understand the impacts of these factors specifically from the socioeconomic point of view as it affects on very fundamental aspects of the ways in which food security, land availability, profit to people and their health, population, environment, and rural development issues. Moreover, there is the realization that use of bio fuel has the potential for job creation, energy independence, regional development and the development of economy of the nation. Food security being a strategic, moral and social issue, need to make a national policy on bio fuels, which inevitably would involve the issue of land use change especially agricultural and wastelands.

REFERENCES

1. A. Murugesan , C. Umarani , R. Subramanian , N. Nedunchezian ,2008, "Bio-diesel as an alternative fuel for diesel engines—A review", Renewable and Sustainable Energy Reviews.
2. George Francis, Raphael Edinger and Klaus Becker, 2009 "A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: Need, potential and perspectives of Jatropha Plantations" Natural Resources Forum 29, 12–24.
3. Brian Dyson, Ni-Bin Chang, "Forecasting municipal solid waste generation in a fast-growing urban region with system dynamics modeling", Department of Environmental Engineering, Texas A&M University-Kingsville, MSC 213, Kingsville, Tx 78363, USA
4. Showing Young, Yi-ming Tu, Ya-tsai Tseng, "A Dynamic Alignment Approach to the Leverage Design in System Dynamics Models: Use Strategem-2 As an Example", Department of Business Management, National Sun Yat-sen University, Taiwan, R.O.C.,
5. Stave, K.A., 2002, using system dynamics to improve public participation in environmental decisions, System Dynamics Review, 18, 2, 139-167.
6. Planning Commission, Government of India. Report of the committee on Development of Bio-Fuel, 16 April 2003.
7. India, 2002. India Vision 2020. Planning Commission, Government of India. December. (Available at http://planningcommission.nic.in/plans/planrel/pl_vsn2020.pdf)
8. Marina Enguádanos, Antonio Soria, Boyan Kavalov, Peder Jensen, "Techno-economic analysis of Bio-diesel production in the EU: a short summary for decision-makers" May 2002, Report EUR Report EUR 20279 EN
9. Andrew D. Foster, Mark R. Rosenzweig, Jere R. Behrman, "Population Growth, Income Growth and Deforestation: Management of Village Common Land in India", April 2002, University of Pennsylvania
10. Deepak Agarwal, Lokesh Kumar, Avinash Kumar Agarwal, 2008, "Performance evaluation of a vegetable oil fuelled compression ignition engine" Renewable Energy 33 (2008) 1147–1156

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

11. Dr. Jyoti Parikh and Dr. Amit Walia, 2009 “Techno-economic Assessment of Bioenergy in India”, Technology Information Forecasting and Assessment Council (TIFAC) under Ministry of Science and Technology.
12. C.D. Rakopoulos, D.C. Rakopoulos, D.T. Hountalas, E.G. Giakoumis, E.C. Andritsakis, 2008, “Performance and emissions of bus engine using blends of diesel fuel with bio-diesel of sunflower or cottonseed oils derived from Greek feedstock”, Fuel 87 , 147–157
13. V. Stamatov, D. Honnery, J. Soria, 2006, “Combustion properties of slow pyrolysis bio-oil produced from indigenous Australian species”, Renewable Energy 31 , 2108–2121
14. Wing-Tat Hung, 2006, “Taxation on vehicle fuels: its impacts on switching to cleaner fuels”, Energy Policy 34 , 2566–2571
15. Donna K. Fishera, Jonathan Norvellb, Steven Sonkaa, Mark J. Nelsonc, 2000, “Understanding technology adoption through system dynamics modeling: implications for agribusiness management”, International Food and Agribusiness Management Review 3 , 281–296
16. Mahopatra, P.K.J., Purunendu, M., and Madhav, C.B., 1994, “Introduction to System Dynamics Modeling”, Universities Press (India), Hydrabad.
17. Prakash Verma, “Dynamic Modelling for Emission Control Policies in the Delhi Urban Transport System”, PhD thesis, Department of Mechanical Engineering, Indian Institute of Technology Delhi, October 2004.
18. J. Domaca, K. Richardsb, S. Risovicc , “Socio-economic drivers in implementing bioenergy projects ”, Biomass and Bioenergy 28 (2005) 97–106
19. EIA (2007), Country Analysis Briefs: India, Department of Energy, USA, Online Source [<http://www.eia.doe.gov/cabs/India/pdf.pdf>]
20. Stave, K.A., 2003, A system dynamics model to facilitate public understanding of water management options in Las Vegas, Nevada, Journal of Environmental Management, 67, 303-313.
21. Agarwal, Avinash Kumar, 2007, “Bio fuels (alcohols and biodiesel) applications as fuels for internal combustion engines” Progress in Energy and Combustion Science 33, 233–271