OPEN ACCESS

1st World Sustainability Forum
1-30 November 2011

www. wsforum.org

Communication

Public Perception and Feedback Dynamics - Understanding Sustainability Scenarios for New Renewable Resource based Energy Technologies using Systems Approach

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Received: / Accepted: / Published:

Abstract: Country-wise variation in availability of different natural energy resources (renewable and non-renewable) critically affects the intra-country resource management policies and international relations as well as treaties towards resource sharing and utilization. Since human consumption is at the core of world natural resource debate, it is critical to understand public interest perspectives towards fossil energy resources, alternative renewable resources and parameters related to them. In this paper, first public interest towards these key issues is evaluated using online trends analysis. It is found that public interest for such key issues vary considerably from country to country, many times, irrespective of the criticality of such issues. Public interest perspective have also been found to vary at different time points, irrespective of the criticality. Further, some natural and renewable resources have been found to rank higher in terms of public interest as compared to others, even though they may be equally critical. Second Feedback models have been developed to understand endogenous relationships between parameters which could be critical building blocks of sustainability in renewable resource based energy technologies, for example, algae biodiesel system. Using online trends analyses and systems oriented investigation, through feedback models, it is shown how this approach could help in understanding sustainability scenarios and devising informed, optimal policies and mechanisms for sustainable development of new renewable resource based technologies.

Keywords: Feedback dynamics, sustainability, online trend analysis, public perception, algae biodiesel, renewable energy resources, systems perspective.

1. Introduction

World fossil energy resources are increasingly suffering from scarcity of supply while the increase in demand remains uninterrupted. Increasing population, increasing industrialization, increasingly high consumption lifestyles in both developed and developing world are critical factors fueling increase in demand – manifolds. A future with this trend is not likely to be sustainable and it is an impending problem. Thus, action with impact in positive direction is needed. Focus has been shifting towards renewable energy resources in different parts of the world not only due to fossil fuels becoming increasingly scarce but also due to indications that some renewable energy resources may have lesser impact on global warming.

Economic growth, development and resource consumption are inter-related factors that are at the core of natural resource management issue. Resource consumption fuels economic growth and economic growth fuels development which in turn, directly or indirectly, fuels resource consumption. This is alike for both non-renewable fossil energy resources and renewable energy resources. At the core is the consumer, the people, and their actions and reactions are affected by policies made by policy makers apart from their own needs and mental models.

Apart from basic needs, interest, perspectives and perceptions about resources can also affect consumption patterns. Further, public interest, perspectives and perceptions may depend on various factors. These could include resource availability in a region, education and know-how, general social and political environment, economy, media influence etc. Eventually, these all factor in to help culmination of mental models of people which can potentially affect resource consumption patterns. Since consumption by public is at the core of world natural resource debate and issues, it is critical to understand public interest perspectives towards key parameters such as natural fossil energy resources, alternative renewable energy sources, etc. Understanding public interest perspectives can help throw some light on public perception about relevant issues. Such knowledge could greatly enhance development of effective, meaningful and informed mechanisms and policies to deal sustainably with the natural resource management (Loiter and Norberg-Bohm, 1999).

Another important factor that is critical for natural resource management is sustainability (Ardawatia et al, 2010). New renewable resource based energy technologies may not be able to develop and succeed in market with policies which have not been developed around sustainability. It is also a key factor that should be considered while developing policies for faciliating development, propagation and management of new renewable energy technologies.

In this work, as described in the following sections, public interest has been investigated using online search trends and systems oriented feedback models have been developed to understand endogenous relationships between key parameters which can also be building blocks of sustainability in new renewable energy technology systems – in particular algae biodiesel system.

2. Investigating Public Interests in Energy Resources using Online Trends Analysis

Online trends analysis is based on the simple idea that people search for things on internet based on their interests. Therefore, if we can capture search patterns on internet search engines, we can potentially have an understanding of what people in different countries have been interested in at different time points. In this work, this concept has been used to understand public interest in natural resource related issues. Google (www.google.com), being one of the largest search engine, was used to establish search patterns through its "insights for search" and "trends" tools. Data only from year 2004 onwards is available for these tools. These tools scale the search data based on the average search traffic for keywords (search terms). The data are also normalized for proper comparison purpose because absolute numbers could give biased search results for places with larger populations! The focus here is on understanding public interest in fossil energy resources and new renewable energy resources. Data can also be normalized based on fraction of internet users in total population of different countries which makes comparison of country-wise data more meaningful. Limited data is shown in the paper due to space limitations.

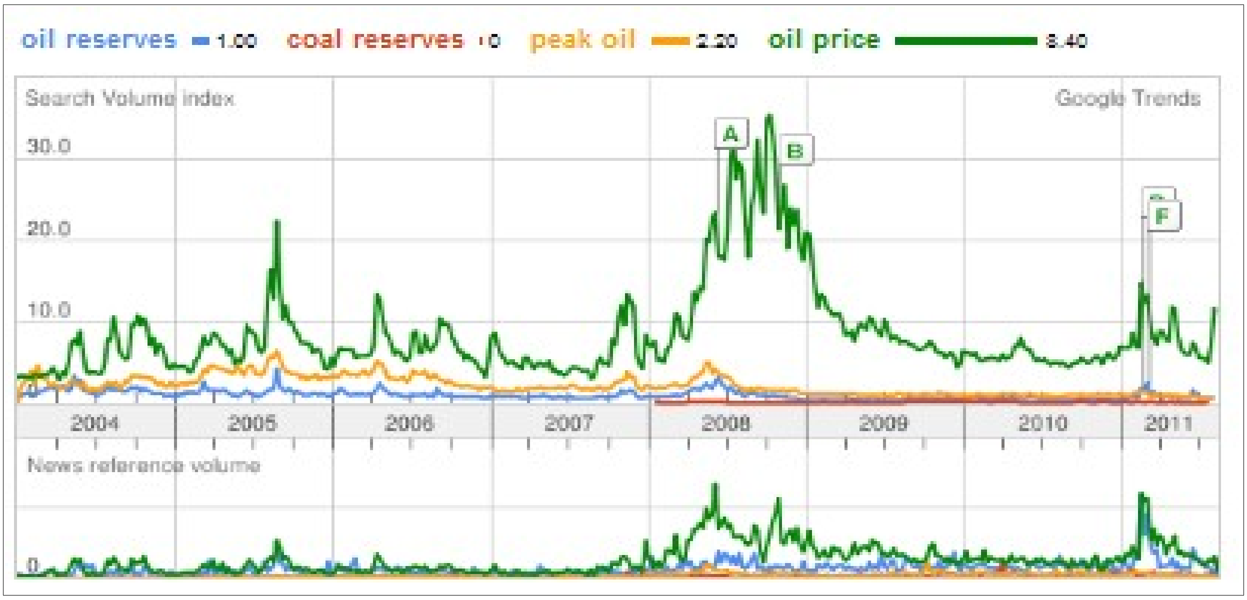
For understanding public interest in fossil energy resources related issues, a set of four keywords was used: "oil reserves", "coal reserves", "peak oil" and "oil price". The analysis was started with keywords "oil reserves" and "coal reserves" as they carry the same idea (i.e., availability) for two different fossil energy resources – oil and coal. This is shown in figure 1. As we see in figure 1, "oil reserves" has a much higher search volume as well as larger news coverage as compared to "coal reserves". One straightforward explanation for this could be that proven oil reserves may be much less than proven coal reserves. Another explanation could be that most people do not use coal directly for anything (for example, coal may be used for producing electricity which people use without thinking much about the coal resource or any other resource which might have been used to produce that electricity) but they use oil directly for transport.

Figure 1. Search trends analysis for "oil reserves" and "coal reserves". The upper graph shows search volume index and lower graph shows news volume index. The alphabet markings signify relevant news items (not shown in the paper).

Therefore, their resource scarcity perception towards coal may not be as strong as towards oil reserves. Visual inspection of the graph shows that the peaks in news volume index for "oil reserves" corresponds with its search volume index. This could imply that availability of news media helps develop some level of public perception towards key issues. On the other hand, although, for "coal reserves" there has been some level of news reference volume since mid 2004 (albeit small), but it starts to show correspondence with search volume only from 2008 onwards. Perhaps it may be due increasing knowledge of contribution of coal power plants towards green house gas emissions. However, from the data it can not be explained with certainty. It is also important to note that no data on graph does not necessarily mean that there was no search or no news, but it means that that data amount was not significant as compared to the other data shown on the graph. The next keyword "peak oil" was added to the analysis (as shown in figure 2) to see corresponding differences in search patterns. As we see in figure 2, public interest in "peak oil" is much higher than that of "oil reserves" although the graphs show good level of correspondence. Interestingly, the news for "peak oil" has much larger effect on search trends for "peak oil" as compared to those of "oil reserves". This could be because "peak oil" is "perceived" as almost the ultimate oil scarcity problem (Robert, 2004) and, therefore, ranks higher in search patterns due to public interest association with this perception. Finally, keyword "oil price" was used along with the first three keywords and the results are shown in figure 3. As we see in figure 3, "oil price" search volume is much higher relative to all three other keywords and this could be because "oil price" is what people face directly and therefore have a stronger interest and perception about it.

Figure 2. Search trends analysis for "oil reserves", "coal reserves" and "peak oil"

Figure 3. Search trends analysis for "oil reserves", "coal reserves", "peak oil" and "oil price"



Country-wise variation was also investigated for above fossil energy resource related keywords. In figure 4 (peak oil) & 5 (oil price), we see that for countries Australia, Canada, India, United Kingdom (UK) and United States (US) there is considerable variation in search volumes for "peak oil" but the search volumes for "oil price" are considerably similar although both keywords are related. This could again imply that interest and perception towards "oil price" is much higher globally as this hits the consumers directly although the other keywords too have link to "oil price" (although several times oil price can be artificially manipulated due to trading). These 5 countries were chosen to create a mixture of developed and developing (India) countries and because english is the major language in these countries (thus increasing the likelihood of using english keywords for search – which helps in making the study coherent). Inclusion of China, Brazil etc would have been very interesting but it was observed that the internet searches in those countries was done more in local languages and not much in english.

Figure 4. Search trend analysis for "peak oil" across India, Canada, UK, US, Australia.

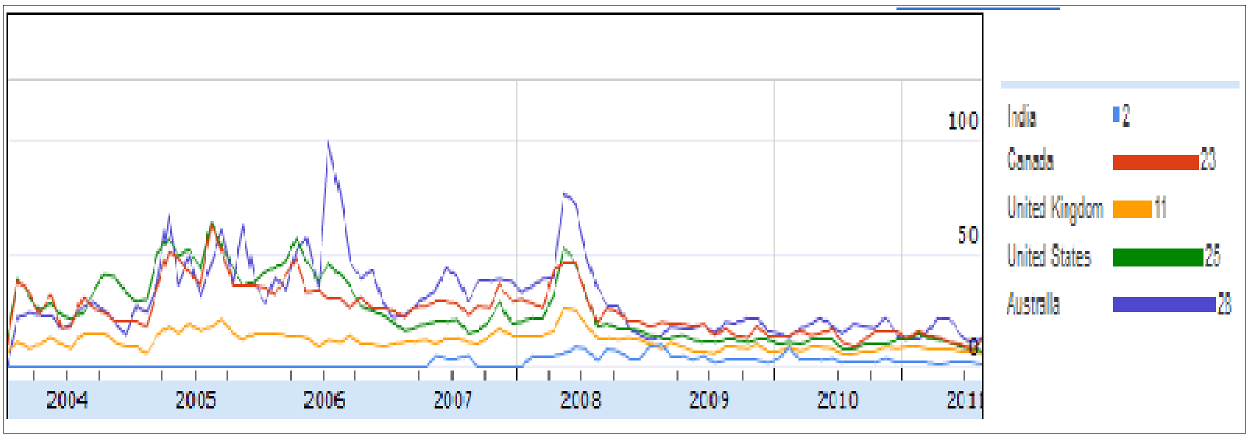
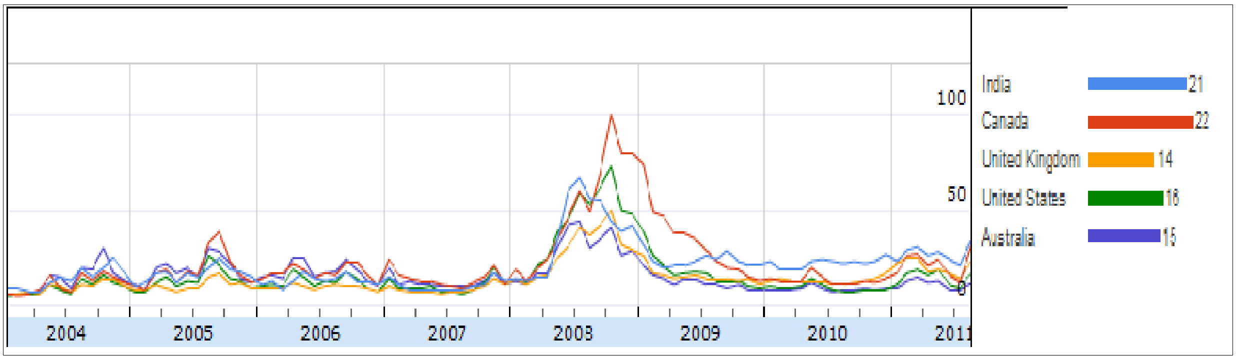
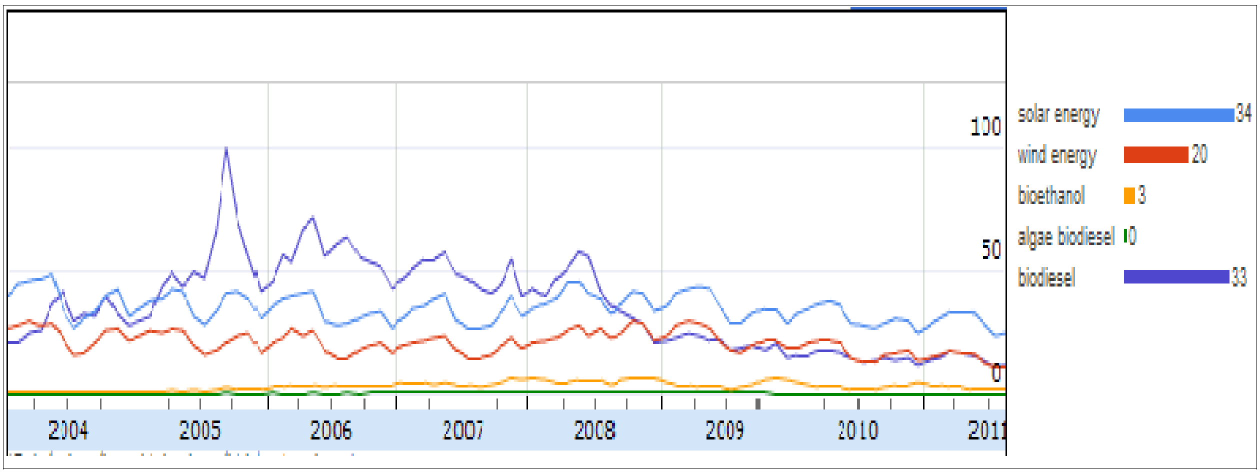


Figure 5. Search trend analysis for "oil price" across India, Canada, UK, US, Australia.



Next public interest for different renewable energy resources was investigated. "Solar energy", "Wind energy", "Bioethanol", "Biodiesel" (in general) (Kent and Andrews, 2007) and "algae biodiesel" (biodiesel made from algae) were used. These represent a large fraction of renewable energy resources which are being developed. Algae biodiesel is a relatively new technology and pilot studies have shown that it is a promising resource for biodiesel which can be used for transport (Chisti, 2007, Sheehan et al, 1998, US DOE, 2010). Figure 6 shows the search trends analysis for these renewable energy resources.

Figure 6. Search trend analysis for Solar energy, wind energy, bioethanol, algae biodiesel, biodiesel.



As can be seen, search patterns for solar and wind energy are sustained and consistent (wind less than solar) indicating sustained public interest in these renewable energies. For biodiesel, the interest soared in 2005 and since then has been waning. Bioethanol search volumes are much lesser as compared to the other three and higher only than algae biodiesel (whose search volumes are inconspicuous as compared to the other four). Public interest in biodiesel and bioethanol may have waned because of food versus fuel conflict, rising feedstock and related costs which lead the sector to become more or less unsustainable (Ardawatia, 2010) except in countries like Brazil and US (where too long term effects are yet to be seen).

It is intriguing to see that public interest in algae biodiesel (as reflected from search volume) is very low as compared to other renewable energy resources. Algae biodiesel can be produced industrially in a controlled manner, does not require as much land as compared to other biofuels (corn and soyabean based bioethanol, palm, rapeseed and jatropha etc. based biodiesel), does not compete with food resources, has a higher yield as compared to other biofuel feedstocks, can use the same transport mechanism as regular fossil oil and can help carbon sequestration (algae needs CO_2 for survival) in a controlled manner (Chisti, 2007, Lee, 2001). It does not clash with food resources unlike other biomass feedstocks which give rise to food-versus-fuel conflict (Sandvik and Moxnes, 2009). Further, continuing research and development may lead to methodological innovations which could push the process for algae biodiesel production towards the one emitting less greenhouse gases (GHGs). One reason for low interest could be that it is a new technology which many people apart from scientific and specific industrial communities may not know about. Another reason could be that algae biodiesel, like all renewable energies is much costlier than conventional fossil fuels (Kovocevic and Wesseler, 2010). Further, there are uncertainties associated with algae biodiesel, as can be with regards to any new technology (Kromer, 2010). Given the debacle of crop based biodiesel, people, in general, may be skeptical about algae biodiesel.

3. Feedback Models for Algae Biodiesel Sector

Given the fuel promise of algae biodiesel (Chisti, 2007), it is worthwhile for policy makers to develop policies with long-term perspective and around sustainability issues. This can be achieved through systems approach by developing feedback models and investigating and understanding endogenous relationships between key parameters in the algae biodiesel system. Policies could be built around parameters which are related to building blocks of sustainability for algae biodiesel system. Such policies would potentially be more informed and potentially facilitate taking off and sustainable development of algae biodiesel sector. With this view, systems oriented feedback models of the algae biodiesel sector were developed and that work is presented in this section.

The algae biodiesel sector was conceptually divided into 7 different overlapping sub-sectors (with 4 counteracting (balancing) feedback loops (B1, B2, B3, B4) and 4 reinforcing feedback loops (R1, R2, R3, R4)) to explain experience development and cost evolution in algae biodiesel system. In counteracting feedback loops effect of any parameter, if traced all through the loop, has a counteracting or balancing or negative effect on the growth of that parameter itself (Sterman, 2000). In reinforcing feedback loops effect of any parameter, if traced all through the loop, eventually reinforces the growth of the said parameter (Sterman, 2000). Vensim software (www.vensim.com) was used to formulate the feedback models. The following are critical sub-sectors which are part of overall system structure algae biodiesel system. Policies developed by understanding behaviour of the system based on their interplay could potentially facilitate sustainable development in algae biodiesel system are:

- Algae Biodiesel supply demand sub-sector (B1)

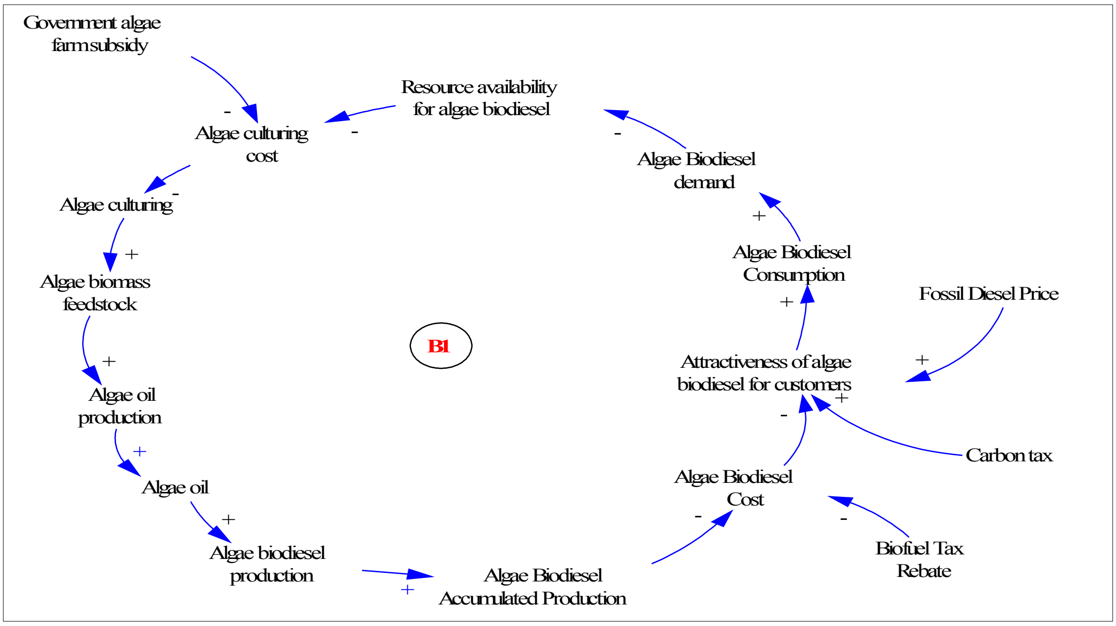
- By-product supply demand sub-sector (B2)
- Cost sub-sector (B3)
- Algae Biodiesel Production attractiveness sub-sector (B4)
- Algae Biodiesel attractiveness sub-sector (R1, R2)
- Algae Biodiesel feedstock production sub-sector (R3)
- By-product development sub-sector (R4)

3.1. Algae biodiesel supply demand sub-sector

The supply chain of biodiesel starts with algae cultivation. Initially, the increase in algae cultivation leads to more production of algae oil which further leads to higher production of biodiesel. More biodiesel in the market leads to higher supplies and thus decrease in biodiesel price. Price can be further decreased through government support in the form of tax rebate and subsidies. A higher biodiesel price can decrease the attractiveness of biodiesel for customers (and vice versa) and if the mineral oil price is low, the attractiveness decreases further. The more the attractiveness, the higher the consumption and thus higher the biodiesel demand. Higher biodiesel demand leads to higher algae oil demand putting increasing pressure on algae cultivation resources and thus increasing the cultivation cost. This higher cultivation cost can be prohibitory and lead to decrease in algae cultivation. Figure 7 shows the Biodiesel supply-demand sub-sector and also counteracting feedback loop (B1) in this sector. Attractiveness of Biodiesel for Customers can be given by a simple equation (Equation 1)

[Attractiveness of Biodiesel for Customers = Mineral Diesel Price / Biodiesel Price (1)

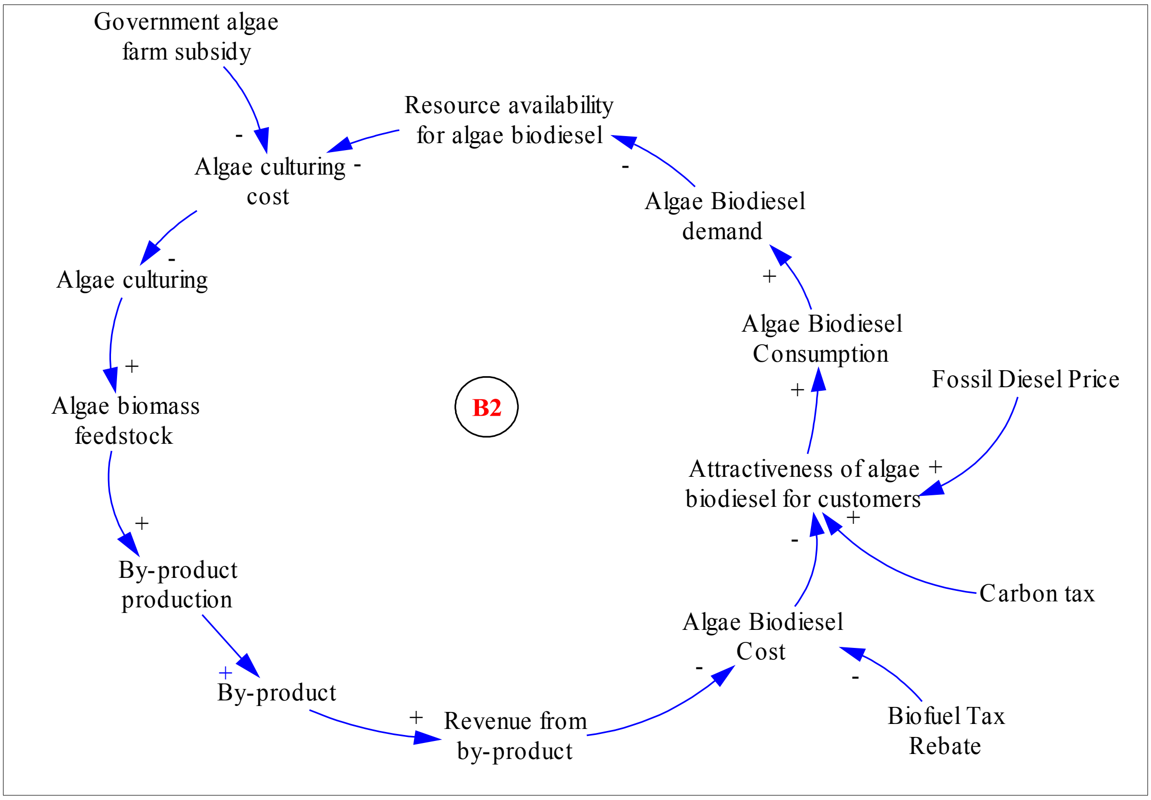
Figure 7. Causal loop diagram for Algae supply demand sub-sector.



3.2. By-product supply demand sub-sector

Similar to the algae biodiesel supply-demand sub-sector, another counteracting loop (B2) exists in the by-product supply-demand sub-sector (figure 8). This sub-sector emphasizes the importance of by-products in the overall algae biodiesel sector and how revenues from by-products can influence the biodiesel price. The loop polarity in this case is also balancing (counteracting) because of the same reasons as explained above..

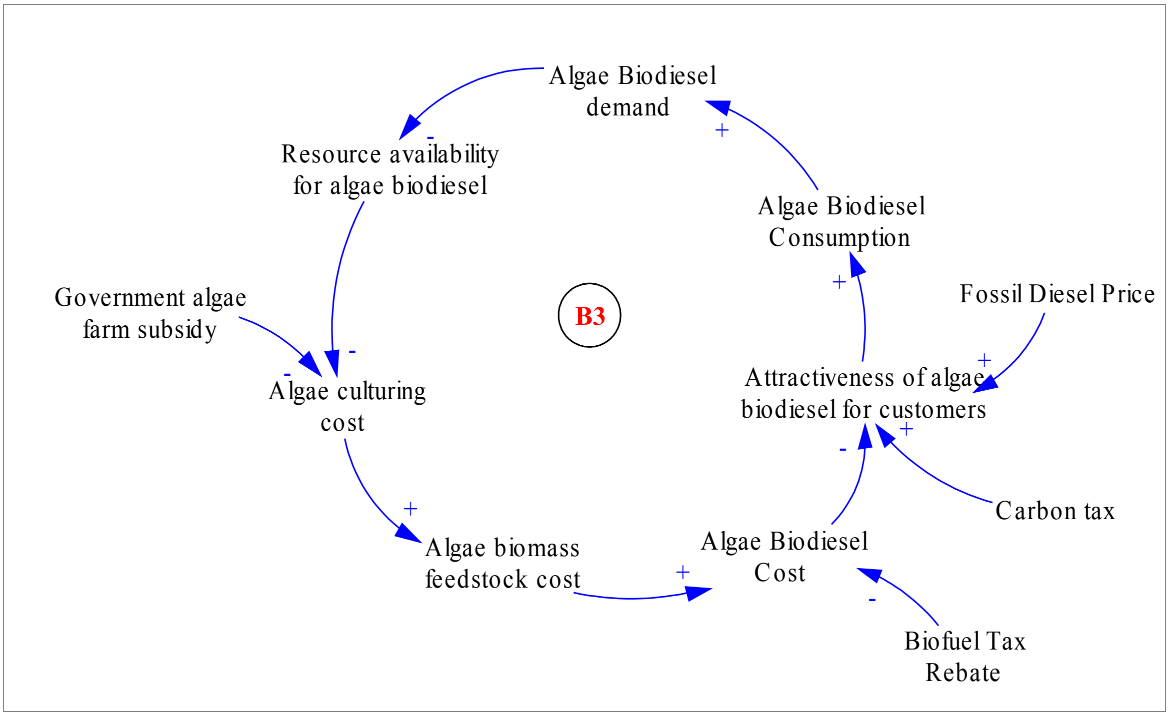
Figure 8. Causal loop diagram for by-product supply demand sub-sector.



3.3. Cost sub-sector

This sector (figure 9) signifies how high demand can put pressure on resources thus increasing their cost. The higher the resource cost, the higher the cultivation cost and the higher the cultivation cost, the higher the algae biomass cost and further algae biodiesel cost which further leads to increase of the overall algae biodiesel price. It is assumed, for simplicity sake, that algae biodiesel production cost directly translates to algae biodiesel price (which is further adjusted based on foreign biodiesel price, taxes etc). This also constitutes another counteracting loop (B3).

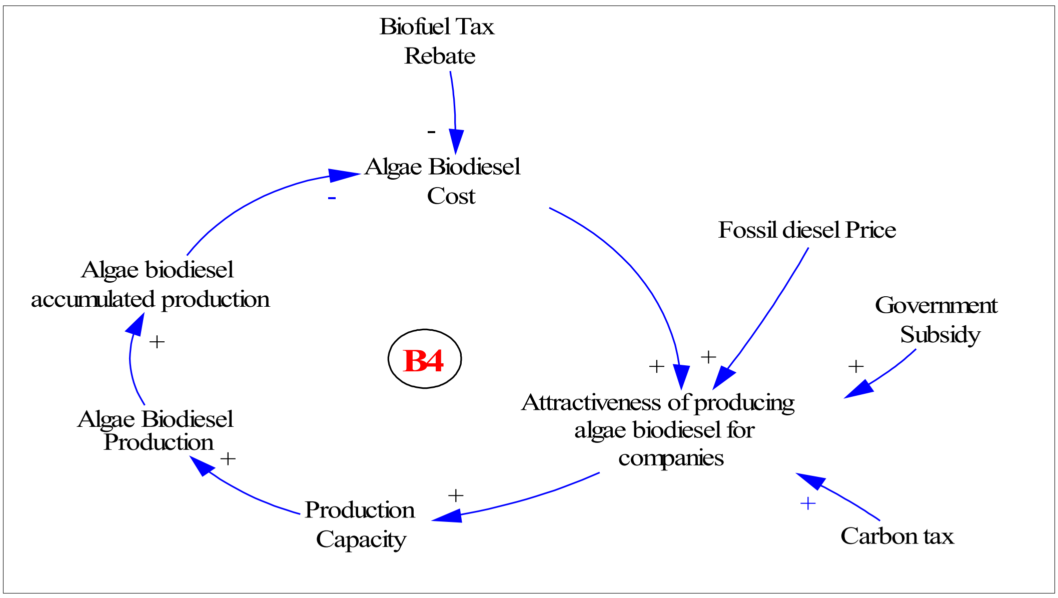
Figure 9. Causal loop diagram for cost sub-sector.



3.4. Algae biodiesel production attractiveness sub-sector

The balancing loop B4 plays the major role in this sub-sector (figure 10). This sub-sector signifies the role of higher prices in increasing the attractiveness for the industry to build more production capacity. Such higher production capacity further increases algae biodiesel volumes thus increasing the supply. Higher biodiesel volumes in market can lead to lower prices which can further lower the attractiveness for producing algae biodiesel.

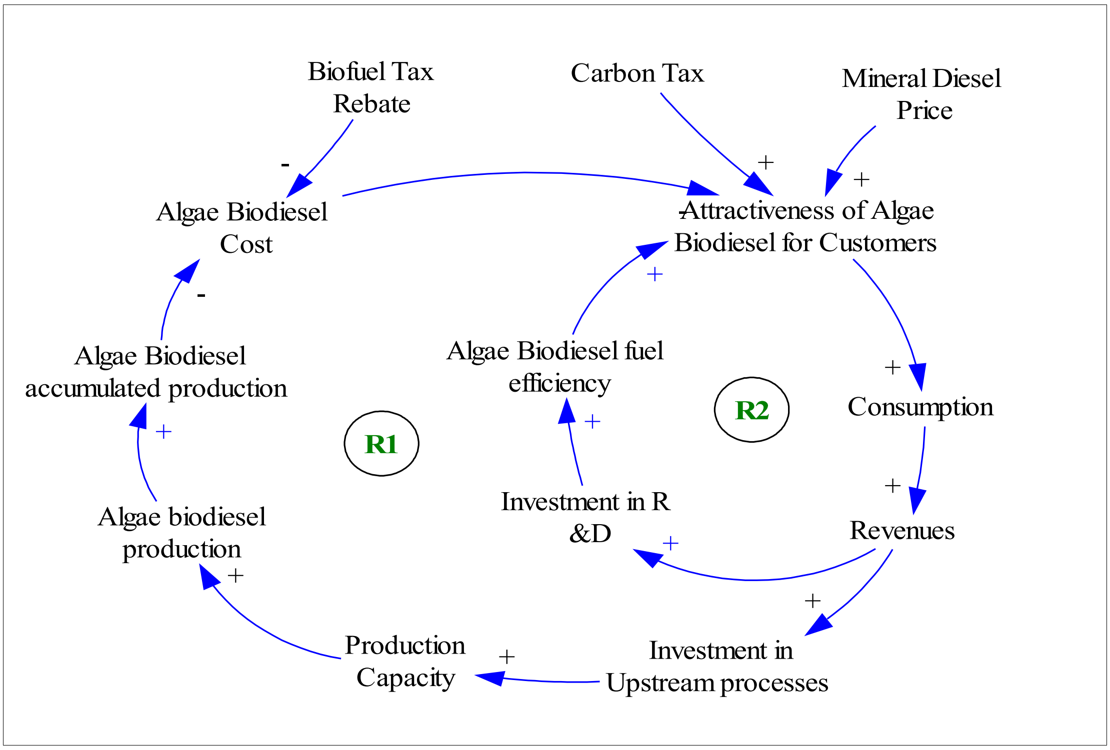
Figure 10. Causal loop diagram for algae biodiesel production attractiveness sub-sector.



3.5. Algae biodiesel attractiveness sub-sector

This sub-sector (with reinforcing loops R1 and R2) brings the customer and investment perspective in the picture. As shown in figure 11, the lower algae biodiesel prices can increase its attractiveness for customers thus further increasing consumption and market share. High Fossil diesel price and high carbon tax corroborate increased algae biodiesel attractiveness for customers. Higher consumption leads to higher revenues which lead to higher investments in upstream processes like towards increasing biodiesel production capacity which increases production which further increases accumulated production and biodiesel volumes in the market thus decreasing price. Biodiesel production capacity is an aggregation of labor capacity, machine capacity and any factor which consitutes towards increasing production capacity. Higher revenues also lead to higher investment in R&D activities which can improve fuel efficiency of algae biodiesel thereby increasing the attractiveness of algae biodiesel for customers (loop R2).

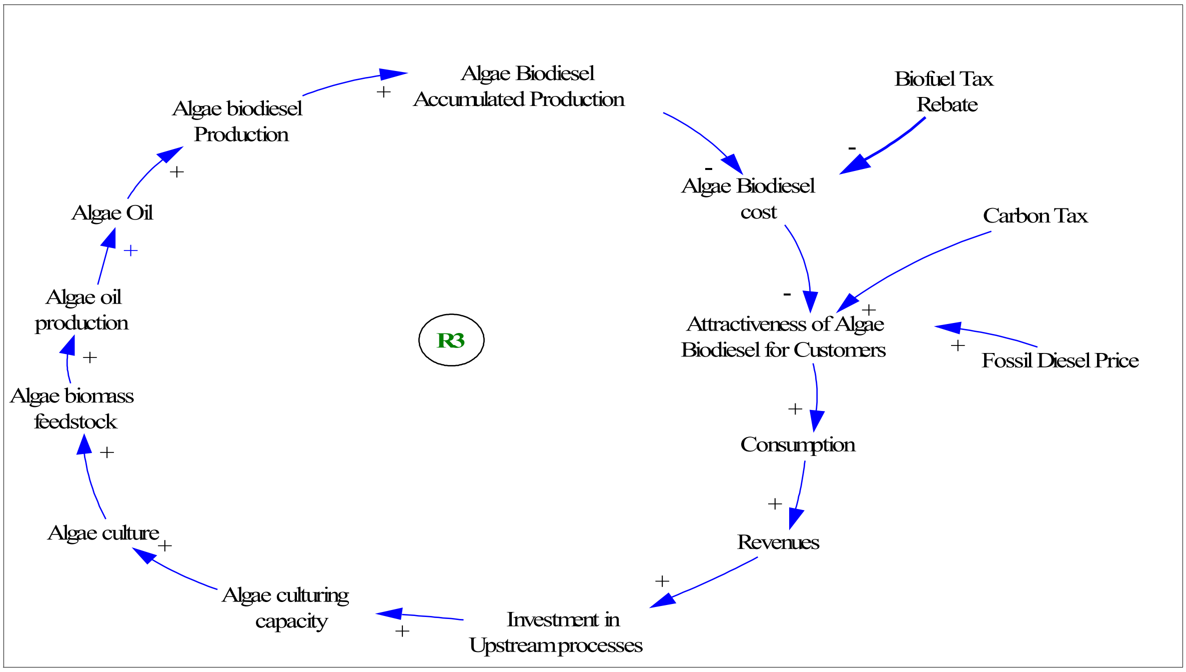
Figure 11. Causal loop diagram for algae biodiesel attractiveness sub-sector.



3.6. Algae biodiesel feedstock production sub-sector

This sub-sector is similar to the algae biodiesel production sub-sector except that the higher revenues generated from higher consumption lead to higher investment in building higher algae biomass cultivation capacity which affects parameters further in the loop causing the overall loop polarity to be reinforcing (positive) This loop is R3 and the sub-sector is shown in figure 12.

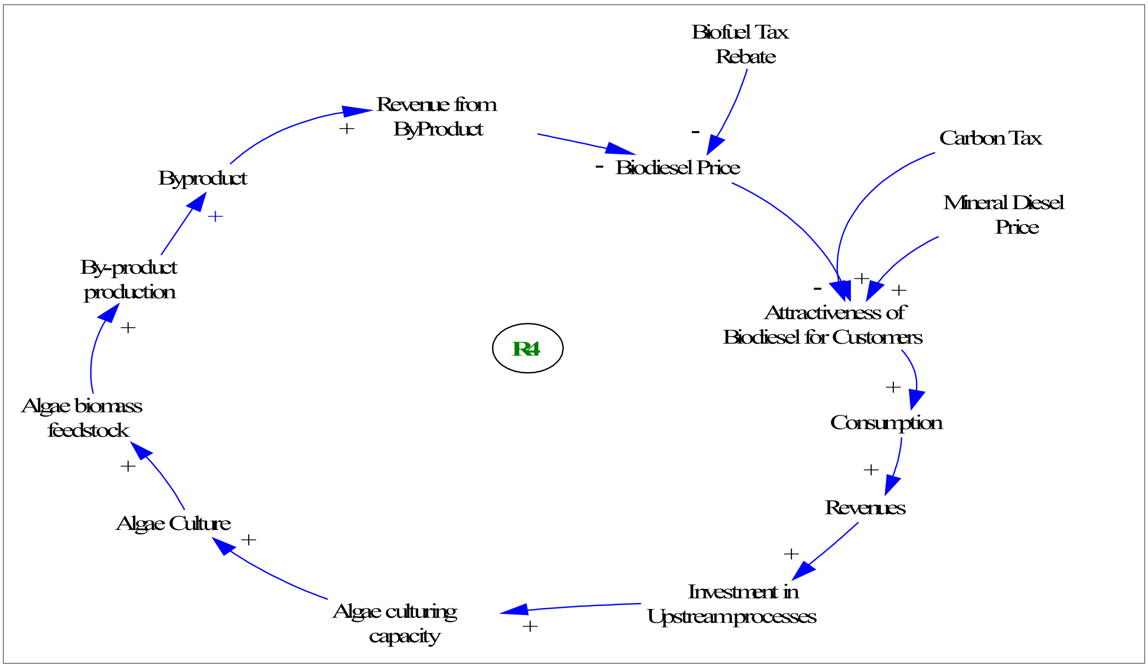
Figure 12. Causal loop diagram for algae biodiesel feedstock production sub-sector.



3.7. By-product development sub-sector

This sub-sector is similar to the previous sector, except that by-products are involved in this sub-sector. Inclusion of by-products in the industry can help offset costs through the revenue generated through sale of by-products. The higher the revenue from by-products, the lower the algae biodiesel price. This culminates into the reinforcing loop R4 (figure 13).

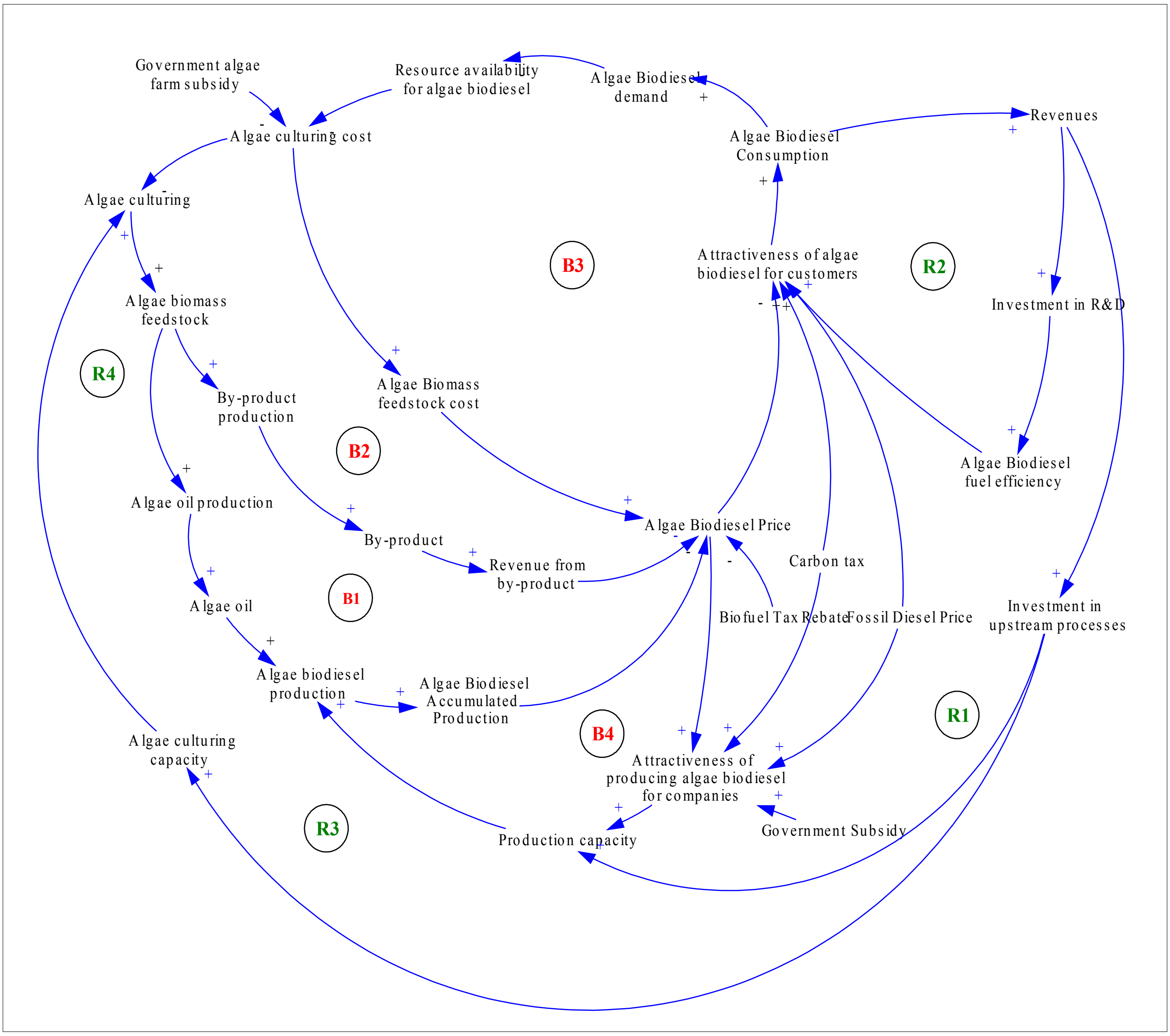
Figure 13. Causal loop diagram for by-product development sub-sector.



3.8. Integrated model

The overall integrative feedback model is shown in figure 14. All the reinforcing and balancing feedback loops have been integrated into this model and it can potentially help in understanding the interplay of different loops in different scenarios.

Figure 14. Feedback model for understanding endogenous learning in algae biodiesel system.



4. Conclusions

Online trends analysis was used to understand public interest patterns across different natural resources and countries. Considerable difference in interest was found in different aspects of resources and public interest for different aspects was found to be coupled and de-coupled with reference in corresponding news media in different cases. This indicates that public perception may not be guided just by media or criticality but also be "how directly or indirectly" people are affected by a resource issue. Aspects which affect consumers directly (for example, oil price) ring similar public interest patterns across countries. Therefore, for global negotiations and policies such aspects should be given prime consideration – this may help in larger participation with more consensus across countries. This could potentially help in policy formulations for sustainable development around critical issues.

Considerable variation also exists in public interest in different types of renewable energy resources (for example, wind, solar, biomass related). New promising renewable resource based technologies may not rank so much higher in search patterns as compared to established ones. This may not necessarily be due to less interest but may be due to less knowledge or skepticism based on previous similar technologies (bioethanol and biodiesel versus algae biodiesel). Although this can not be confirmed with certainty but systems oriented policies could potentially be of use in facilitating sustainable development of such new technologies. Systems oriented feedback models for algae biodiesel system were developed which may be of good help to understand algae biodiesel system and designing policies around key parameters associated with building blocks of sustainability for algae biodiesel system or any related system for that matter. Such models can be used by policy makers and public alike to make informed and optimal decisions (Vennix, 1996).

Acknowledgments

The author would like to thank Professor Erling Moxnes, University of Bergen, Norway for discussions about feedback models in algae biodiesel system.

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