Research Diary

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Biofuel-based energy generation in India – is this a feasibility at the country level?

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One of the vibrant global issues i.e. how to tackle the increase in energy demand with depleting conventional fossil fuels is currently addressed through optimal usage of non-conventional energy sources namely solar, wind, tidal, geothermal, and bio sources. For a developing nation like India, where 70% of the population depends on forest and agriculture, the bioenergy sector can play a vital role that is yet to be utilized to its full potential. The national initiatives towards blending 20% biofuels with fossil fuels are catalyzing this fact further. Some of the existing challenges in this sector are (i) biofuels have a calorific value less than fossil fuels leading to more quantity of biomass needed for energy generation, (ii) need of Flexi-fuel engines costlier than regular engines, (iii) food vs fuel issues for 1st generation biomass, (iv) availability of biomass throughout the year due to seasonal nature of crops in addition to their heterogeneity in composition across geographies.

Despite a lot of research happening at individual levels to ameliorate the current state-of-the-art technologies for energy conversion from different bioresources, a novel approach has been adopted by Global Optimization and Knowledge Unearthing Laboratory (GOKUL) to attack these problems holistically from the vantage point of a supply chain (SC) network designer.

An SC bridges several entities present in different echelons (material supply, manufacturing, distribution, and collection) involved in converting the raw material into the finished goods and enables a designer to find possible avenues of improvement in the whole product life cycle. An endeavor towards designing such a country-wide supply chain network has been successfully attempted for the first time considering the target of blending 20% of both bioethanol and biodiesel for a future time horizon (2018-2026) using 2nd generation biomass.

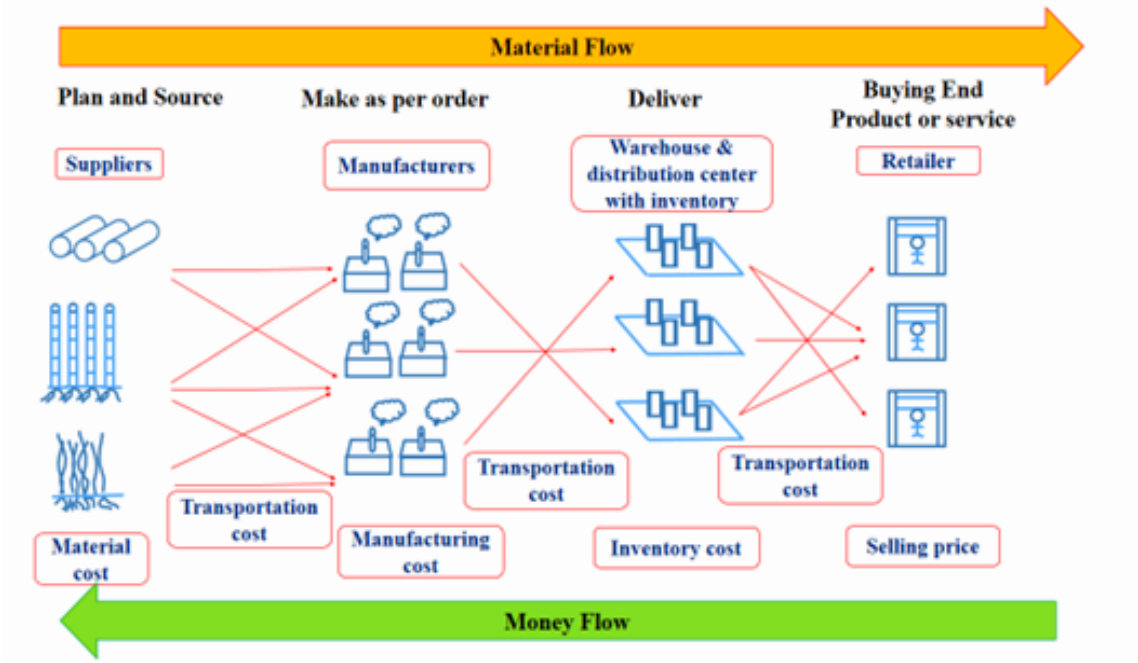

Fig. 5: General overview of Supply Chain Network Design

The objectives of the SC to maximize the profit net present value and simultaneously minimize the pollution causing greenhouse gas emissions (GHGe) have been achieved through mixed-integer linear programming, which is NP-hard to solve. External importers are also included to manage the shortfall in indigenous production and to maintain the product quality in terms of research octane number. The unique SC model covers all three aspects of technology, economy, and environment keeping sustainability in mind. From the technology side, the model deals with the choice of site location, capacity planning, multi-connection routing, the choice for mode of transport considering biomass to biofuel conversion yields for several raw material choices to handle seasonality issues. Considering the time value of money and depreciation, economic calculations are performed not only tackling the capital and operating expenditure but also through the GHGe emission, GHGe savings, and conversion of carbon savings into carbon credits representing the environmental aspects.

Further, to make the SC design realistic, stochasticity in biofuel demand, import price, and biomass feed supply has been modeled using a data-driven robust optimization approach. Overcoming the drawbacks of conventional robust optimization, the adopted approach performs accurate transcription of uncertain parameter space using unsupervised machine learning approaches, which resulted in more accurate, non-conservative robust solutions. In addition to being bestowed with the best paper award by the International Federation of Automatic Control Conference (ACODS 2020), the project findings are published in the prestigious International Journal of Cleaner Production on several occasions.

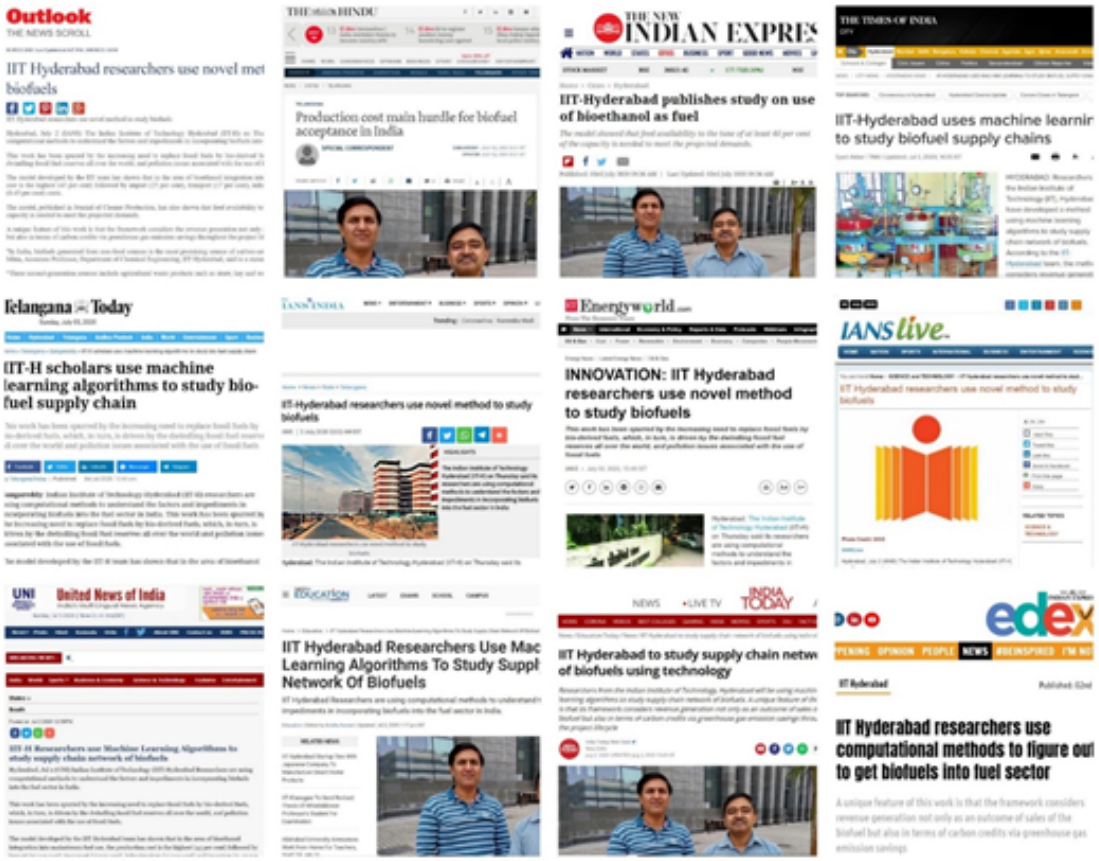

Fig. 6: Collage of Media response to the Bio-fuel based energy generation idea