Biofuel Supply Chain Sustainability Assessment through Circular Economy

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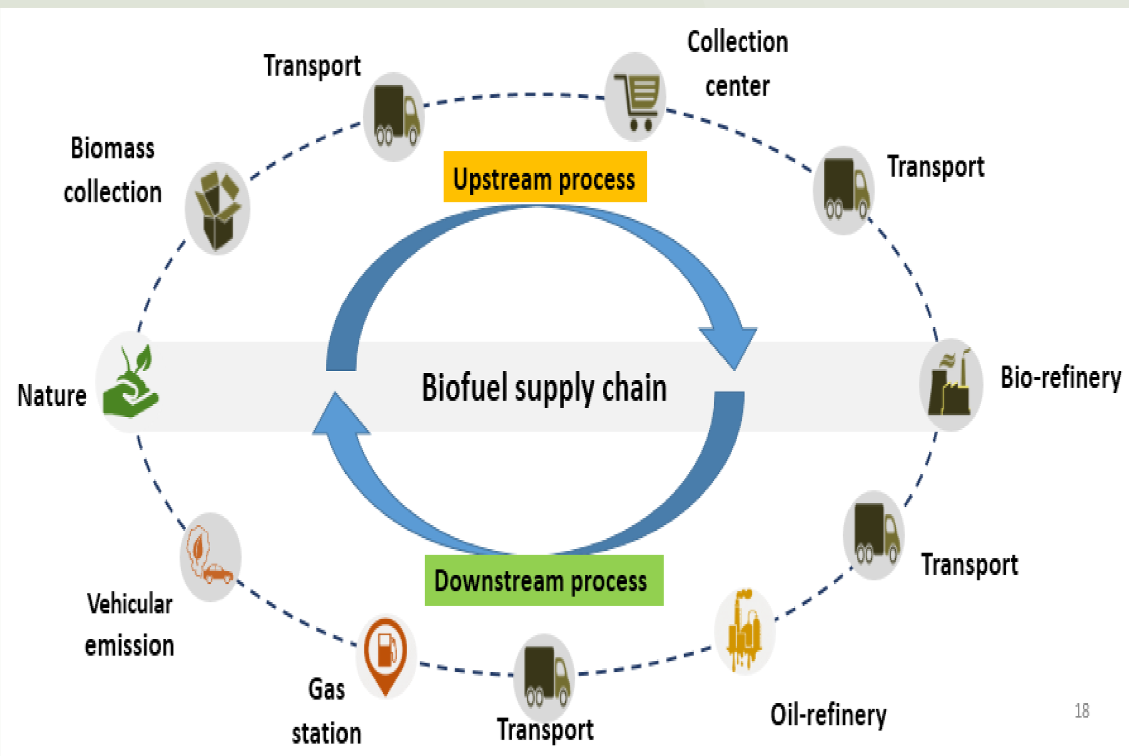
ABSTRACT

Global concerns on depleting fossil fuel supply and growing emission of GHGs have led to development of sustainable technology .In this study, as a contribution to the research domain, it is proposed to assess the sustainability of second-generation **biomass** to **ethanol** supply chain with enhanced emphasis on research related to renewable and sustainable energy. The focus has spanned from fundamental science and engineering research leading to renewable energy using cradle-to-cradle or circular economy approach. The proposed biofuel supply chain includes a (2G) Bioethanol production system that uses biomass sourced from surplus agro-waste and the ethanol produced is utilized in the transport sector. Given this, the objective is to design a conceptual framework that maps the circular economy of biofuel supply chain by including all the stages of transformation – (i) Agriculture, (ii) Biomass logistics, (iii) Biofuel production, and (iv) Biofuel utilization. Both the inputs to and outputs from (positive and negative, useful and waste) every stages of transformation are captured. Next, the sustainability assessment is performed by including indicators related to techno-economic, social and environmental dimensions of each of the transformation. Modern optimization approach (Particle Swarm Optimization) has been implemented in the optimization process. We are trying to optimize the system profit while surplus biomass is transported and stored in collection center. The model is validated using data obtained from the feasibility study of a proposed second generation bioethanol plant in India. Results shows the importance of surplus amount of biomass as deciding parameter. It confirms that there is positive correlation of surplus amount of biomass and profit in the economic model, thus, increasing overall economic stability of ecosystem.

OBJECTIVES

1. To develop a generalized second-generation biofuel supply chain adopting a circular economy framework.
2. To validate the above framework for selected biomass types in the case of Karnataka.
3. To develop and validate an optimization model to assess cradle-cradle sustainability of biofuel supply chain.
4. To provide inputs for industries and policy makers based on the results and findings.

Representation of proposed biofuel supply chain



Introduction to Circular Economy

The foundation of Circular Economy is based on the 3R principle.

Reduce, Reuse, Recycle

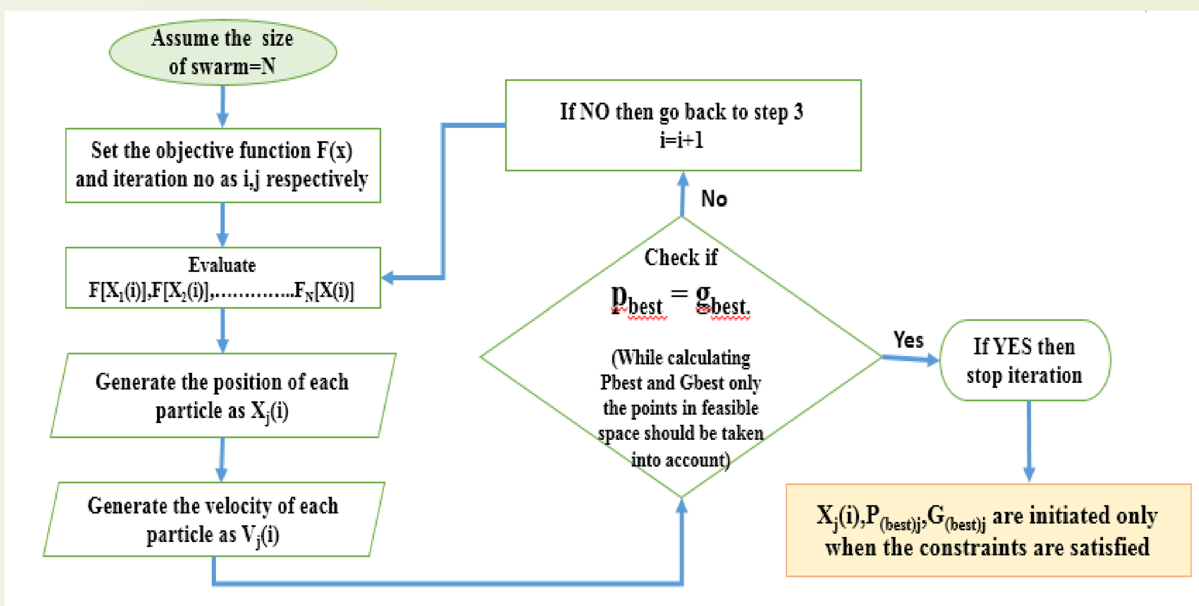
This definition states that Circular Economy is restorative and eliminates waste by design through better materials, products and systems design, enabled by innovative business models. Circular Economy's principles are to embrace systems thinking, design out waste, embed diversity, use waste as food and run closed-loop systems on renewable energy. Circular Economy experts have postulated many theories to prove cradle to cradle approach. They are 1- Blue Economy 2- Performance Economy 3- Biomimicry 4- Industrial Ecology .

The model follows Biomimicry path in the first phase of cradle to cradle approach.

Systems thinking which is a subset of Biomimicry is adopted ,where Nature is taken as 1-Mentor 2- Measure 3- Model.

In the first phase of analysis 'System Profit' is calculated by implementing a Modern Optimization Technique ,Particle Swarm Optimization.

ALGORITHM



A single variable PSO Model is adopted. The system profit is calculated as

System profit = Selling price of biomass at the factory gate – (Fixed Cost + Variable Cost in collection center)- Fixed Cost of Transportation – Variable cost of transportation.

While solving the Objective function several constraints are taken into account They are supply Constraint, transportation constraint, capacity constraint, workforce constraint.

$$\sum_{k\in K}\sum_{f\in F}\sum_{t\in T1}\sum_{a\in A^{+}_{frt}} CkZ_{ka} - \sum_{f\in F}\sum_{r\in R}(C_{fr}x_{fr} + V_{fr}\,q_{fr}) - \sum_{a\in A} C^{a}_{T}\,y_{a} - \sum_{k\in K}\sum_{a\in A} V^{a}_{T}\,Z_{ka}$$

Nomenclature

f	facility
r	technology type
t	time
p	biomass type
e	biofuel type
k	commodity type
l	layer

x_{fr} = 1 if facility "f" of type "r" is open,0 otherwise

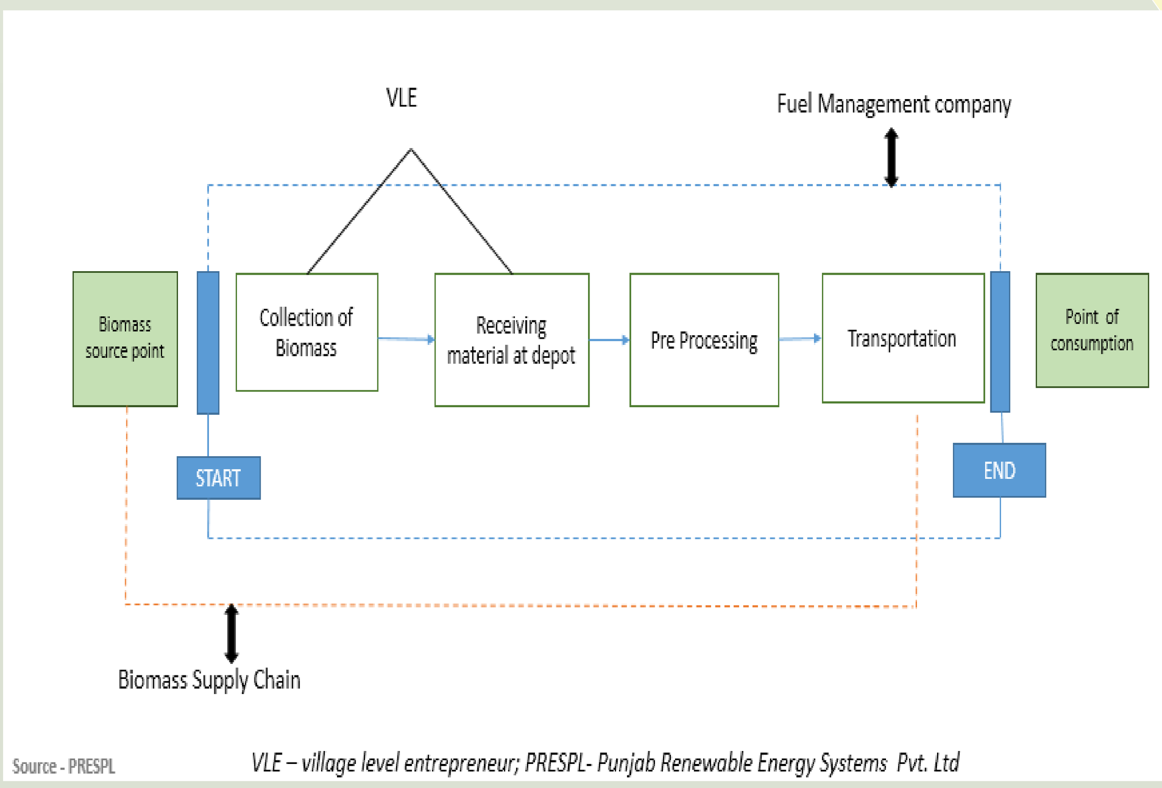
y_{a} = 1 if arc a is directed ,0 otherwise

q_{fr} = capacity of facility "f" of type "r"

z_{ka} = flow amount of commodity k on arc "a"

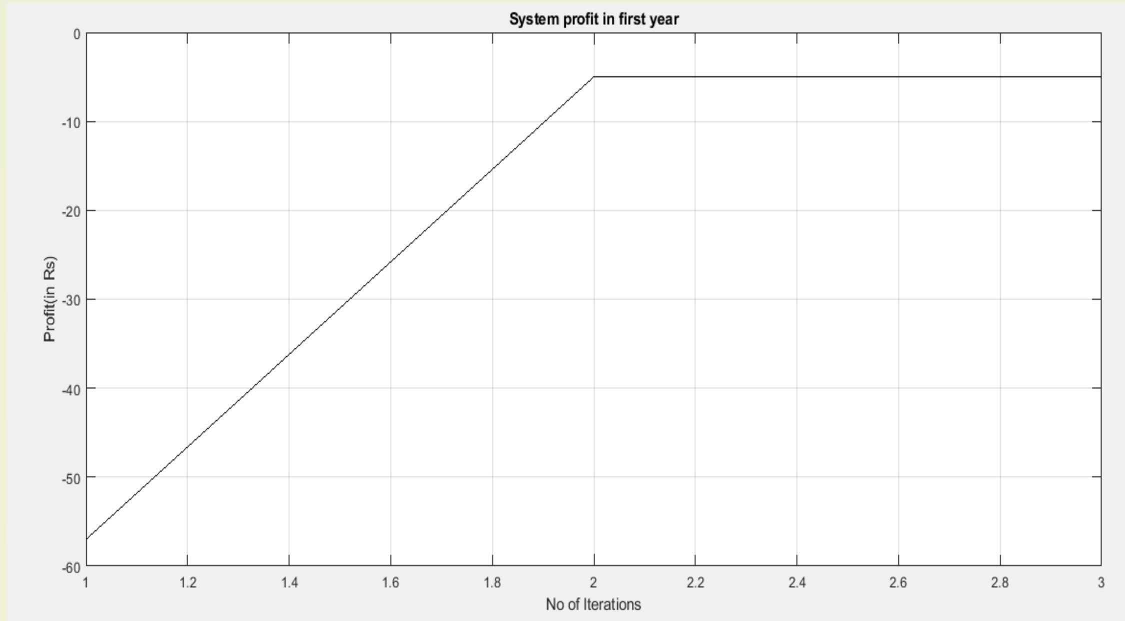
Case study of Ranebennur area & Calculation of system profit

Ranebennur comes under Haveri district and is a taluk of the state Karnataka. The collection center is situated in Rannebenur. Three villages are supplying crops to the collection center. These three villages are Anagodu, Hirekerur, Harpanahalli. The maximum distance between biomass supplier and collection center is 70 km.
The model is inspired by a consulting firm's (PRESPL) model .
The description of the model is given below.



The collection center deals with Maize stalk, Maize cobs and Paddy. In the first case Maize stalk as the crop for determination of system profit.

RESULTS



DISCUSSIONS

The above plot gives the idea that there is no profit in the first year. As the installation cost/Fixed cost is more in the first year ,hence negative profit is inevitable. But if we go further ,in the consecutive years the break even point will be achieved. We are working on real time data and due to the unavailability of data the plot for the further years has not been achieved. We have tried to plot the influence of parameters on the system profit .The study shows that neither the number of farm areas nor the distance of the farm area from collection center is a significant variable. Rather **Surplus Biomass** is the deciding parameter.

SUMMARY & FUTURESCOPE

In the second phase of the proposed research, **mass balance** in the farm area has been established. It shows that maximum difference in the mass in and mass out is due to Biomass for 1) food 2) drainage before harvesting (12 days before) 3) Run off 4) Percolation 5) Evapotranspiration. Next socio-economic sustainability of the people associated to supply chain, optimization of GHG Emissions will also be addressed. Here only ethanol as a biofuel has been optimized. The same model will be utilized to optimize methanol and DME based supply chain.

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