Development of a Sustainable Biomass Supply Chain in Pakistan

Rubab Nazar[1], Abdul-Sattar Nizami[1]

[1]Sustainable Development Study Centre, Government College University, Lahore 54000, Pakistan

Keywords: biomass energy, biomass supply chain, solid waste management, gasification

Presenting author email: rubabnazar1234@gmail.com

Pakistan is the world's 6th largest populous country, with 2% annual growth rate, accounting for its lagging condition of various social, environmental, and energy concerns Irfan *et al* (2020); Shahid *et al* (2020). There is a prevailing electricity shortage in all urban (6-8 hours) and rural (12-16 hours) areas, especially during summer Ghafoor and Munir (2015); Shakeel *et al* (2016). Fossil fuels dominate the energy mix of Pakistan, where natural gas and oil have 49.5% and 30% share, respectively Hu *et al* (2020). It is estimated that in 2019, Pakistan imported 6.6 million tons of oil worth 3.4 billion US$ Yaqoob *et al* (2021). Currently, renewable energy makes a small contribution, 1.1%, to the country's energy mix Iqbal *et al* (2018).

There is a promising potential of biomass energy in Pakistan where most abundant and feasible biomass sources such as crop residues, municipal solid waste, and animal dung can be utilized to reduce electricity crises in Pakistan as adopted in the current study. In Pakistan, annually 230 billion t biomass is produced from various biomass sources collectively Iqbal *et al* (2018). In Pakistan, annually 115Mt crop residues are produced, and 524,580GWh electricity can be generated Irfan *et al* (2020). 48 million tonnes municipal solid waste is generated yearly with 2.5% annual growth rate Korai *et al* (2017); Hlaba *et al* (2016). Annually, 368,434,650 metric tons of animal dung is produced in Pakistan Naqvi *et al* (2018).

The aim of the study is to develop a biomass supply chain network design in Pakistan which is cost-effective. The present study is novel as a biomass supply chain mathematical model has been presented at country level using mixed integer linear programming, and gasification has been adopted as the suitable biomass conversion technology. GIS mapping has been done to locate these three biomass sources in the country and suggest potential locations of gasification plants based on the source locations and road structure. The results based on the output of Lingo 19.0 presented the optimal locations for supply and storage centers, optimal amount of biomass to be transported to gasification centers, and total biomass available at supply and storage centers. The results of the study show that 350,000kWh, 350,000kWh, 350,000kWh, 500,000kWh, 600,000kWh, 500,000kWh, 400,000kWh, and 3,330,000kWh electricity can be generated at Khairpur, Mianwali, Gujrat, Multan, Faisalabad, Sheikhupura, Tando M. Khan and Karachi, respectively from produced syngas with 20% electric efficiency.

The need is to increase reliance on biomass energy as evident from the current study. The adoption of gasification will enable to mitigate the impacts of climate change, encourage appropriate solid waste management, and meet the electricity supply and demand gap in Pakistan. The government of Pakistan should promote R&D, devise financial mechanism, and ensure international corporation to flourish biomass industry in Pakistan. Such researches on cost-effective biomass supply chain network design must be conducted to resolve the energy crisis of other developing countries and to fulfill the existing gaps in biomass supply chains of other Asian and European countries. In the present study, the utilization of secondary data and unseen practicality of the proposed biomass supply chain in Pakistan are the major limitations. The study still provides a successful picture of biomass supply chain in Pakistan by considering approximate conditions.

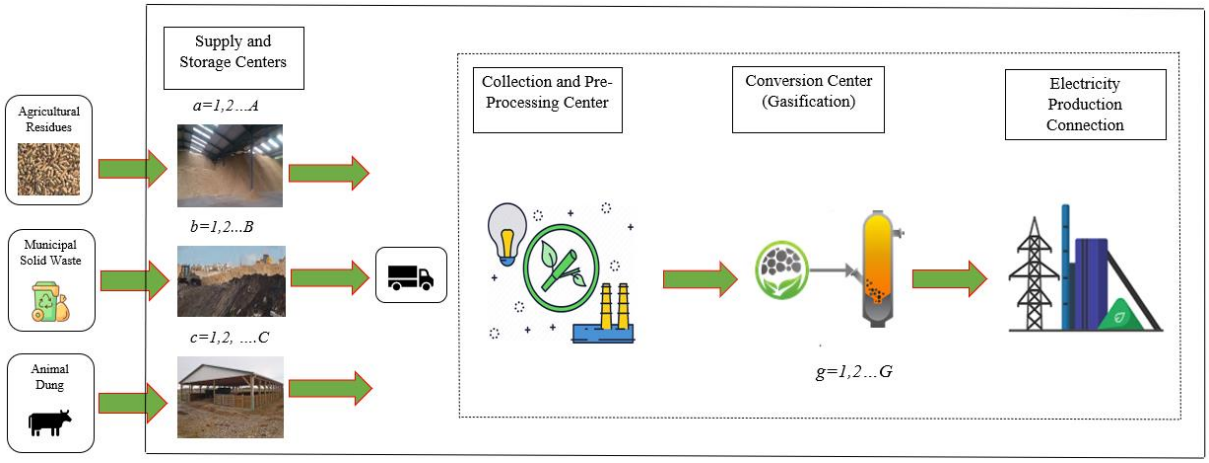

Fig 1. Framework for the proposed BSC network

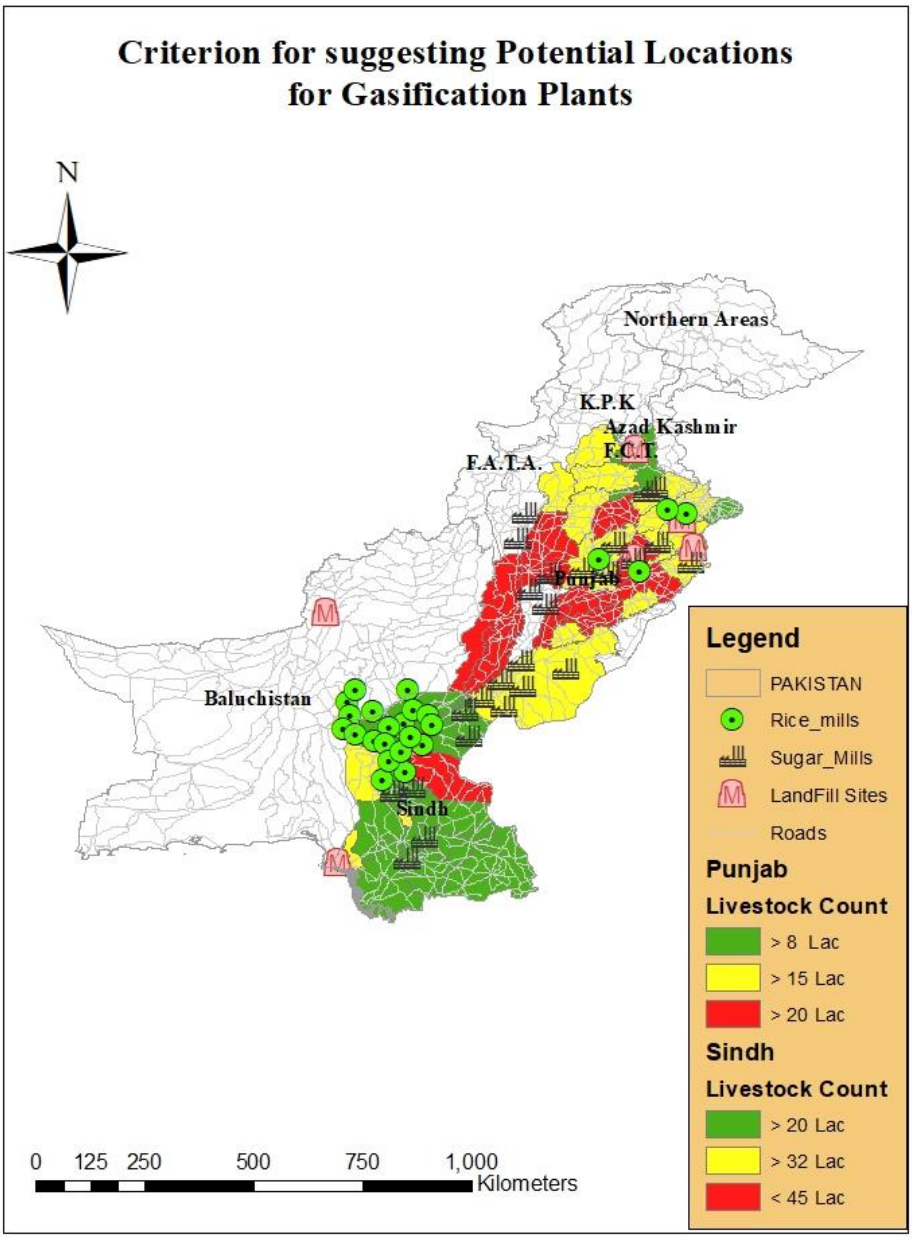

Fig 2. GIS mapping for suggesting potential locations of gasification plants in Pakistan

Table 1. Total mixed biomass availability (tonnes), syngas production (m3), Kcal, Total kWh, and actual kWh produced at gasification centers

Gasification centers (G)		Location	Total mixed biomass at (G) (tonnes/y)	Quantity of syngas produced at (G) m^3/y	Kcal/y	Total Kwh/y	Actual Kwh/y (0.45)
	1	Khairpur	486	2431	1,944,444	1,750,000	350,000
	2	Mianwali	486	2431	1,944,444	1,750,000	350,000
	3	Gujrat	486	2431	1,944,444	1,750,000	350,000
	4	Multan	694	3472	2,777,778	2,500,000	500,000
	5	Faisalabad	833	4167	3,333,333	3,000,000	600,000
	6	Sheikhupura	694	3472	2,777,778	2,500,000	500,000
	7	Tando M. Khan	556	2778	2,222,222	2,000,000	400,000
	8	Karachi	4625	23125	18,500,000	16,650,000	3,330,000

1. Ghafoor, A., & Munir, A., 2015. Design and economics analysis of an off-grid PV system for household electrification. Renew. Sustain. Energy Rev. 42, 496-502. https://doi.org/10.1016/j.rser.2014.10.012
2. Hlaba, A., Rabiu, A., & Osibote, O. A., 2016. Thermochemical Conversion of Municipal Solid Waste--An Energy Potential and Thermal Degradation Behavior Study. Int. J. Environ. Sci. Dev. 7(9), 661. https://doi.org/10.18178/ijesd.2016.7.9.858
3. Hu, X., Imran, M., Wu, M., Moon, H. C., & Liu, X., 2020. Alternative to Oil and Gas: Review of Economic Benefits and Potential of Wind Power in Pakistan. Math. Probl. Eng. 2020. https://doi.org/10.1155/2020/8884228
4. Iqbal, T., Dong, C. Q., Lu, Q., Ali, Z., Khan, I., Hussain, Z., & Abbas, A., 2018. Sketching Pakistan's energy dynamics: Prospects of biomass energy. J. Renew. Sustain. Energy. 10(2), 023101. https://doi.org/10.1063/1.5010393
5. Irfan, M., Zhao, Z. Y., Panjwani, M. K., Mangi, F. H., Li, H., Jan, A., ... & Rehman, A., 2020. Assessing the energy dynamics of Pakistan: prospects of biomass energy. Energy Rep. 6, 80-93. https://doi.org/10.1016/j.egyr.2019.11.161
6. Korai, M. S., Mahar, R. B., & Uqaili, M. A., 2017. The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan. Renew. Sustain. Energy Rev. 72, 338-353. https://doi.org/10.1016/j.rser.2017.01.051
7. Naqvi, S. R., Jamshaid, S., Naqvi, M., Farooq, W., Niazi, M. B. K., Aman, Z., ... & Afzal, W., 2018. Potential of biomass for bioenergy in Pakistan based on present case and future perspectives. Renew. Sustain. Energy Rev. 81, 1247-1258. http://dx.doi.org/10.1016/j.rser.2017.08.012
8. Shahid, M., Ullah, K., Imran, K., Mahmood, I., & Mahmood, A., 2020. Electricity supply pathways based on renewable resources: A sustainable energy future for Pakistan. J. Clean. Prod. 263, 121511. https://doi.org/10.1016/j.jclepro.2020.121511

9. Shakeel, S. R., Takala, J., & Shakeel, W., 2016. Renewable energy sources in power generation in Pakistan. Renew. Sustain. Energy Rev. 64, 421-434. http://dx.doi.org/10.1016/j.rser.2016.06.016
10. Yaqoob, H., Teoh, Y. H., Goraya, T. S., Sher, F., Jamil, M. A., Rashid, T., & Yar, K. A., 2021. Energy evaluation and environmental impact assessment of transportation fuels in Pakistan. CSCEE. 3, 100081. https://doi.org/10.1016/j.cscee.2021.100081

Thankful to Dr. Abdul-Sattar Nizami, Associate Professor, Sustainable Development Study Centre, Government College University, Lahore for his guidance, support and motivation throughout this research work.
