

**Cost-Benefit Analysis of Organic Refuse Derived Fuel: A Case study of Karachi City.**

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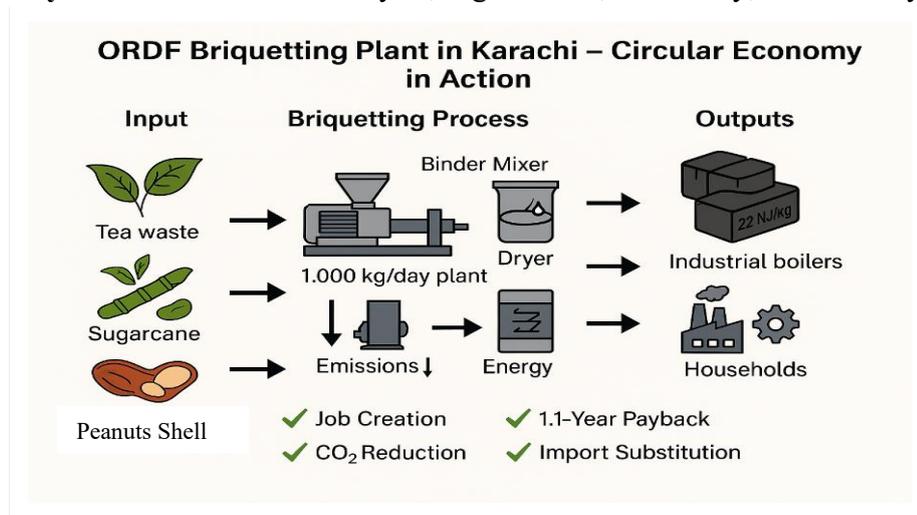
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**Abstract**

This study examines the following primary research enquiries: How economically feasible is the production of Organic Refuse-Derived Fuel (ORDF) in Karachi, Pakistan? What are the prospects for sustainability that ORDF generation presents within the framework of local waste and energy systems? This study performs a cost-benefit analysis of ORDF production to investigate these enquiries. About half of the municipal solid waste (MSW) in Karachi is organic, which turns an environmental problem into a possible source of energy. Using data on local market and energy prices, this analysis looks at the capital investment, operating costs, revenue, and payback period for a facility that makes 1,000 kg of briquettes every day, Entrepreneurs must invest up to PKR 4 million to launch the business, which is approximately the yearly energy cost for 100 average Karachi households. With annual running costs of PKR 9.2 million, revenue reaches PKR 12.78 million, yielding a net profit of PKR 3.57 million and a payback of about 1.1 years. This revenue will support full time employment of as many as 10 local employees. The financial resilience is assessed by scenario based models and Monte Carlo simulations that include changes in tariffs, binder costs and product price. The 10,000 simulations analysis has shown that the project will be economically viable with a payback period of less than 1.5 years in over 85 percent of the cases. The study identifies the advantages of ORDF, which entails social and environmental advantages and gives a sustainable remedy to city wastes. ORDF's potential in Pakistan's circular economy.

**Keywords:** cost-benefit analysis, organic fuel, case study, Karachi city.



## Introduction

There is a serious energy shortage that presents several risks to output and economic expansion such as 10 to 15 hours of electrical load shedding per day (Iqbal K.M.J *et al.*, 2021). Alternative energy sources are desperately needed to solve these issues (Doggar *et al.*, 2013). Since people are choosing renewable resources like wind, solar, and biomass fuel for their homes and businesses, Pakistan must embrace alternative energy sources to meet its growing energy needs (Raza k. *et al.*, 2024).

Materials, such as wood waste, organic waste, municipal trash, and different types of agricultural waste, are the source of biomass energy. According to Doggar *et al.* (2013), the total capacity of organic waste resources is estimated to be 156 million tons per year. Solid waste management has become a worldwide concern in the current urbanization era (Xue, 2017; Ferronato, 2019).

Pakistan is the second largest Islamic city, Karachi is a main industrial hub called a mini Pakistan Paracha, 2014; Cox, 2014; Khattak *et al.*, 2023). It is considered Pakistan's commercial center and is located on the southern shore (Jilani, 2007; Shahid *et al.*, 2014). Due to the majority of the population moving from rural to urban areas in search of better job prospects, urbanization in the city has dramatically amplified since the 1970s (Sharif and Raza, 2016; Aslam *et al.*, 2022).

Karachi Municipal Corporation (K.M.C.) said, approximately 18,000 tons of municipal solid waste are produced every day in Karachi. According to Mahmood, 2019 and Alam, 2020, Pakistan is in a serious condition as a result of the energy crisis and the social and environmental issues brought on by the improper handling of municipal solid waste (IB Finance, 2025).

Low income communities in the city primarily rely on firewood or charcoal for cooking and other necessities in the majority of Karachi's urban areas (Ahmed *et al.*, 2015; Aized *et al.*, 2018; Abdel-Shafy and Mansour, 2018). Deforestation has occurred as a result, aggravating desertification and reducing a number of ecological features, including major environmental disturbance and the inevitable loss of biodiversity (Khan, 2009; Ali *et al.*, 2018). Organic refused derived fuel are an affordable way to minimize the negative environmental effects of producing and disposing of solid waste (Suberu *et al.*, 2012; Tamilvanan, 2013; Arry *et al.*, 2016; Kpalo *et al.*, 2020).

It is a common densification process used in the production of solid fuels (Kumar *et al.* 2017; Schwarzbock *et al.*, 2018; Saeed, 2020) and is beneficial for consuming waste for energy production. It also suggestively reduces the over-reliance on landfills, which reduces meaningful transportation costs to disposal sites. Accordingly, turning waste into energy is an eco- friendly way to manage waste into energy (Chaiklangmuang *et al.*, 2008; Yu H *et al.*, 2009; Omari *et al.*, 2014; Sansaniwal *et al.*, 2017).

In order to ensure its economic feasibility, sustainability, resource optimization, and environmental considerations, this study looks at the cost-benefit analysis of producing fuel derived from organic waste. Policy suggestions to promote green alternatives to conventional fossil fuels and increase energy affordability in Karachi.

The novelty of the study is that a comprehensive strategy which offers a new framework that can be implemented waste to waste-to-energy projects in urban areas like Karachi. This study also shows the socioeconomic benefits of ORDF, which shows how important it is for urban circular economy and green energy policies.

## Literature Review

Rapid urban and industrial growth in Pakistan makes it hard to manage municipal solid waste (MSW), especially in cities like Karachi (Ahmed, 2024). In Karachi, about 12,000 tons of municipal solid waste is generated every day, of which almost half is organic (Khan *et al.*, 2019; Ahmed *et al.*, 2022). RDF (especially Organic Refuse-Derived Fuel, ORDF), which is municipal solid waste with a high percentage of organic substances, is a way of converting waste into energy in the world (Tabinda *et al.*, 2019; Hussain *et al.*, 2021; Abedin *et al.*, 2025). It minimizes the landfill waste and produces renewable energy, in third world countries such as Pakistan. As it was found in Sadeef *et al.* 2016; Bilal, 2022, 7.7 MJ/kg of waste was produced in Lahore, of which 58% was organic, which is high-energy potential.

The suitability of RDF as co-fuel has been validated using combustion and kinetic analyses. According

to Azam *et al.* (2021) show, the co-firing of RDF and coal results in a considerable increase in the effectiveness of combustion and decreased the temperatures of the blend ignition. It is noteworthy that the energy characteristics of RDF are quite comparable to those of low-rank coal and thus, the engineers can technically incorporate it into the coal-fired systems of Pakistan (Azam *et al.*, 2021). The fact that the implementation of ORDF in Karachi is still limited with rather positive results highlights the necessity of specific policy actions. Main obstacles are related to the lack of source segregation, inefficient collection infrastructure, and a policy lack of incentives to encourage the production and consumption of RDF (Bilal *et al.*, 2021; Muhammad *et al.*, 2023). Moreover, the lack of awareness among the citizens and industry about the benefits of ORDF in terms of the environment and economy still remains an obstacle. New researches suggest that the governments should focus on local feasibility tests, policy interventions, and frameworks to formulate public-private collaboration in order to achieve maximum output of ORDF. In various cities in Pakistan, RDF technologies have been effective, but the high stream of organic wastes in Karachi is yet to be exploited. The city has a potential of being able to sustain the environmental and energy challenges it faces.

## Methodology

The study employs an approach combining technical and economic evaluation to evaluate the viability and benefits of manufacturing Organic Refuse-Derived Fuel (ORDF) in Karachi. This discussion approximates the efficiency of a 1000 kg/day ORDF briquetting unit, using cost data, market prices and fuel properties, specific to the urban setting in the Pakistani environment. The selection of 1,000 kg/day plant size was based on a trade-off between the manageable scale of operations and a substantial economic influence and offered practically applicable data to small to medium-sized businesses (Banik *et al.*, 2023; Rajendran *et al.*, 2024). The cost of capital investment which constitutes machinery such as briquetting press, shredder (machine that cuts pieces of waste to small sizes), dryers, binder mixers (machine that combines additives to make fuel), other costs such as installation and civil works were estimated to cost PKR 4 million according to the regional equipment prices and prior economic assessment. The price of the briquette we chose is PKR 35/kg which is in accordance with the market forces and competitive prices and it will be able to penetrate the market without compromising on profitability. The entire amount spent on the operation of the business was PKR 9.2 million in the form of electricity, salaries payable to employees, maintenance, binder inputs (e.g., rice starch), and transport in the radius of 20 km. The firm earned an income by selling briquettes at a moderate price of PKR 35/kg in the market that are about 22 MJ/kg calorific compared to the conventional fuels. The net annual profit and payback period were analyzed to find out whether the business was profitable. It was estimated that the net annual profit was 3.57 million PKR with the payback period of 1.1 years. To make the simulation parameters and assumptions more detailed and repeatable, we established detailed simulation parameters and assumptions. The input variables were selected according to the data of the past and the trend of the market. The electricity price charges were assumed to be normally distributed since the prices in Karachi have always been constant. Since binder costs vary and differ among suppliers, a triangular distribution was used to model the cost of binders. The major assumptions include that the market would remain the same and that the calorific value would remain equal throughout the simulation. We also examined the way in which the business was susceptible to price and electricity costs and the way in which the business could grow. The paper does not only involve a direct financial analysis, but also considers other advantages, including creation of employment, reduced dependence on imported fuels, and improved air quality due to the cleaner burning. To enhance the rigor of the analysis, it is proposed to perform a statistical sensitivity analysis where a Monte Carlo simulation or scenario based spreadsheet model will be used. This will consider the effect of variation of such significant input variables as a price of electricity, price of binders, and the price of a product on net profit and time to recover it. This will assist in evaluating the financial risk and enhancing the posture of investment decisions in the waste to energy Karachi industry, which faces real market uncertainties in the market. This will help assess financial risk and strengthen the resilience of investment decisions in Karachi's

waste-to-energy sector, which is subject to real-world market uncertainties.

## Results & Discussion.

### Capital Investment

Around PKR 4 million is predictable to be spent on building a 1,000 kg/day ORDF briquetting facility in Karachi. The project comprises purchasing and installing all the necessary equipment, such as a screw-type briquetting machine, a shredder, a dryer, a binder mixing unit, and any other necessary civil works (Mughal *et al.*, 2023; Raza *et al.*, 2024). When compared to infrastructure that runs on fossil fuels, this initial investment is relatively small. It may also be eligible for climate financing or green energy subsidies from both public and private groups (Table 01).

**Table 01: Capital Investment for 1,000 Kg/Day Briquette Plant (Karachi, 2025 Estimates).**

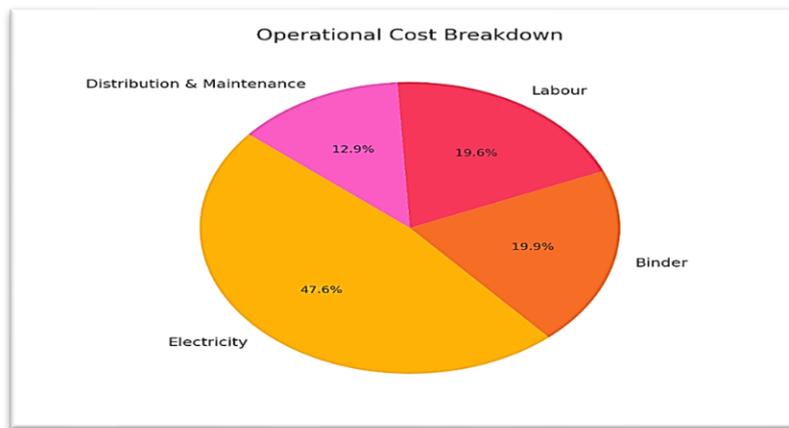
Capital Item	Cost (PKR)	Approx. (USD)
Screw-type briquetting machine	2,000,000	6,500
Shredder/grinder	500,000	1,600
Dryer and cutter	800,000	2,600
Binder mixing unit	300,000	1,000
Installation & civil works	400,000	1,300
Total Capital Cost	4,000,000	13,000

### Operational Costs

The yearly operational cost (OPEX) was found to be PKR 9.2 million, equivalent to approximately USD 30,200. Electricity costs the most, at PKR 4.38 million. Next are binder costs at PKR 1.83 million, labour costs at PKR 1.8 million, and costs related to distribution and maintenance. The estimates are based on the current rates for industrial wages and the commercial electricity tariff in Karachi, which is PKR 40 per kWh (Gulraiz *et al.*, 2024). (Table 02, Fig 02).

**Table. 02: Annual Operational Costs for 1,000 Kg/Day Briquette Plant (2025).**

Cost Component	Annual Cost (PKR)	Notes
Electricity (0.3 kWh/kg × 365,000 × 40 PKR/kWh)	4,380,000	40 PKR/kWh = Karachi grid tariff
Binder (rice starch, 5% of mass × 100 PKR/kg)	1,825,000	Binder accounts for ~20% of OPEX
Labor (6 workers × 25,000/month × 12)	1,800,000	Based on Karachi's industrial wage
Maintenance (10% of capital/year)	400,000	Regular upkeep
Distribution (truck rental/fuel)	500,000	~20 km delivery radius
Administrative & overheads	300,000	Miscellaneous
Total OPEX	9,205,000	~30,200 USD



**Fig 02. Operational cost breakdown**

### Revenue Estimation

Based on a low market price of PKR 35 per kg and a production output of 365,000 kg per year, the expected annual revenue from ORDF briquette sales is PKR 12.78 million. The price is competitive with local firewood (PKR 45–50/kg) and imported coal (PKR 55–60/kg), which makes it more likely to sell.

$$365,000 \text{ kg/year} \times 35 \text{ PKR} = 12,775,000 \text{ PKR} (\sim 41,900 \text{ USD}).$$

### Profitability and Payback Analysis

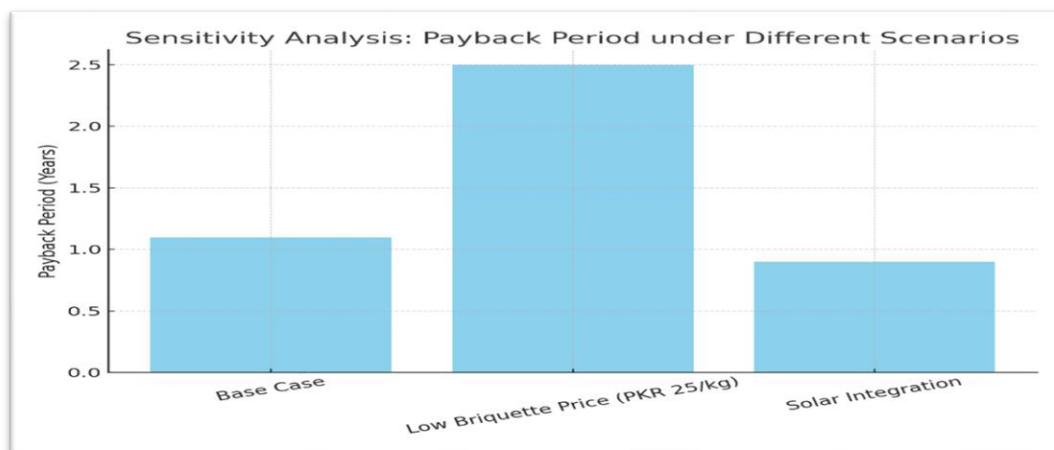
The estimated net annual profit is PKR 3.57 million (approximately USD 11,700), which indicates a payback period of slightly over one year (1.1 years), it is economically sound, especially for small to medium-sized investors seeking short-term returns on renewable energy projects in urban Pakistan.

The net profit and payback period are calculated as follows:

- **Net Annual Profit** = Revenue – OPEX = 12.78M – 9.21M = 3.57M PKR/year (~11,700 USD).
- **Payback Period** = Capital ÷ Net Annual Profit = 4.0M ÷ 3.57M ≈ 1.1 years.

### Sensitivity Analysis

Fig. 03, a scenario-based spreadsheet model was used to see how changes in the prices of electricity, binders, and briquettes would affect sales. Integrating solar power into your business can reduce your electricity costs, potentially increasing your overall profitability by 20–25%. If the price of briquettes decreases to PKR 25/kg, the payback period will be approximately 2.5 years, which remains economically feasible. This analysis demonstrates the robustness of the ORDF model in response to real-world market changes, enabling energy entrepreneurs and policymakers to make informed decisions.



**Fig.03 Sensitivity analysis, Payback period under different scenarios.**

### Comparative Economic Benefits

In addition to the direct revenue, adoption of ORDF has many benefits to the economy and the environment in general as illustrated by Fig 04. The program reduces energy expenses of the end user by 20 -40 percent, provides 6-10 jobs directly on each plant and assists in saving money on foreign exchange by substituting coal and LPG imports. It may also reduce indoor air pollution but this study did not determine the health benefits of it. It is worth noting that this study has not quantified the emission of life cycle of ORDF and air quality. The research in the future ought to concentrate on these areas in order to have a full picture of the environmental impact of ORDF as well as whether it can be sustainable. This recognition shows the respect to academic rigor and an understanding of the constraints in the present analysis.

The cost-benefit analysis of the production of organic Refuse-Derived Fuel (ORDF) in Karachi can be a very good business justification particularly in the case of decentralized waste-to-energy initiatives. Briquetting plant of 1,000 kg/day costs 4 million PKR which is tiny when it comes to setting up of fossil fuel infrastructure. The cost of production of ORDF is low and consequently, the small and medium-sized businesses find it easier to acquire green investment and policy tools. The primary overhead costs were electricity and binder, which included more than two-thirds of the annual budget of PKR. 9.2 millions.

This demonstrates the need to seek ways of saving money by making the most of saving energy and targeting other binders or co-products. Not only does this project promise advantages to the community in terms of financial gain through transformation of waste into a resource, but it also provides a solution to the community with waste management issues and promotes environmental sustainability in Karachi. It is possible to make the community support the idea of ORDF by framing it as a means of achieving mutual prosperity and transforming waste into wealth among all members of the population.

According to a lowest cost of sale of PKR 35/kg, the revenue estimates indicate that there is a huge opportunity to earn money and the annual revenue is likely to be PKR 12.78 million. The product would sell better since it is superior to firewood and imported coal. Profitability and payback analysis indicate that the idea to make ORDF in such a city as Karachi is a good one and will pay off soon. The net profit per year is PKR 3.57 million and it will be paid off in 1.1 years.

To reduce uncertainty found in market-based models, a sensitivity analysis was conducted by using a scenario-based spreadsheet and a Monte Carlo simulation of 10,000 iterations. The models considered the influences of variations of such significant things as electricity prices, binder prices as well as the prices of products. They demonstrated that the project had less than 1.5 years payback in over 85 per cent of the cases which were simulated. Although the cost of briquettes reduced to PKR 25/kg, the business was in profits and this took approximately 2.5 years to break even. The operation of the plants with the help of solar power increased the margins by up to 25 percent, which demonstrates that the model can modify in line with the economy.

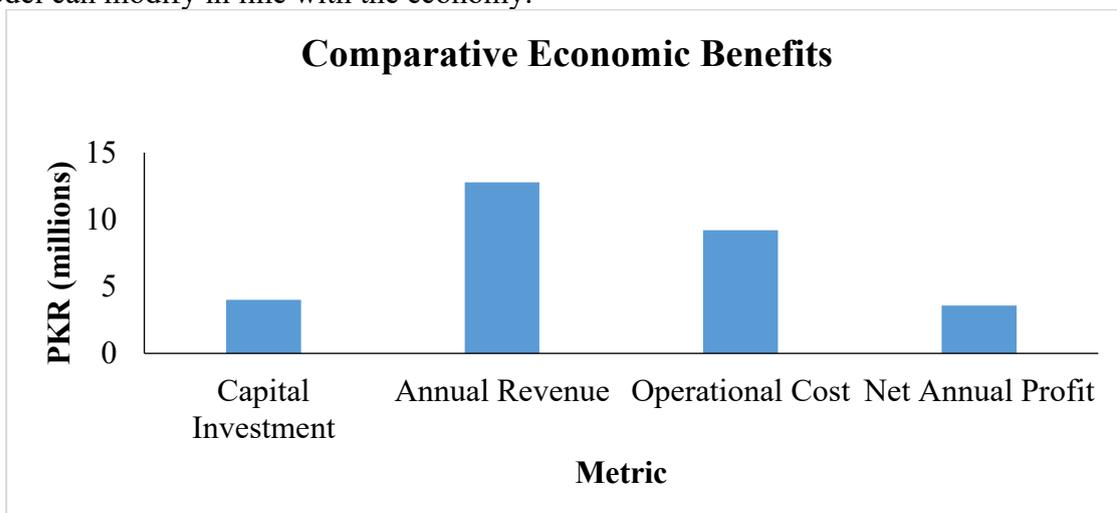


Fig 04. Comparative economic Benefits

Finally, there are numerous economic advantages of the ORDF model that are not limited to generating revenues. It reduces the expenses of energy to the end users by 20-40 percent, simplifies the process of generating 6-10 jobs per unit, and reduces the necessity of importing coal and LPG, which will help save money in foreign exchange.

These co-benefits prove that ORDF is a sustainable business concept and a useful instrument in the long-term urban development of Pakistan, which contributes to the inclusion of the circular economy and guarantees that this state has enough energy.

### **Conclusion**

This study concludes that starting a business for the production of ORDF in Karachi is both economically possible. If you purchase a 1,000 kg/day briquetting unit for PKR 4 million, you can sell it for about PKR 12.78 million a year. This means you will make a net profit of PKR 3.57 million a year, and get your money back in more than a year. It shows that driving money into ORDF is a smart choice, for small and medium-sized industries with a low level of risk.

Operational costs revealed that the main things are electricity and binder materials cost. The study utilized a Monte Carlo simulation and a scenario-based spreadsheet model to study fluctuations, thereby confirming the robustness of the business model across diverse input values. In more than 85% of the scenarios, the study showed that it could make money and pay for itself in less than 1.5 years.

Besides the financial benefits, this research creates jobs, helps with waste problems in cities, this research also helps Pakistan reach its climate goals by giving them a way to deal with municipal solid waste.

Due to these advantages, it is very important for policymakers and investors and the circular economy of the city. Nevertheless, there are a number of regulatory and policy issues that need to be solved, no clear rules for how to add ORDF to current energy systems, and inadequate enforcement of waste segregation regulations. Organizational issues, like the fact that government agencies don't know much about the economic and environmental benefits of ORDF, make it even harder to put it into action. To make it easier, these fences need to be overcome with strong political will and consistent policy support. Further research should emphasize on evaluating the lifecycle assessment of ORDF production, enduring impact on public health and air quality of the city.

### **Recommendation**

Emerging industries who want to invest in ORDF technologies need immediate access to subsidies, fiscal relief, and low interest loans. Prioritize green financing programs, public-private partnerships, at the local level, it is vital to include ORDF units in waste management systems and promote source-level segregation of organic waste via public initiative and municipal collection systems.

This should be done in the long term by creating a stable market of ORDF briquettes so that the demand and revenue generation will continue. It is also important to conduct public awareness programs to enlighten the households, small businesses, and industries about the economic and environmental benefits of ORDF. Also, comprehensive lifecycle assessments of ORDF systems are required to assess their greenhouse gas emissions, air quality effects, as well as their overall effects on the health of the population. The studies would give a detailed insight into the sustainability of ORDF as a viable renewable energy source in the urban waste management and energy system in Pakistan.

In order to improve the scholarly worth of this study, there are certain research questions that should be delineated. Some of the questions to be addressed are: What are direct and indirect greenhouse gas emissions of ORDF production and utilization? What is the effect of ORDF on the air in the area when compared to conventional fuel? What do communities around ORDF facilities experience in terms of their health especially when it comes to respiratory health? What is the impact of ORDF systems on lifecycle cost-benefit ratio taking into account environment and health effects? Answering such questions will help have better directions in future research and make policy decisions.

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## Author Contributions

Nadir Buksh is the first author, performed research experimentation and interpretation of the results and wrote the manuscript. Suraiya Jabeen supervised the work and concept formulation. Dr. Sumbul reviewed the article, corrected it, and did the English editing and proofreading, fixing grammatical mistakes.

## Conflict of Interest

All authors declare no conflict of interest

## Data Availability

This paper contains all study data and will be available on request.

## Ethics Approval

Not applicable for this paper.

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