Final Year Design Project Showcase
Batch-2022
Year 2026

Department: Economics and Management Sciences Programme: BS Economics & Finance	
1	**Project Title** Cost-Benefit Analysis for Prioritizing Green Public Investments in Rural Sindh: Solar Mini-Grids versus Irrigation Modernization
2	**Project Idea** Rural Sindh undergoes two interrelated development issues: unreliable electricity supply and water inefficiency in irrigation. There are 9,200 villages under the jurisdiction of SEPCO, HESCO and KE that remain completely off-grid, while reliance on flood irrigation by farmers give off water efficiency as low as 35-40%. The provincial government is thus faced with a resource allocation dilemma between installation of solar mini-grids and irrigation modernization through drip and sprinkler systems. This research carries out a cost-benefit analysis (CBA) of the two interventions in order to establish an evidence base for public investment prioritization in rural Sindh.
3	**Process** The cost-benefit analysis (CBA) adopts a quantitative, secondary data-based approach using official provincial data, international technical standards and local supplier rates. The cashflow estimations were made for a project lifetime of 25 years with a discount rate of 9%. For the solar mini-grid of 20 kilowatt-peak (kWp) system supplying 80 households. The capital expenditure (PV, inverter, battery, distribution, installation), operating expenditure and battery replacement were used to compute Levelized Cost of Electricty (LCOE) and Net Present Value (NPV), benchmarked against NEPRA's national tariff. For irrigation, the drip and portable sprinkler layouts were modelled for tomato and maize on a per acre basis. The drip and sprinkler were evaluated through Benefit-Cost Ratio (BCR) for tomato and maize crops. Additionally, monetized carbon reduction benefit from the solar mini-grid were calculated and the monetized water savings benefit and shadow wage rate for the two crops were calculated for irrigation. As a result, components of benefits and costs were estimated to calculate the Net Present Value (NPV) for both the interventions Further, a sensitivity analysis with ±30% variation for all parameters was conducted to test the robustness and reliability of the results. These results were then presented in the report through tornado charts for better visualization of the results.
4	**Outcome** The solar mini-grid has an NPV of PKR 24.8 million and annual benefits of PKR 3.68 million, primarily due to avoided grid electricity costs and diesel fuel savings. The LCOE of PKR 20.78 per kWh is significantly lower than the national average electricity tariff of PKR 45.06 per kWh. The solar mini-grid NPV is most sensitive to discount rates and is

	positively related with the change in prices of diesel (for diesel geneerators during power outage hours) and the grid electricity. Hence, subsequent increase in prices of diesel and and grid electricity will justify the solar mini-grid even more. For irrigation, the results are contingent upon the crop type. Drip and sprinkler irrigation systems have positive NPVs for tomato crop, PKR 854,583 and PKR 741,317 per acre respectively and BCRs are 2.93 and 2.65, which implies economic efficiency. However, for maize crop, both irrigation systems have negative NPVs and BCRs less than unity, making them economically unviable. Thus, the high efficiency irrigation systems (HIES) like drip and sprinkler are only viable with cash crops like tomato. The NPV of tomato crop is most sensitive and positively related with the revenue benefit associated with it. In terms of social welfare return per rupee of capital invested, in cases where none have a negative NPV, all interventions show similar returns at PKR 3.20 for drip, PKR 3.18 for solar mini-grids and PKR 3.17 for sprinkler irrigation. The study concludes that solar mini-grids are the best scalable public investment option since its benefits trickle down to community level, resulting in improved household welfare. Irrigation modernization through drip and sprinkler, however, is a conditional investment option only economically justified when integrated into high-value crop production.
5	**Evidence (Theoretical Basis)** Grounded in public finance theory of Musgrave (1959) on allocating scarce public funds, and Boardman et al.'s (2018) CBA framework for comparing welfare gains across interventions. The LCOE methodology follows Branker et al. (2012) and Xu et al. (2019); irrigation CBA structure follows Pakistan-specific studies (Bakhsh et al., 2015; Razzaq et al., 2018; Muzammil et al., 2021), used to calibrate CAPEX/OPEX, the 9% discount rate, and yield and water-saving parameters to Sindh. This closes a literature gap, that off-grid solar electrification and irrigation modernization for rural Sindh had not previously been evaluated on the same comparative CBA footing for rural Sindh.
6	**Competitive Advantage or Unique Selling Proposition** (Cost Reduction, Process improvement, Attainment of any SDG (Sustainable Development Goal), increase of market share or capturing new market or having superior performance over a competitor. In summary, any striking aspect of the project that compels the industry to invest in FYP or purchase it. Some detailed description is required in terms of how, why when what. The following aspects apply to this project.
a	**Attainment of any SDG** (e.g. How it is achieved and why it is necessary for the region) The project directly supports SDG 7 (Affordable & Clean Energy) by cutting the delivered cost of rural electricity to less than half the grid tariff and SDG 13 (Climate Action) via diesel-fuel displacement with monetized carbon-emission reductions and monetized water savings associated with modern irrigation systems (drip and sprinkler), both necessary for rural Sindh given that 9,200 Sindh villages remain off-grid and irrigation relies on flood methods with water losses more than 70%. Hence, this research supports evidence-based investment in renewable energy for climate-resilient rural development.

b	**Any Environmental Aspect** (e.g. carbon reduction, energy-efficient, etc.) The solar mini-grid displaces about 4,745 litres of diesel/year per 80-household cluster (15,184 kg CO2 avoided annually), which is approximately equal to PKR 13,954 per year. On the other hand, the drip and sprinkler systems cut irrigation water use by up to 57% versus flood irrigation, easing pressure on the over-stressed Indus system and saving approximately PKR 28,940 and PKR 25,510, respectively per acre for tomato crop while PKR 11,563 and PKR 10,194, respectively per acre for maize crop.	
c	**Cost Reduction of Existing Product** Estimated LCOE of solar mini-grid electricity is PKR 20.78/kWh, about 54% below the national grid tariff of PKR 45.06/kWh, even after including battery replacement costs. Thus, this will enable significant cost reductions per rural household on grid electricity, along with reducing the import bill for non-renewable energy sources (eg; crude oil, fossil fuel).	
d	**Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process** (e.g. What is the issue is current process and what improvement you suggests) The project's primary contribution is the development of a comparative investment prioritization for informed policy making of sector-specific economic comparison such that investment decisions give the maximum welfare returns within the limited fiscal resources. This project provides the Sindh's Energy and Irrigation Departments a replicable, regionally-calibrated CBA and sensitivity analysis, rather than ad hoc estimates to prioritize green public investment consistently across villages and crops.	
e	**Expanding of Market share** (e.g. how it expand and what is the problem with the current market Not applicable	
f	**Capture New Market** (e.g. Niche market or unaddressed segment) Not applicable	
g	**Any Other Aspect** The framework is generalizable beyond Sindh to other water scarce, off-grid provinces and can be extended to other crops or mini-grid sizes with minimal recalibration.	
7	**Target Market** (Industries, Groups, Individuals, Families, Students, etc) Please provide some detail about the end-user of the product, process, or service Provincial and district government bodies responsible for rural development spending including, the Sindh Energy Department, Sindh Irrigation Department, Sindh Solar Energy Project (SSEP) / P&D Department, and donor-funded rural development programs (e.g. World Bank, ADB). Indirectly, the households of rural Sindh aiming for cost reduction in electricity expenditure and farmers of rural Sindh.	
8	**Team Members** (Names along with email address)	Aliya Zehra (aliyazehra.ned@gmail.com) Azhar Uddin (azhar02uddin@gmail.com) Nishwa Nadeem (nishwanadeem11@gmail.com) Affan Khalid (affankhalid2017@gmail.com)

10	**Supervisor Name** (along with email address)	Dr. Mirza Faizan Ahmed - Project Supervisor, Assistant Professor & In-Charge EMD Dr. Shabbir Ahmed - Project Co-Supervisor, Assistant Professor
11	**Video (If any)**	Not applicable.

Pictures (to be pasted below