



Off-grid electrification in Pakistan and beyond: status, trends, and opportunities

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8th March 2024



The Problem?

- How do we electrify **770 million people¹ worldwide without** access to electricity including around **50 million in Pakistan²**?

1. IEA (2022), World Energy Outlook 2022, IEA, Paris <https://www.iea.org/reports/world-energy-outlook-2022>
2. <https://trackingsdg7.esmap.org/country/pakistan>

Need for Off-grid Electrification

Access to electricity enhances:

- Health opportunities
- Employment opportunities
- Agriculture opportunities
- Education opportunities
- Socio-economic development



Figure : A primary school in Naran Valley, Pakistan, without access to electricity and basic education facilities [1].

How to define “Access” to Energy?

- **Conventional definitions:** binary definitions of access (presence of an electric pole in a village or a wired connection coming into a house) fail to capture aspects such as the technology used for producing energy, the level of energy consumption, and the affordability or reliability of supply.
- **The multi-tier framework (MTF) by ESMAP (2015)**
 - **A Fuel and technology- independent approach** that measures household electricity access in a tiered fashion.

INDICATIVE CALCULATION OF CONSUMPTION FOR MTF TIERS 1-5

Appliance/ Service	Power (W)	Hours/day	Baseline Annual Usage (kWh)				
			Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Task lighting	½	4-8	1.5	2.9	2.9	5.8	5.8
Mobile Phone charger	2	2-4	1.5	2.9	2.9	2.9	2.9
Radio device	2 or 4	2-4	1.5	5.8	5.8	5.8	5.8
General lighting	12	4-12		17.5	17.5	35.0	52.5
Fan	20 or 40	4,6,12,18		29.2	87.6	175.2	262.8
TV	20 or 40	2		14.6	29.2	29.2	29.2
Food processor	200	½			36.5	36.5	36.5
Washing machine	500	1			182.5	182.5	182.5
Refrigerator	300	6				657.0	657.0
Iron	1,100	1/3				120.5	120.5
Air conditioner	1,500	3					1,642.5
Total (kWh)			4.5	73	365	1,250	3,000

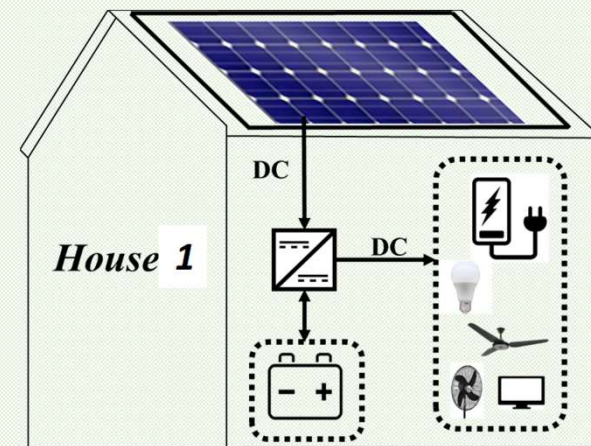
- **Electricity services** are central to the framework:
- Lighting
- Entertainment & communication
- Space cooling & heating
- Refrigeration
- Mechanical loads
- Product heating
- Cooking

Potential Solutions?

1. Utility Grid
2. Diesel Generators
3. Centralized Microgrids
4. Solar Home Solutions (typically DC Standalone systems)
5. Bottom-up Microgrids with decentralized generation and storage
(prosumer concept)

Common Electrification Strategies for Off-grid

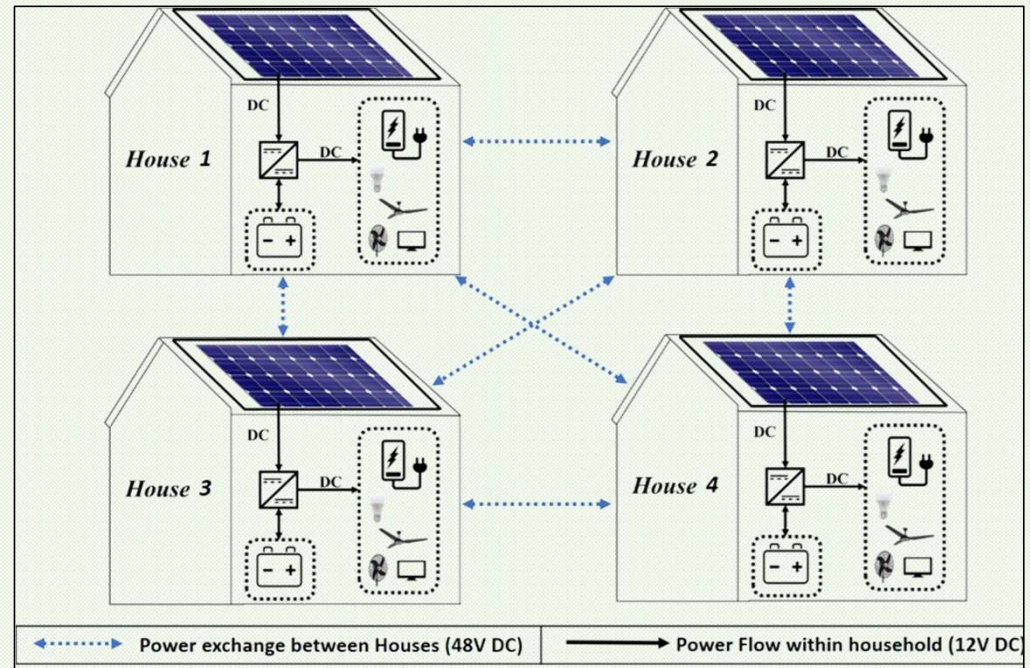
- **Solar Home System:** A solution for remote communities that are left out of national electrification projects.
- **High energy wastage in SHS:** up to 50% of the generated energy is wasted.



[1] Narayan, Nishant (2018): Electrical power consumption load profiles for households with DC appliances related to Multi-tier framework for household electricity access. Version 1. 4TU.ResearchData. dataset. <https://doi.org/10.4121/uuid:c8efa325-87fe-4125-961e-9f2684cd2086>

Common Electrification Strategies for Off-grid

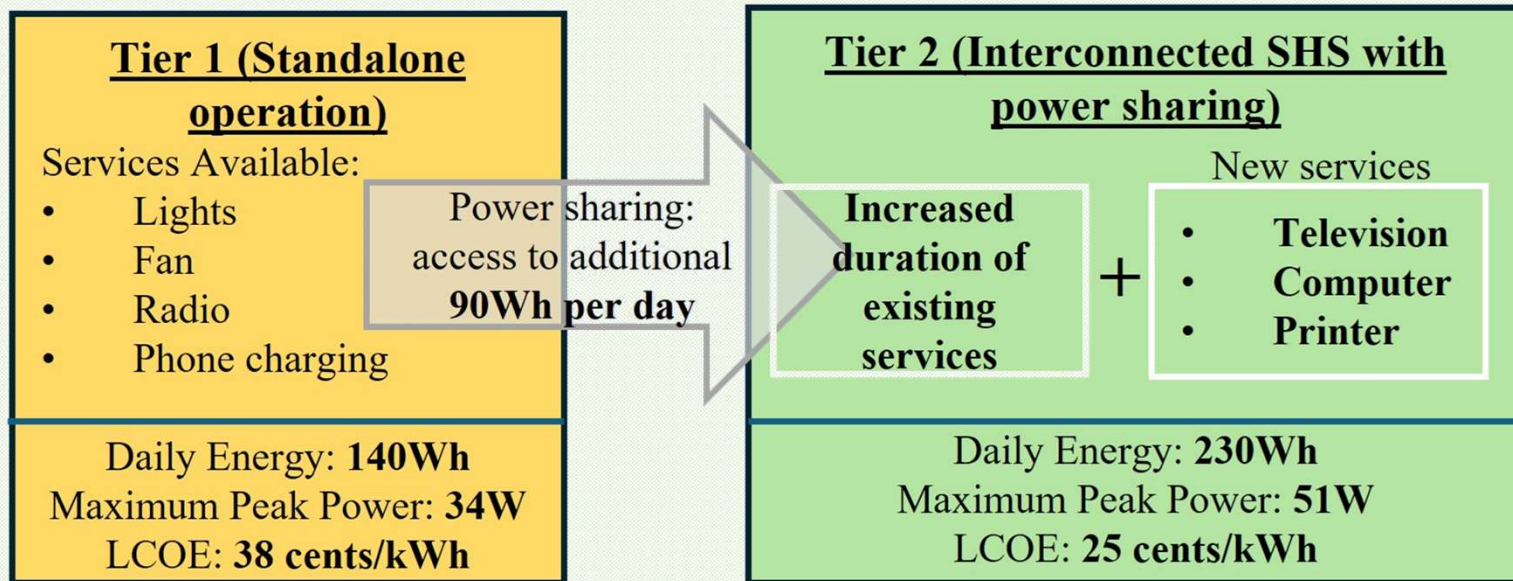
- **Solar Home System:** A solution for remote communities that are left out of national electrification projects.
- **High energy wastage in SHS:** up to 50% of the generated energy is wasted.
- **Power sharing in decentralized microgrids** (low losses, more scalability, possibility to expand later).
- **Microgrids have a potential for excess energy provision through power sharing.**
- **High potential of tier elevation from 1-4.** Tier 5 cannot typically be viably powered using SHS-based electrification [1].
- Through sharing, each house becomes a **prosumer (producer + consumer)**.



[1] Narayan, Nishant (2018): Electrical power consumption load profiles for households with DC appliances related to Multi-tier framework for household electricity access. Version 1. 4TU.ResearchData. dataset. <https://doi.org/10.4121/uuid:c8efa325-87fe-4125-961e-9f2684cd2086>

Decentralized Prosumer Microgrids: Improving Access to Energy¹

Case 1: Tier 1 Household moving to Tier 2 Solar PV Panel Rating: 120Wp Battery Size: 30Ah



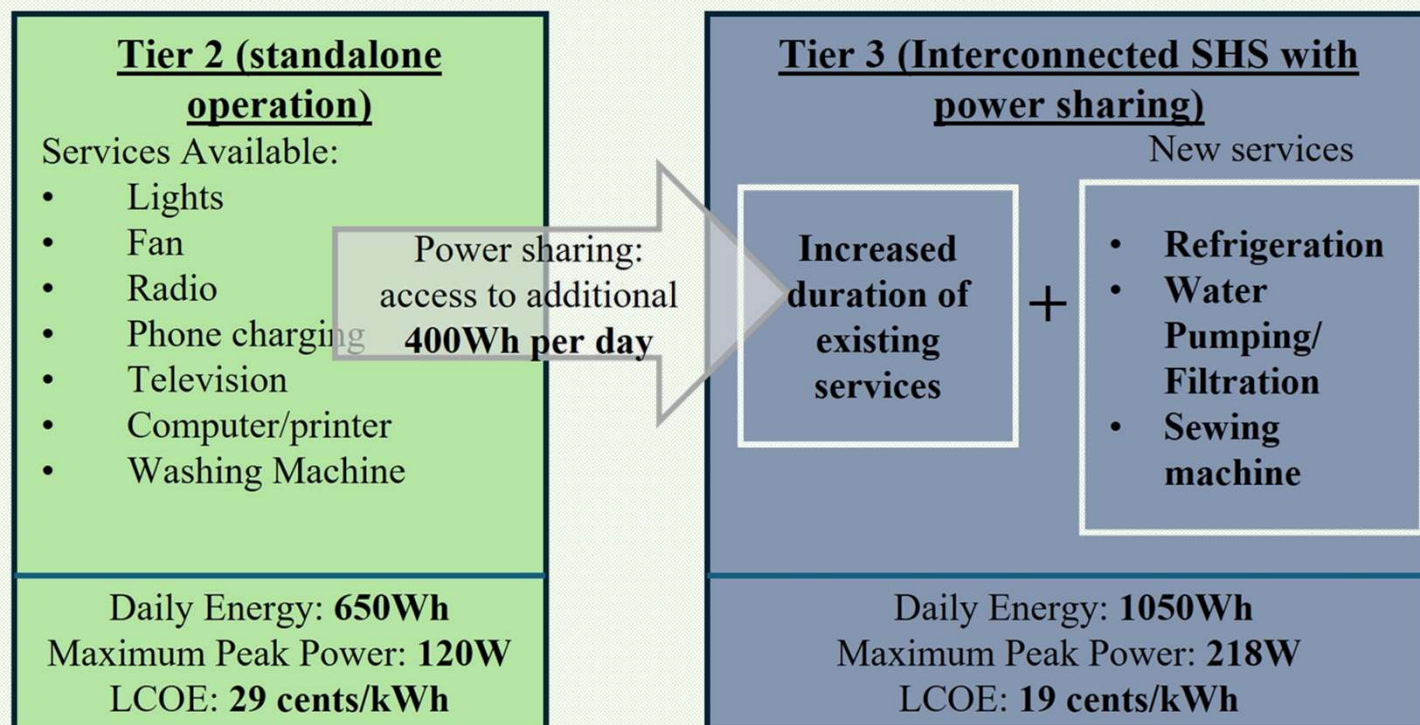
1. R. Arshad, H. A. Khan, and R. Khalid, "Prosumer Power Sharing and Climate Change Adaptation in a Gendered Context," in *IEEE GreenTech, Sustainability, and Net Zero Policies & Practices (GTSNZ)*, 2023.

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Case 2: Tier 2 Household moving to Tier 3

Solar PV Panel Rating: 460Wp

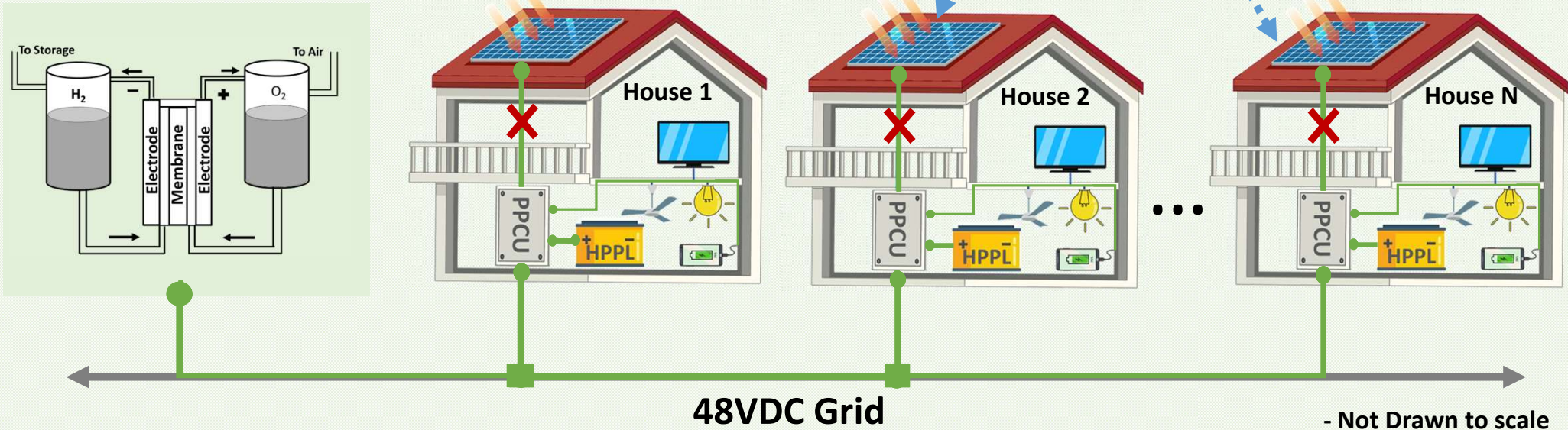
Battery Size: 100Ah



New innovations: Prosumer System



- Decentralized power generation from renewable resources
- Houses have multiple fans, lights and mobile phone charging.
- Houses inter-connected via a DC microgrid network to trade surplus power.
- The surplus electricity is used by the houses and to power up communal loads e.g., water pumps, schools, places of worship.



48VDC Grid

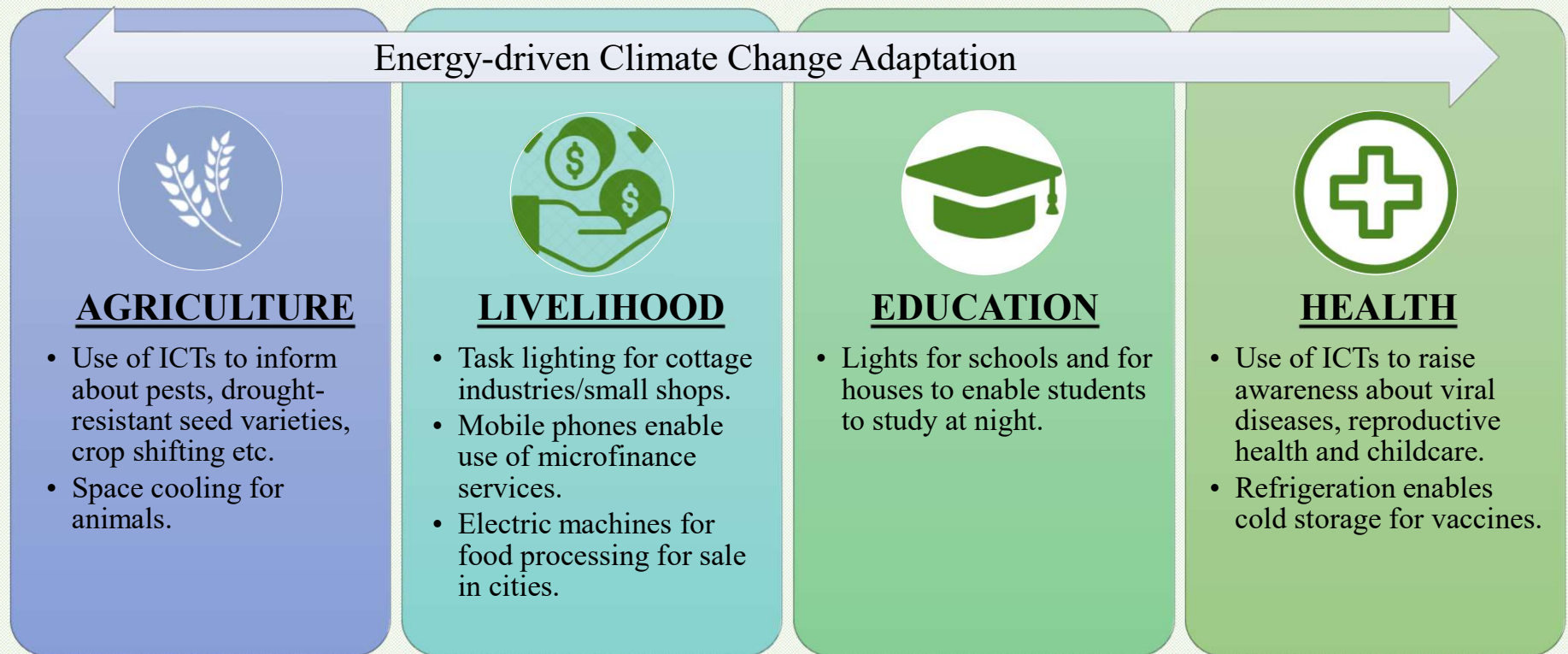
- Not Drawn to scale

E. Key Advantages of Prosumer Power Sharing

- Access to **surplus power** without additional investment.
- **Lower cost of energy** due to optimized utilization by power sharing attracts new consumers and improves social bonds in the community.
- **Scalability** due opportunities for future expansion & large-scale deployments.
- **Flexible tariff** and possibly **reduced payments** due to power sharing.
- Longer **sustainability** due to flexibility of ownership makes the investment sustainable.
- **Monitoring** can significantly improve system performance, & early fault detection and optimized resolution.

Key Advantages of Prosumer Power Sharing

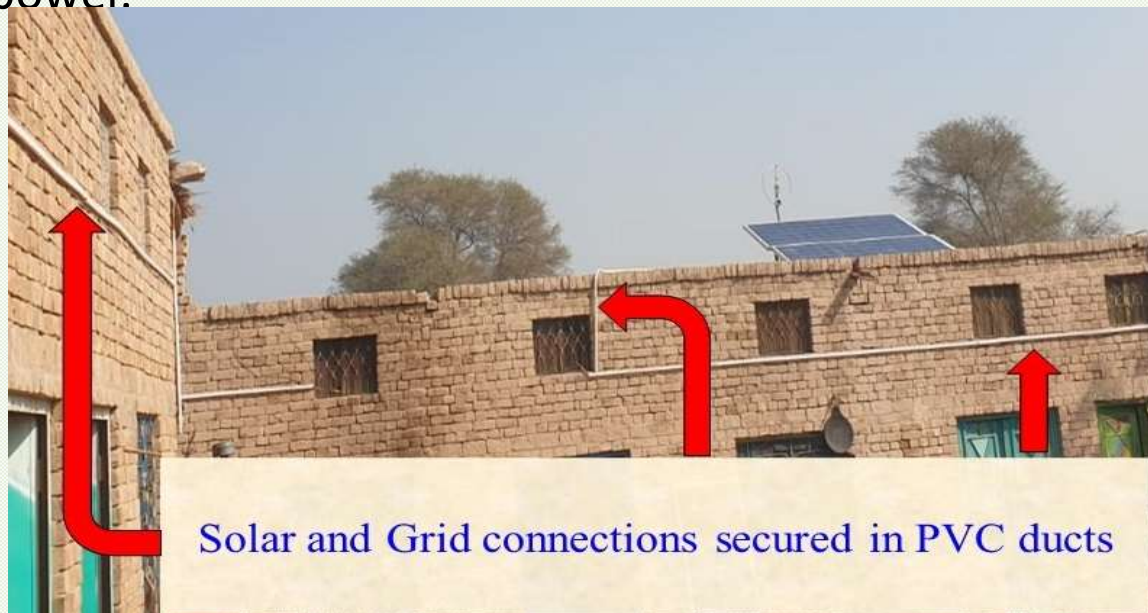
Improved Access To Energy also leads to Climate Change Adaptation!



F. Case Study: Off-Grid Village in Pakistan

Cluster-Arrangement in Village

- Every house in the pilot village is connected with a 350W solar PV panel on rooftop, which generates 12V DC power for household electricity consumption.
- All the houses in the village are inter-connected via a 48V microgrid network to share/trade surplus power.





Thank you
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Co-funded by the European Union



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