Microgrids for Energy Beyond Subsistence

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Overview

- ~ 40-50 million people in Pakistan (23-25%) and further 1.1 billion
  - Not just for convenience
  - Beyond Subsistence – Value addition using energy
  - To become contributing members of the community
- Urban Electrification - particularly in an intermittent grid environment
- What will it take?
  - Generation – Renewable, distributed and grid-connected as needed
  - Loads – Control of dynamics and efficiency considerations
  - Storage – Capacity, Life, Power density, Energy density, optimal operation and LCOE
  - Interconnectivity – Scalability and stability in standalone and inter-connected systems

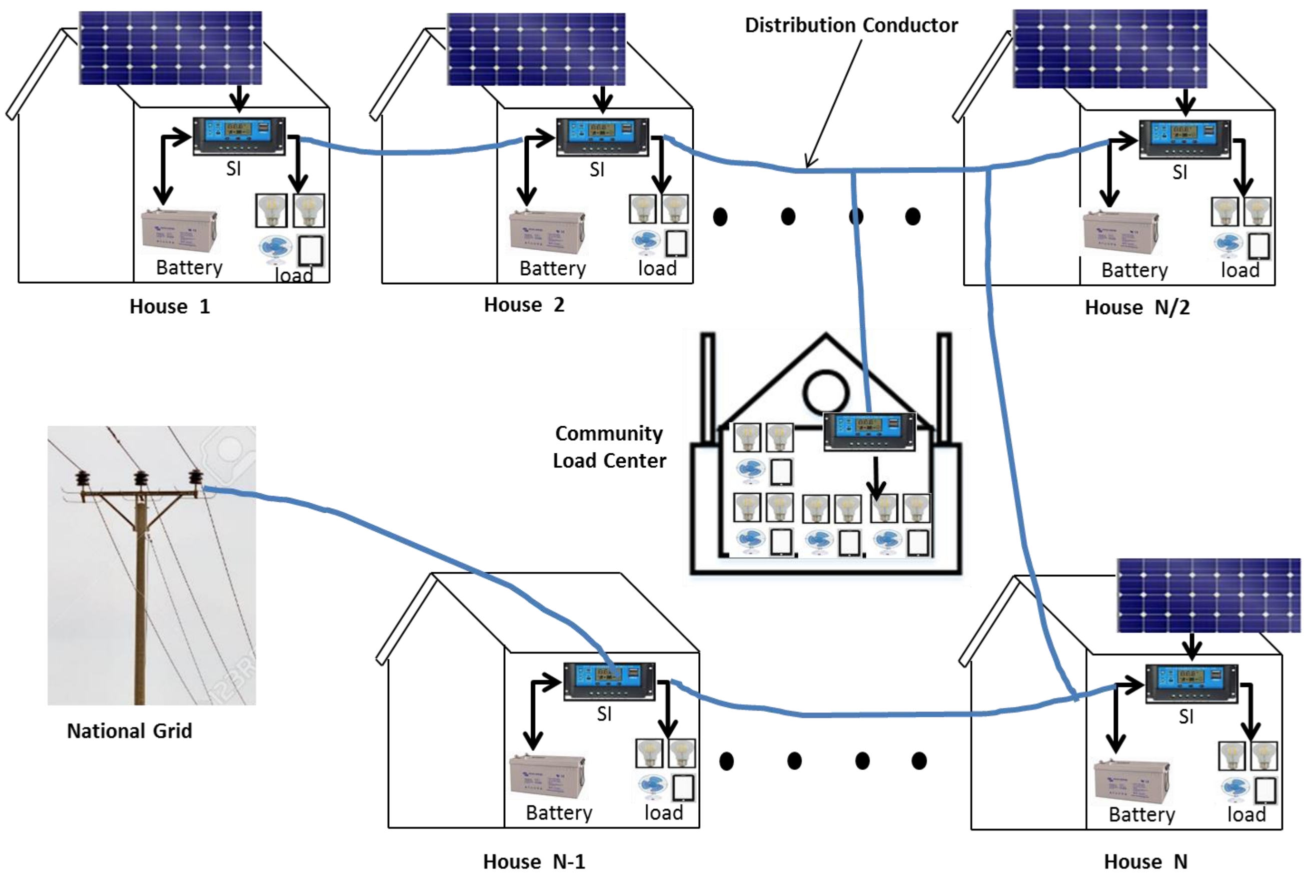
What is Needed

- An Architecture having
  - Low Cost Deployment
  - Lower Distribution and Conversion Losses
  - Higher End to End Efficiency
  - Reliability
  - Scalability
  - Resource Sharing Feature
  - Capability to Drive High Power Communal Load

An architecture with above characteristics is an **Electrification Architecture** that can provide **beyond subsistence level power provisioning** and can genuinely contribute towards the **socio-economic uplift of the society** through **creation of an Energy Micro-Economy**

Architecture

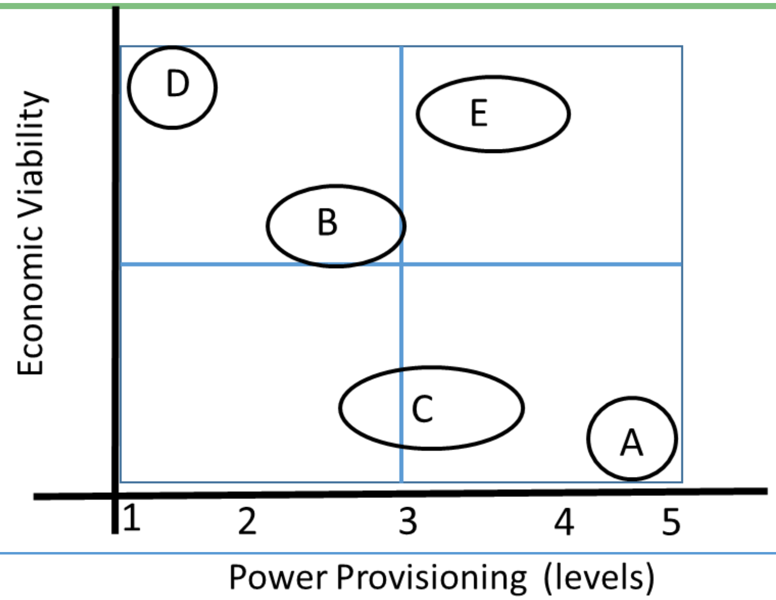
- Distributed Generation Distributed Storage Architecture (DGDSA)
- Peer-to-peer sharing of electricity High upfront and recurring cost
- A Self-Sustaining Network based upon Renewable Energy Mix (Solar PV, Wind, Bio-Energy and Micro-Hydro
  - Nanogrid (Household) as a basic building block
  - Each Nanogrid has its own generation, battery storage and connected with bus
  - Each nanogrid can work independently, islanded-mode, as well as in coordination
  - Bidirectional power flow capability is realized via bidirectional converters
  - Decentralized Control on actual power delivery



Comparison

Type of Solution	Option
Utility (National) Grid	A
Standalone Solar	B
Diesel Generators	C
Commercial Microgrid Solutions	D
ENERNET (proposed)	E

Other Aspects	**A**	**B**	**C**	**D**	**E**
Scalability	Low	Low	Low	Low	High
Modularity	Med.	Low	Low	High	High
Utilization Efficiency	High	Low	Low	Med.	High
Communal Loads	High	Low	High	Low	High
Potential for Energy Micro-economy	Low	Med.	High	High	High
Potential for Poverty alleviation	High	Med.	Low	Low	High
Legal Challenges	Low	Med.	Low	Med.	Med.



Typical Power Provisioning (levels)	**Details**
1	Light/mobile phone charging up to 8 hrs a day
2	24/7 Light/mobile charging
3	Light(s) + mobile charging + house loads (Fans etc.)
4	Light(s) + mobile charging + Fan(s) + larger communal loads
5	All loads (including industrial)

Energy Provisioning Beyond Subsistence

Generation Mix

- Generation and Integration - Renewables
  - Hydrokinetics
  - Micro-Hydro
  - Wind
  - Scalable Solar
  - Bio-Energy

Load Control

- Loads with networked VFDs – provide multiple advantages.
  - Current spike at turn-on is eliminated.
  - Multiple standalone units can be integrated over a network and controlled centrally.
  - This allows possibility of integration with CentralSystem for:
    - Smarter control.
    - Implementation of Micro-Grid wide energy policy.
    - Customization of operational control for contingencies.
  - “True” econo-mode operation can be enabled depending on the system load capability.
  - All of this at the price of a voltage stabilizer!

Energy Storage Systems

- Commercial batteries
  - Lead-acid
  - Lithium-Ion
- Price and energy density of Li-ion batteries following a steep and favorable trajectory
- High priced solutions such as Tesla Powerwall at $400/kWh still 10X better than Lead-acid
- 2.8 million UPS systems with a $1.2Billion market for storage
- Enable central control of Li-ion batteries

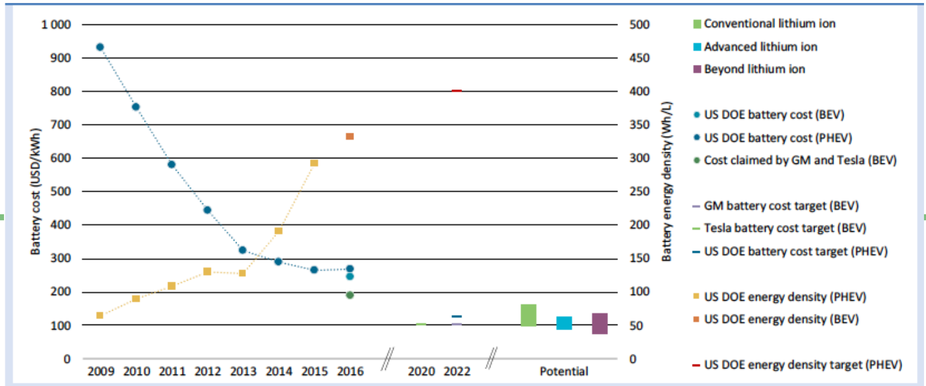
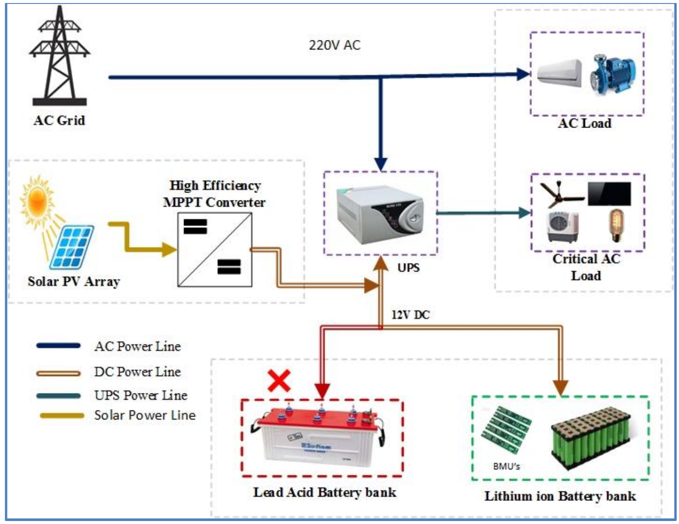


Table 1: Voltage, Energy density and Cycle Life of Batteries [14,17]

Battery Type	Voltage/cell (V)	Energy Density (Wh/Kg)	Cycle Life
Lead-Acid	2.1	35	800
Nickel-Cadmium	1.3	35	700 – 2000
Nickel-MH	1.2	75	600 – 1000
Lithium Ion	2.5 – 4.5	150	1200
High T-sodium	2.1	170	1800



Transdisciplinary …

- Data Analytics
- System Design
- GIS Mapping
- Energy Micro-Economy
- Social Scientists and Environmental Impacts
- Legal