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Summary

- Integrating variable renewable energy into mini-grids increases the challenge of matching demand and supply.
- Current design practices for Renewable Energy Mini-Grid (REMG) systems are supply oriented and can miss some key opportunities on the demand-side to deliver low cost and reliable energy services.
- Users place different relative value on energy services, while some energy services have considerable flexibility due to inherent energy storage in the end-use equipment used, or user willingness to shift their usage, depending on affordability and reliability preferences.
- Present Energy Service Characterisation (ESC) framework, strategies for potential flexibility of services across the day, and results: possibilities of low cost and reliable REMG using ESC framework then HOMER Pro modelling software.
Key Barriers

- ‘UN SE4All’, REMG -High Impact Opportunity (HIO) to provide electricity access and 40% electricity from MG by 2030

Key barriers in REMG deployment are

1. System design complexities (sizing): matching between variable supply and demand
2. High capital cost and uncertainties

Energy Service approach and opportunities:

- Key value of energy supply is in service provision (lighting, cooking, refrigeration) - not kWh delivered
- Users assign relative value to energy services - preferences, capabilities
- Possible flexibility of energy services (inherent storage in appliances and services)
- Opportunity to better utilise RE at lower cost to meet most important energy service needs
  - Solar Home System (SHS) users very engaged to prioritise the Energy services
  - Grid users not very engaged
  - REMG users have opportunity to engage,
Energy service characterisation framework

- **Low Preference High Storability (L-H)**
  - service shiftable or interruptible

- **High Preference High Storability (H-H)**
  - service shiftable or interruptible

- **Low Preference Low Storability (L-L)**
  - service shiftable or interruptible

- **High Preference Low Storability (H-L)**
  - NOT shiftable or interruptible
  - EE measures may be possible

Source: Shakya B., Bruce A., Macgill I., *Survey Based Characterisation of Energy Services for Improved Design and Operation of Standalone Microgrids*, Renewable and Sustainable Energy Reviews, 2018
Survey results:

Annual household energy consumption, breakdown by appliance

Weighted Index of existing and future appliance preferences

Order of preferences- Light, Mobile phone, Television, Refrigerator, Rice cooker
Service Characterisation of Mini Hydro MG

- Light
- Mobile phone
- Rechargeable Light
- Heater-Cooker
- Rice Cooker
- Refrigerator
- Fan
- Desktop Computer
- Laptop
- TV
- Radio
- Electric Kettle
- Iron
- Water pump
- Grinder
- MP3
- VCR
- Printer

Area of bubbles represent the Energy Consumption

Source: Shakya B., Bruce A., Macgill I., Survey Based Characterisation of Energy Services for Improved Design and Operation of Standalone Microgrids, Renewable and Sustainable Energy Reviews, 2018
DSM strategies

Appliance i (i=1…n)

ESC Quadrant?

Quadrant 1

EC < 5%

Quadrant 2,3, 4

EC > 5%

Operation hour?

Peak hour

Off-Peak hour

Check possible Window’s of operation

Shift operating time within window

Appliance Efficient?

Yes

No

Increase to standard efficiency

Generate load profile of appliance

Final load profile of a HH

Energy efficiency

Demand Management Possibilities

<table>
<thead>
<tr>
<th>Energy efficiency</th>
<th>Demand Management Possibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light, TV, Refrigerator</td>
<td>Rice cooker, refrigerator, (mobile phone, iron, rechargeable light, water pump, laptop)</td>
</tr>
</tbody>
</table>

Use “LoadProGen” and Manual calculation for infrequent load
Scenarios:
1. Base case (survey data)
2. Rice cooker as a flexible load
   - Rice cooker capacity- 650 Watt
   - Operating time- 30 min (full power consumption)
   - Evening Rice cooker - shifted by 3 hours and morning by 1-2 hours
3. Application of Energy Efficiency measures: (Light 7 W, TV- 40 W, Refrigerator-80 W)
Result from HOMER Pro modelling: Rice cooker shifting

<table>
<thead>
<tr>
<th></th>
<th>PV (kW)</th>
<th>Diesel Gen (kW)</th>
<th>Battery, kWh (LA)</th>
<th>Converter (kW)</th>
<th>Cost of Electricity Cent/kWh</th>
<th>NPC ($)</th>
<th>RE fraction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>60</td>
<td>45</td>
<td>175</td>
<td>20</td>
<td>58</td>
<td>638,625</td>
<td>58</td>
</tr>
<tr>
<td>After Rice Cooker shifting</td>
<td>63</td>
<td>25</td>
<td>160</td>
<td>20</td>
<td>53</td>
<td>587,783</td>
<td>61</td>
</tr>
</tbody>
</table>

PV size + 3%, Diesel Gen size –44%, Battery size - 9%, Cost of Electricity–9%, NPC -8% RE fraction +3%
Result from HOMER Pro modelling: Energy Efficiency

Average Daily load profile - Base case and Energy Efficiency

<table>
<thead>
<tr>
<th>Hours of day</th>
<th>Power, kW</th>
<th>PV (kW)</th>
<th>Diesel Gen (kW)</th>
<th>Battery, kWh (LA)</th>
<th>Converter (kW)</th>
<th>Cost of Electricity Cent/ kWh</th>
<th>NPC ($)</th>
<th>RE fraction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00 - 01:00</td>
<td>Average_Basecase</td>
<td>60</td>
<td>45</td>
<td>175</td>
<td>20</td>
<td>58</td>
<td>638,625</td>
<td>58</td>
</tr>
<tr>
<td>02:00 - 03:00</td>
<td>Average_EE_RC_SHFT</td>
<td>50</td>
<td>30</td>
<td>160</td>
<td>20</td>
<td>56</td>
<td>422,325</td>
<td>74</td>
</tr>
<tr>
<td>04:00 - 05:00</td>
<td>Average_BASE_EE</td>
<td>53</td>
<td>20</td>
<td>170</td>
<td>20</td>
<td>52</td>
<td>403,275</td>
<td>82</td>
</tr>
</tbody>
</table>

PV size – 12%, Diesel Gen size – 56%, Battery size - 3%, Cost of Electricity–11%, NPC -37%, REF 24%
Conclusion

• Proposed energy service characterisation framework and load profile can be used to develop an effective load shifting strategy
• Provides a basis for designing REMGs to provide important services at reduced cost
• EE measure and load shifting has better impacts
• Financial incentives, awareness, metering and load control mechanisms are possible options for implementation of demand side management
Thank you!

(Questions Please ?)