*Unlocking MG for sustainable development*

# 4. Key technical aspects for mini-grid design

**Suva, Fiji**

June 26th-30th, 2023


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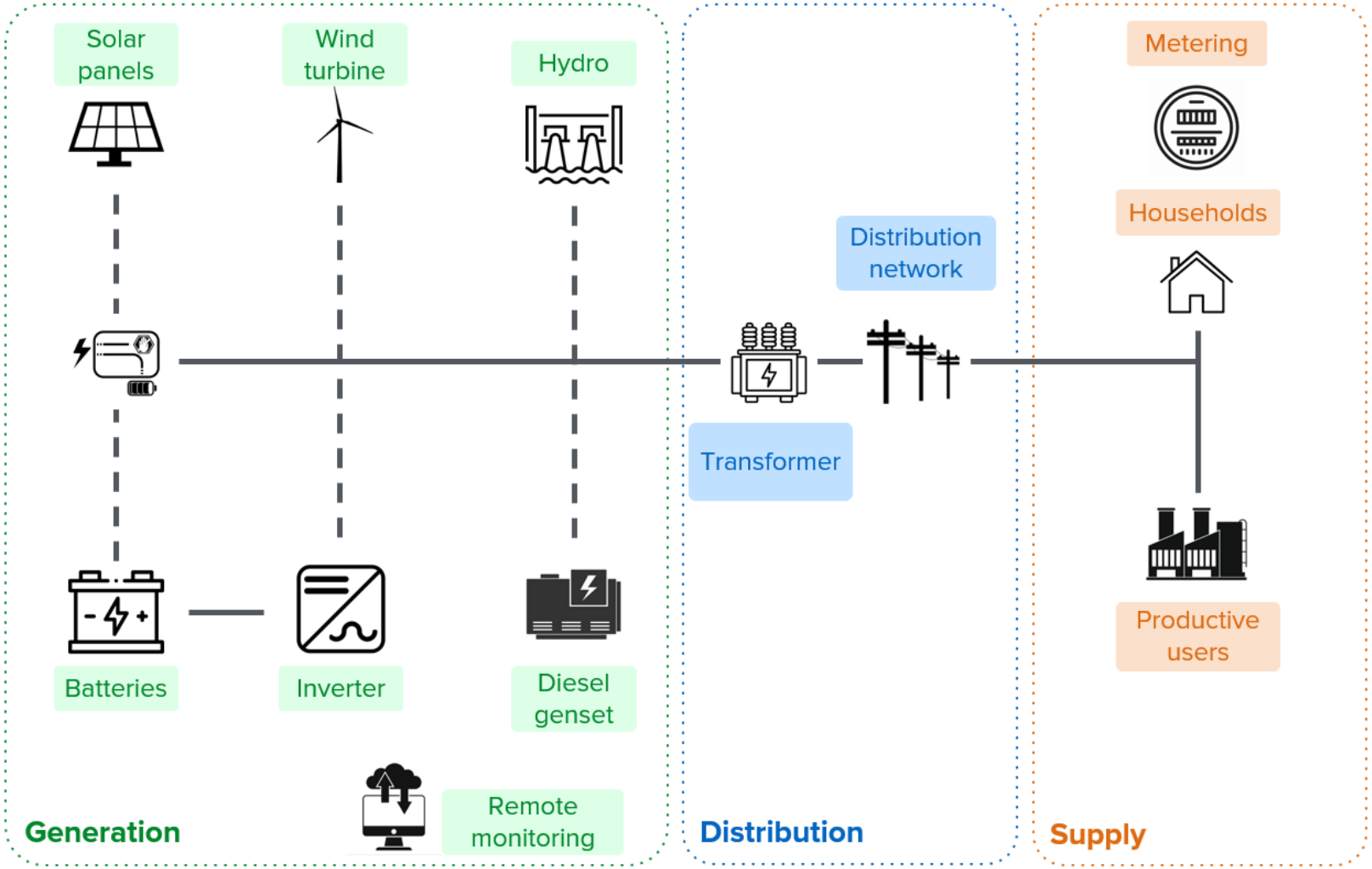
# 1. INTRODUCTION

# OBJECTIVES

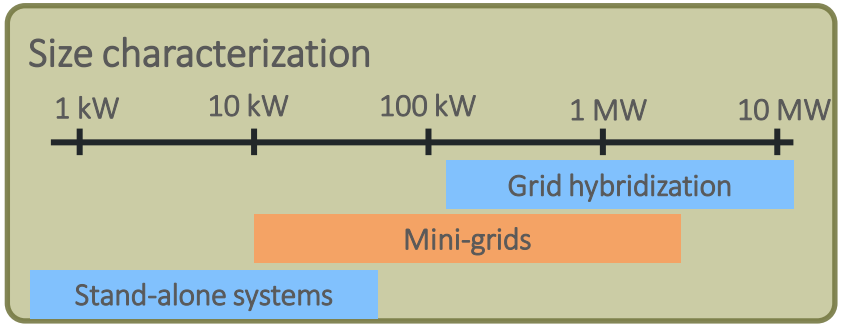
This presentation covers key stages of the mini-grid dimensioning process, including site pre-feasibility assessment, demand assessment, system concept design and optimization, and a brief overview on technical design.

It is important for decision makers to be aware of the aspects that are typically addressed by consultants or mini-grid developers when designing mini-grid systems. The understanding of the methods, tools, standards, and best practices that are used within this process is essential to ensure the deployment of sustainable and reliable systems.

# DEFINITIONS AND KEY COMPONENTS OF MINI-GRIDS




*Source: INES, 2021. Training on Renewable Energy Mini-Grids.*




## What are mini-grids?

Mini-grids are designed for the generation, distribution and supply of electrical power. They are independent of a large, centralized electricity grid and incorporate more than one type of power source, e.g., photovoltaic, wind turbines, micro-hydro and/or fossil fuel generators. Most mini-grids require storage for energy (i.e., batteries). Characteristics:

- Generation must meet demand at every moment.
- Penetration of renewable energy needs to be defined during dimensioning.
- Operation can be intermittent (i.e., only 6 hours per day) or uninterrupted (24/7).

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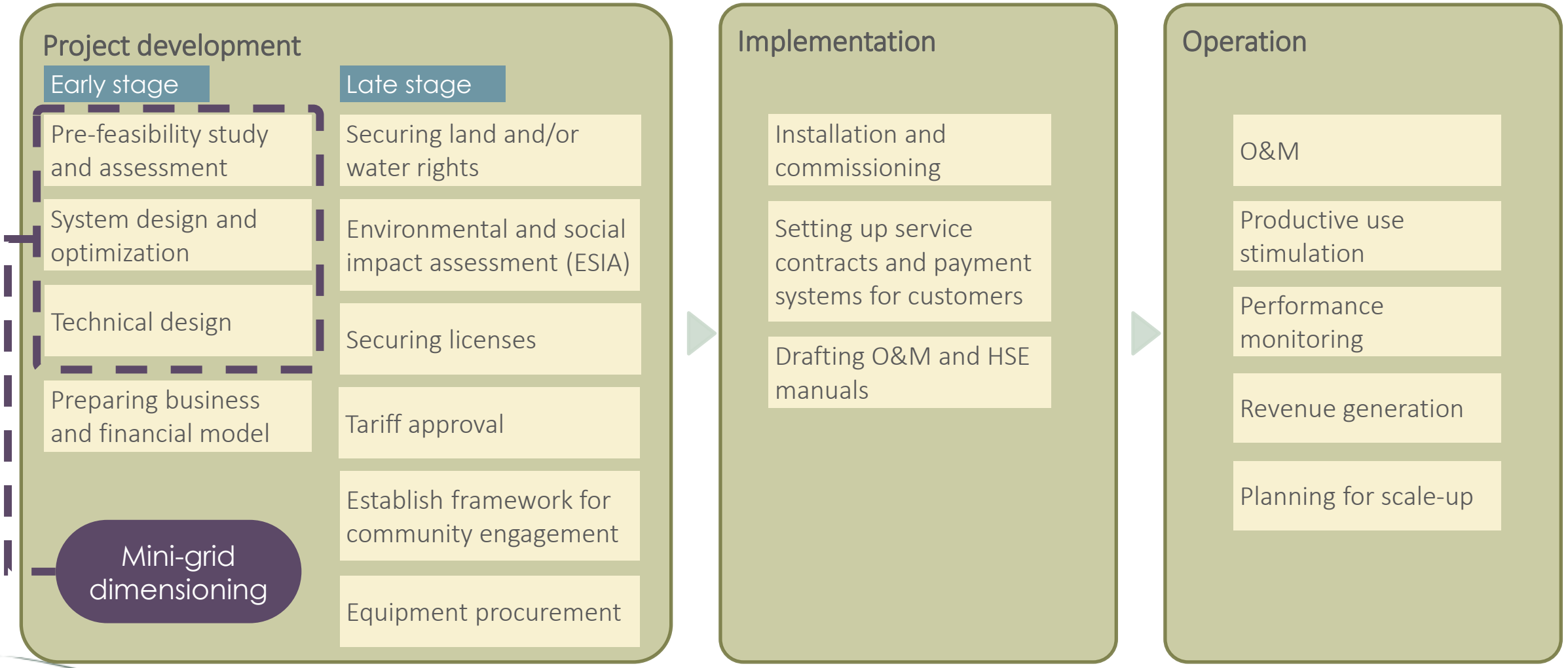
# PHASES OF A MINI-GRID PROJECT

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# PHASES OF A MINI-GRID DIMENSIONING PROCESS

## 1. Pre-feasibility study and assessment

| | | | |
|---|---|---|---|
| Activities | Pre-feasibility study → | Demand assessment → | Integration of services |
| Outputs | Priority sites. Willingness and Ability to pay. | Aggregated load profile at site level. | Feasibility of incorporating additional services. |

**Objectives**

- Create a short-list of potential mini-grid sites.
- Characterize the site and evaluate its energy demand.
- Assess the possibility of incorporating additional services on top of electricity production.

## 2. System design and optimization

| | | | | |
|---|---|---|---|---|
| Activities | Modeling and optimization tool | *Iterative process* | Financial modeling → | System dimensioning |
| Outputs | | | | Concept design of mini-grid. |

**Objectives**

- Obtain a technical and economic mini-grid concept design by simulating the operation of the system under different scenarios.
- Obtain an expected cash-flow of the mini-grid project.

## 3. Technical design

| | | | |
|---|---|---|---|
| Activities | Components specifications | Engineering design | Technical standards |
| Outputs | Technical specifications for mini-grid design. | | |

**Objectives**

- Elaborate a document which compiles the main technical specifications and standards that should be followed by the mini-grid developer.

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# 4.1 Demand assessment

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MG in Bolivia by TTA


MG in Ethiopia by TTA


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# 1. SESSION OBJECTIVES

# SESSION OBJECTIVES

i) Identify the key aspects of field data that are important for mini-grid sizing and design.

ii) Understand how different users contribute to the electricity demand.

iii) Know additional services that can be offered and considered when designing the mini-grid.

# 2. PRE-FEASIBILITY STUDY

# SITE IDENTIFICATION AND PRIORITIZATION

## Key aspects of site prioritization can include:

| | |
|---|---|
| Accessibility | Existing infrastructure |
| Population demographics | Economic potential |
| Energy resource available | Access to finance / appliances |
| Local regulations | Land-use plans |

## Geospatial analysis for site identification and prioritization

**Input**: Satellite imagery and raw GIS data

↓ **Processing**

Identification of population clusters

↓ **Layering**

Characterization of population clusters

↓ **Filtering**

**Output**: Long and short-listing of potential MG sites

***Examples:*** *OpenStreetMap data, administrative boundaries, satellite photos, land-use data, etc.*

***Tools:*** *VIDA, WorldPop's peanutButter, REM*

***Key data:*** *building count, power situation, night-time light intensity, infrastructure, public institutions (schools, health centres, etc.), other socio-economic characteristics.*

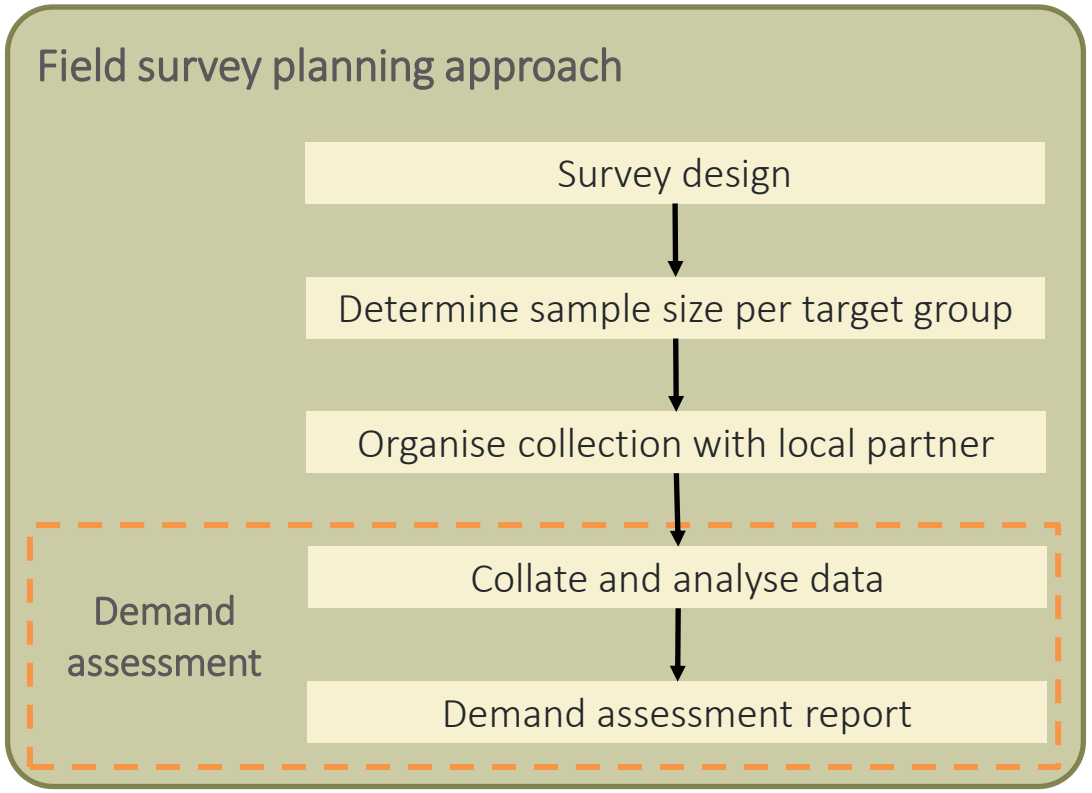
***Criteria:*** *economic potential, national electrification strategy, purchasing power, distance to grid, etc.*

## How is a site prioritization activity performed?

- Prioritizing sites for mini-grid electrification projects typically involves conducting a nationwide GIS campaign to identify areas that are the most suitable for renewable power generation. Key criteria aspects are shown in the box on the left. Other relevant points include:
- Distance to the national distribution grid or other mini-grids, and any planned extensions of existing grids.
- Average income and purchasing power.
- Alignment with national electrification strategy.

**Prioritizing areas with a high economic potential, such as many** small businesses, will be considered as it helps ensure that the mini-grid will be sustainable after its implementation. Considering sites with easy access to existing road and transmission infrastructure is also important to reduce the project's total cost. Additionally, it is crucial to engage with the local communities and other stakeholders to get their input and buy-in before deciding on the specific location.

# FIELD SURVEY




## Why and how are field site surveys carried out?

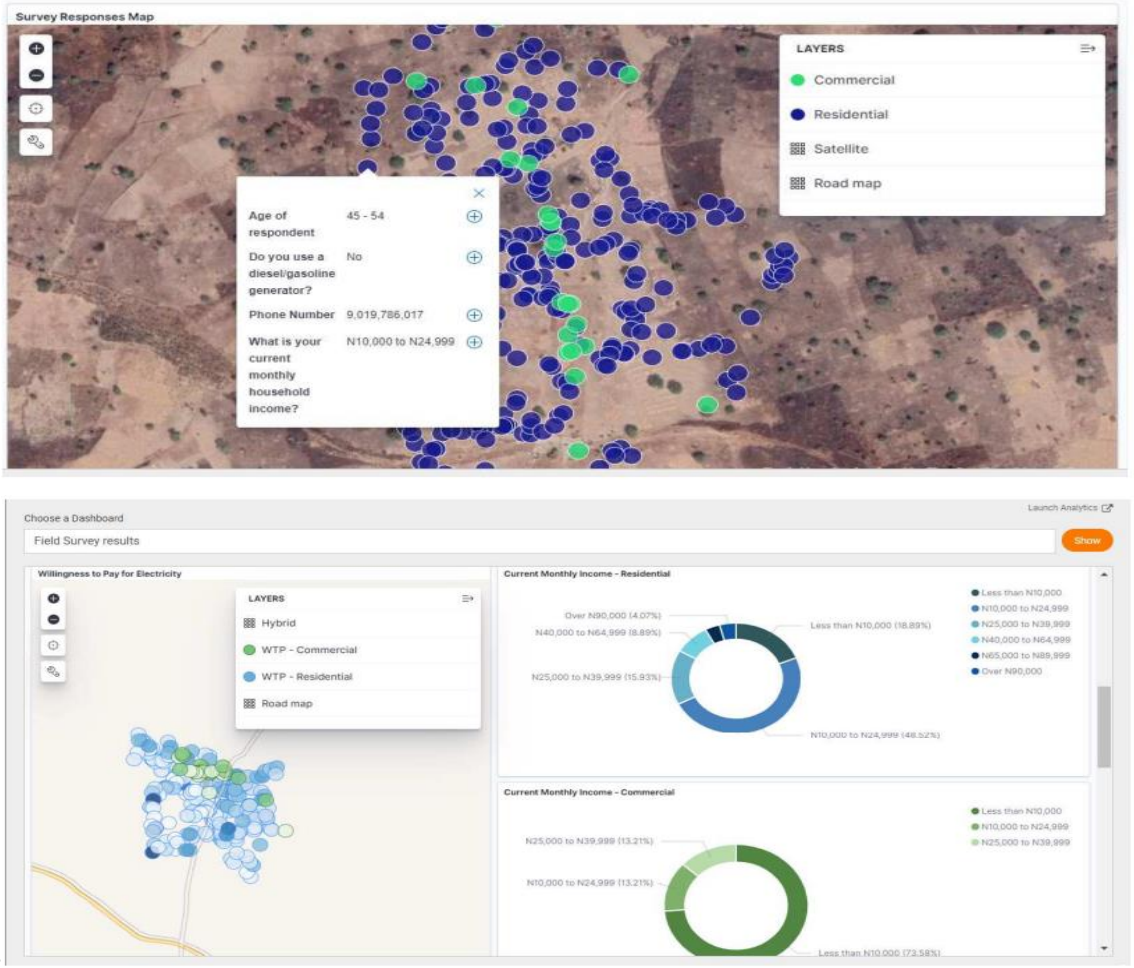
- The field survey constitutes a fundamental phase of the demand assessment and allows to assess the general appetite of the population to adopt the mini-grid. By allowing to understand the current energy usage within the village, this stage helps forecast potential future demand. The following steps should be followed when planning the survey:
- Identify and categorize target respondents (residential, public buildings, health centers, schools, places of worship, etc.)
- Design concise survey questions that allow to isolate critical information, and include technical, socio-economic and willingness-to-adopt aspects.
- Use best-in-class survey data entry tools.

# FIELD SURVEY

| Sections | Example of questions | Key information for demand assessment |
|---|---|---|
| General information | Name, age, phone number, GPS location, main economic activities, employment status, sector of occupation / business, household / business size. | • Business sector and value chains in the community.<br>• Opportunity for productive use of energy.<br>• Community geographical distribution. |
| Socio - Economic data | Construction of the house, regular modes of transport used, monthly income, monthly expenses, airtime expenditure, bank account and finance access, land rights, preferred location of power plant. | • Wealth and disposable income in the community.<br>• Ability to pay for energy.<br>• Available payment methods in the community |
| Current energy usage | • Energy sources in use (diesel, wood, kerosene, batteries, SHS, etc.)<br>• Energy expenses | • Willingness to pay for energy<br>• Potential competing energy sources<br>• Assessment of economic benefits from mini-grid. |
| Electricity demand | • Appliances owned and plans to purchase new appliances<br>• Eagerness to connect to the mini-grid<br>• Desire or need for additional electricity / power | • Assess appetite for mini-grid<br>• Evaluate potential for energy consumption growth<br>• Predict load profile |

# DATA COLLECTION TOOLS

## Example of online platform for data collection




**Source**: Odyssey Energy Solutions, 2022

**What type of tools are typically used in site survey data collection?**

There is a wide variety of software tools available to facilitate data collection. They are designed to be used by interviewers in the field using smartphones or tablets. These greatly facilitate note-taking and improve data quality, while facilitating data analyses after the data collection.

**Their effective use is critical in allowing a developer to significantly reduce the time/cost/labour in data collection, while ensuring the data is as detailed and accurate as possible.**

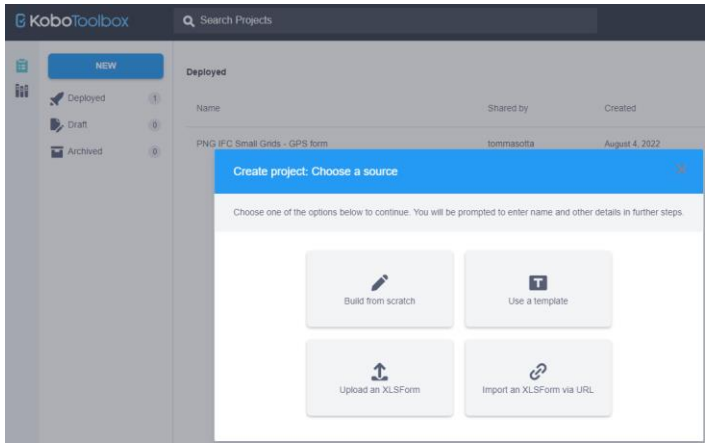
These range from pre-designed online tools to highly custom offline/desktop tools; some are available free of charge, others may require a monthly subscription.

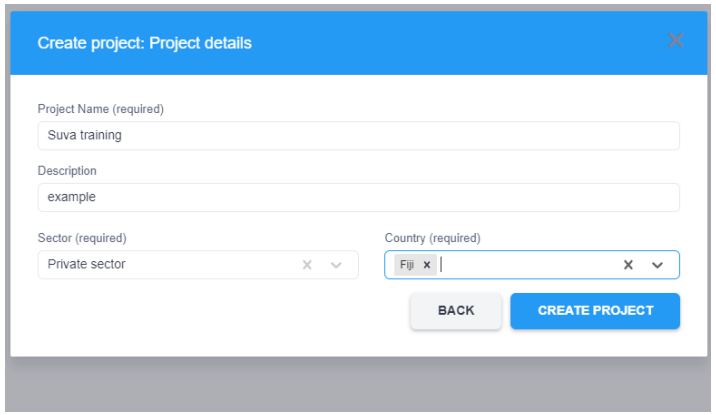
The choice of the tool will depend on:

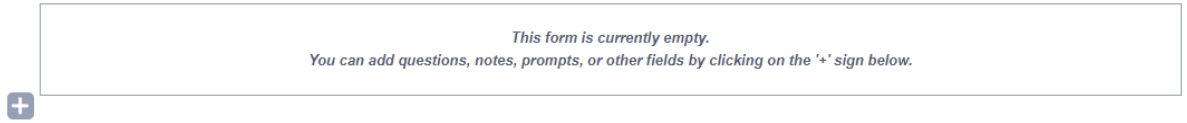
- Remoteness of the location
- Amount of data to be collected
- Availability of devices (smartphones, tablets, computers, etc.)
- Functionalities required
- Budget.

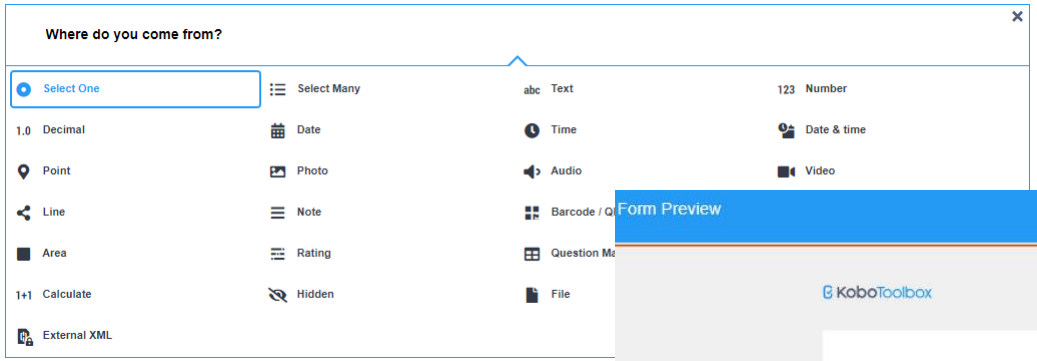
*Examples include: KoBo Toolbox, Odyssey, Quick Tap Survey, Survey Monkey, or Google Forms.*

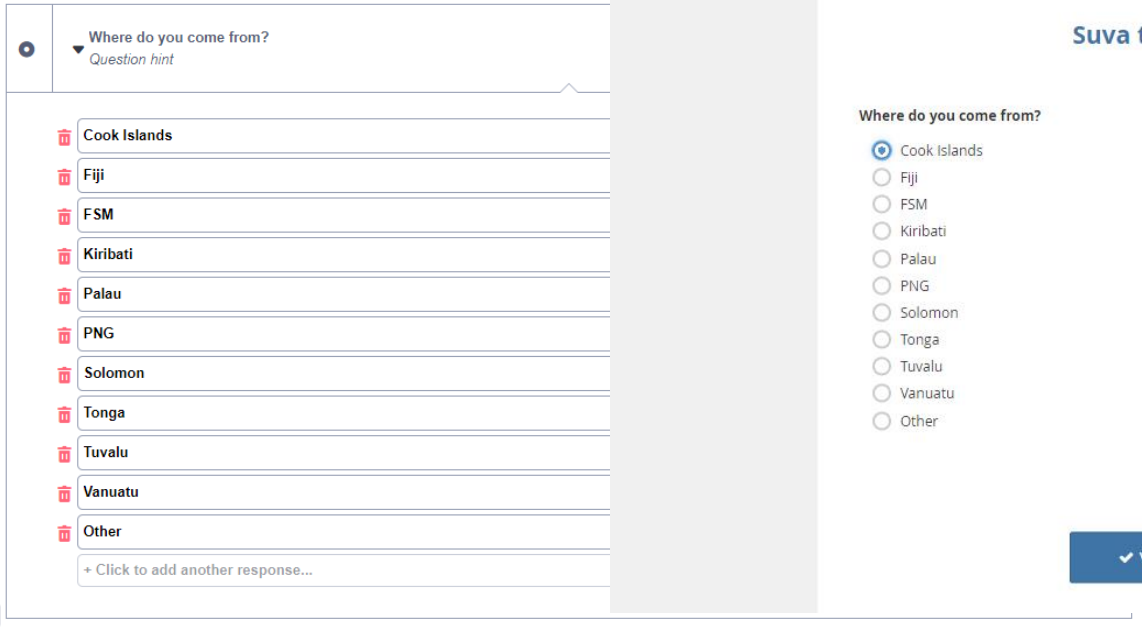
# DATA COLLECTION TOOLS – KOBO TOOLBOX

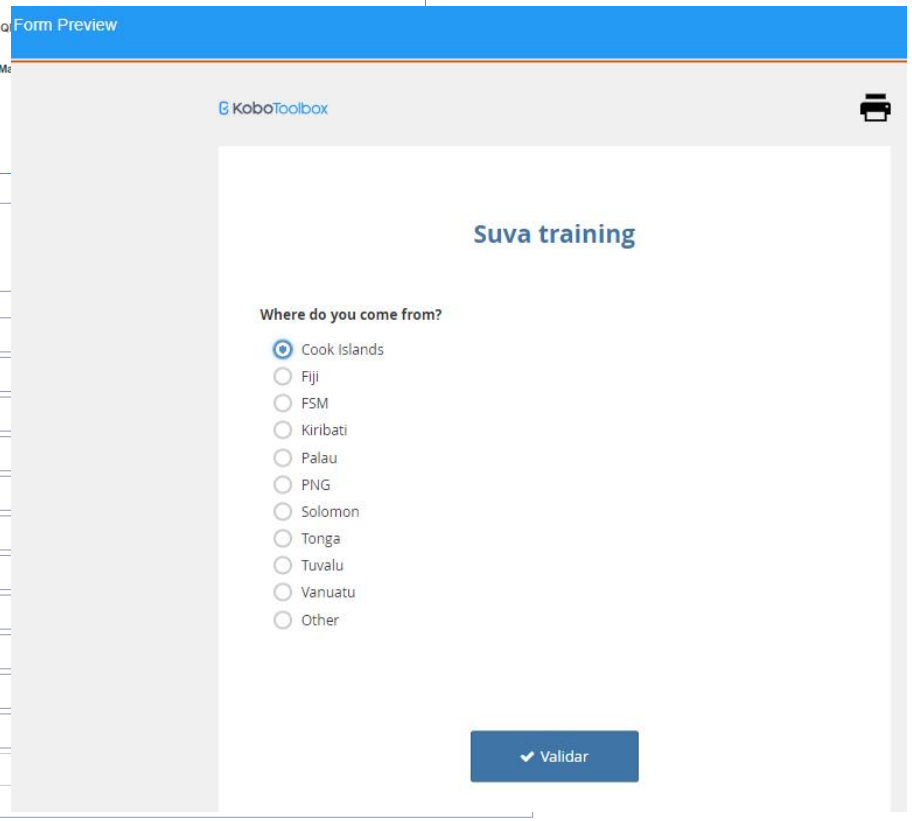
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# WILLINGNESS AND ABILITY TO PAY

## Willingness to Pay (WtP)

**Expressed WtP** - the maximum amount a person say they are willing to pay for electricity ; this value is based on their perception of the value of electricity.

**Revealed WtP** - the maximum amount a person could be willing to pay ; based on their current expenditure on energy.

## Ability to Pay (AtP)

A realistic estimation of how much money a person can pay for electricity; based on their disposable income and their current expenditure on energy.

## Key Information

**Expressed willingness to pay** based on realistic scenario of electricity provision, including tentative price.

**General economic activity** of the community as well as of surrounding communities.

**Current sources of electricity and of energy** vs. preferred alternative sources.

**Perceived value addition** of benefiting from electricity access.

**Income,** income sources, including seasonal variations.

**Monthly expenditure on energy** including maintenance costs of auxiliary equipment.

**Capital cost of current energy sources** including down payments for PAYGO and lease-to-own sources.

**Using proxies to estimate levels of income and wealth of households** e.g. expenditure on mobile airtime, land size, livestock size, housing structures, means of transport, etc.

WtP and AtP are key indicators to understanding how to optimize energy tariffs

# 3. DEMAND ASSESSMENT

# DEMAND ASSESSMENT

## What is included in the demand assessment?

### Composition of customers

- Number and breakdown of connections:
  - Residential
  - Commercial
  - Public
  - Productive
- Assessment of additional loads: public lighting, water pumping, agricultural equipment, etc.

### Daily consumption

A daily kWh value for each customer segment

### Hourly consumption pattern

An hour-by-hour breakdown during the day of energy consumption patterns according to consumer segments. value for each customer segment.

### Seasonality of consumption

An assessment of the variations in demand over the week and over the year, clearly identifying peaks and troughs in consumption due to, for example, agricultural cycles, revenue cycles, or the weather.

### Growth potential

An estimate of a growth rate in energy consumption due to, for example, the adoption of the mini-grid, the purchase of additional appliances, or the economic development of the village.

## How is the electricity demand estimated?

### 1. Present electricity consumption

Current electrical demand of all the inhabitants

Site survey

### 2. Assessed electricity consumption

Amount of electricity that customers state they would use were they to access it at this moment.

WtP & AtP

### 3. Effective electricity demand

Electricity demand that is backed by the financial resources available to pay for it.

Forecast

### 4. Future effective electricity demand

Electricity demand that is expected in future years.

# RESIDENTIAL CONNECTIONS

| Household tier | Electricity loads available | Typical energy consumption example* |
|---|---|---|
| **Tier 0**<br>Non-participant | No appliance | - |
| **Tier 1**<br>Small consumer | Only basics: lights, phone charging, radio. | 140 Wh/day<br>4.2 kWh/month |
| **Tier 2**<br>Medium consumer | + TV<br>+ Fan<br>+ Small domestic appliance | 550 Wh/day<br>16.7 kWh/month |
| **Tier 3**<br>Large consumer | + Fridge | 2,200 Wh/day<br>67 kWh/month |
| **Tier 4**<br>Very large consumer | + Freezer<br>+ Large productive appliance | 3,850 Wh/day<br>117 kWh/month |

* Can be adapted according to country characteristics

**What are the main characteristics of residential mini-grid customers?**

Electricity consumption can vary widely depending on the number and type of appliances a household has:

- Households with no appliances typically have a low and stable load pattern, with minimal consumption primarily limited to lighting.
- Households with many large appliances, such as refrigerators, televisions, and air conditioners, consume significantly more electricity, with higher and more variable load patterns, peaking in the evenings when appliances are in use.

Mini-grid operators may implement different tariffs based on the capacity of the household's connection, with lower tariffs for households with fewer appliances, and higher tariffs for households with more appliances, to ensure fair cost sharing and encourage energy efficiency.

**Residential load management strategies:**

- Time-of-use tariffs, load shedding or demand-response programmes to balance demand with available resources.
- Service-based tiered tariffs
- Education and awareness programmes that inform customers about efficient use of appliances and general energy consumption.
- Promotion of energy efficient appliances.

# PRODUCTIVE USES OF ENERGY

Productive use of energy refers to using electricity to support economic activities such as running small businesses, powering irrigation systems and supporting education and health services in rural areas.

| Sector | Examples of appliances | Power rating |
|---|---|---|
| Agriculture and fishing | Egg incubator | 80 to 160 W |
| | Grinder for pulses and beans | 5,2 kW |
| | Water pump | 3.7 to 22.4 kW |
| | Steriliser (for dairy) | 3 to 6 kW |
| Light manufacturing | Electronic welding machine | 3 to 7.5 kW |
| | Jigsaw | 400 W |
| | Electric drilling machine | 400 W |
| | Popcorn maker | 1.5 to 2.1 kW |
| Commercial and retail activities | Computer | 15 to 100 W |
| | Printer/scanner | 0.5 to 2 kW |
| | Sewing machine | 200 W |
| | Television for local cinemas and bars | 50 to 200 W |

What are the main characteristics of productive mini-grid customers?

Importance of productive use of energy

- Enhanced social and economic benefits
  - Increase local productivity
  - Creation of jobs
  - Capture larger protons of the economic value chains
  - Increase the diversity of customers
  - Reduction of expenses through electrification of processes
- Ensure the viability of the mini-grid
  - Increase revenues through higher electricity consumption
  - Diversify electricity loads

Key success factors in promoting productive use of energy

- Focus on the business needs of local entrepreneurs.
- Focus on existing value chains that would benefit from productive appliances.
- Provide targeted business support and envision mini-grid as part of a holistic intervention
- Supply of water, telecommunications, electric mobility
- Financial support for the development of economic activities
- Set-up demand side management to ensure peak operation happens during peak sun hours
- Provide financial solutions for end-users

# LOAD PROFILE

## Basics of load profile

Load profiles can be determined by processing the data collected during site surveys on the amount and duration of use of electric appliances for each customer and customer type. A simultaneity factor is typically used to consider that not all appliances are used at their maximum power at all times. Typical customer types can be categorized:

- Residential / Household
- Commercial
- Public infrastructure (social)
- Productive (Industrial, Agriculture)

## Field survey planning approach

The energy demand in a mini-grid can come from growth in consumer base (number of consumers) and growth in energy consumption. The main factors that affect demand forecasting are site-specific and can be categorized as:

| Population development | Economic productivity | Consumption patterns |
|---|---|---|
| A growth in population can lead to an increased demand. | Economic growth in the area can result in growing demand. GDP progress could serve as indicator for future trends. | Changes in lifestyle, financial status, planned number of appliances in the next years can lead to a growth in energy demand. |

## How are base and future load profiles established?

Best practices for base load profile:

- The hourly aggregation of the power of the appliances used by one customer will result in the average load profile for each customer.
- The aggregation of load profiles according to customer type results in the average daily load profile per consumer category.
- The aggregation of all consumers load profiles results in the average daily load profile of the village.

Best practices for forecasting demand growth:

- Optimistic scenario: increase of 10% per year on the assessed base load profile.
- Realistic scenario: increase of 2.5% per year on the assessed base load profile.
- Pessimistic scenario: no future increase in demand.

# INTEGRATION OF SERVICES

## Field survey planning approach

| | |
|---|---|
| Service providers offering different services | The benefits of integrating the services can help in making the business case more compelling while keeping tariffs affordable. |
| Productive uses | The service provider offers other services in addition to electricity, such as community freezer, water pumping or food processing services. This increases the revenue of the service provider and promotes local economic activity. |
| Kiosk | The service provider uses its facilities to offer low energy need services such as battery charging for cell phones or solar lights. |
| E-mobility | The service provider can offer charging infrastructure and vehicles for the community such as electric scooters or motorbikes. |
| Multi-purpose facility | In case of using solar PV, the generation plant infrastructure can have an added value if it provides an open shaded space, which can be used by the community. |

**What other services can be integrated within the mini-grid?**

Residential customers connected to a remote mini-grid typically have a low ability to pay, which often leads to barely profitable business cases. Connecting commercial and productive users to the system is one way of optimizing profits. A second approach is integrating different types of services under the mini-grid operator to diversify the revenue streams and make the overall project financially more sustainable.

Limited scale and limited ability to pay do not allow dedicated staff to provide each service separately. A small team can typically handle O&M and customer management of multiple utility services (electricity, water, telecommunications, etc.).

There are strong synergies in integrating the different services during the construction or O&M stage. For example, poles or trenches can be used to distribute different services.

# 4. ADDITIONAL RESOURCES

# ADDITIONAL RESOURCES

- Kobo toolbox: https://www.kobotoolbox.org/
- Quick Tap Survey: https://www.quicktapsurvey.com/
- Survey Monkey: https://en.surveymonkey.com/
- Google Forms: https://docs.google.com/forms

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# Vinaka!

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