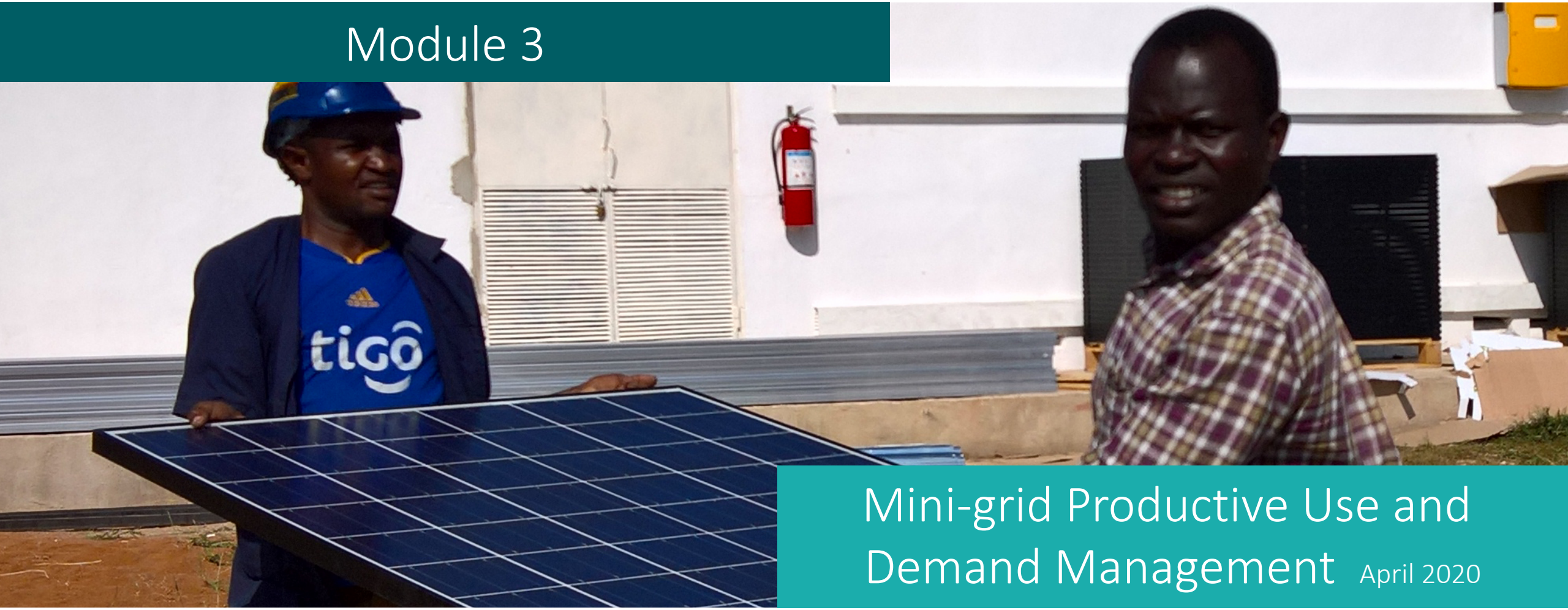
GREEN MINI-GRID HELP DESK

Module 3



Mini-grid Productive Use and Demand Management

April 2020

ENERGY4IMPACT
ACCELERATING ACCESS TO ENERGY

INENSUS

SUSTAINABLE ENERGY FUND FOR AFRICA

Module Overview

Introduction to the Module
- Learning objectives
- Module requirements
- Agenda

Part 1: **Productive Use**

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
Definition of PU	Why does PU matter?	PU business categories	PU best practices	Appliance financing

Part 2: **Demand-side Management**

Topic 1	Topic 2	Topic 3	Topic 4
Introduction to DSM	Supply-demand imbalance	DSM strategies	Choosing DSM strategies

End of Module
- Case studies
- Module recap
- Further reading

Objectives & Requirements

Learning Objectives

- Learn about the importance and challenges of productive use (PU) of electricity around mini-grids.
- Learn about the different categories of productive user and how to support them.
- Learn about the options for appliance financing.
- Learn about the importance of demand-side management for mini-grids.
- Learn about the different DSM interventions and when they should be applied.
- Learn how to develop an appropriate DSM strategy.

Module Requirements

- This module is targeted at mini-grid developers and operators at all stages of development.
- They are expected to have a basic understanding of rural, off-grid energy markets and community dynamics in developing countries.
- No prior knowledge of productive use of electricity or demand side management is required.

Agenda

Part 1 – Productive Use

1. Definition of PU
2. Why does PU matter?
3. PU business categories
4. PU best practices
5. PU appliance financing
6. Case Study: REDP Tanzania

Part 2 – Demand-side Management

1. Introduction to DSM
   - Definition
   - Challenges and Role
2. Supply-Demand Imbalance Scenarios
   - Peaks, Valleys, Offset Demand, Excess Demand, Excess Supply
3. DSM Strategies
4. Choosing DSM Strategies
   - Process map
   - Constraints & mitigations
5. Case Studies

Part 1: Productive Use (PU)

Definition of Productive Use

No single definition of Productive Use

- **Livelihoods focus** - agricultural, commercial and industrial activities that **generate income** through consumption of electricity
- **Energy focus** - income generating activities that **increase consumption of electricity**
- **Socio-economic focus** - livelihood activities plus other activities related to **health, education , connectivity, e-mobility etc**

This module => Livelihoods and Energy definitions

Photo: Welding at Absolute Energy's Rutenderi mini-grid in Rwanda
Source: Energy 4 Impact

Why Do Productive Users Matter?

Enhanced social and economic impact

- Increase productivity
- Capture larger portion of value chains locally
- Increased diversity

Increased sales from PU energy consumers are **critical for the viability** of mini-grids

Photo: Productive use customers - bakery, welding, movie theatre, and cafe
Source: Booth, S., Li, X., Baring-Gould, I., Kollanyi, D., Bharadwaj, A., & Weston, P. (2018).

PU Business Categories

Category	Sub-categories & examples	Advantages	Disadvantages

Small village businesses	▪ **Primary** e.g. agriculture, fishing, livestock
	▪ **Light manufacturing** e.g. carpentry, welding, ice-making
	▪ **Commercial and retail** e.g. grocers, hair salons, phone chargers
		▪ Most common in rural areas
		▪ More diversified customer base
		▪ Greater scope for local economic development
		  ▪ Jobs creation: expanding existing & new businesses
		  ▪ "Multiplier Effect": workers spend most of their income within the local economy
			▪ Smaller individual off-take of energy, which is less reliable / stable
			▪ Appliance ownership can be low in remote areas, so schemes to provide customers with suitable appliances (selling / financing / grants) must be set up and managed

Large anchor clients	Examples: telecom towers, flower farms, tourist lodges, banks	▪ Large, reliable off-take of energy ▪ More stable, predictable & long-term revenues	▪ Limited number of such clients in remote areas ▪ Need to provide more competitive tariffs to anchor clients, and often have onerous service requirements

PU Best Practices

- There is **no standard business model** for developing PU in mini-grids, but many models have been tried
- Key success factors include
  - Focus on the **business needs of local entrepreneurs**
  - Focus on **existing value chains** and **increasing their productivity**
  - Targeted **business support** for local entrepreneurs
  - **End user finance** for income generating equipment / appliances
  - **Demand side management** to ensure peak operation at peak sun hours

Photo: Saw mill at KIS, a mini-grid in Uganda
Source: Booth, S., Li, X., Baring-Gould, I., Kollanyi, D., Bharadwaj, A., & Weston, P. (2018)

PU Appliance Financing

Enable customers to

- Buy appliances that they cannot afford outright
- Benefit from increased income during loan period

Appliance financing may be provided in form of loans or grants

Customers can pay off loans for some PU appliances in less than 12 months

But grants may still be needed – some donor programmes fund up to 70% cost of appliances

Sector	Activities / Appliances	Power required (kW)	Cost from supplier ($)	Payback period (months)
Primary industries (agriculture, fishing)	Egg incubator	80 to 160W	$50 to $100	1 to 3
	Grinder for pulses and beans	5.2 kW	$1,500 to $4,000	6 to 12
	Water irrigation pump	3.7 to 22.4 kW	$200 to $1,000	3 to 6
	Sterilizer (for dairy processing)	3 to 6kW	$600 to $2,000	1 to 3
	Packager	250W to 3kW	$500 to $1,000	6 to 12
Light manufacturing	Electronic welding machine	3 to 7.5 kW	$200 to $300	6 to 12
	Jigsaw	400W	$100	3 to 6
	Electric drilling machine	400W	$20 to $50	3 to 6
	Popcorn maker	1.5 to 2.1 kW	$50	1 to 3
Commercial and retail activities	Computer	15 to 100W	$250 to $800	3 to 6
	Printer/scanner for stationery	0.5 to 2kW	$150 to $250	3 to 6
	Sewing machine	200W	$30 to $100	3 to 6
	Television for local cinemas and bars (including decoder)	50 to 200W	$100 to $200	1 to 3

Source: ESMAP, Alibaba, Inensus.

Table source: ESMAP (2019)

Case Study: REDP Tanzania

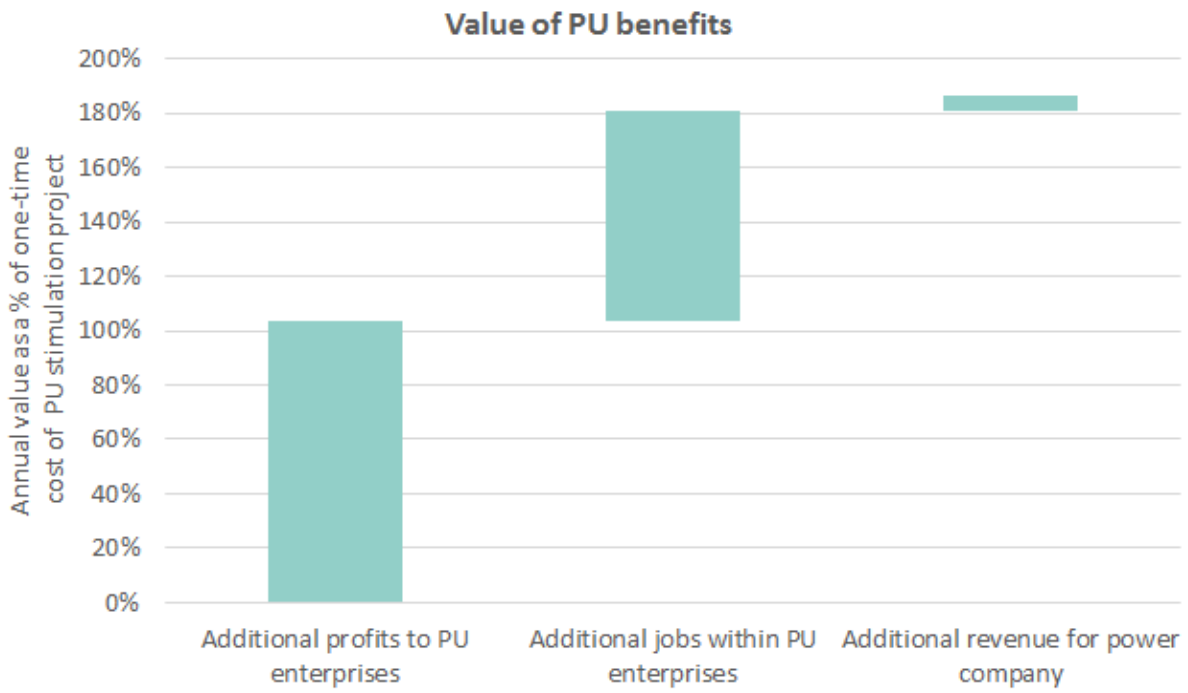
- Energy 4 Impact provided PU support to 349 entrepreneurs in 59 rural villages in Tanzania that had been newly electrified by the national grid. Dec 2017 - March 2019
- Conducted assessments of villages, identified PUs, selected local champions and ran awareness campaigns
- Each entrepreneur was given technical training, business mentorship, and support to access customers, finance, and small-scale PU appliances
- No subsidies for appliances were provided. Most took out informal loans from family and friends rather than formal loans

Photo credit: Energy 4 Impact

*Rural Electrification Densification Programme

Case Study: REDP and Value for Money

- **Excellent returns**: annual benefits = 187% of public investment
- **Benefits** (at current tariffs) **=> community**, not power supplier



PROJECT HIGHLIGHTS

1. **Increased Profitability** by Entrepreneurs by +87%
2. Increased Awareness and Knowledge on PUE
3. **Market Linkages** with equipment suppliers and financial institutions
4. Increased Electricity Consumption by +80%
5. **Access to Finance for PU Appliances – 121 loans from local FIs**
6. Job Creation - 214 permanent jobs
7. **Gender** (40% were women compared to typically below 30% women participation)

Source: Energy 4 Impact, Rural Electrification Densification Programme

Part 2: Demand-side Management (DSM)

Definition of DSM

Demand-side Management (DSM) is the planning, implementation

and monitoring of activities to

encourage (and sometimes force) customers to

alter their electricity consumption habits, in respect to

time of use, peak consumption levels and overall energy consumption.

Challenges and Role of DSM

Developers need to balance electricity supply with demand.

High demand can exceed generation capacity, cause power outages and lead to customer dissatisfaction. Investment in more generation and storage may be required to meet demand.

Low demand means underutilisation of mini-grid, power is wasted if battery storage capacity is full, which means lesser than planned revenues resulting in a poor return on investment.

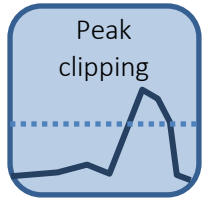
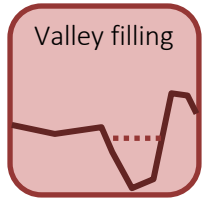
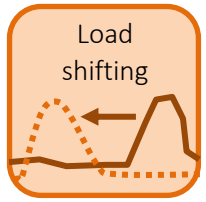
DSM manages the load of a mini-grid without:

1. needing to purchase generation assets (e.g. solar panels)
2. increasing dependence on diesel fuel

There is no “one size fits all” approach to demand-side management.

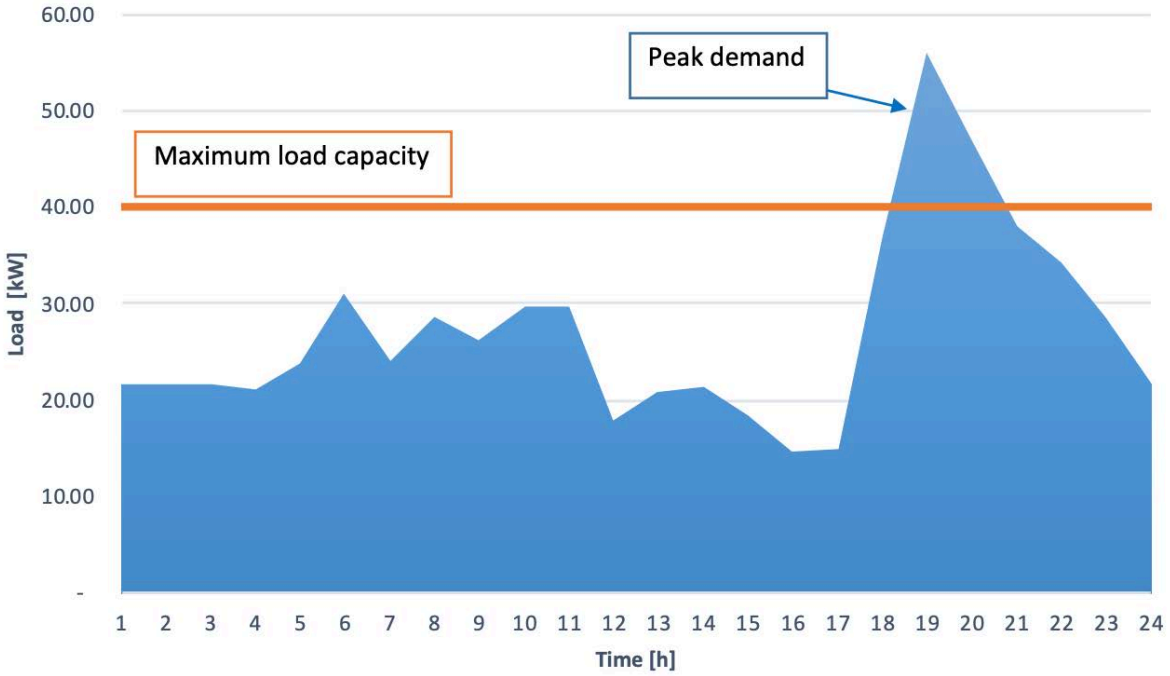
Different strategies must be employed depending on the scenario.

When can DSM be used?

Scenario	Intervention
Peaks: Periods of high demand (peaks) which exceed the peak generation capacity.	
Valleys: Periods of low demand (valleys) in which storage capacity is full and electricity generated is wasted.	
Offset demand: Periods of peak demand which do not coincide with periods of peak generation.	

Scenario	Intervention
Excess demand: Overall electricity demand is higher than electricity supply.	
Excess supply: Overall electricity supply is higher than electricity demand.	

Scenario 1: Peaks



What happens?

Periods of high power demand (peaks) which exceed the generation capacity of the mini-grid system.

Why?

The generation system is undersized, due to inaccurate demand assessment.

High coincident peak as customers connect more appliances to mini-grid over time.

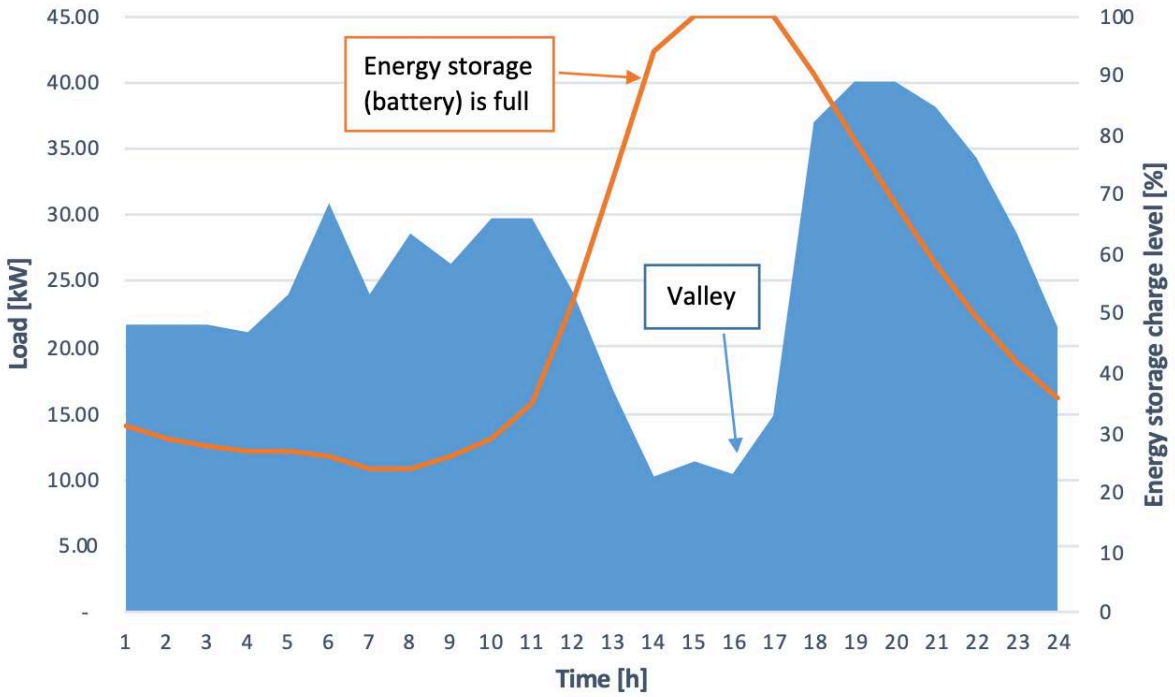
Impact

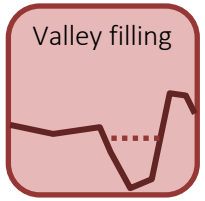
Brown-outs (poor quality power) and complete power outages.
Leads to customer dissatisfaction.
Energy storage (e.g. batteries) can be strained by high current draw at a peak.

Intervention:

Peak clipping – restricting/reducing consumption at peak

Scenario 2: Valleys





What happens?

Periods of low demand (valleys) in which storage capacity is full, but energy is still being generated.

Why?

There are times of the day where electricity use is lower, e.g. while farmers are out in their fields.

In most mini-grids, these valleys occur in the daytime.

Impact

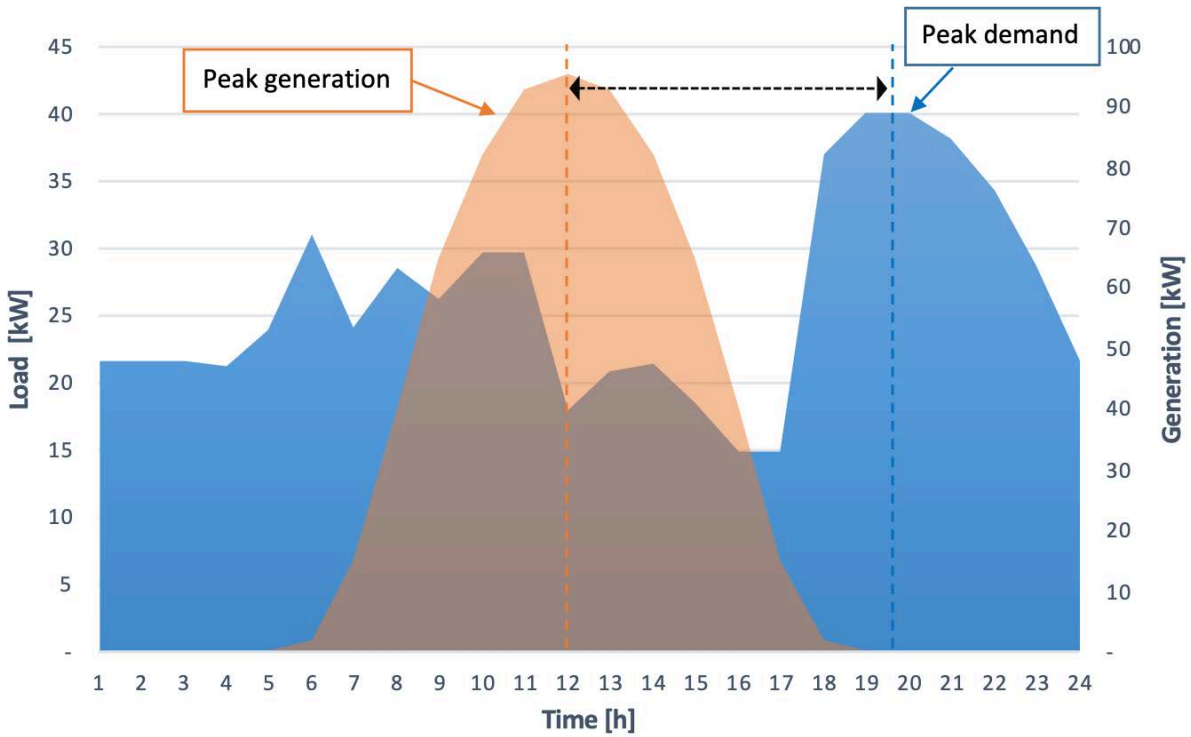
Energy is generated, but not stored or used.

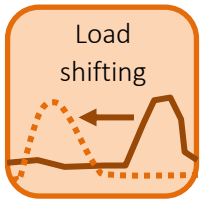
Lost revenue for the mini-grid.

Intervention:

Valley filling – stimulating demand in the valley

Scenario 3: Offset demand





What happens?

Periods of peak demand often do not coincide with periods of peak generation.

Why?

Renewable generation relies on sources of energy that are available at different times of day to when electricity is consumed.
In a solar mini-grid, generation is highest around midday, while demand is often higher in the evening.

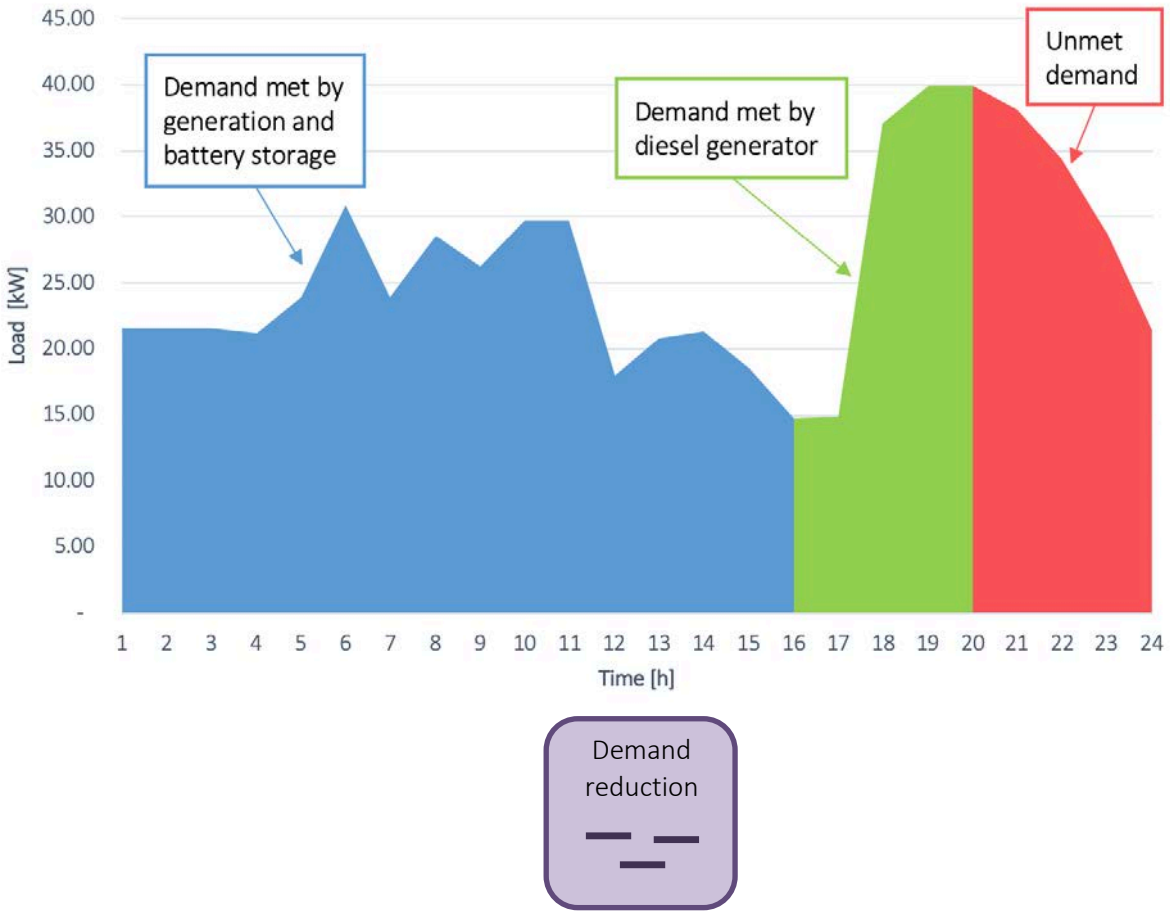
Impact

Large investment is required to store energy (batteries) or create hybrid generation systems (diesel generators) to meet the offset demand.

Intervention:

Load shifting – shift demand to the peak generation periods.

Scenario 4: Excess Demand



What happens?

Overall energy demand is more than what the system is designed to generate, even with secondary diesel generation.

Why?

The generation system is undersized due to inaccurate demand assessment or deliberate investment strategy by operator.

Customer demand increases over time as number of connections rises and customers use more appliances.

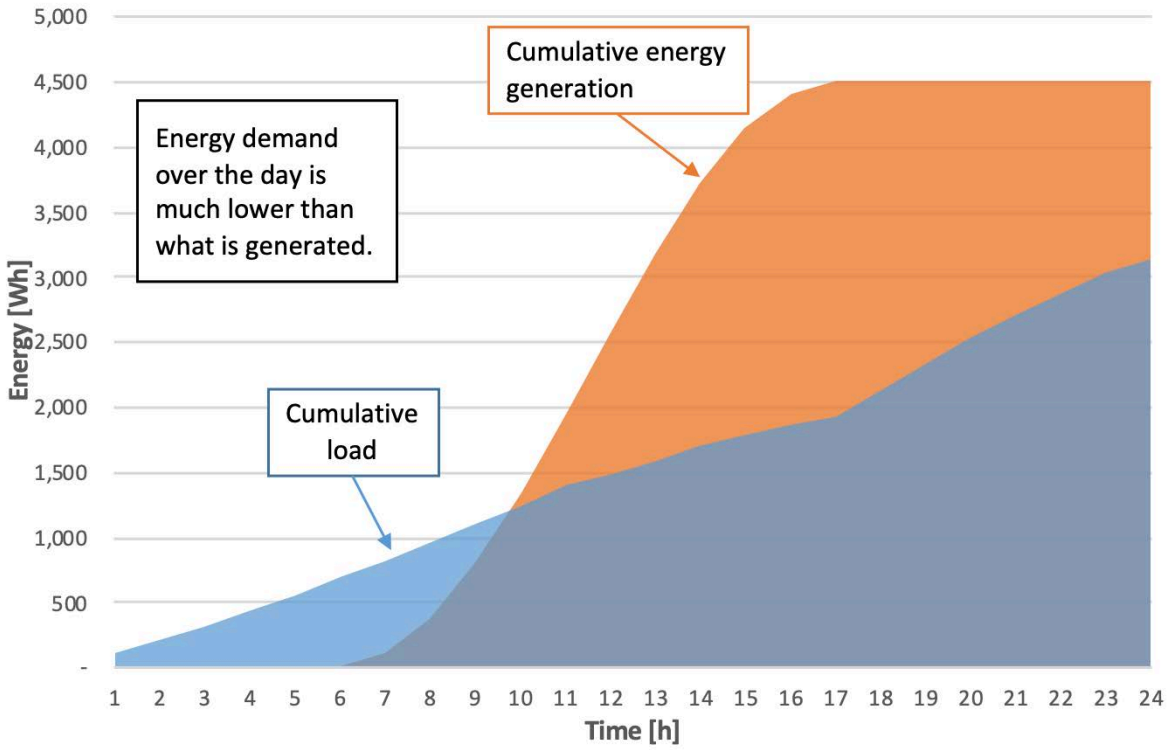
Impact

Brown-outs (poor quality power) and complete power outages. Leads to customer dissatisfaction.

Intervention:

Demand reduction – reduce overall demand to within generation capacity.

Scenario 5: Excess Supply



Demand stimulation

What happens?

Energy generated over the day is much more than customers can use.

Why?

1. The system is oversized, due to inaccurate demand assessment.
2. Customer demand decreases over time due to poor relationship with the mini-grid operator.

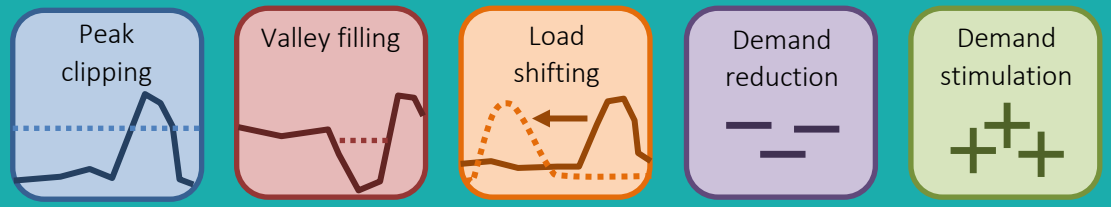
Impact

System is underutilised. Lower revenues will impact profitability of the mini-grid.

Intervention:

Demand stimulation – increase demand to match generation.

DSM Strategies

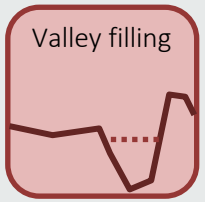


8 main strategies for DSM that developers can use:

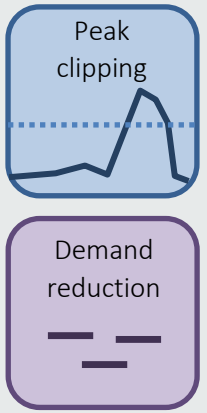
Effect on demand:
reduce, shift, increase

	Strategy	Intervention
↑	Sell new (energy efficient) appliances to household customers.	
↑	Sell appliances to business customers to stimulate demand during the day.	
↓	Replace existing appliances with ones that are more energy-efficient.	
→	Schedule commercial loads to match generation time.	
↓	Limit power consumption of customers.	
↑	Develop ancillary, energy-consuming businesses to create more demand.	
↑	Educate customers about the benefits of electricity, and technologies that increase productivity, stimulating demand.	
↑→↓	Custom tariffs/pricing to increase, shift, or reduce demand as required.	

Sell Appliances

Strategy	Impact	How?	Intervention
Sell household appliances to residential customers e.g. lights, radios, TVs, fans	Increases general demand on the mini-grid, but especially in the evening when residential customers consume more.	• Sell directly or partner with appliance distributors • Set up and sell appliances through a financing scheme with a third-party • Educate customers about the benefits of appliances, and provide clear information on how they can be used and purchased	
Sell productive-use appliances to business customers e.g. hair clippers, welding machine, power tools, milling/grinding machines, food processing	Increase in demand during business hours – usually during daytime.	• Survey businesses on mini-grid to understand value chains and activities that require powered machines • Research alternative, electrically-powered appliances for those activities • Offer appliances that speed up volume, create complimentary appliances and reduce operating costs • Sell directly or partner with appliance distributors • Educate customers about the benefits of appliances, and provide clear information on how they can be used and purchased	

Replace Existing Appliances

Strategy	Impact	How?	Intervention
Replace existing, inefficient appliances with ones that are more energy-efficient	Reduction in demand and total energy usage, especially at peak times (peak clipping). This reduces the strain on energy storage and secondary generation (e.g. diesel) at peak times.	• Survey the customer-base to determine existing appliances on the grid • Determine appliances that can be replaced to reduce demand at the right time and to the target level • Offer customers replacements to their existing appliances that are of higher quality • Educate customers about the need for efficient appliances on the grid	

Schedule commercial loads

Strategy	Impact	How?	Intervention

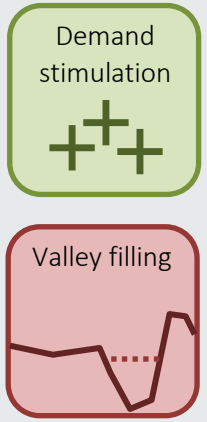
Schedule loads which can run at any time of the day, during times of high supply and low demand	Shifts demand to coincide with generation. Increase demand at times when there is surplus energy generated, and reduce demand at times when there is not enough.	• Identify loads which are not time-dependent (e.g. Irrigation pumps)
		• Enforce load scheduling by
		  • Creating incentives (e.g. Lower tariffs, Time of Use)
		  • Install time switches
			

Limit Power Consumption

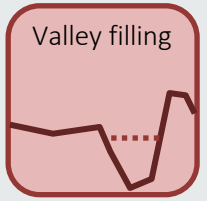
Strategy	Impact	How?	Intervention

Limit power consumption of individual customers, so that large appliances cannot be powered	Limits load that can be on mini-grid at a single point in time. This is especially required for the evening loads as this will strain the battery.	• Restrict the power for each customer using either
		  • Load Limiters
		  • Smart Meters
			

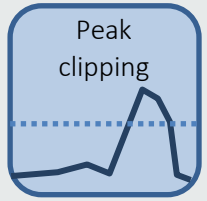
Develop Ancillary Business

Strategy	Impact	How?	Intervention
Developer owns and operates another business which consumes directly from the mini-grid	• Increased demand which can be timed to fill valleys in the day • Works as a flexible anchor load • Secondary source of income for the developer	• Perform an assessment of the business value chains especially the agro-value chains • Identify the current gaps in the value chain where electricity produced by the mini-grid can be an enabler • Design and procure appliances suited to the supply and demand • Obtain necessary permits • Community engagement to identify the best model for the ancillary business	

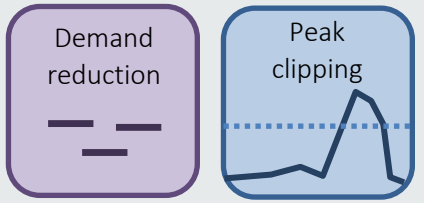
Customer Education

Strategy	Impact	How?	Intervention
Educate customers about the benefits of electricity and electrical appliances that have productive uses. This could be done in conjunction with other strategies, like providing appliances.	• Increase in demand • Increase awareness on using power responsibly by using efficient appliances • Increase day time load by supporting businesses	• Survey customers to assess their understanding and perception of electricity • Run an awareness session to educate customers • Set a customer helpline • Have a strong business incubation programme to support business growth	 

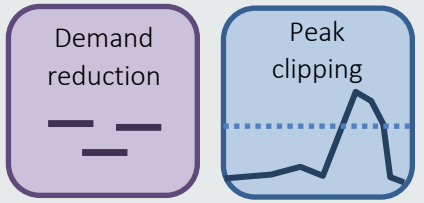
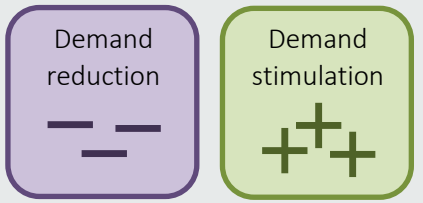
Tariffs (1)

Tariff Type	Description	Impact	Intervention
Consumption-based	Customer pays per unit of energy consumed ($/kWh)	Reduced consumption, as customer will be wary of paying more.	
Time of use	Defined peak times and off-peak times. Lower tariff during off-peak period.	Shift of demand away from peak time to off-peak.	
Capacity-based	Flat-rate subscription. Unlimited usage but with a cap on power consumption.	A set limit on individual and total power demand.	

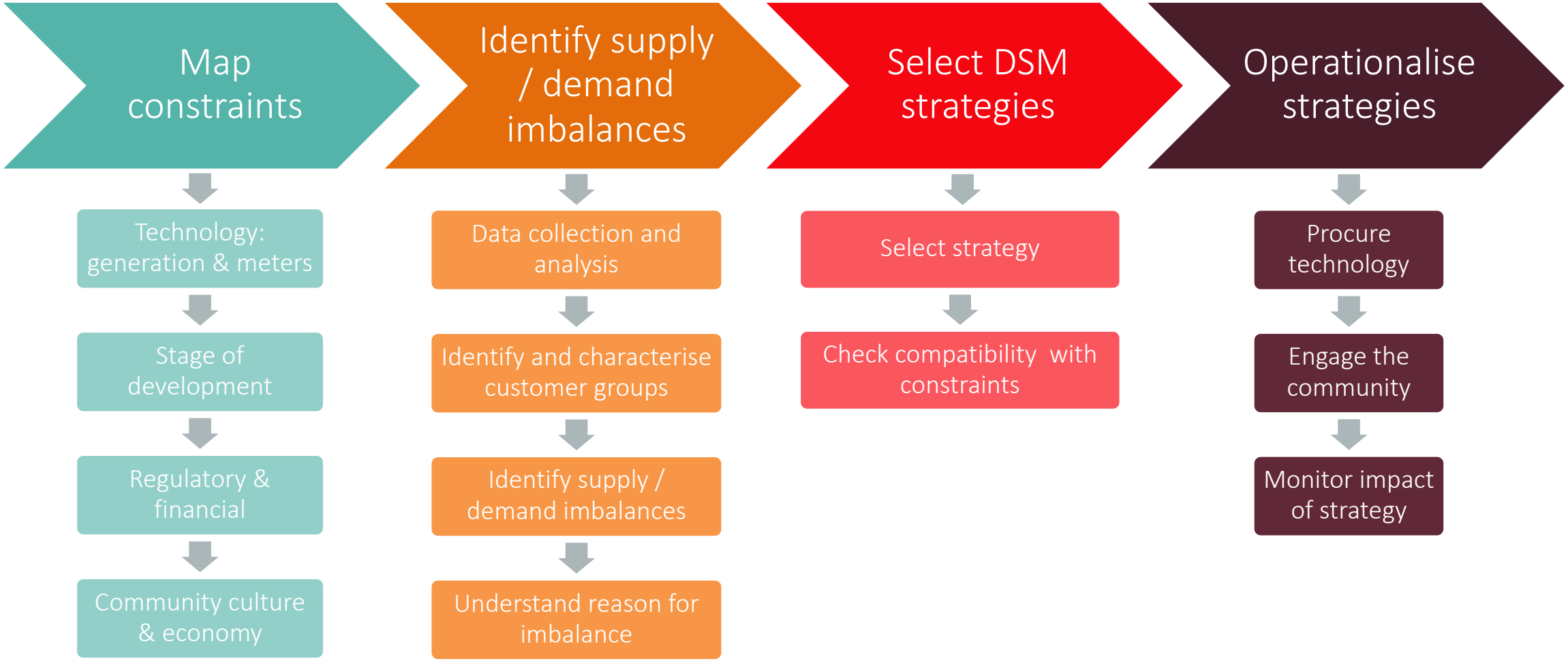
Tariffs (2)

Tariff Type	Description	Impact	Intervention
Block	Subscription-based. Customer pays for access to electricity for an amount of time per day – usually unscheduled. This is combined with a power & energy usage limit.	Reduced peak demands (power-limited), and reduced consumption overall (energy-limited).	
Energy use (progressive)	Pays per unit of energy. Price per unit increases as more energy is consumed.	Demand is reduced, as customers will be discouraged by higher tariff.	
Energy use (regressive)	Pays per unit of energy. Price per unit decreases as more energy is consumed.	Demand is increased, as customers will be encouraged to consume more by lower tariff.	

Tariffs (3)

Tariff Type	Description	Impact	Intervention
Per device	Customer pays flat fee: • Fee is determined from the amount of connected devices. • No metering required, tariff is pre-paid. • Need to enforce.	Reduced demand overall, as customers will be wary of connecting more devices. Limits peak power demand, as customers cannot connect more devices.	
Seasonal	Price defined by seasonal availability of the renewable energy source. Higher tariffs during low season, lower during high season.	Reduced overall demand in low-season. Increased overall demand in high-season.	
Energy as a service	The operator sells services rather than electricity. For example a customer can buy 4 hours of use of a lightbulb, or per hour of use for a TV. This requires technology to monitor / control which appliances are used, and for how long.	Very transparent pricing is understandable for customers and leads to energy conservation.	

Choosing DSM strategies: Process map



More information in slide notes.

DSM Constraints & Mitigation

Strategy	Constraint	Mitigation
Developing ancillary businesses	Identifying appropriate new business opportunities and managing a new revenue line	Personnel and capital: Requires different skills and experience, different regulatory compliance, local community support
Educating customers	On ground support is resource intensive and the impact of the strategy is lesser than others	Personnel: developing training material, on-the-ground trainers, intensive business support for potential high-consumers
Replacing existing appliances	A detailed assessment of the appliances to be replaced and the desired effect after replacing	Managing supplier relationship, sales personnel and monitoring replacements.
Selling new appliances (residential and business)	Setting-up and monitoring financing	Managing supplier relationship, sales personnel and monitoring assets.
Scheduling commercial loads	Identifying time-dependent loads and enforcing change	Hardware to record time of use and personnel to enforce scheduling
Limiting power consumption	Reducing demand on residential customers will have limited desired effect	Current limiters or smart meters
Tariffs	Tariffs too complex for customers to understand	Transparent community engagement to explain the different tariffs

Case Study: Rafiki Power – Sale of Appliances

Developer: Rafiki Power

Location: Tanzania, ~1,000 customers

Generation: Solar PV-battery hybrid

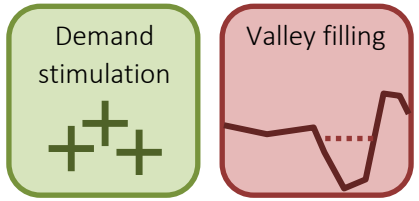
DSM strategy / technology:

1. Distributing and financing of appliances for households & businesses. 300+ appliances sold.
2. Customer education: 50+ business customers reached through workshops, and information material distributed to nearly all customers.
3. Smart meters integrated into mobile money platform. Data collection/analysis through the AMMP system,

Impact of strategy / technology: Selling efficient appliances and educating customers has increased overall demand by 20-30%, and spread it over more connections, without significantly increasing peak demand.

Productive-use appliances have increased consumption during day-time when electricity production is cheaper.

Data from smart meters has given Rafiki Power visibility over consumption on their mini-grids and helped them to design DSM solutions from what they observed.



One of Rafiki Power's solar mini-grids in Digodigo, northern Tanzania, where appliance sales take place.
(Source: Rafiki Power)

Case study: Jumeme – Ancillary Business

Developer: Jumeme

Location: Lake Victoria, Tanzania

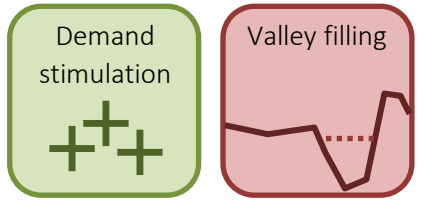
Generation: PV-diesel hybrid

Scenario: Low demand in the day.
Irrigation pumps used in early morning and evening to protect seeds.
Large fishing community in village which sells only to local markets.

DSM strategy / technology: **Ancillary business**: fish freezing and trading business (KeyMaker model, developed by Inensus).
Jumeme purchases tilapia from local fishermen at a set rate, stores them in freezers, then transports them to the capital city Dar es Salaam to sell in wholesale. An ice machine powered by the mini-grid is used to make ice for transporting the fish.

Impact of strategy / technology: Local fishermen have a secure customer to whom they can sell their fish at a fixed price.

The ancillary business has increased **overall demand**, especially during the day. It now consumes about 10% of the total electricity produced, and generates revenues that are the same, or greater than, the electricity sales made to all other customers on the mini-grid.



JUMEME's mini-grid facility on the shore of Lake Victoria. (Source: JUMEME)

Module Recap

- Productive use customers use energy to generate income and are important for the economic viability of mini-grids.
- Successful strategies to increase PU focus on the business needs of the customers, increasing productivity in existing value chains and targeted business support for entrepreneurs.
- End user financing is often necessary for customers to afford the upfront cost of PU appliances.
- Demand side management influences the electricity demand of customers to fit the generation profile of the energy source. It is generally cheaper to change demand than supply e.g new generation or battery storage
- DSM is used when there is an imbalance between electricity demand and supply e.g peak demand is too high, demand is at wrong time of day (e.g during evening rather than daytime when solar generation is high), overall demand or supply is too high
- There are many technical and commercial demand strategies for addressing these imbalances e.g introduction of energy efficient appliances, load scheduling, load limiting, time of use tariffs, and consumer education.

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