GREEN MINI-GRID
HELP DESK

Demand Side Management for Mini-grids

Energy 4 Impact & INENSUS
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ENERGY4IMPACT ACCELERATING ACCESS TO ENERGY

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Executive summary

Demand-side Management (DSM) is the process of actively influencing electricity demand on mini-grids so it matches electricity generation. This report provides a framework for mini-grid developers to select and implement DSM strategies.

DSM matters because it is usually cheaper to adjust the demand than the supply infrastructure (generation, battery storage). Supply/demand imbalances fall into 5 categories: peak demand higher than peak supply; peak supply higher than peak demand; demand peaks do not coincide with supply; overall demand higher than supply; and overall supply higher than demand. There are 5 respective interventions to manage these imbalances: **peak clipping**; **valley filling**; **load shifting**; **demand reduction** and **demand stimulation**.

These interventions take many forms, both push (e.g new technology and hardware) and pull (e.g customer incentives). Examples include selling electric appliances to different customer groups and providing associated financing; replacing inefficient appliances; scheduling commercial loads for certain times of day; limiting power consumption; mini-grid operators setting up ancillary businesses that consume electricity; customer education; and tariff incentives. The pros and cons of the different interventions are explained in detail.

The report describes a 4-stage process map for determining the best DSM strategy: Stage 1 involves mapping the constraints, including technical, regulatory, financial and community-based; Stage 2 is about identifying the supply/demand imbalances using hard data as evidence; Stage 3 involves selection of the DSM strategy based on the results of Stage 1 and 2; and Stage 4 is about operationalizing the strategy which includes technology procurement, community engagement and ongoing monitoring to check the strategy achieves the desired results.

While there is plenty of anecdotal evidence for the success of DSM in mini-grids, the industry lacks robust analysis to directly compare the impact and cost of different strategies. In order to quantify the impact of DSM strategies in different contexts, it will be important to gather data from a wide number of developers and develop a common framework for data collection and analysis.

Authors

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Energy 4 Impact is a UK-registered non-profit organization which seeks to reduce poverty through accelerated access to energy, providing technical, commercial and financing advice to off-grid energy businesses in Sub Saharan Africa, including over 100 mini-grid developers.

Energy 4 Impact provides support on the ground to these businesses in the form of pilots for new technologies and business models and mentorship services for micro-enterprises. Supported by a small head office in London, most of Energy 4 Impact's staff are based out of its offices in Kenya, Tanzania, Rwanda and Senegal.

Energy 4 Impact has operated in Africa for the past 12 years and delivers results. The NGO's efforts have supported the growth of 4700 businesses, resulting in 17 million people gaining better access to energy, 10000 jobs, and 12.8 million tonnes of CO_2 being abated. The capital raised by those businesses with our support has amounted to $135 million.

INENSUS is a mini-grid expert providing holistic technical, business and policy expertise based in West and East Africa. Its clients include private and public mini-grid project developers, international development organizations and financiers, and governments in the target countries.

INENSUS provides consulting and engineering services that cover all aspects related to solar-hybrid mini-grids for rural electrification. INENSUS has been in operation since 2005 and is headquartered in Goslar, Germany. The combination of consulting and engineering expertise makes INENSUS a unique "one-stop shop" for mini-grids and decentralized renewable energy systems.

Its expertise results from working as a mini-grid investor, developer and operator for more than 10 years in Senegal (through its joint venture ENERSA Energie Rurale Sahélienne S.A) and more than 5 years in Tanzania (through its joint venture JUMEME Rural Power Supply Limited).

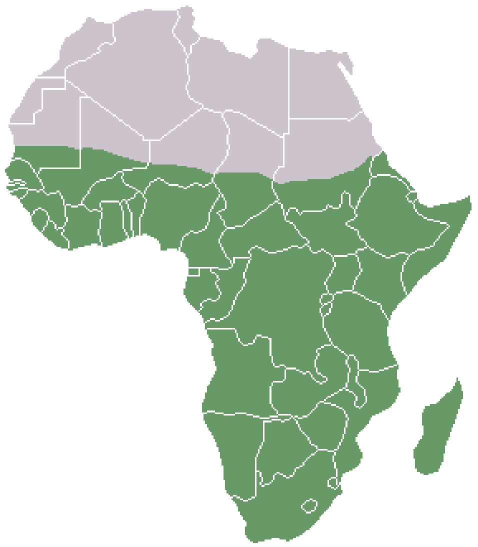
Background

Goal: Provide guidelines on developing and implementing demand-side management strategies for mini-grids.

Target audience: Mini-grid developers in Sub-Saharan Africa, particularly pure solar mini-grids and solar hybrids that use battery and diesel power as back-up.

Background: Report produced by Energy 4 Impact and Inensus (the Green Mini-Grid Help Desk) under the Green Mini-Grid Market Development Programme for the African Development Bank (AFDB) – Business Development Services and Policy Support Business Lines.

Methodology: Report is based on interviews with mini-grid developers, literature review and the experience of Energy 4 Impact and Inensus.



Outline & Contents

Click the links to jump to the relevant section of report.

This report will:

The report includes **5 case studies** of DSM strategies:

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**.

Supply versus demand

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 filled, and a poor return on investment

Interventions to achieve this balance:

1. Adjust the generation capacity to match demand.
2. Install energy storage which can supply electricity when demand exceeds supply and store electricity when demand is low
3. **Influence the demand to match the supply.**
   → This is **Demand-side Management.**

Why not adjust electricity supply?

It is **expensive**.

Increasing generation capacity, energy storage, e.g. more solar panels, diesel generators and batteries, and distribution infrastructure needs a large capital investment. Typical costs of a solar mini-grid are 2.9 USD/W [9] – including panels, batteries, inverter – or 0.2-0.25 USD/kWh [10] over the lifetime of the system. These costs are higher for smaller mini-grids.

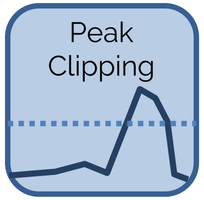
Diesel generators are flexible, but require significant fuel and high maintenance, which significantly increases operating costs. Typical lifetime costs of a diesel generator are 0.2-0.45 USD/kWh [10].

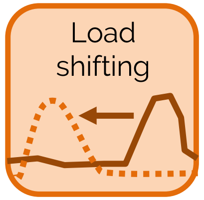
Extra power generation can be underutilised during low demand, which affects the profitability of the mini-grid. It is better to match demand to supply, so that utilisation is high at all times.

When can DSM be used?

5 scenarios with 5 interventions:

Scenario	Intervention
Peaks: Periods of high demand (peaks) which exceed the generation capacity.	Peak Clipping
Valleys: Periods of low demand (valleys) in which storage capacity is full and electricity generated is wasted.	Valley filling
Offset demand: Periods of peak demand which do not coincide with periods of peak generation.	Load shifting
Excess demand: Overall electricity demand is higher than electricity supply.	Demand reduction
Excess supply: Overall electricity supply is higher than electricity demand.	Demand stimulation





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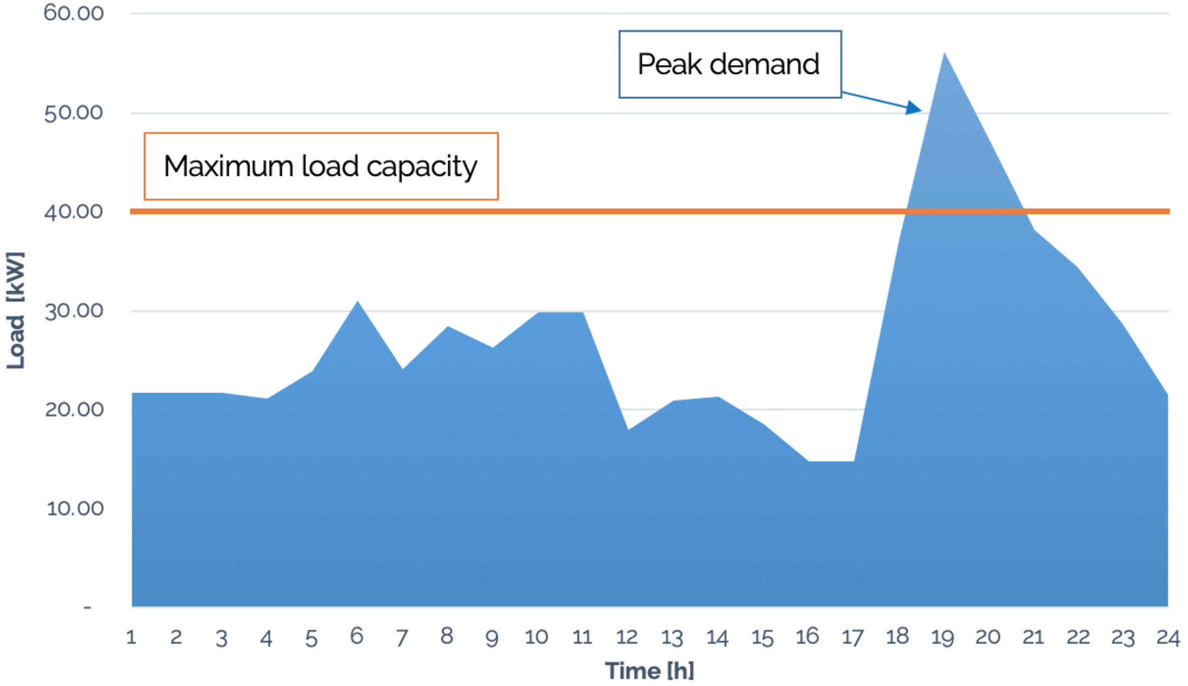
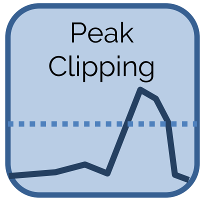
Scenario 1: Peaks





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.
Customers connect more appliances to mini-grid over time.

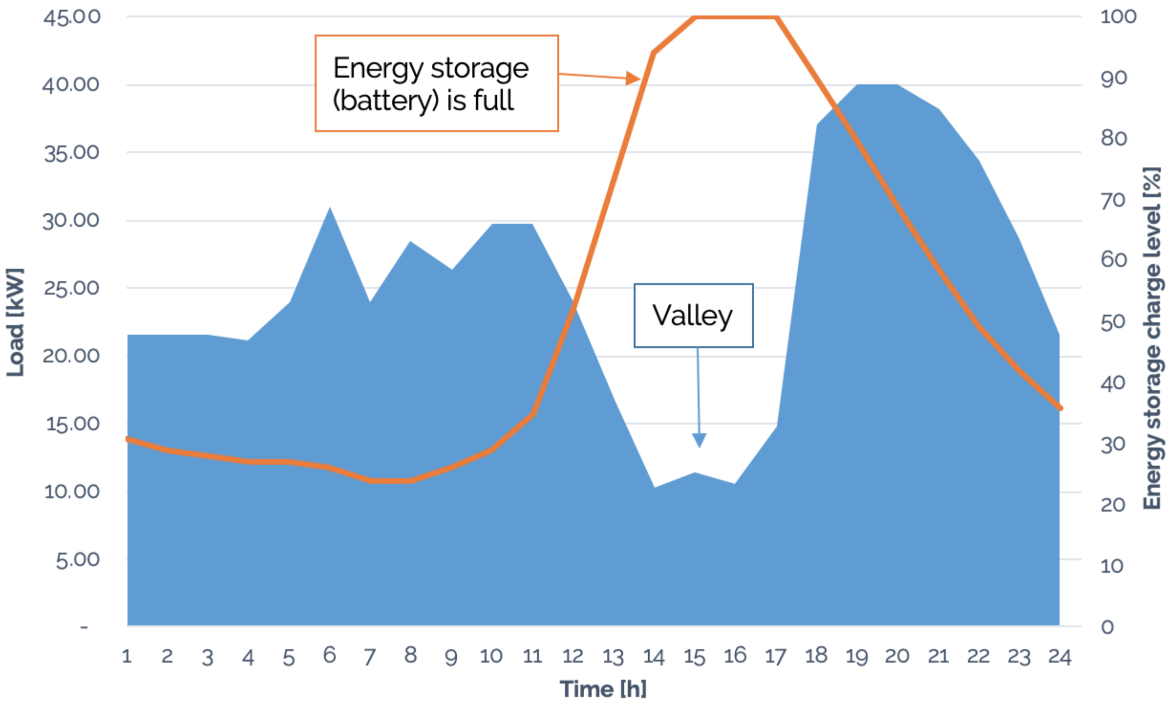
Impact

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

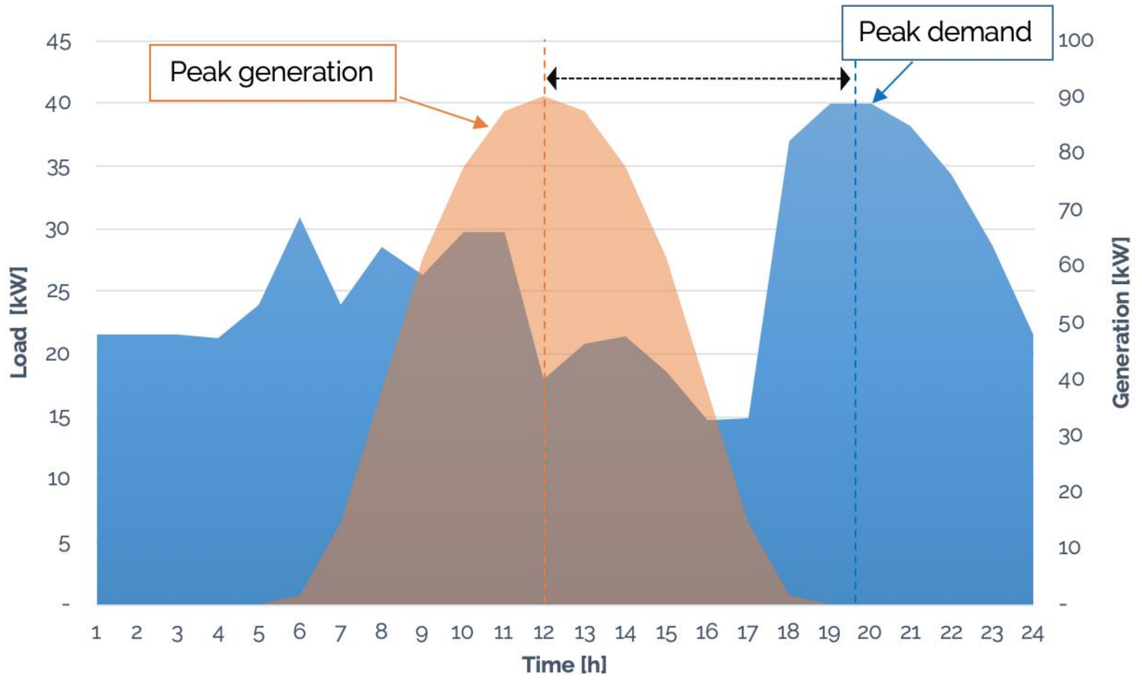
Energy is generated, but not stored or used.

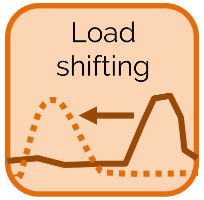
Lost revenue for the mini-grid.

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 evenings.

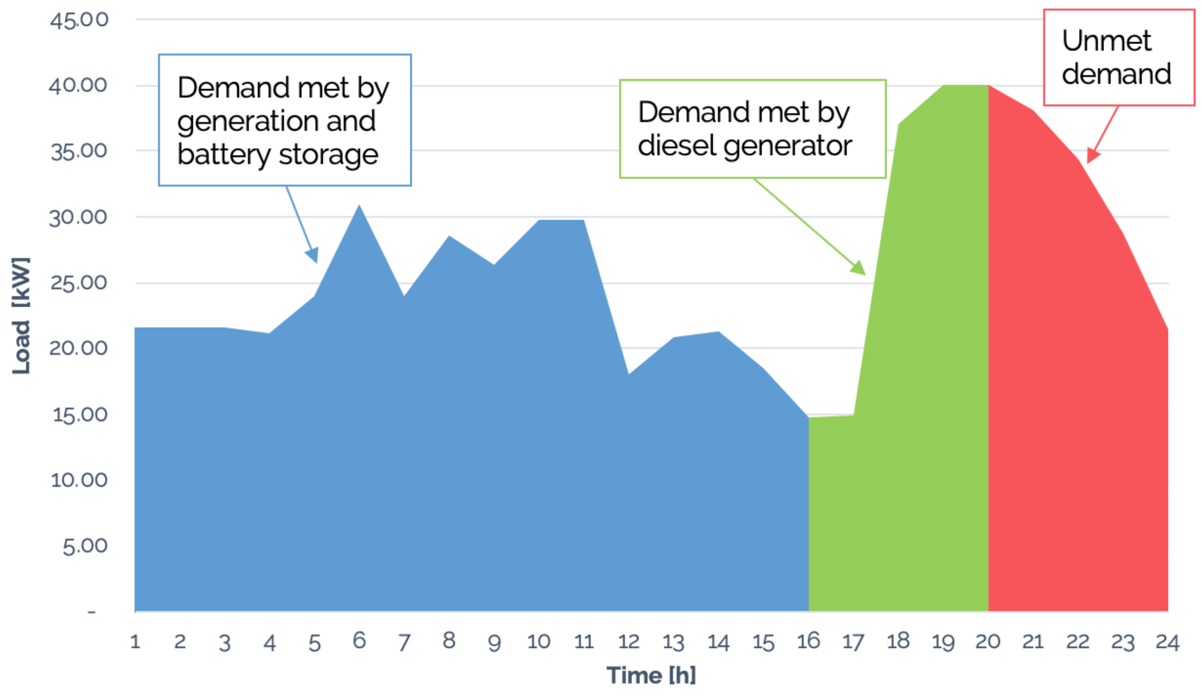
Impact

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.

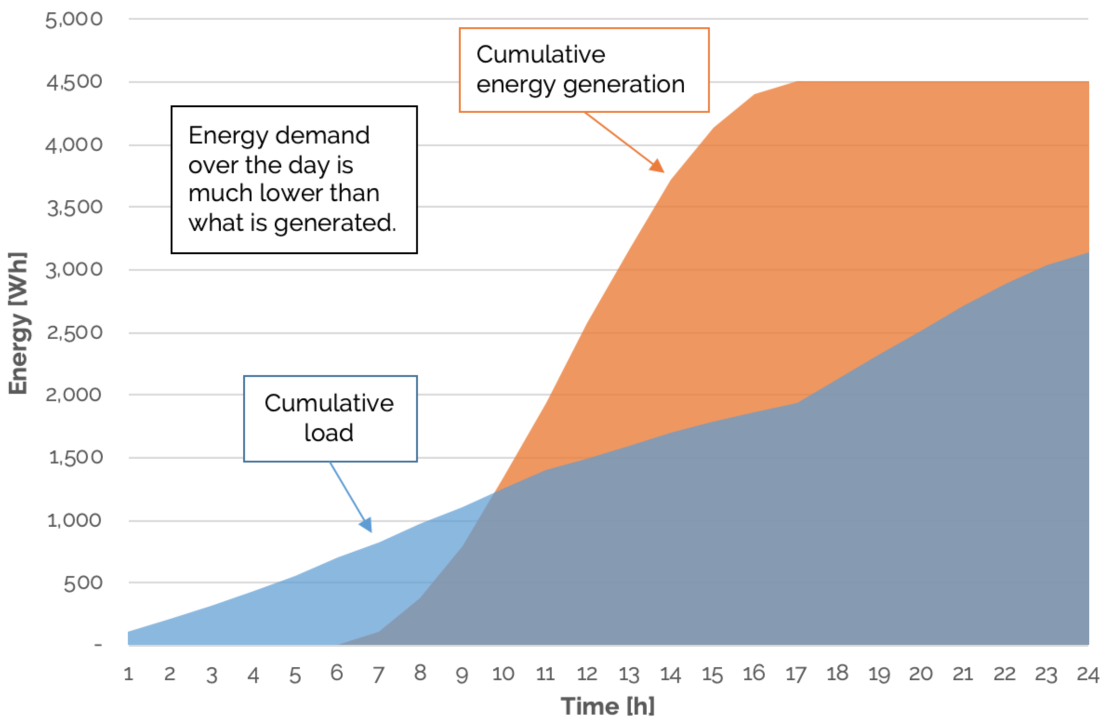
Impact

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



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

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.

DSM strategies

Peak Clipping | Valley filling | Load shifting | Demand reduction | Demand stimulation

8 main strategies for DSM have been identified in this study:

Effect on demand:
↓ reduce, → shift, ↑ stimulate

	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.	

1) Sell appliances to residential customers

Demand stimulation

Intervention

Sell household appliances to residential customers e.g lights, radios, TVs, fans

Impact

Increases general demand on the mini-grid, but especially in the evening when residential customers consume more. From data aggregated over programmes in Sub-Saharan Africa, we have found that this strategy can increase consumption by up to 100%, compared to customers who did not receive appliances.

Potential second revenue stream for developers if selling appliances directly.

How?

- Sell directly or partner with appliance distributors. Supplier must be able to support repairs and warranty claims.
- Set up and sell appliances through a financing scheme with a third-party (e.g. micro-finance institution).
  - Appliances typically sold with a margin of 5-10% inclusive of logistic and other costs (e.g. overheads).
- Educate customers about the benefits of appliances, and provide clear information on how they can be used and purchased.

2) Sell appliances to commercial customers (1)

Valley filling

Intervention

Sell productive-use appliances to business customers e.g hair clippers, welding machine, power tools, milling/grinding machines, food processing.

Impact

Increase in demand during business hours – usually during daytime.

Useful for **valley filling**, especially for solar mini-grids during day time when generation peaks and demand is low.

Potential second revenue stream for developers, if selling appliances directly.

Cassava grater and a dewatering machine, Tanzania.
Source: iita.org

2) Sell appliances to commercial customers (2)

How?

- Sell directly, or partner with appliance distributors. Supplier must be able to support repairs and warranty claims. 5-10% margins are typical..
- Survey businesses on mini-grid to understand value chains and activities that require powered machines.
- Research alternative, electrically-powered appliances for those activities. *This research can identify appliances that the businesses would not find themselves.*
- Offer appliances that:
  1. Speed up / increase volume in existing activities.
     Example: a tailor buys a sewing machine and can make many more products in a day.
  2. Create complimentary activities that capture more of the value chain.
     Example: a business that grows and sells maize buys a milling machine to start producing maize flour.
  3. Reduce operating costs as compared to previous activity.
     Example: an electric grain mill may have lower operating costs, compared to an existing diesel mill.
- Set up and sell appliances through a financing scheme with a third-party (e.g. micro-finance institution).
- Educate customers about the benefits of appliances, and provide clear information on how they can purchase.

Note: Financing appliances

Why offer financing?

Customers often require financing because they cannot afford the up front cost of appliances.

Businesses can generate income from the appliance to help pay back a loan.

Financing facts/tips:

- How to select a finance partner:
  - Locally-based or at least have local branch network
  - Have track record lending to local entrepreneurs
  - Examples: cooperatives (e.g. SACCOs), micro-finance institutions, local banks
- Typical loan amounts:
  - Up to 500USD for household appliances
  - Can be much more for productive use appliances e.g. 2500 USD for a grain mill
- Payback periods vary from 6 to 24 months and deposits can be between 15-30%.
- Local interest rates can range from 20-40%.
- Consider bundling loan repayments with energy payments to reduce chance of defaults.

Case study 1: **Rafiki Power – sell new appliances**

Valley filling

Demand stimulation

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 materials 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)

3) Replace existing appliances (1)

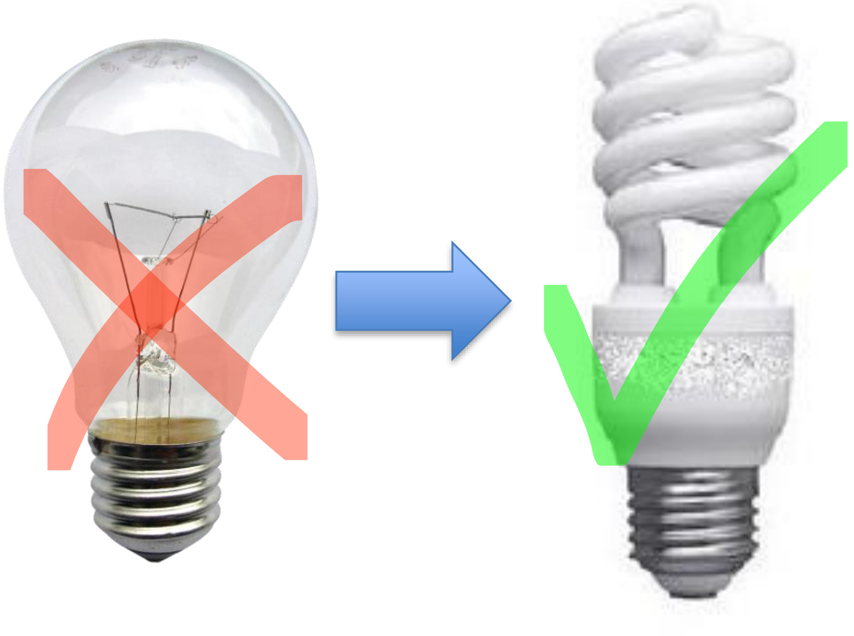
Intervention

Replace existing, inefficient appliances with ones that are more energy-efficient.

Impact

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.

Example: Introduction of energy efficient appliances at a healthcare facility in Mali **reduced consumption by 70%**, from **5kWh/day** to **1.5kWh/day**. [3]



Source: CC BY-SA

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3) Replace existing appliances (2)

How?

- Survey the customer-base to determine existing appliances on the grid. Check:
    - Power factor and number of existing appliances.
    - Time of day that appliances are used.
- 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.
    - This can be done in tandem with financing schemes to sell new appliances to customers.
- **New customers:** Provide efficient appliances (e.g. light bulbs) with connection to the mini-grid to ensure customers do not buy their own inefficient appliances.
- Educate customers about the need for efficient appliances on the grid, so that they continue to buy efficient appliances in future.

3) Replace existing appliances (3)

Peak Clipping

Demand reduction

Other considerations

- Customers might want to continue using their old appliances, instead of replacing them, which could have the opposite of the intended effect, and increase demand.
  - Ensure replaced appliances are not used anymore.
  - Educate customers about the reasons why the appliances need to be replaced.
- Replacing appliances can be done in tandem with selling new appliances to customers, using the same appliance suppliers.
- **Warning:** if demand reduction is too significant, the mini-grid can become underutilised.
  - It is important to carry out thorough surveys, and analysis, to understand which appliances should be replaced to achieve the desired impact on demand and operational performance.

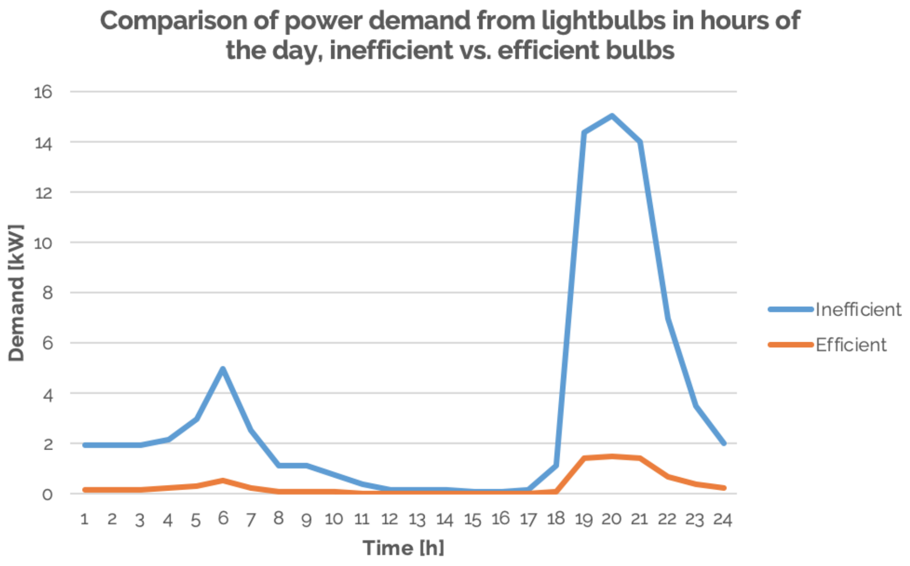
Costs

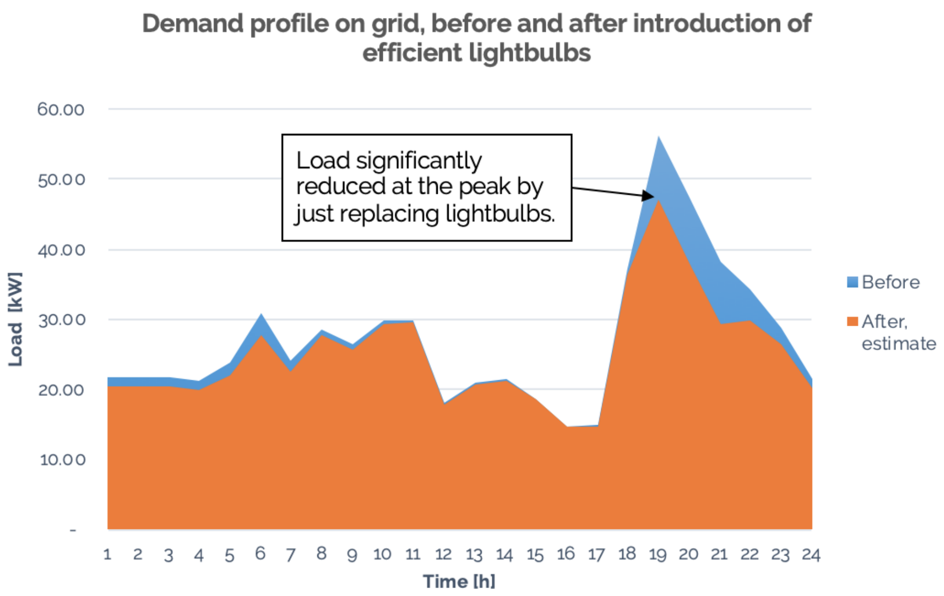
- Surveys: 2-10 USD per survey, depending on the length, and logistical costs (smart phones, transport, accommodation).
- Personnel costs to manage supplier relationships, appliance distribution and loan repayments.

3) Replace existing appliances (4)

Example:

- Your survey finds the number of light bulbs used on the grid, their power consumption and when they are used.
- You estimate the power required for these **inefficient** lightbulbs throughout the day, and that the average light bulb is **50W**.
- You estimate you can replace **70%** of light bulbs in the village with **efficient 5W** LED light bulbs. The new demand profile shows a significant reduction in demand – especially at the peak in the early evening.





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Case study 2: **SSREL – replace existing appliances**

Demand reduction

Demand stimulation

Developer: Super Star Renewable Energy Ltd. (SSREL)

Location: Bangladesh

Generation: 242kW PV-diesel hybrid

Scenario: Having achieved the target of 1,000 connections, customer demand was not enough to be financially sustainable.

DSM strategy / technology: SSREL sold energy efficient appliances to customers, through a government financing partner.

Impact of strategy / technology: The impact was **mixed**.

Customers who bought appliances were either replacing old, existing appliance or buying something completely new.

Customers buying new appliances **increased the overall demand** on the grid, while customers replacing old appliances **reduced the overall demand**.

This case study highlights the importance of surveying customers to understand existing appliances, and customers' willingness to replace existing / purchase new ones.

Solar array from SSREL's 242kW mini-grid in Bangladesh.
(Source: SSREL)

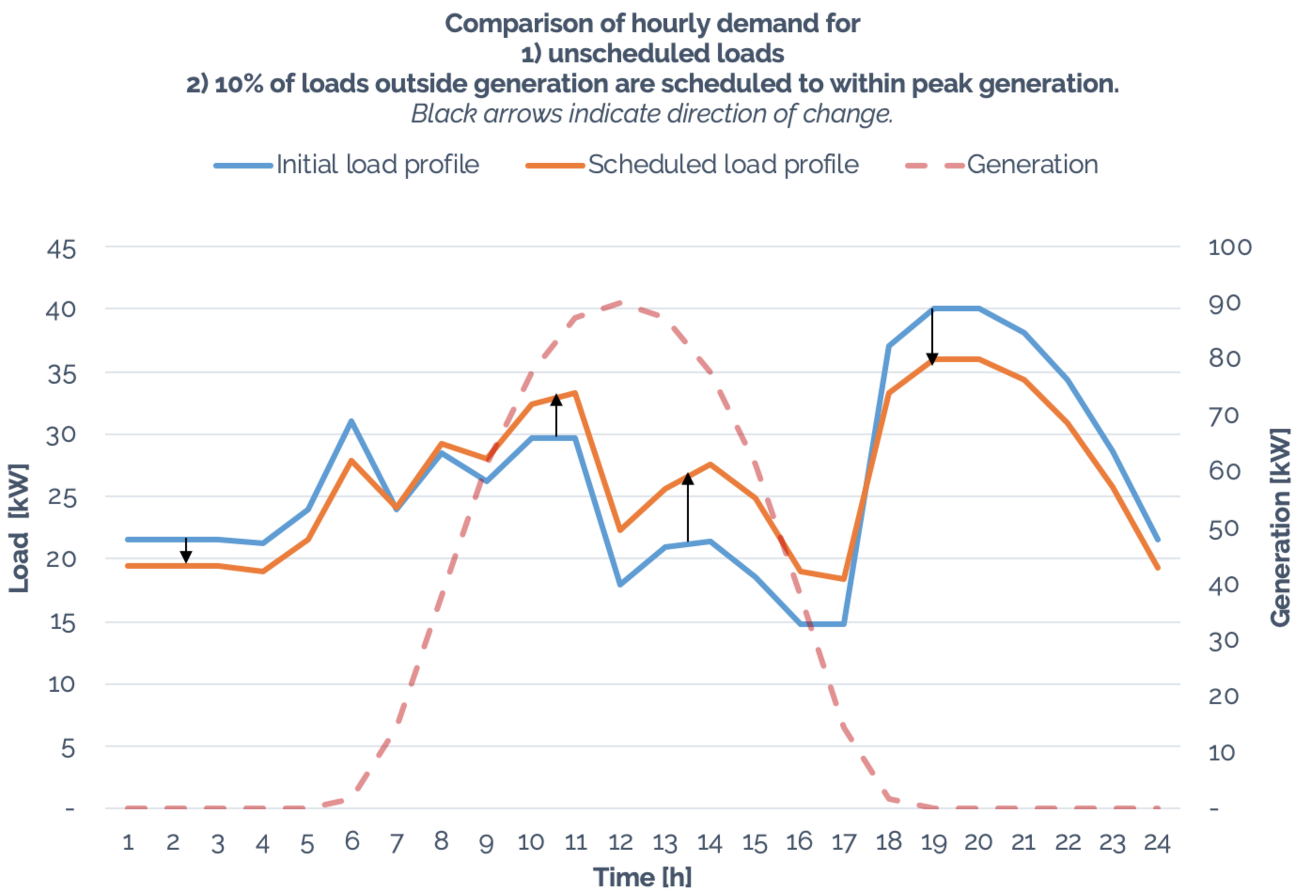
4) Schedule commercial loads (1)

Intervention

Schedule loads which can run at any time of the day, during times of high supply and low demand.

Impact

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.



4) Schedule commercial loads (2)

Load shifting

How?

- Identify loads which are not time-dependent.
  - Domestic and irrigation water pumps can be used at any time of day to pump water up to a water tank.
  - Usage of grain milling machines is not tied to a particular time of day.
- Enforce load scheduling:
  1. Create **incentives** eg lower tariffs for the customer to use loads at specified times. May need to allocate some management time to ensure compliance depending on metering solution used.
  2. Install **time switches** (hardware which allows the load to only be powered at certain times)
     - Hands-off, technical solution, but capital costs are higher
     - Approximate cost: 10-50 USD per unit

Off-grid grain mill in Tanzania
(Source: Energy 4 Impact)

5) Limit power consumption (1)

Intervention

Limit power consumption of individual customers, so that large appliances cannot be powered..

Impact

Limits load that can be on mini-grid at a single point in time (**peak clipping**).

- Highest demand peak is often in the early evening due to many small household loads., These will not usually be restricted and so this strategy might not be effective to reduce household demand.

How?

- Restrict the power for each customer using either:
  1. **Current/power limiters** (also known as load limiters).
     - Stand-alone devices that can limit load.
     - **Distributed Intelligent Load Controllers** (DILCs) are an advanced type of current limiter. They are controlled centrally to optimise the grid by connecting/shedding loads depending on available energy.
  2. **Smart meters** with in-built functionality to set limits on loads.
     - Main advantage of smart meters is the amount of data that can be collected. Much of this data is vital to diagnose the need for DSM strategies and evaluate their impact.

5) Limit power consumption (2)

Current limiters versus smart meters

	Advantages	Limitations
Current limiter	• Can limit power for customers. • Ideal for lifeline customers (i.e. lower income customers) with very low peak demand. • Can set tariff based on current limit rather than consumption. • Less expensive: ~10USD per unit. • Isolate the grid from households in cases of short circuits.	• Vulnerable to tampering. • Limited or no data collection.
Smart meter	• Inbuilt current limiter. • Majority of data needed for DSM decision-making is recorded. • Easy to implement tariff structures. • Remote assistance and close-to-real-time data.	• More expensive: 40-60USD per unit, with ~1USD/month service and subscription per meter. • Upfront and on-going subscription for service. • Relies on communication infrastructure (e.g. mobile data) to send data.

6) Develop ancillary businesses (1)

Demand stimulation

Valley filling

Intervention

Developer starts and operates another business which consumes directly from the mini-grid. Common examples of such businesses:

- Water pumping – especially useful for **valley filling** during the day.
- Processing of locally produced agricultural /aquacultural / livestock products e.g. freezing fish or meat, milling, grinding, fruit pressing, etc.

The business should expand upon, or create new value chains in the village, and not directly compete with existing businesses because this could cause dissatisfaction among local population.

Impact

Increased demand which can be timed to **fill valleys** in the day.

Secondary source of income for the developer.

6) Develop ancillary businesses (2)

Demand stimulation

Valley filling

How?

- Perform assessment of value chains in villages to identify position of a potential ancillary business. Consider:
    - Products/crops that are produced in village, but are transported elsewhere for processing.
      Example: grains grown in the village, but transported elsewhere for milling.
    - Products that are brought into the village because they cannot be made there.
      Example: Welded products that can be made in the community.
    - Available technologies that can compliment value chains in the village.
      Example: ice making for fish/meat storage.
- Obtain necessary permit/licence, and approval from community administrator for the business.

Case study 3: **JUMEME – ancillary business**

Demand stimulation

Valley filling

Developer: JUMEME

Location: Lake Victoria, Tanzania (same project as Case Study 5)

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 Dar es Salaam to sell wholesale. An icemaker 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)

7) Customer education (1)

Demand stimulation

Valley filling

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.

Impact

Increase in general demand, as more customers become aware of electricity and connect.

Also, as businesses adopt more appliances, **day-time demand may increase**.

Note: this is not the same as selling appliances directly to customers, it is providing education and advice.

Community meeting in Ghana
(Source: Energy 4 Impact)

7) Customer education (2)

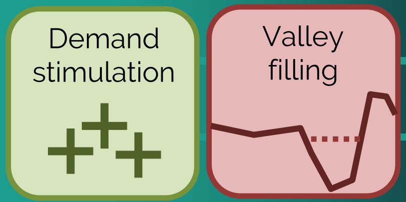
Demand stimulation

Valley filling

How?

1. Survey customers to assess their understanding and perception of electricity and find out where there are gaps in their knowledge.
2. Run **information sessions** to educate customers about:
   - Benefits of electricity at home
   - How to use it eg types of domestic appliances available
   - Productive use appliances available for their business and the possible impact
     - *Example:* advise a miller to replace their diesel mill with an electric hammer mill rather than just buying an electric motor to replace the diesel one. Higher productivity and efficiency usually outweighs the extra cost of an electric hammer mill.
3. Set up **customer helpline** where people can ask questions about the existing service, their consumption and tariff, and how to make the most out of the mini-grid service.
4. Provide business support to people who are setting up businesses – especially those who could become larger consumers.

7) Customer education (3)



Costs

On-the-ground support and education is expensive and resource intensive (travelling & personnel).

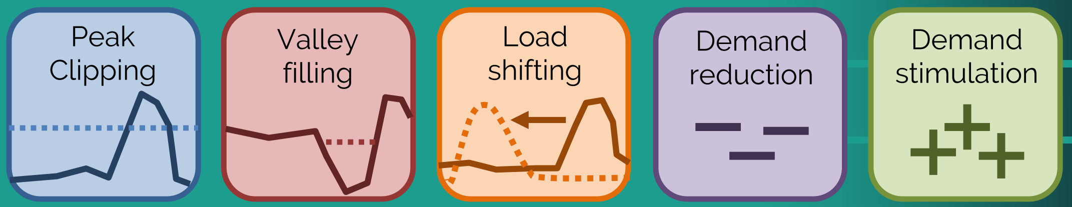
We recommend intensive education of all customers at the start of mini-grid operations.

Consider a more "light-touch" approach once the grid is more established e.g. remote support via customer helpline.

Hands-on coaching support can be reserved for only potential and existing high-consumption business customers to develop, and fully utilise the the grid.

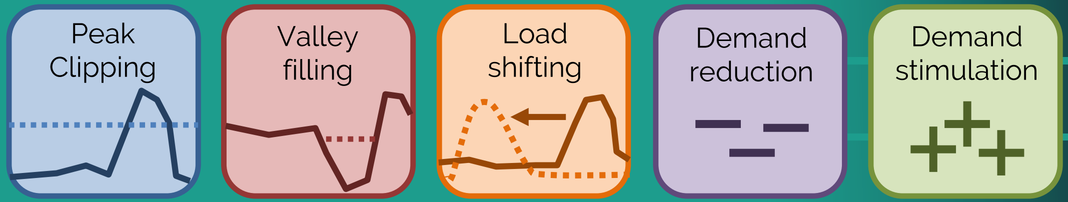
Carpentry workshop: an example of a business which could become a high-consumer after receiving business development support.
(Source: Energy 4 Impact)

8) Custom tariffs: **Types (1)**



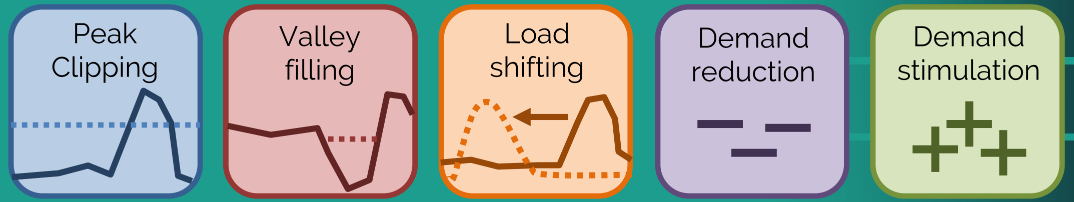
Tariff type	Description	Impact	Intervention
Consumption-based	Customer pays per unit of energy consumed.	**Reduced** consumption, as customer will be wary of paying more.	Demand reduction
Time of use	Defined peak and off-peak times. Lower tariff during off-peak period.	**Shift of demand** away from peak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

8) Custom tariffs: **Types (2)**



Tariff type	Description	Impact	Use for
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.	Demand reduction
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.	Demand stimulation
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.	Demand reduction Peak Clipping

8) Custom tariffs: **Types (3)**



Tariff type	Description	Impact	Use for
Seasonal	Price defined by seasonal availability of the renewable energy source. Higher tariffs during season of low availability, lower during season of high availability.	**Reduced** overall demand in low-season. **Increased** overall demand in high-season. Efficient usage of grid to match availability of the energy source.	Demand reduction, Demand stimulation
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. Tariff can be used in cases to circumvent laws where only the national utility can sell electricity.	Very transparent pricing is understandable for customers and leads to **energy conservation**.	Demand reduction

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8) Custom tariffs: **Combining tariffs**

Tariffs can be combined in various ways:

1. **Assign different tariffs to different customer groups**, to adjust demand as desired for that group.

   Example:

   - *Business customers*: time-of-use tariff to stimulate daytime demand.
   - *Residential customers*: block tariff, with power limit capping the peak evening demand.

2. **Combine more than one tariff** for a single customer group to achieve multiple effects.

   Examples:

   - *Block tariff*: commonly used - usage sold by time, with a power and energy limit.
   - Add a power-limit to any tariff is common, especially when the target is to decrease peak demand.
   - Add a seasonal aspect to any tariff in locations where the energy source availability is seasonal.

3. **Add a fixed-cost component** to ensure minimum revenue and demand.

   - Sell cheaper energy in this fixed cost bundle to encourage more consumption and stimulate demand, works especially well for businesses.

Case study 4: **ENERSA - Block tariffs**

Demand reduction

Peak Clipping

Developer: ENERSA

Location: Senegal

Generation: PV-battery hybrid

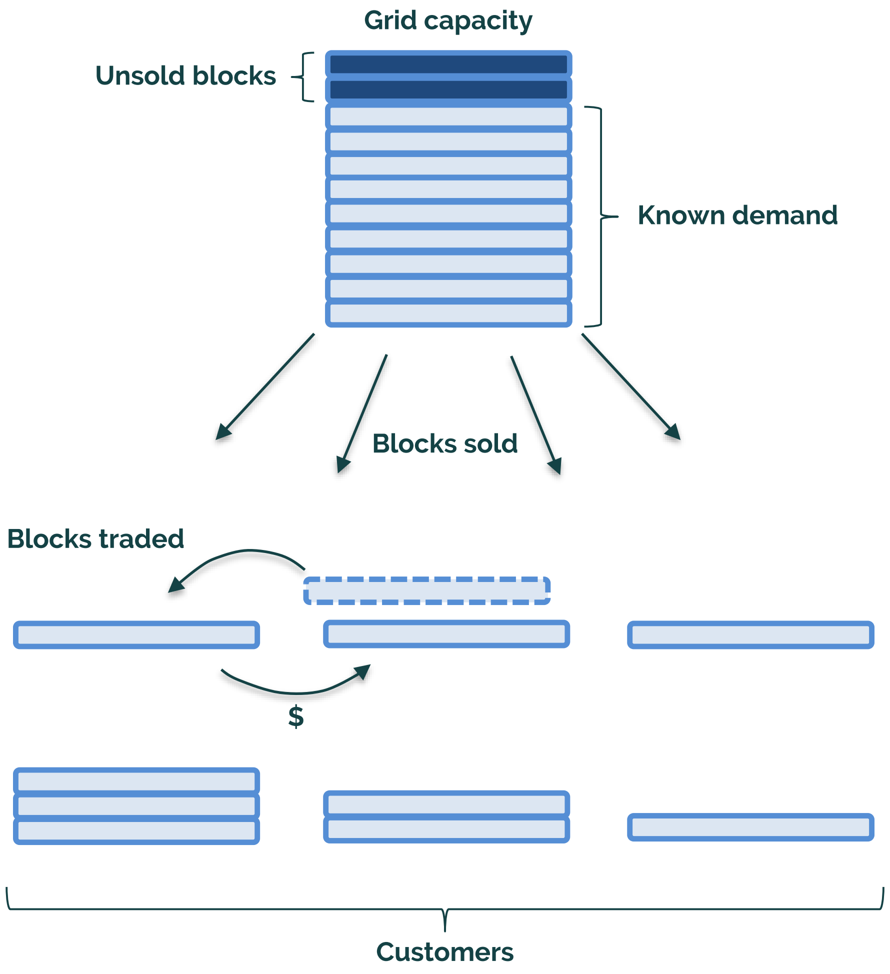
DSM strategy / technology: Block tariffs:

1. Energy sold in time 'blocks', with power & energy limits.
2. Typical block: 4 hrs per day, up to 50W power, and up to a limit of energy (kWh) usage per week.
3. Customers buy a subscription of blocks that cover the next 6 months. They can only change the subscription at the end of the 6 month period.
4. Blocks can be traded between customers on a third-party platform.
5. Smart meters used to implement the time/power/energy limits.

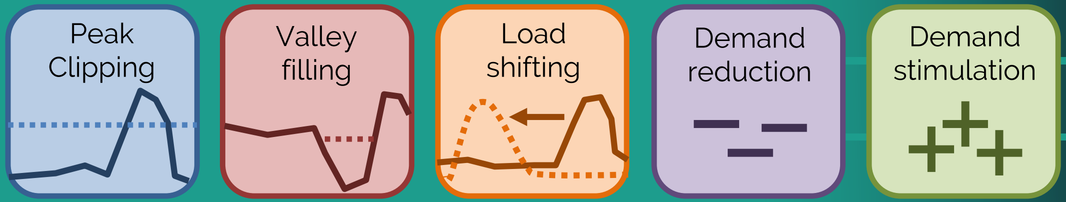
Impact of strategy / technology: Power-limited and energy-limited blocks **limit peak and overall demands**.

Forecasting: selling blocks in advance gives ENERSA a good idea of future demand, and what capacity they will need to provide. It also allows customers to plan and budget their energy consumption.

Trading blocks means customers still have ability to adjust their consumption, if their is demand is more or less, than anticipated.



8) Custom tariffs: **Payment Models**



It is important to define *how* customers pay for their electricity.

Pre- or Post-pay:

- Select a model that is easily enforceable. Post-pay models can lead to payment defaults but, with pre-pay, customers might be put off by up-front payments.
  - Assess customer's income stability. Is there a single-earner in the household? Will they be able to reliably pay for larger, periodic bills?
  - National grid operators (e.g. Kenya & South Africa) are phasing out post-pay due to high default rates.

Effects of seasonality:

- Pre-sell electricity to seasonal customers during time of high income (e.g. harvest time), so that they are able to consume during low-season.
- Provide discounts during low-season to encourage utilisation.

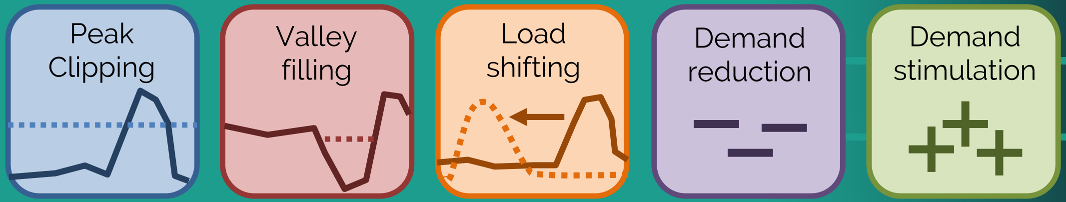
Ensuring bills are paid:

- Use technology to provide clear/alternative methods of payment (e.g. smart meters with mobile-money).

and / or

- Have permanent, on-ground representative in village to follow up with customers with bills in arrears.

8) Custom tariffs: **Lessons**



When setting up tariffs for DSM, be aware that:

- Complicated tariffs can confuse customers leading to dissatisfaction and lower consumption.
  - Solution: Keep tariffs **transparent** and **easy to understand**.
- Differences in tariff between customer groups may be perceived as unfair by customers if they do not understand the reasons for the difference.
  - Solution: Provide **clarity** and **justification** for different tariffs.
- Post-pay models that require a large payment at the end of the tariff period, e.g. block tariffs, can be ineffective in communities with unreliable income, or only a single earner in the household.
  - Solution: Consider **ability to pay** when selecting tariff and payment model.

Case study 5: **JUMEME – Tariffs & pricing**

Developer: JUMEME

Location: Lake Victoria, Tanzania (same project as Case Study 3)

Generation: PV-diesel hybrid

Scenario: Large peak demand in the early evening, when farmers return home from the fields. Low demand in the day.
Irrigation pumps used to be used in early morning and evening to protect seeds.
Large fishing community in the town who sell only to local markets.

DSM strategy / technology: Attempt to **shift commercial demand** away from the evening, and **stimulate demand in the day**, when energy is cheapest to produce.
Time of use tariff: cheaper rates during the day.
Tariff discounts: partnership with drinking-water business. Water pumps were switched on automatically when there was excess supply, and lower-rate tariffs given to the business for this energy usage.

Impact of strategy / technology: Time of use tariff **'nudged' farmers to use irrigation systems in the day** while there is cheaper energy, reducing evening demand.

Productive use partner **filled the gaps in electricity demand** during the day, and increased demand.

Irrigation water pumping used during day after time of use tariff.introduced
(Source: JUMEME)

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Strategies: Benefits, challenges & required resources (1)

Strategies sorted by required resources (highest first)

Strategy	Main benefit / driver	Main challenge / pitfall	Required resources
Developing ancillary business	Demand can be encouraged to fall during valleys in existing consumption. Extra revenues for developer.	• Identifying new business model, with technology that can be used when demand is low.	• Personnel and capital: managing a separate business to the mini-grid. Requires different skills and experience, different regulatory compliance, local community support
Educating customers	Stimulate overall demand, as customers connect more appliances. Support growing businesses to become high-consumers in the day.	• On-the-ground support and education is resource intensive. • Education is necessary to improve general understanding of service, but its effect on demand is not as significant as other strategies.	• Personnel: developing training material, on-the-ground trainers, intensive business support for potential high-consumers.
Replace existing appliances	Reduce overall consumption.	• Assessment of how many, and which, appliances to replace to have the desired effect on demand.	• Extensive survey of community (~2 USD per survey) • Personnel: managing supplier relationship, product sales, and repayments.

Strategies: Benefits, challenges & required resources (2)

Strategies sorted by required resources (highest first)

Strategy	Main benefit / driver	Main challenge / pitfall	Required resources
Selling new appliances (residential)	Increased consumption, usually more in the evening.	• Setting up & monitoring financing. • Increasing evening demand too much.	• Personnel: managing supplier relationship, product sales, and repayments. • Working capital
Selling new appliances (business)	Increased consumption, usually during the day.	• Setting up & monitoring financing. • Finding relevant PU appliances for businesses in community.	• Personnel: managing supplier relationship, product sales, and repayments. • Working capital
Scheduling commercial loads	Ability to set demand so that it occurs during times of higher generation.	• Identifying loads that are time-independent. • Enforcement of scheduling.	• Contract: Personnel to enforce / manage scheduling • Hardware: Time switches ~ 10-50USD per unit
Limiting power consumption	Limits demand that can be on the grid at one time.	• Only reduces demand on a single connection. High demand from many low-power consumers will be unaffected by this measure.	• Current limiters or smart meters

Tariffs: Benefits, challenges & required resources (1)

Tariffs sorted by required resources (highest first)

Tariff	Main benefit / driver	Main challenge / pitfall	Required resources
Energy as a service	Tariffs are easy to calculate, and easily understood by users.	Monitoring / controlling which appliances are used, and for how long.	• Hardware or personnel to ensure customers are only using what they pay for.
Per device	Discourages more appliances being connected per household.	Making sure the customer has only connected the appliances they have paid for.	• Interviewing households to determine number of connected appliances, and tariff to pay.
Block	Easy forecasting of demand - as customers subscribe to blocks in advance.	Understanding ability to pay: customers must have income or savings to be able to pay for large blocks.	• Smart meters (to apply power, energy and time limits) • Trading platform to allow blocks to be traded
Time of use	Encourages consumption during times of low demand and high generation times.	Customers may not be able to consume during low-demand period due to external factors e.g. farmers working in fields during day.	• Smart meters (to apply tariff for different times of the day)

Tariffs: Benefits, challenges & required resources (2)

Tariffs sorted by required resources (highest first)

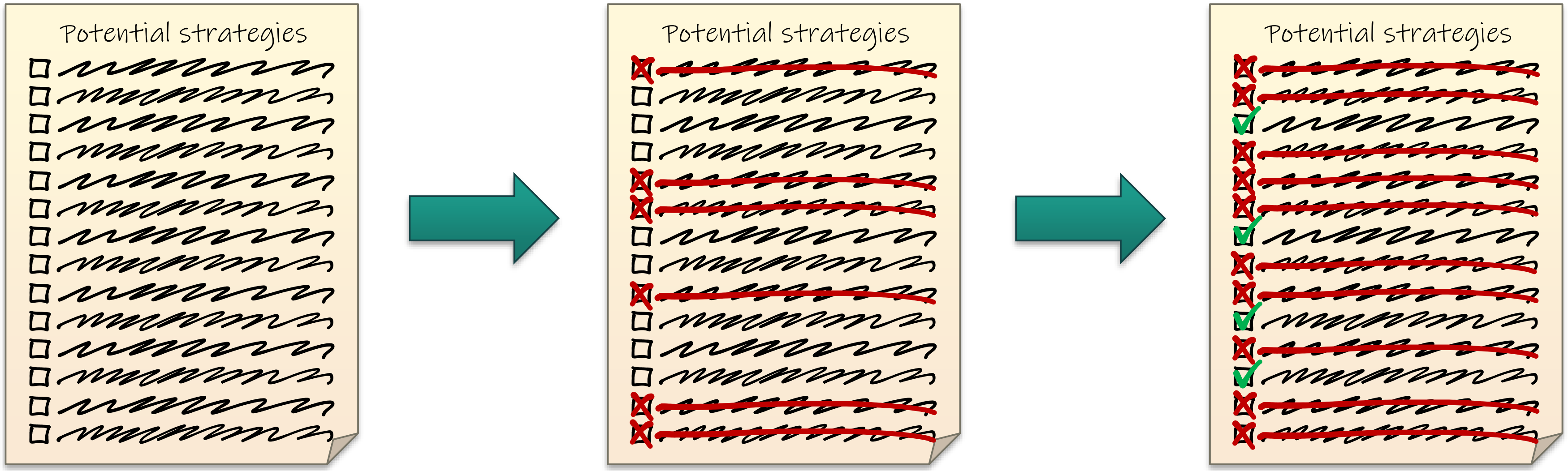
Tariff	Main benefit / driver	Main challenge / pitfall	Required resources
Energy use (progressive)	Discourages high energy usage.	n/a	• Smart meters (application of tariff)
Energy use (regressive)	Encourages high energy usage.	n/a	• Smart meters (application of tariff)
Simple consumption-based	Simple. Discourages customers from consuming more energy.	n/a	• Energy metering (could be a smart meter)
Simple capacity-based	Limits power consumption of individual users and therefore the the whole grid.	Tariff ineffective in reducing peaks due to many small loads below power limit.	• Current limiters or smart meters
Seasonal	Drives demand to follow availability of the energy source.	n/a	• None - applied to exiting metering method.

Choosing DSM strategies: **Filtering**

There are many possible strategies for DSM.

Choosing which to implement is a process of **ruling out potential options**, because of constraints on the developer, until viable strategies are found. *(This process of filtering is described in the next slides.)*

At each stage of filtering, it will be found that **some strategies do not work for the particular problem / context / available resources**, and so can be ruled out:



Choosing DSM strategies: **Process map**

Map constraints
- Technology: generation & meters
- Stage of development
- Regulatory & financial
- Community culture & economy

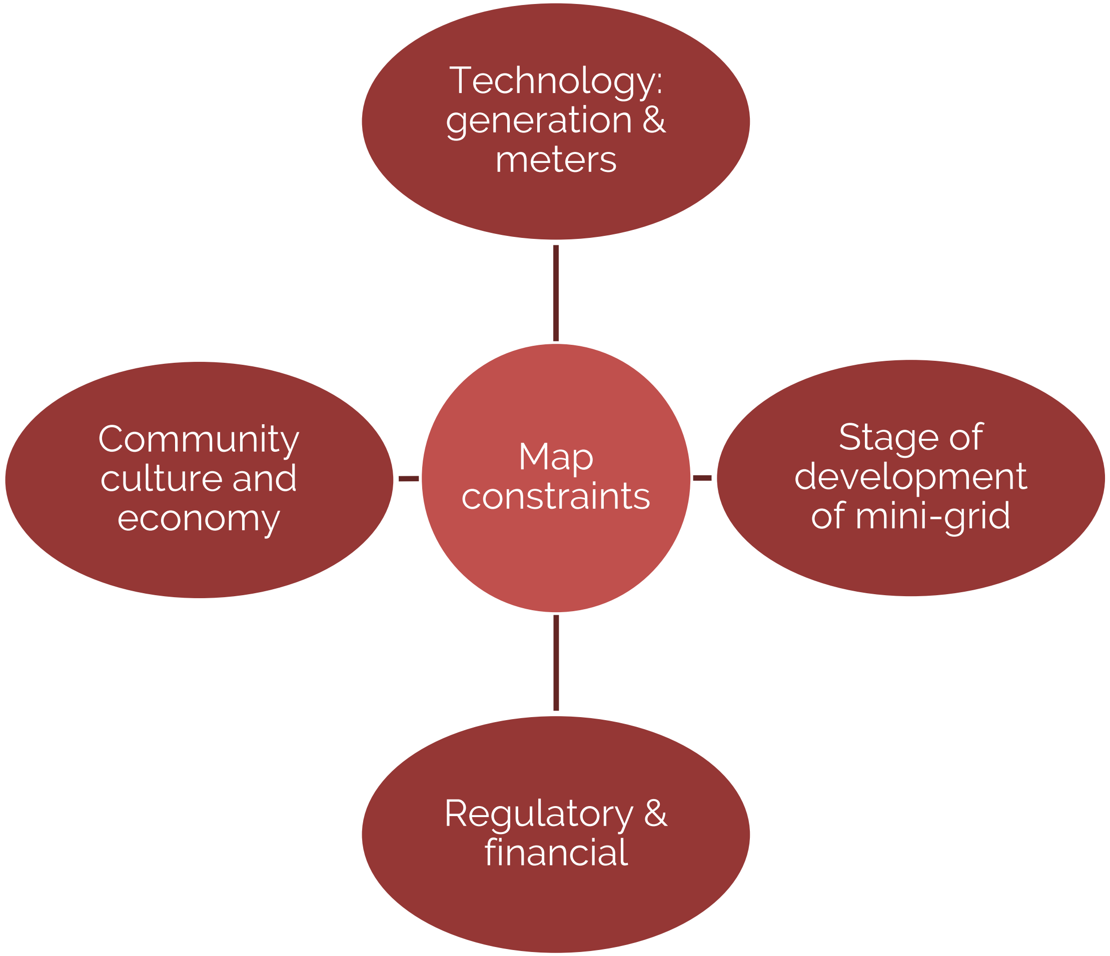
Identify supply / demand imbalances
- Data collection and analysis
- Identify and characterise customer groups
- Identify supply / demand imbalances
- Understand reason for imbalance

Select DSM strategies
- Select strategy
- Check compatibility with constraints

Operationalise strategies
- Procure technology
- Engage the community
- Monitor impact of strategy

Map constraints

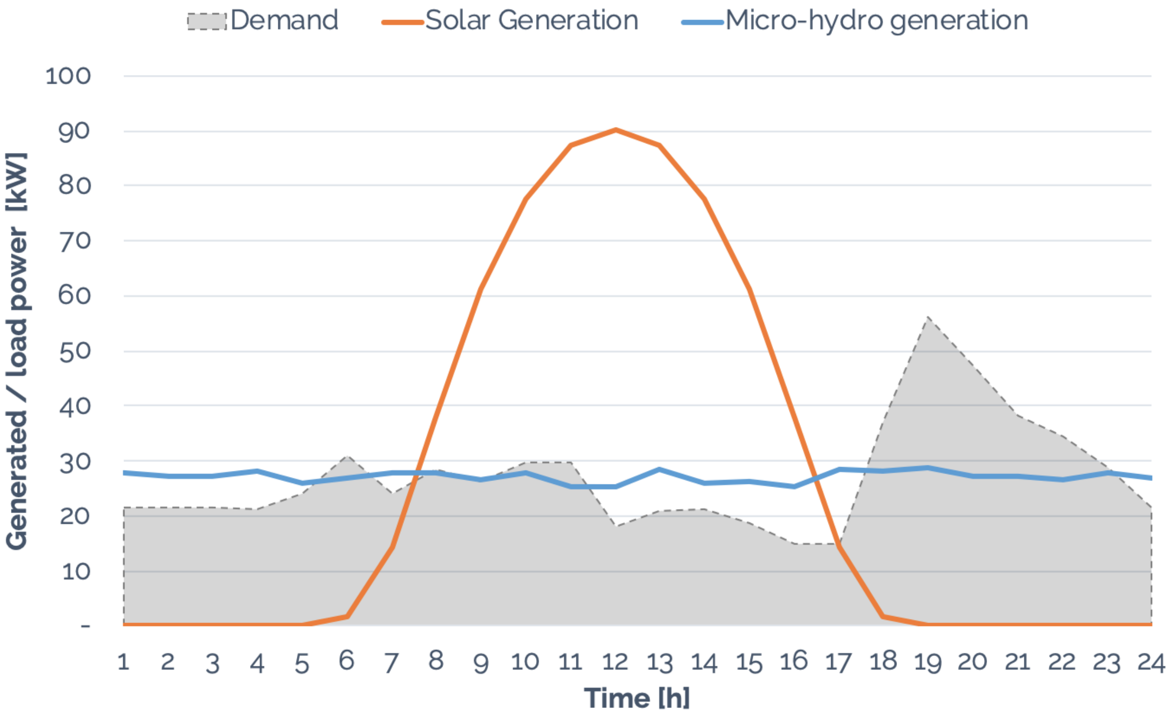
- These constraints could impact the success of any DSM strategy.
- They can be characterised by the following:
  - Generation and meter technology
  - Stage of development of mini-grid
  - Regulatory & financial
  - Community culture and economy
- Map constraints before considering DSM options.



Constraints: **Technology: generation & meters**

- Generation profile:
  - When and how much energy is generated?
  - How much power can be delivered during and outside of generation?
- The generation profile represents the ideal shape of demand, after DSM, but it is rarely actually attainable..
- Are there planned expansions / upgrades?
  - Will these enable DSM?
  - Can upgrades incorporate planned DSM strategies?
- Are there existing meters? What is their capability?
  - Data collection
  - Control
  - Remote access / mobile data availability

Example comparison of daily demand, and generation profiles for solar / micro-hydro plants.
Total energy demand and generation is the same in all cases.



Constraints: **Stage of implementation of mini-grid**

Plan DSM strategies as early as possible in mini-grid development

- Planning stage
  - Design system to facilitate future DSM strategies
    - Consider using certain types of meter e.g smart meters from the start.
    - For a PV mini-grid, plan to shift demand to daytime and reduce investment needed for batteries / diesel generation.
- Operation stage
  - Changes made are dependent on existing infrastructure.
    - What changes are necessary to implement DSM strategy?
    - How will this impact existing technology, stakeholders, and funding?
    - Is capital available to make these changes?

Constraints: **Regulatory & financial**

Is there anything which might prohibit/limit any DSM strategies?

- Government rules and regulations
  - Many governments require regulatory approval for new tariffs.
  - Energy meters in Nigeria require regulatory approval before use. This can lead to delays using new, innovative meter technologies.
  - Lack of relevant regulations for mini-grids can mean the regulations for grid utilities are applied. These are often not adapted to the mini-grid market & operations, and so can hinder DSM.
    Example: tariffs must align with the utility, which blocks custom tariff DSM option.
  - Taxes can discourage or incentivise certain strategies or technologies.
    Example: LED lightbulbs have tax exemptions in some countries, encouraging their use.
- Developers' resources
  - Capital / financing
  - Personnel
  - Other resources

Constraints: **Community culture and local economy**

Are there parts of the community's culture or economy that will impact the effectiveness of DSM?

- Common occupations / value chains.
  - *Example*: farm work limits residential consumption during the day.
- Economic activities.
  - *Example*: market trading days
- Religious / cultural activities.
  - *Example*: times of prayer, days of rest, attitudes toward electricity.
- Accepting change:
  - *Example*: small 'nudges' likely to be better received than large changes.

It is not always obvious which of these factors affect the demand, or how. Assessing the demand profiles in the next stage will help to reveal this.

Choosing DSM strategies

Map constraints → Identify supply / demand imbalances → Select DSM strategies → Operationalise strategies

Identify supply / demand imbalances:

1. Data collection and analysis
2. Identify and characterise customer groups
3. Identify supply / demand imbalances
4. Understand reason for imbalance

Identify supply / demand imbalances (1)

Step 1 – Data collection and analysis.

- Collect historical data on consumption, tariffs, and other customer & village information including:
  - Connection type (residential / business)
  - Occupation / income levels
  - Other data collected during demand assessment
- If historical data is not available for the community, use proxy data:
  - Size & geographic location
  - Generation technology
  - Economic activities / value chains

Step 2 – Identify and characterise customer groups.

- Customers groups are those that consume and pay for energy in the same way e.g. public institutions, small / medium / large businesses, farmers, households.
- Identify groups and understand their load consumption habits, and income / consumption seasonality patterns.

Identify supply / demand imbalances (2)

Step 3: Identify supply / demand imbalances on the grid.

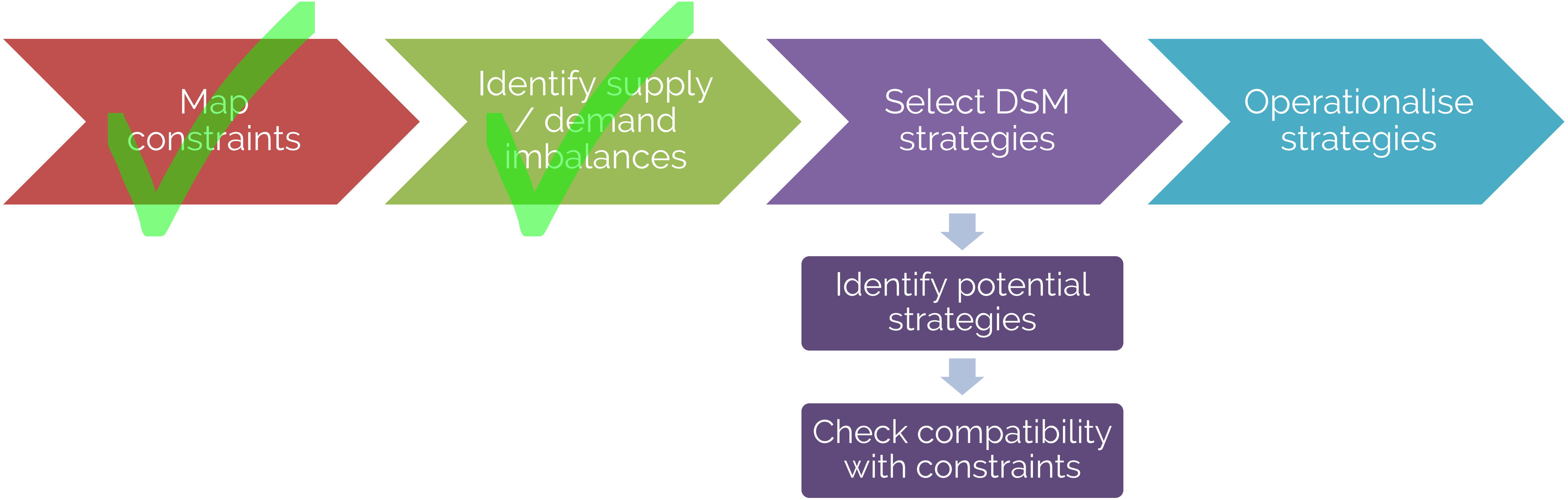
- From the historical consumption data, identify scenarios where DSM can be applied: **peaks**, **valleys**, **offset demand**, **excess demand**, **excess supply.**
- Determine which customer groups are contributing to these imbalances, by looking at groups' load profiles.

Step 4: Understand reason for imbalance.

Understand the circumstances or customer behaviour that leads to the imbalance.

- Who is creating the demand?
- What activities are they carrying out during this period?
- What type of appliances are being used in this period?
- Is it possible to shift consumption to a different time or, if not, limit/stimulate consumption through other means?

Choosing DSM strategies



Select DSM strategies: **Basics**

DSM strategies should aim to match demand to supply, but also follow the behaviour of the target customer group.

- *Example:* A ***time-of-use*** tariff is likely to ineffective in shifting residential demand from evening to daytime, because residents tend to be out of the home in the day. A ***capacity-based*** tariff is likely to be more effective in reducing evening demand.
- *Example*: DSM strategies that benefit productive users (e.g. lower tariffs during the day) can also improve the financial performance of the mini-grid (e.g by shifting demand to times of peak generation).

Select DSM strategies that will:

1. Reduce/eliminate the imbalance in supply and demand
2. Be accepted by the customer group
3. Benefit productive use customers

Select DSM strategies: **Cost versus impact**

Strategies: Cost of activity & resources required, vs. Impact on supply / demand imbalance

Impact on supply / demand imbalance	None	Minor	Medium	Major
High	Custom tariffs (without purchasing extra hardware)		Custom tariffs (incl. purchasing extra hardware)	Developing ancillary business
Medium	Limiting power consumption (without extra hardware)	Limiting power consumption (incl. extra hardware)	Load schedulling & Selling appliances (residential/business)	
Low			Customer education & Replacing appliances	
None				

Cost of activity & resources required

Select DSM strategies: **Compatibility with constraints**

Once strategies have been identified, check them against the constraints identified earlier:

Constraint:	Technology	Viability for the developer	National policies and regulation	Community acceptance
Strategies that can be limited by this constraint:	• Tariffs (metering tech required) • Load scheduling & limiting power (hardware required)	• Ancillary business (resource intensive) • Selling & replacing appliances (management costs, cost of stock, financial risk from appliance loans)	• Ancillary business (licensing) • New meter technology & tariffs (regulatory approval)	• Ancillary business (must fit with existing economy) • Tariffs (matching livelihoods)

Move forward with a strategy only if is compatible with all of these.

If not, can the strategy be modified to become compatible?

Choosing DSM strategies

Operationalise: **Procure technology e.g smart meters**

- Smart meter features on offer:
  - Data recording: consumption, voltage
  - Remote access to data:
    - Via mobile network
    - Real-time data
  - Remote control
    - Enable / disable connection
    - Energy / current limiting
    - Setting tariffs
    - Load scheduling
  - Integration with mobile-money payment services
  - Software platform with dashboard and inbuilt data analytics.

- Companies offering smart meter technology (alphabetically):
  - Baobab
  - Conlog
  - EDMI
  - eTactica
  - Inhemeter
  - Shenzhen Calinmeter
  - SparkMeter
  - Steama.co

Operationalise: **Community engagement**

Community engagement is vital to facilitate the introduction of DSM strategies:

Create community groups: empower group members to weigh in on energy issues. This should involve the community from the start, and provide a platform to get feedback and disseminate information about the new strategies. The size and structure of the group will depend on the village, but it should be made up of representatives from key stakeholders/groups in the community.

Appoint village champions: well respected and influential community members who are able to spread information, reinforce training, and promote customer engagement. Select those who are most engaged and quickest to adopt, and spread new ideas. Members of the community group are good candidates.

Focussed training: engage with the community to help them understand the rationale behind the DSM strategy and how it will be implemented. Training can be one-to-one, during the connection process, or can be continuous, running in public spaces with other village events.

Distribute materials: create posters, leaflets and other educational materials, and distribute to members of the community.

Operationalise: **Monitor impact of DSM strategy**

It is important to monitor the impact of any new DSM strategy to understand if it is having the desired effect on demand.

- Analyse consumption data for all customer groups to see if and how the strategy has changed consumption habits.
- Survey customers, or use the feedback mechanisms described on the previous slide, to understand the perceptions of the new strategy.
- Make adjustments as necessary, from above analysis and survey findings.

Conclusion

This report looked at:

- What is DSM?
- Causes of supply and demand imbalances
- DSM strategies to reduce these imbalances:
- Choosing appropriate DSM strategies
- Implementing strategies

Future research needed

Currently there is no quantitative research being done comparing DSM strategies for mini-grids in Africa.

Instead we rely on qualitative accounts from a number of case studies.

We would like to see a **cost benefit analysis carried out on each DSM strategy** to provide such a quantitative comparison.

This should be based on evidence from around Africa which demonstrates the effectiveness of different DSM strategies in different contexts. For this we will need:

- Common framework of data sharing, collection and consolidation
  - The African Minigrid Developers Association is attempting to do this.
- Data presented in a consistent format which allows direct comparison between different projects and strategies

References

[1] **Alliance for Rural Electrification. (2014).** Hybrid Mini-Grids for Rural Electrification - Lessons Learned. Retrieved from https://www.ruralelec.org/sites/default/files/hybrid_mini- grids_for_rural_electrification_2014.pdf

[2] **AMDA (2018)**. Mini-Grids on the Trajectory of Rural Electrification in Africa. Retrieved from http://africamda.org/wp-content/uploads/2018/10/WHITE-PAPER-Mini-Grids-on-the-Trajectory- of-Rural-Electrification-in-Africa.pdf

[3] **Augusto, C. F. R. (2017).** Evaluation of the potential of demand side management strategies in PV system in rural areas. UNIVERSIDADE DE LISBOA. Retrieved from http://repositorio.ul.pt/bitstream/10451/30607/1/ulfc121584_tm_Catarina_Augusto.pdf

[4] **Boait, P. J., & Snape, J. R. (2014).** Demand management for isolated mini-grids supplied by renewable generation. In 2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET) (pp. 1–6). https://doi.org/10.1109/ICDRET.2014.6861688

[5] **EEP Africa. (2018).** Opportunities and Challenges in the mini-grid sector in Africa. Retrieved from https://eepafrica.org/wp-content/uploads/EEP_MiniGrids_Study_DigitalVersion.pdf

[6] **ESMAP. (2000).** Mini-Grid Design Manual. Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP). Retrieved from https://www.esmap.org/sites/default/files/esmap- files/TR_minigriddesignmanual21364.pdf

[7] **Gupta, P. (2013)** Forum - Impact of Demand Side Management Programs on Peak Load Electricity Demand in North America, 1992 to 2008 Retrieved from https://www.iaee.org/en/publications/newsletterdl.aspx?id=189

[8] **Harper, M. (2013).** Review of strategies and technologies for demand-side management on isolated mini- grids.

[9] **IRENA (2016)**, Solar PV in Africa: Costs and Markets

[10] **Oviroh, Peter, and Tien-Chien Jen (2018)**. "The energy cost analysis of hybrid systems and diesel generators in powering selected base transceiver station locations in Nigeria." Energies 11.3: 687, Figure 4, page 10.

About the Green Mini-Grid Help Desk

The Green Mini-Grid Help Desk has been created to support developers of green mini-grids in Africa through the provision of online information and more tailored advisory services in different areas including technical and engineering, business planning, capital raising, and legal and compliance.

The Green Mini-Grid Help Desk has been developed by Energy 4 Impact and INENSUS, is hosted by the African Development Bank and is funded through the Bank's Sustainable Energy Fund for Africa (SEFA). The Green Mini-Grid Help Desk is part of the Green Mini-Grid Market Development Program which aims to facilitate the creation of a green mini-grid movement and enabling environment across Africa.

Website: https://greenminigrid.se4all-africa.org/