Billing Models for Energy Services in Mini-Grids

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GIZ PEP Workshop on Hybrid Mini-Grids

March 9th 2014

MICRO ENERGY INTERNATIONAL

The non-essential line?

Tsumkwe Hybrid Mini-Grid, Namibia

Outline

Challenges in Mini-Grid Operation

Tariffs Basics & Options

Billing and Tariff Enabling Technology

Tariff's Role in Demand Side Management

Challenges in Mini-Grid Operation

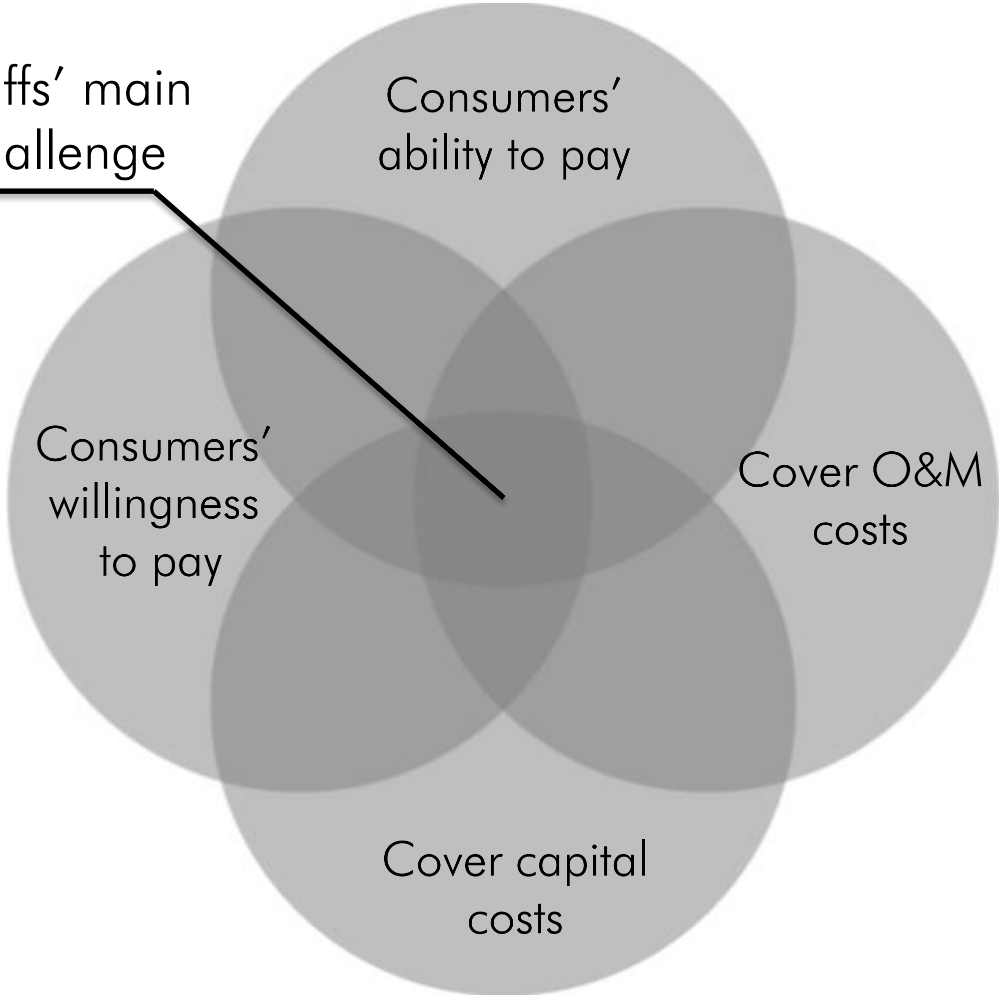
Challenges in Mini-Grid Operation

- Securing payment and collection
- Recover OPEX and CAPEX
- Reciprocity with local communities
- Close match of supply and demand
- Size and technology determination
- Ensuring long term service provision

Tariff Basics & Options

Basics of tariffs

Tariffs' main challenge



<u>Tariffs should aim to</u>

- Attract private parties to invest in MGs
- Make MGs financially viable and sustainable
- Pursue to support economic development and improve living standard in the villages
- Enable understanding of mini-grid operation
- Balance Sustainability vs Affordability

Based on
Peterschmidt *et al.* (2013)

Tariff Options

Tariff Options for Mini-Grids

Capacity-based tariff
Maximum power amount

Energy as a Service
Fee for service provided

Per-Device
Number of devices allowance

Consumption-based Tariff
Energy consumption per time

Lifeline and Inverted Block Tariff
Tariff increases with consumption

Seasonal Tariff
Price established regarding environmental constraints

Binomial Tariff
Different price regarding to power source type or period of the day

ARE (2011)
MES (2013)
Tenenbaum *et al.* (2014)

Consumption-based Tariff

Consumption-based Tariff

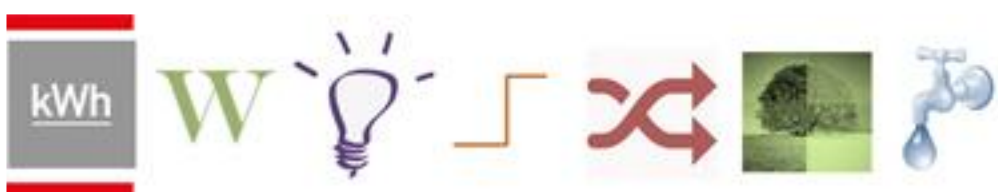
Energy consumption per time

- Customer pays per energy consumption
- Meter and reader required
- Incentivices energy efficiency

Tenenbaum *et al.* (2014)

Example – Bangladesh PVDH Mini-Grid

- Connection fee: 5,000 BDT (~46,39 €)
- Price: 30 BDT / kWh (~0.28 / kWh)
- Post-paid on a monthly basis



Capacity-based Tariff

Capacity-based tariff

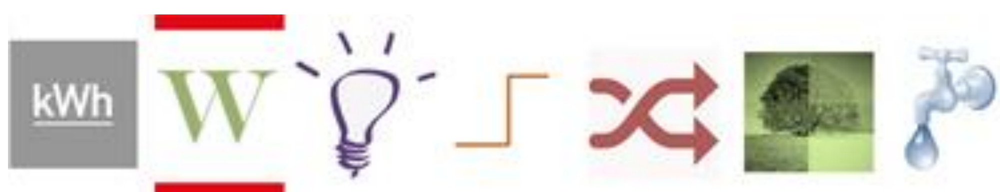
Maximum power amount

- Flat-Rate or subscription tariff
- Customer pays a maximum power amount
- Overcurrent device / No metering

Example – Nepal, Hydro-power Mini-Grid

- Combined subscription tariffs with load limiters
- Total wattage subscription below power plant capacity

Tenenbaum *et al.* (2014)



Per-device Tariff

Per-Device

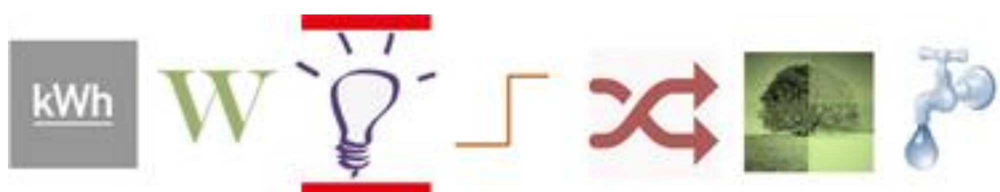
Number of devices allowance

- Power tariff adaptation
- Customer pays per number of devices
- Reduces initial costs / No meter nor load limiter
- Pre-paid but requires on-site control

Example – India (Husk Power Systems), Biomass gasifier

- Two allowed fluorescent light (15W) per household
- 50 rupees per month (∼$1)

Tenenbaum *et al.* (2014)
Energy Access Report (2012)



Lifeline / Inverted Block Tariff

Lifeline and Inverted Block Tariff

Tariff increases with consumption

- Customer charge increases with consumption
- Cross-subsidy from high to low-consumption customer

Example – Tanzania (Mufindi), Mwenga Hydro Limited project

- T Sh 60 / kWh (~4cents) < 50 kWh cons.
- T Sh 234 / kWh (~15.6 cents) > 50 kWh for more than 3 months a year

Based on ARE (2011)
Tenenbaum *et al*. (2014)

Binomial Tariff

Binomial Tariff

Different price regarding to power source type or period of the day

- Tariff varies by time of day (peak / non-peak) and need for battery/diesel generator
- Attractive tariff for hybrid MGs
- Aims for energy efficiency

Example – Brazil PV distributed power generation

- Tariffs varying according to time of use
- Day periods:
  - Peak-hours
  - Non-peak hours
- Non-peak hours Tariff is 30% reduced

Douglas & Guimarães (2003)

Seasonal Tariff

Seasonal Tariff

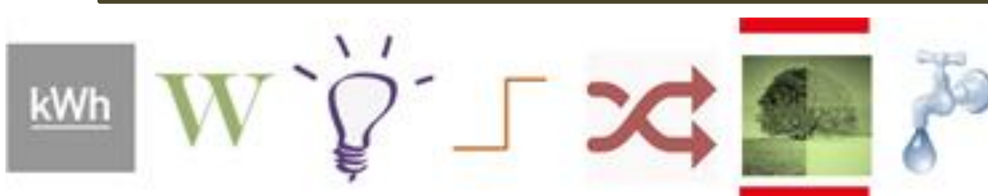
Price established regarding environmental constraints

- Price defined by seasonal variation of renewable energy availability
- Aims for energy efficiency

Example – Brazil Tariff for Hydro power plant

- Year periods:
  - Dry: May to November
  - Wet: December to April
- Tariff during wet season is reduced ~17%

Douglas & Guimarães (2003)



Energy as a Service

Energy as a Service

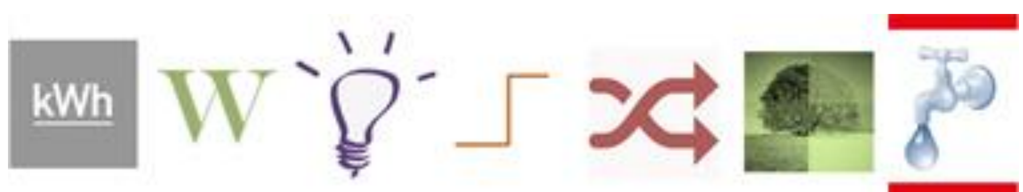
Fee for service provided

- Energy not sold per unit of energy but for service provided
- Pre or post paid:
  - Kg, Hours, Liters, etc.

Example – Odisha, Solar PV based MUBC

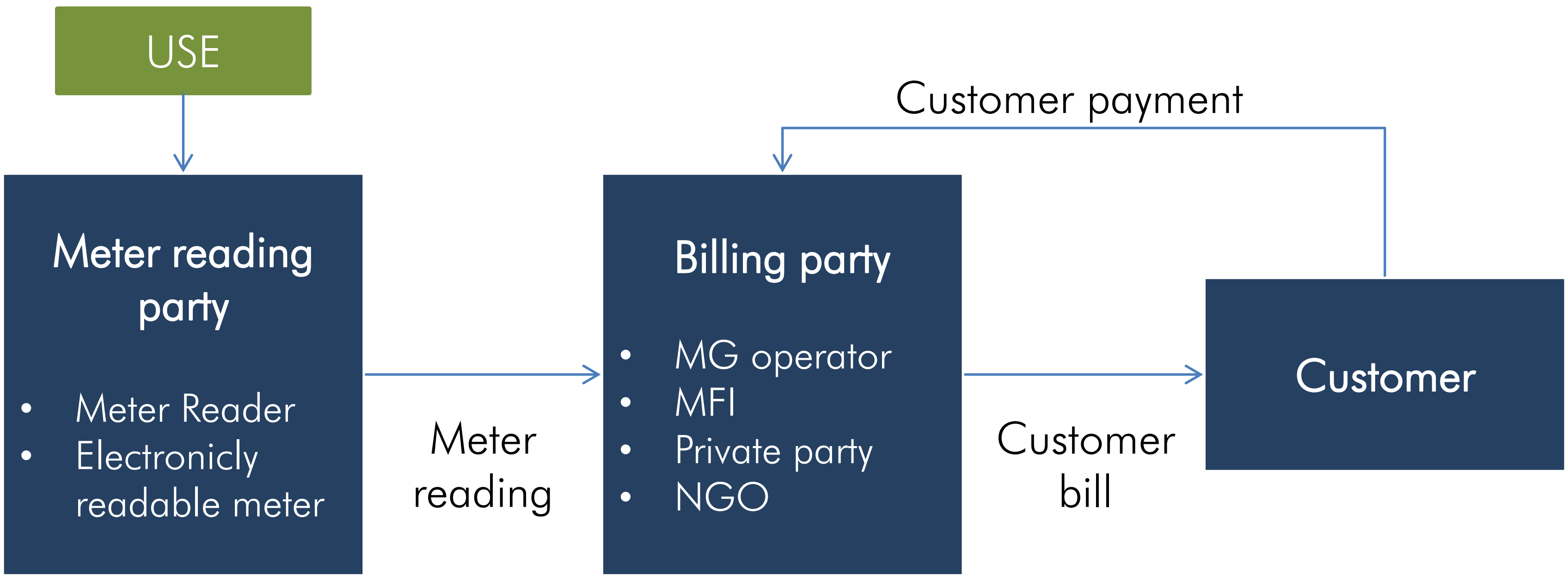
- Prices:
  - TV service: 0.9 US$ per hour per person
  - Water purification: 0.036 US$ / litre

Sharma and Sen (2013)

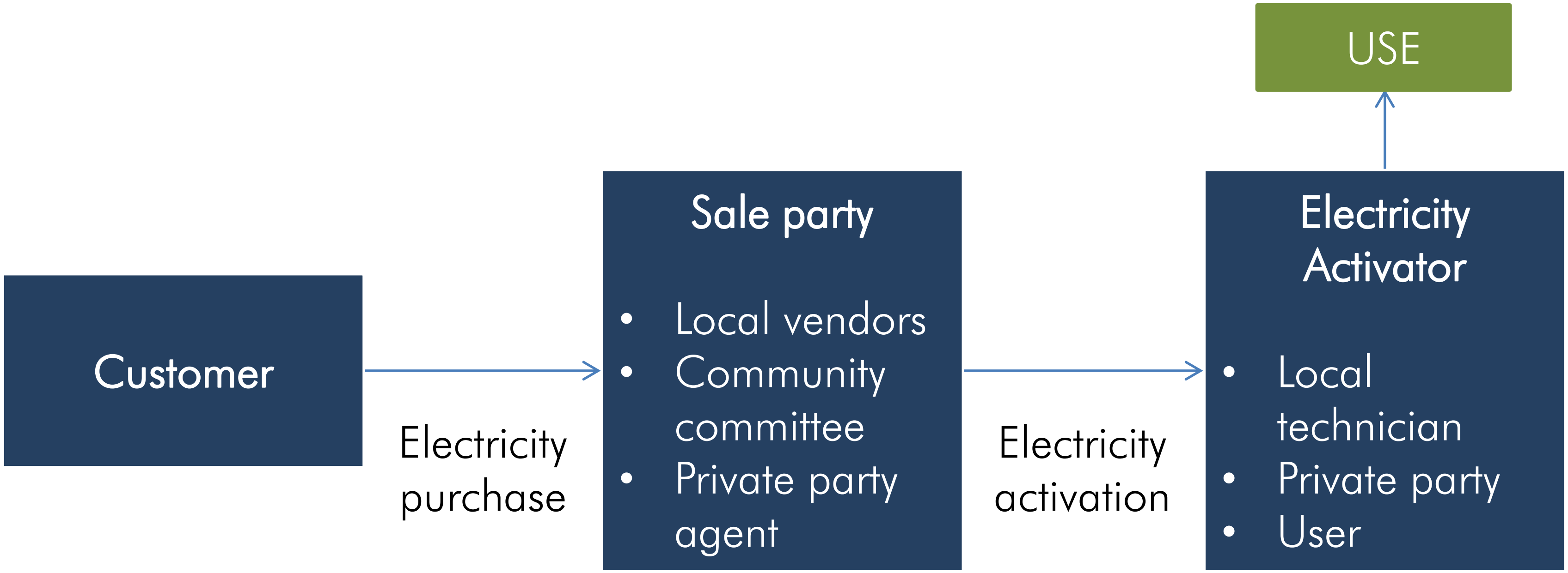


Billing and Tariff Enabling Technology

Collection Methods



Collection Methods



Electricity purchase
- Mobile phone payment
- Pre-paid card/code
- Scratch cards

Electricity activation
- Manually
- Inserting code
- Remotely (Central communication AMS)

Pre-paid Systems and Load Limiters

Pre –paid meters

Micro Utility Solution – INENSUS
- Customers buy “electricity blocks”
- 1 Block: 28h and 50W and 1.4 kWh limit per week
- Block not usable after the week
- Activated by programmed card

Price:
120 – 165 € per meter
40–55€ per connection
Self-Consumption:
0.3-1.5 W
(INENSUS)

Electricity Dispenser – Circutor
- Energy Daily Allowance: Balance can increase and decrease
- EDA: 6 credits maximum, when 0 disconnection
- EDA credits can be **transfered between users**
- Activated by programmed card

Self-Consumption:
<2 W
(Circutor)

Load Limiters

- Fuses
- Miniature Circuit Breakers
- PTCs Thermistors
- Electronic Circuit Breakers →

Circuit Breaker “Load Checker”
- Produced by Aartech Solonics Ltd (India)
- Inaccessibility → Bypass prevention
- Self-resetting
- Retail cost: ~US$ 5 unit

Harper (2013)

Tariffs’ role in demand side management

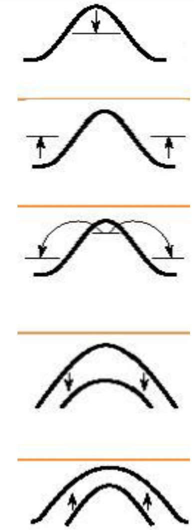
Idea of Demand Side Management & Strategies

MGs Limitations

- Peak power output
- Available energy supply
- Recurring fuel costs
- Energy storage

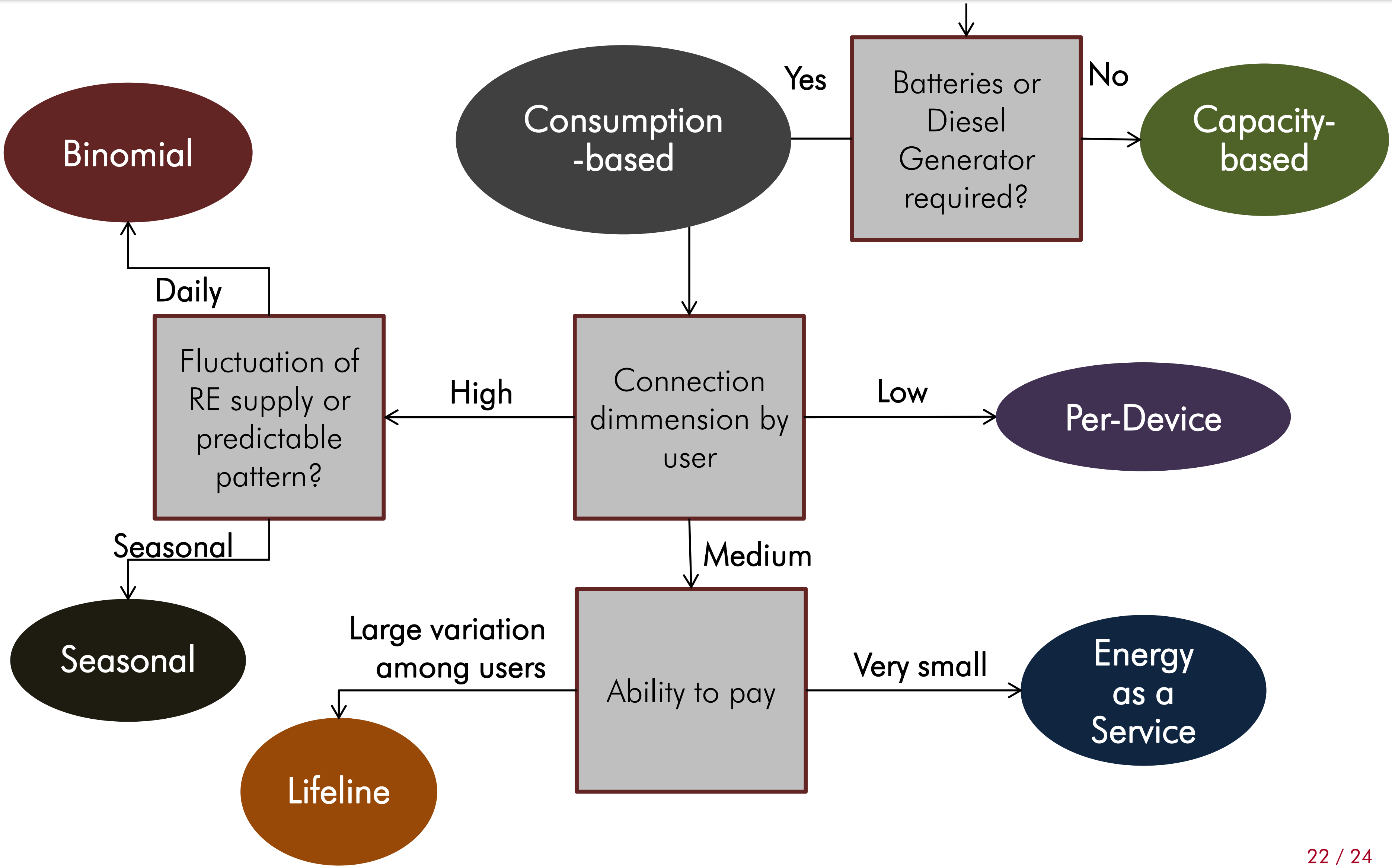
→ DSM Strategies →

- Reduce and spread load preserving MG reliability
- Ensure equitable distribution among MG users



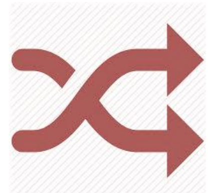
DSM Strategies	
	Efficient appliances and lights
	Commercial load scheduling
	Restricting residential use
	Community involvement, consumer education, and village committees
→	Price incentive and structure

DSM – Tariff Determination



Challenges adressed

Pre- or post
paid meter



Securing payment and collection

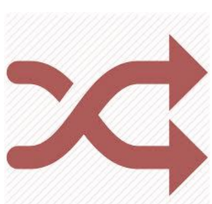
Recover OPEX and CAPEX

Reciprocity with local communities

Close match of supply and demand

Size and technology determination

Ensuring long term service provision



W vs.

Summary

- Tariff is the binding element between a **sustainable** business model and an **affordable** electricity access
- The core determinates in the selection of the tariff model are the **renewable energy source** and the **socio-economic context**
- Tariffs play an important role in **demand side management**
- **Billing schemes selection** is depending on the customer type, the expected sales per connection and the level of tariff variation

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Annex

Consumption-based Tariff II

Characteristics

- Customer pays per energy consumption [i.e. per kWh]
- Metering required
- Meter Reader required or Electronic readable meter

(Dis)Advantages

+ No limiters required
+ Incentivies energy efficiency
- Meter reader
- Electronic readable system
- Risk of customer's unpayability

Metering & Billing

- Post-paid
  - Meter reading
  - Bill calculation
  - Customer payment
- Pre-paid
  - Customer buys energy before consumption

Example Bangladesh – PVDH mini-grid (100kWp mini-grid)

- Connection fee: 5,000 BDT (46.39€)
- >10 hours/day
- All household appliances allowed
- Max power per household : 2,2 kW
- 10 A limited circuit
- Price: 30 BDT/kWh (~0.28€ /kWh)
- Electricity meter
- Post-paid on a monthly basis

Capacity-based Tariff II

Characteristics

- Know as Flat-Rate, subscription tariffs
- Customer pays a maximum power amount
- Overcurrent device required or load limiter
- Theft risk

(Dis)Advantages

\+ No meter required, no bill calculation, no meter reading required

- Hide charge per kWh
- No efficiency incentive
- Difficult demand prediction
- Discourage productive use

Metering & Billing

- Pre-paid
  - Customer agrees energy price before consumption
  - Cash payment, Mobile phone payment or scratch cards

Example Nepal – Flat rate tariffs using load limiters

- Combined subscription tariffs with load-limiting devices
- Total wattage subscription below power plant capacity
- No risk of brownout
- Carefully scheduled load by consumers to meet conditions

Tenenbaum *et al.* (2014)

Per-device Tariff

Characteristics

- Power tariff adaptation
- Customer pays per number of devices
- Used to reduce initial costs with very low-income populations
- No meter nor current limiter required

(Dis)Advantages

\+ No tariff equipment required
\+ Reduced grid consumption
- Hide charge per kWh
- No efficiency incentive
- Difficult demand prediction
- Discourage productive use
- Unnanounced visits required

Metering & Billing

- Pre-paid
  - Customer agrees energy price before consumption
  - Cash payment, Mobile phone payment or scratch cards

Example India – Fixed price model by Husk Power Systems (HPS)

- Each household is allowed to run two fluorescent lights (15W) and charge mobile phones
- 50 rupees (~$1 per month) + connection cost 100 rupees (~$2)
- Further adjustment of the model for two 45W connections and 1,000W package

Based on Tenenbaum *et al*. (2014)

Energy Access Report (2012)

Lifeline / Inverted Block Tariff

Characteristics

- Customer class differentiation
- Customer charge increases with consumption
- Represent a cross-subsidy from high to low-consumption customer

(Dis)Advantages

\+ Easy adaptation for low consumers

\+ Fair system for low income customers

\+ Wide number of new technologies focusing in this method

Metering & Billing

- Post-paid
  - Cash or mobile phone
- Pre-paid
  - Customer buy electricity blocks
  - Cash payment, Mobile phone payment or scratch cards

Example Nepal

- 250 kW Micro-Hydro Mini-Grid
  - 4.43 rupees/kWh – **domestic use** (~0.03€/kWh)
  - 5.84 rupees/kWh – **tourist lodges and enterprises** (~0.04€/kWh)

Example Tanzania – Mufindi

- Lifeline tariff
  - T Sh 60 (4 cents/kWh) < 50 kWh
  - T Sh 234 (15.6 cents/kWh) if consumption is over 50 kWh for more than 3 months a year

Based on ARE (2011)
Tenenbaum *et al*. (2014)

Binomial Tariff

Characteristics

- Tariff varies by time of day
- Depending on peak/non-peak hours
- Necessity to use batteries and/or diesel is considered
- Aims to reduce use of back-up systems

(Dis)Advantages

+ Supports use of energy during peak production and off-peak demand hours
+ Aims for energy efficiency
+ Attractive for hybrid MGs
- Sophistiaced meter requirec
- No pre-paid possibility
- Increases unpayment risk

Metering & Billing

Post-paid

- Cash or mobile phone payment according to consumption and tariff
- Meter must be able to identify the time-based tariff

Example – Tariffs used in the Regulated Contracting Environment in Brazil distributed power generation

- Blue & Green time-of-use tariff
- Both vary according to the time of the year
- Daily periods:
  - Peak-hours
  - Non-peak hours
- Price example: Dry Season: Peak-hour: 32.96€ / MWh
  Non-peak hour: 23.32€ / MWh

Douglas & Guimarães (2003)

Seasonal Tariff

Characteristics

- Price differentiation during seasons. E.g. Winter-summer
  - PV: lower price→Summer
- Based on environmental possibilities depending on season
- Aim's for application in hybrid MGs

(Dis)Advantages

+ Aims for energy efficiency

+Can be sold as blocks or metered

- Difficult to determine operation costs regarding to season

Metering & Billing

- Post-paid
  - Cash or mobile phone payment
- Pre-paid
  - Customer buy electricity blocks
  - Cash payment, Mobile phone payment or scracth cards

Example – Tariffs used in the Regulated Contracting Environment in Brazil distributed power generation

- Blue & Green time-of-use tariff
- Both vary according to the time of the year
- Year periods:
  - Dry: May to November
  - Wet: December to April
- Price example: Peak-hour Dry Season: 32.96€ / MWh
  Wet Season: 28.93€ / MWh

Douglas & Guimarães (2003)

Energy as a Service

Characteristics

- Energy is not any more sold per units of energy/power
- Energy priced per units of time, kg, etc
- Adequate for rural areas where costs of solar power electricity would be too high for villagers

(Dis)Advantages

+ Required precisse and adequate calculation of prices

+ Relates energy to other activities

- Hide price per kWh

- Customer not aware of energy efficiency

Metering & Billing

Pre or post-paid:

- Hours of TV/DVD
- Kg of ground wheat processed
- Litters of clean water processed

Example Odisha – Solar PV based Multy Utility Business Centre (MUBC) in Patapolasahi

- 35 households
- Agriculture as primary livelihood
- Service charged either on kilogram, litre or hourly
- Service charged is caped by an upper limit of the Ability To Pay of customers
- Price considering O&M costs, Logistics Cost, Business Risk, Inflation,
- TV service: 0.9 US$ /hour per person – Water purification: 0.036 US$ /litre per person

DSM – Price Incentive and Structure

Tariff selection

Determining criterion

- Dependency on battery bank?
- Vulnerability to excessive energy consumption?
- Importance of fuel cost and energy?
- Metering required?

Yes

Consumption-based tariff

- Time-of-use (Inverted block)
- Dynamic rate (Real Time Pricing, Time Varying Pricing, Critical-Peak Pricing)

No

Capacity-based tariffs

- Flat-rate (pre-arranged power limit)
- Per-device
  - Current/Load limiter
  - Max amount of power used

DSM – Consumption based Tariffs

Operator reader, billing, collection?

Yes → **Meter**

- Energy usage limited to pre-set rate
- Enables load-shedding
- Can use pricing signals to encourage DSM

- Proved that decrease consumption
- Innacurate billing and poor managed billing can be controversial
- Fraud, theft, tampering

No → **Pre-paid meter**

- No overdue payment
- Allow users to have real-time record of consumption
- Incentivizes efficiency measures

- Cost of (pre-payment) meter
- Fraud, theft, tampering

DSM – Capacity based Tariffs

NO operator reading, billing, collection requried

↓

Pre-paid meter

- No overdue payment eases cashflow for operator
- Limits peak demand, prevents system overload
- Ensures equitable distribution
- Cheaper than meter

- Fraud, theft, tampering

Pre-paid Collection Systems

Micro Utility Solution – INENSUS

- Monthly subscription
- Consumers buy "electricity blocks"
  - 1 Block: **28h/week** OR **50W/week** OR **1.4kWh/week**
- Energy block is <u>**not**</u> usable after the week
- Blocks are sold by an INENSUS agent (monthly)
- Customer activates meter
- Demand management
  - Customer must decide the energy wanted every 6 months
- Security of investment (by operator)
  - Blocks paid in advance
  - Ordered long time horizon
  - Priced regarding modular generation components
- System active in Senegal

Indicative prices

- for MPM 10A 3x1P version (three single phase household connections of 10 A each per meter): 165€ with a 100 unit order (55€ per connection)
- for MPM 2A 3x1P version (three single phase household connections of 2 A each per meter): 120 € with a 400 units order (40 € per connection)

(INENSUS)

Pre-paid Collection Systems

Electricity Dispenser – Circutor

- Monthly subscription
- Consumers subscript to a maximum power and "flow" of energy → Energy Daily Allowance
- Users start service with 3 EDAs:
    - If consumes less EDA **balance increases** (6 max)
    - If consumes more EDA, **balance decreases** (when 0, disconnection)
- Monthly EDA rate programmed onto a card by local vendor
- EDA credits can be **transferred between users**
- Can provide additional DSM
    - Encouraging consumption when batteries are full
    - Discouragin when are low
- Can be turned on or off to enable loadshedding
- Used in Morocco, Ecuador and Cape Verde
- Power consumption: < 2 W

(Circutor)

Cost-effective alternatives

Load Limiters

Types	Main Characteristics
• Fuses • Miniature Circuit breakers (MCBs) • Positive Temperature Coefficient Thermistors (PTCs) • Electronic Circuit Breakers	• No metering required • Used for flat rate • Simplifies billing • Cost between US$ 1 to US$ 5

Harper (2013)

Circuit Breaker "Load Checker"

- Produced by Aartech Solonics Ltd (India)
- Positive Temperature Coefficient (PTC) thermistor incorporated
- Restrict load levels between 0.031 – 0.4 A (Depending on model)
- Inaccessibility → Bypass prevention
- Self-resetting
- Retail cost: ~US$ 5 unit