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Shaping our world

With the trusted expertise of LAHMEYER INTERNATIONAL

Load profile reconstitution for the design of hybrid systems

Application for rural electrification projects in mini-grid environments

François Botreau
23/05/2019

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Agenda

01

Company Profile

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Tractebel Key Figures 2018

LAHMEYER INTERNATIONAL

2014: Acquisition by Tractebel

2019: Change of name

5,000
employees

35
countries

675 M€
turnover

> 150 years
of experience

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More than ever your engineering partner

ENERGY

- Renewables
- Energy System Consulting
- Digital & Decentralized Energy Solutions
- Hydropower
- Nuclear
- Thermal Energy
- Transmission & Distribution
- Gas & LNG

WATER

- Reservoirs & Dams
- Flood Protection
- Water Transfer
- Water Treatment and Supply
- Irrigation
- Coasts & Estuaries
- Dredging Consultancy
- Offshore Infrastructures

URBAN

- Smart & Complex Buildings
- Transport & Mobility
- Urban Design & Master Planning
- Energy Efficiency
- Environmental, Sanitation & Social Programs

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Hybrid Project References

02

Motivation

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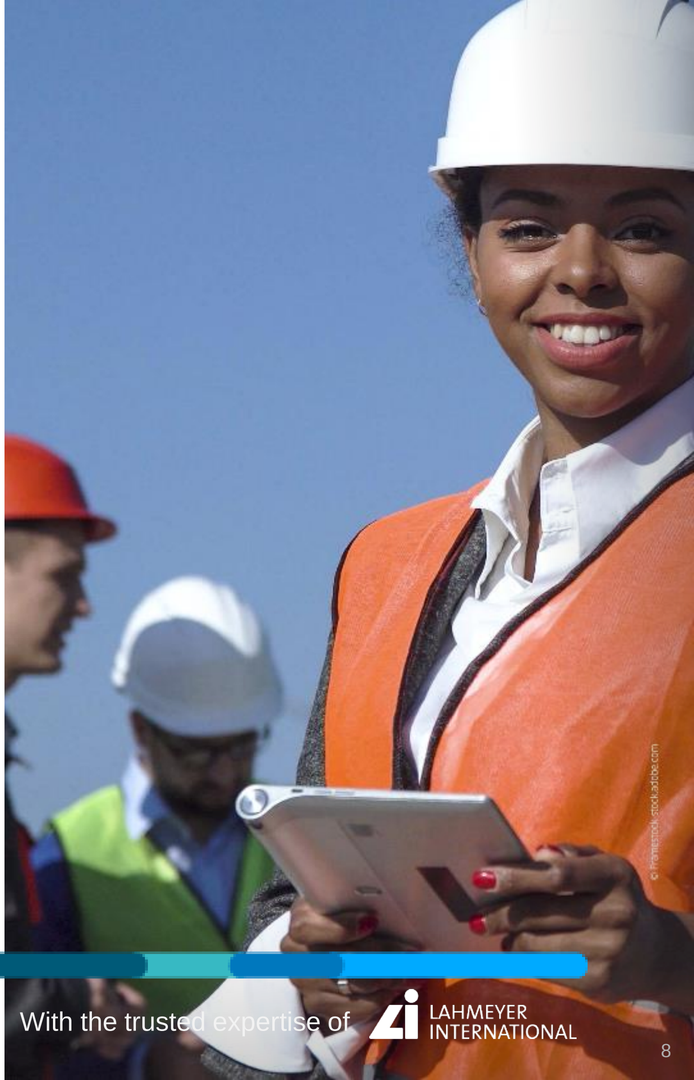

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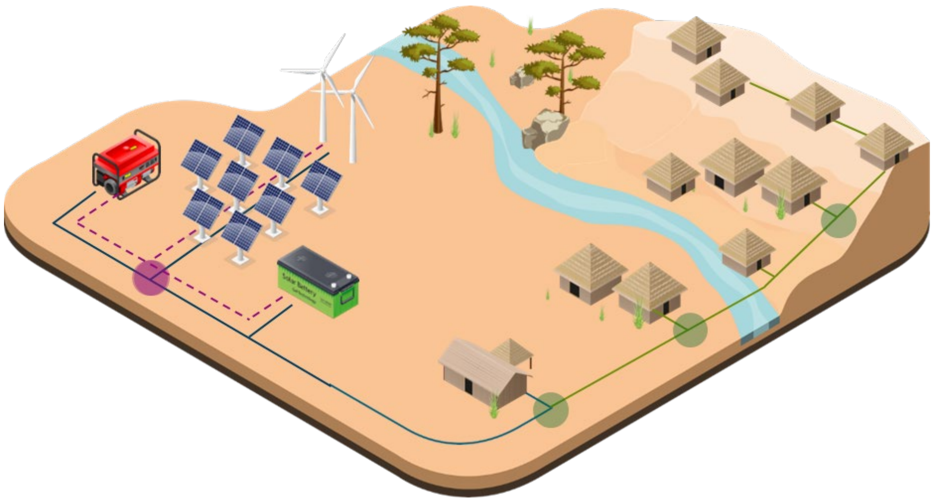
Motivation

If we look at a mini-grid and RE-Hybrid system…



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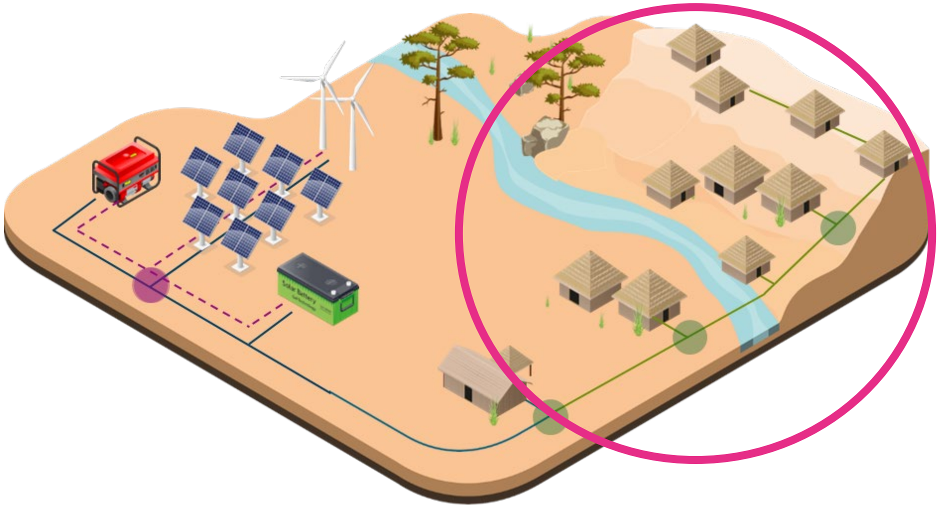
Motivation

Hourly load profiles **+** electrical demand

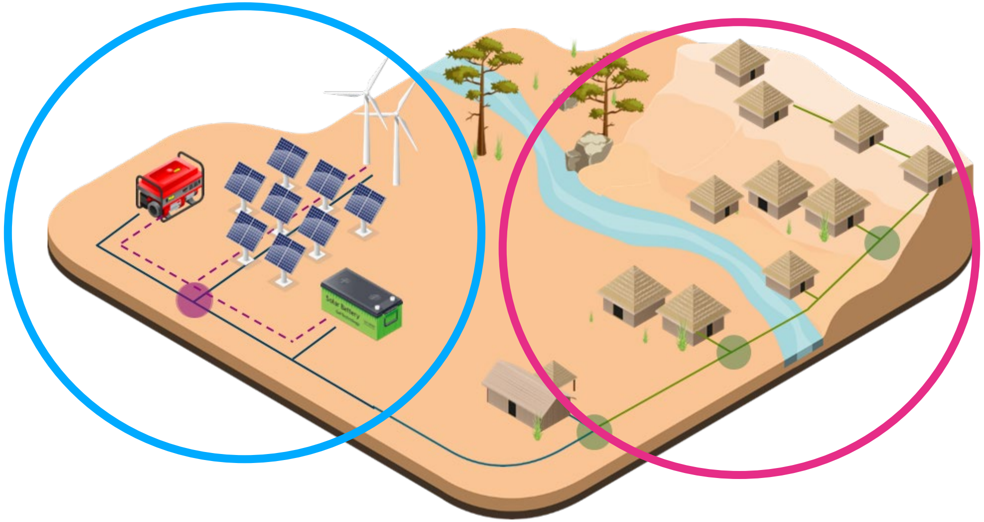


Motivation

Hourly load profiles **+** electrical demand

=

Key **input parameter** for designing RE-based Hybrid Systems



Motivation

Hourly load profiles **+** electrical demand

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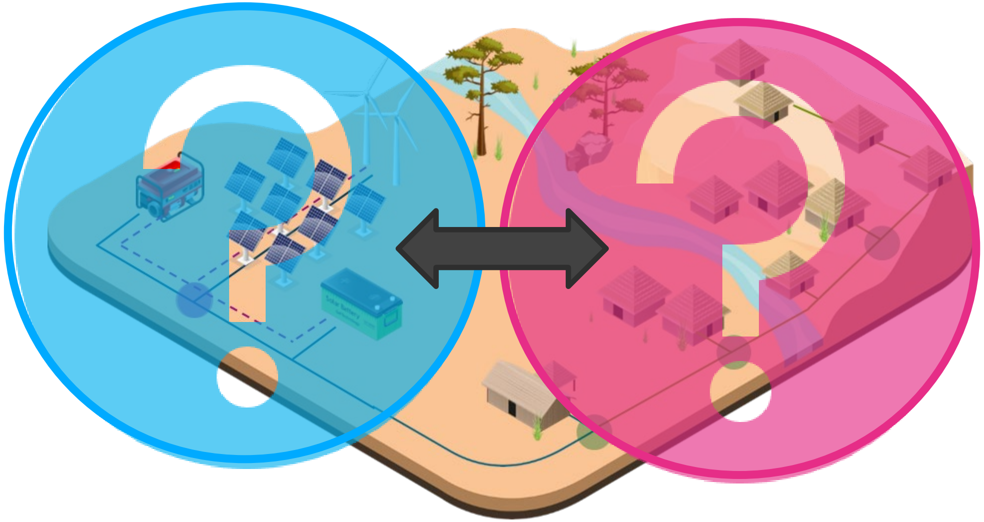
Key **input parameter** for designing RE-based Hybrid Systems



Motivation

Case 1: no electricity to date

Motivation

Case 1: no electricity to date

Case 2: Unreliable power supply

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Motivation

Case 1: no electricity to date

Case 2: Unreliable power supply

Load demand **cannot** be estimated from historical data

Motivation

Case 1: no electricity to date

Case 2: Unreliable power supply

Load demand **cannot** be estimated from historical data

Need to define a coherent approach to construct the **hourly load profiles** at the village scale

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Proposed Approach

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Three-step Approach

STEP 1

Site survey and data collection

STEP 2

User categorization and typical load curves

STEP 3

Preparation of the Design Load profile

Three-step Approach

STEP 1

Site survey and data collection

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Socio-economic environment survey

Energy-use survey and Willingness To Pay (WTP)

Input from the future Operator

Projection of the electrical demand

Assessment of the neighbouring electrified villages

Three-step Approach

STEP 1

Site survey and data collection

- Socio-economic environment survey
- Energy-use survey and Willingness To Pay (WTP)
- Input from the future Operator
- Projection of the electrical demand
- Assessment of the neighbouring electrified villages

STEP 2

User categorization and typical load curves

- Definition of the user categories
- Preparation of the typical load curves per category
- WTP as adjustment factor

STEP 3

Preparation of the Design Load profile

Three-step Approach

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- Preparation of the typical load curves per category
- WTP as adjustment factor

STEP 3

Preparation of the Design Load profile

- Reconstitution of the global load profile at village scale

Case study

Based on real project experience in West Africa

- **Village of 12,000 inhabitants - 2,000 households**
- **Electrified in 2010 with Diesel mini-grid**
  - Worked 4hr/day until 2015
  - Switched off since then

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STEP 1

Site survey and data collection

1- Socio-economic environment survey

STEP 2

User categorization and typical load curves

STEP 3

Preparation of the Design Load profile

Objectives

- Understand socio-economic environment of the village
- Identify the quantity and type of future users

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

1- Socio-economic environment survey

Objectives

- **Understand socio-economic environment of the village**
- **Identify the quantity and type of future users**

- Meeting with local authorities

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STEP 1

Site survey and data collection

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Preparation of the Design Load profile

1- Socio-economic environment survey

Objectives

- Understand socio-economic environment of the village
- Identify the quantity and type of future users

- Meeting with local authorities

- Inventory at village scale of:
  - Total quantity of households
  - Community based infrastructures (schools, health posts, etc.)
  - Commercial applications (shops, bars, etc.)
  - Productive use (mills, welding workshops, etc.)
  - Public lighting

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1- Socio-economic environment survey

Case Study Results

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1- Socio-economic environment survey

Case Study Results

Parameter	Value
Households connected to the existing diesel power plant	365 Penetration rate: 18% (of total households)
Community-based infrastructures	2 health posts + 1 maternity 1 rural development centre + 1 training centre 12 administrative offices 3 pharmacies 12 schools 10 religious centres
Commercial applications	10 sewing workshops 22 shops 12 bars and restaurants
Productive-use	3 welding workshops 1 carpentry 1 bakery 6 mills 1 water pump

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Site survey and data collection

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Preparation of the Design Load profile

2- Energy-use survey and Willingness To Pay (WTP)

Objectives

- Assessing typical electrical appliances and daily usages
- Evaluating the monthly budget dedicated to electricity

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2- Energy-use survey and Willingness To Pay (WTP)

Objectives

- **Assessing typical electrical appliances and daily usages**
- **Evaluating the monthly budget dedicated to electricity**

- Energy-use survey through questionnaires and field visits
  - Listing of typical appliances and power ratings per user category
  - Assessment of daily foreseen usages + seasonal effects

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2- Energy-use survey and Willingness To Pay (WTP)

Objectives

- Assessing typical electrical appliances and daily usages
- Evaluating the monthly budget dedicated to electricity

- Energy-use survey through questionnaires and field visits
  - Listing of typical appliances and power ratings per user category
  - Assessment of daily foreseen usages + seasonal effects

- Willingness to Pay study
  - Assessment of current monthly expenditures for energy services
  - What could be replaced by electricity?

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2- Energy-use survey and Willingness To Pay (WTP)

Objectives

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  - Listing of typical appliances and power ratings per user category
  - Assessment of daily foreseen usages + seasonal effects
- Willingness to Pay study
  - Assessment of current monthly expenditures for energy services
  - What could be replaced by electricity?

Structured questionnaires + Trained surveyors are KEY

Example: NRECA's technical assistance guideline

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2- Energy-use survey and Willingness To Pay (WTP)

Case Study Results

User Category	Electrical appliances
Households	• 8 Fluorescent lamps (15 W, 6 hr/d) • 3 fans (65 W, 6 hr/d) hot season • 1 TV + antenna (100 W, 4 hr/d) • Fridge (75 W, for 25% HH) • 5 Mobile chargers (5 W, 6 hr/d)
Community-based infrastructures	• Sound system (150 W) • Fluorescent lamps (15 W) • Fans (65 W) • Computer (150 W)
Commercial applications	• Computer (150 W) • Laptops (80 W) • DVD+TV (120 W) • Fan (65 W) • Fluorescent lamps (15 W per unit) • Sound system (150 W) • Fridge/ freezer (200 W) • Sewing machine
Productive use applications	• Grindstone (2 kW) • Mills (3 kW) • Drilling machine (2 kW) • Water pump (3 kW) • Welding iron (3 kW)

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2- Energy-use survey and Willingness To Pay (WTP)

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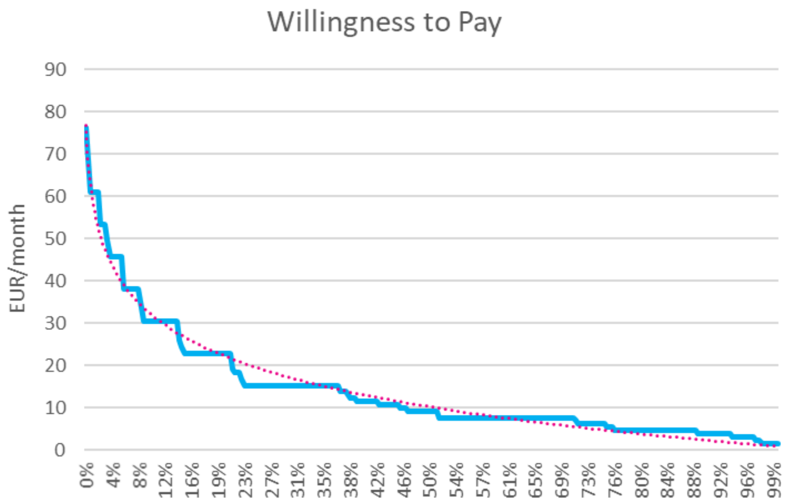

WTP $\geq$ 15 EUR/month for 25% of HH

WTP $\geq$ 9 EUR/month for 50% of HH

WTP $\geq$ 6 EUR/month for 75% of HH

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3- Input from the future Operator

Objectives

- Understanding the electrification strategy from Operator’s perspective
- Getting familiar with electricity tariff and payment scheme

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3- Input from the future Operator

Objectives

- **Understanding the electrification strategy from Operator’s perspective**
- **Getting familiar with electricity tariff and payment scheme**

- Institutional framework determines the type of the Operator
  - Community-based, public utility, private company
  - User prioritization might differ according to type of Operator

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3- Input from the future Operator

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- Institutional framework determines the type of the Operator
  - Community-based, public utility, private company
  - User prioritization might differ according to type of Operator
- Impact of the electricity tariff and payment scheme
  - Financial viability is crucial to maintain the system
  - Flat-rate tariff vs. bill per kWh

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3- Input from the future Operator

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- **Understanding the electrification strategy from Operator's perspective**
- **Getting familiar with electricity tariff and payment scheme**

- Institutional framework determines the type of the Operator
  - Community-based, public utility, private company
  - User prioritization might differ according to type of Operator

- Impact of the electricity tariff and payment scheme
  - Financial viability is crucial to maintain the system
  - Flat-rate tariff vs. bill per kWh

- Consistency between quantity of users and distribution network
  - Physical access to the network to be confirmed

STEP 1

Site survey and data collection

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Preparation of the Design Load profile

3- Input from the future Operator

Case Study Results

Parameter	Value
Type of Operator	Private
Institutional framework	Public-Private Partnership (20 year contract) Subsidy on investment costs to reach the targeted electricity tariff
Targeted tariff	0.20 EUR/kWh
Low voltage distribution network	10 km existing 3 km extension planned to reach more users

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4- Projection of the electrical demand

Objectives

- Assessing the electrical demand on a 5-year timeframe horizon
- To avoid that the hybrid system design is getting outdated rapidly

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4- Projection of the electrical demand

Objectives

- **Assessing the electrical demand on a 5-year timeframe horizon**
- **To avoid that the hybrid system design is getting outdated rapidly**

- Trend indicators
  - Penetration rate in % gives an idea of the total quantity of potential customers
  - Population growth rate (past census)
  - Historical data from electrified villages in the surroundings

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Site survey and data collection

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4- Projection of the electrical demand

Objectives

- ➢ **Assessing the electrical demand on a 5-year timeframe horizon**
- ➢ **To avoid that the hybrid system design is getting outdated rapidly**

- Trend indicators
  - Penetration rate in % gives an idea of the total quantity of potential customers
  - Population growth rate (past census)
  - Historical data from electrified villages in the surroundings

- Two contributions for each user category
  - Increase of quantity of user
  - Increase of specific consumption

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Preparation of the Design Load profile

5- Assessment of the neighbouring electrified villages

Objectives

- **For comparison and adjustment purpose**
- **Improving the confidence level in the obtained results**

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5- Assessment of the neighbouring electrified villages

Objectives

- **For comparison and adjustment purpose**
- **Improving the confidence level in the obtained results**

- Village ideally with similar socio-economic context in the project area

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Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

5- Assessment of the neighbouring electrified villages

Objectives

- **For comparison and adjustment purpose**
- **Improving the confidence level in the obtained results**

- Village ideally with similar socio-economic context in the project area

- Review of the historical operational data to calculate indicators such as:
  - Daily average energy consumption per user [kWh/day.user]
  - Peak power demand per user [kW/user]
  - Monthly variations of energy consumption

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Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

1- Definition of the user categories

- Expected similarities in power range and daily usage (time and duration)

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User categorization and typical load curves

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Preparation of the Design Load profile

1- Definition of the user categories

- Expected similarities in power range and daily usage (time and duration)
- Five user categories commonly identified:
  - **Category 1**: Domestic demand (household)
  - **Category 2**: Community-based infrastructures (schools, health-posts, etc.)
  - **Category 3**: Commercial applications (shops, sewing workshops, restaurants, etc.)
  - **Category 4**: Productive use (welding workshop, carpentry, mills, water pump, etc.)
  - **Category 5**: Public lighting

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

1- Definition of the user categories

- Expected similarities in power range and daily usage (time and duration)

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  - **Category 3**: Commercial applications (shops, sewing workshops, restaurants, etc.)
  - **Category 4**: Productive use (welding workshop, carpentry, mills, water pump, etc.)
  - **Category 5**: Public lighting

Additional and tailor-made categories to be considered on project specific requirements

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2- Preparation of the typical load curves per category

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

- Estimation of average hourly load profiles for each user category

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2- Preparation of the typical load curves per category

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Site survey and data collection

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Preparation of the Design Load profile

- Estimation of average hourly load profiles for each user category

- Difficult exercise which includes uncertainty especially for categories 2, 3 and 4
  - Not exact same behavior within same category: hourly averages are used
  - Daily energy consumption distributed almost uniformly

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Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

2- Preparation of the typical load curves per category

- Estimation of average hourly load profiles for each user category

- Difficult exercise which includes uncertainty especially for categories 2, 3 and 4
  - Not exact same behavior within same category: hourly averages are used
  - Daily energy consumption distributed almost uniformly

Variability factors added at later stage to materialize the peak demand requirements

STEP 1

Site survey and data collection

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User categorization and typical load curves

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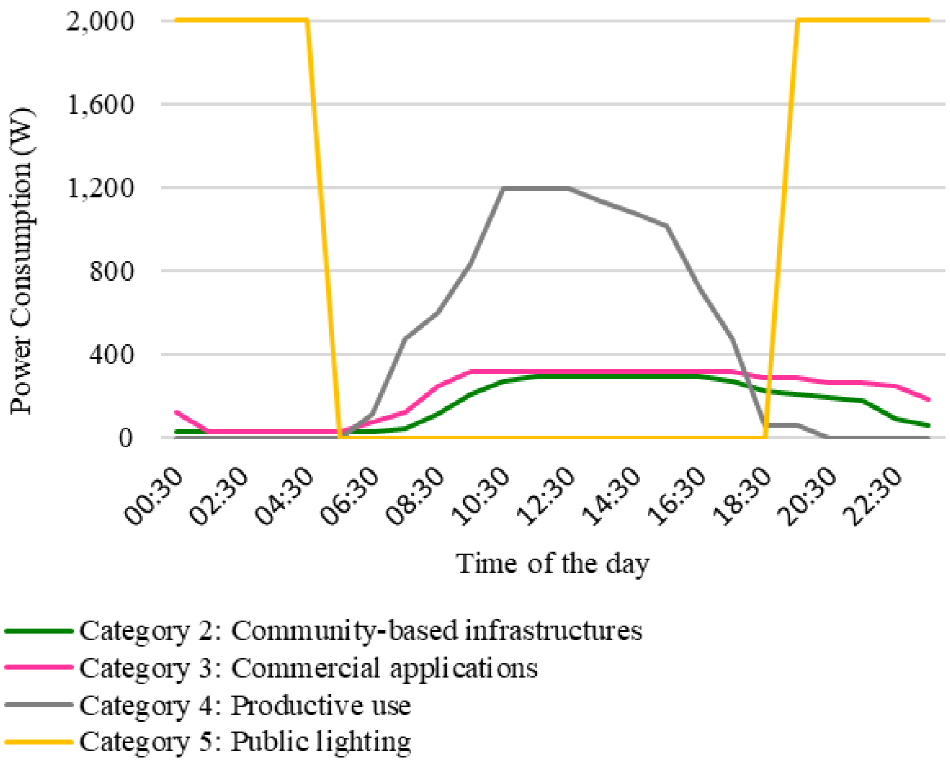
Preparation of the Design Load profile

2- Preparation of the typical load curves per category

Case Study Results



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3- WTP as adjustment factor

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

- Adjust the energy consumption to the WTP

To avoid overestimation of energy consumption based on energy-use survey only

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Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

3- WTP as adjustment factor

- Adjust the energy consumption to the WTP

→ **To avoid overestimation of energy consumption based on energy-use survey only**

- WTP adjustment factor mainly applicable for domestic demand

3- WTP as adjustment factor

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

- Adjust the energy consumption to the WTP

To avoid overestimation of energy consumption based on energy-use survey only

- WTP adjustment factor mainly applicable for domestic demand

- Public lighting: an important application within the village
  - Cost covering scheme has an impact of the type/quantity of lighting bulbs
  - Strategy to be agreed upfront between Operator and village authorities

STEP 1

Site survey and data collection

STEP 2

User categorization and typical load curves

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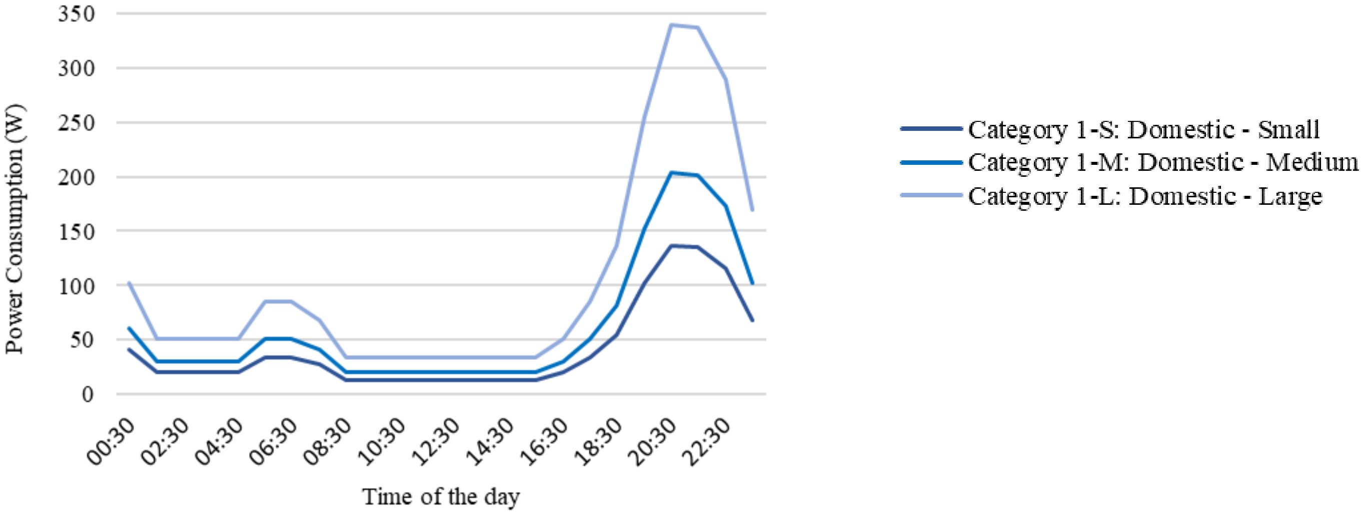
Preparation of the Design Load profile

3- WTP as adjustment factor

Case Study Results



Category	Share	WTP per user	Daily consumption per user
Category 1-S: Small	33%	6 EUR/month	1.0 kWh/day
Category 1-M: Medium	33%	9 EUR/month	1.5 kWh/day
Category 1-L: Large	33%	15 EUR/month	2.5 kWh/day

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Preparation of the Design Load profile

Reconstitution of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

Reconstitution of the Design Load profile

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

→

Global Load Profile
@village scale

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STEP 1

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User categorization and typical load curves

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Preparation of the Design Load profile

Reconstitution of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

→

Global Load Profile
@village scale

Growth factor
@design year

Reconstitution of the Design Load profile

STEP 1

Site survey and data collection

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User categorization and typical load curves

STEP 3

Preparation of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

Global Load Profile @village scale

Growth factor @design year

Technical losses Distribution network

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Reconstitution of the Design Load profile

STEP 1

Site survey and data collection

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User categorization and typical load curves

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Preparation of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

Global Load Profile
@village scale

Growth factor
@design year

Technical losses
Distribution network

Non-technical losses

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Preparation of the Design Load profile

Reconstitution of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

→

Global Load Profile
@village scale

Growth factor
@design year

Technical losses
Distribution network

Non-technical losses

Variability factors
Inter-day, inter-hour

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Reconstitution of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

→

Global Load Profile @village scale

Growth factor @design year

Technical losses Distribution network

Non-technical losses

Variability factors Inter-day, inter-hour

→

Design Load Profile

Reconstitution of the Design Load profile

STEP 1

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Preparation of the Design Load profile

Quantity of users per category (Step 1)

Typical load profiles (Step 2)

→

Global Load Profile
@village scale

Growth factor
@design year

Technical losses
Distribution network

Non-technical losses

Variability factors
Inter-day, inter-hour

→

Design Load Profile

Calculation of Indicators
- kWh/day.user
- kW (peak per user)

To be compared with figures from electrified villages

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Reconstitution of the Design Load profile

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Site survey and data collection

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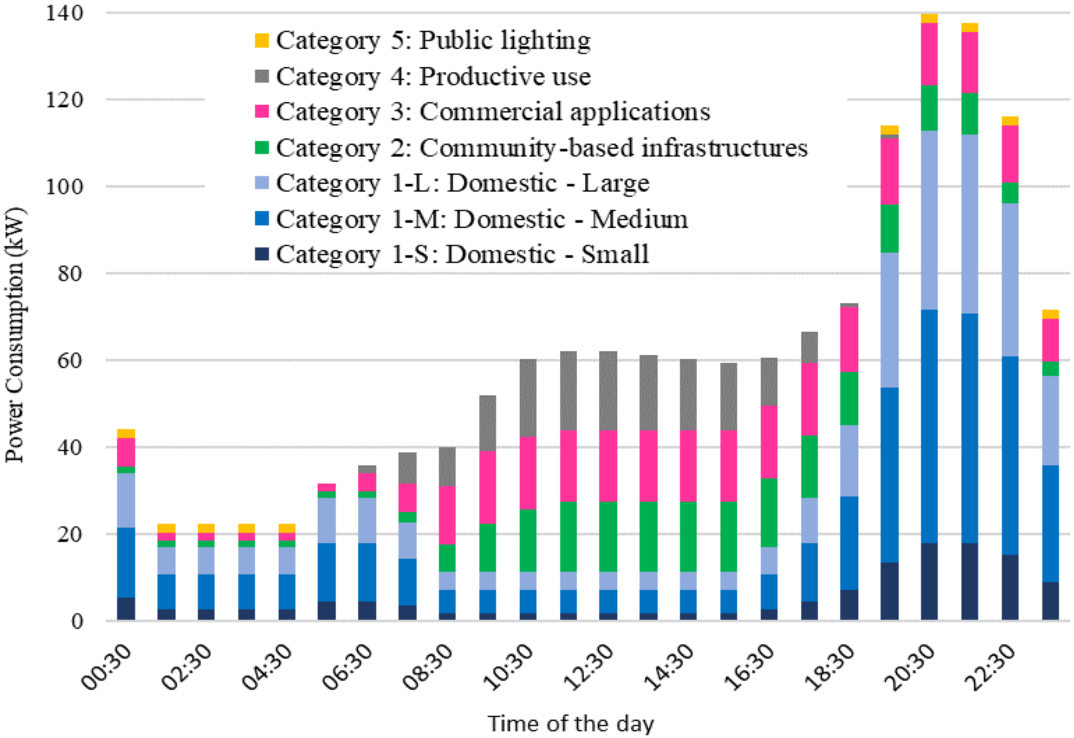
Case Study Results



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Reconstitution of the Design Load profile

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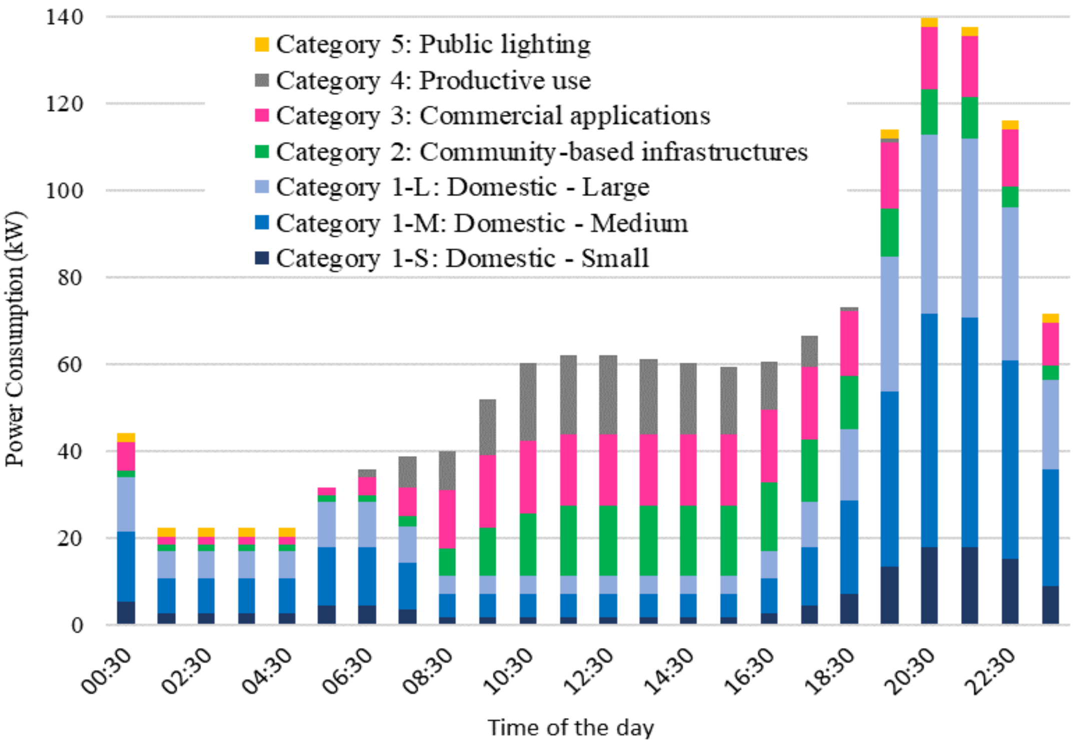

2.5 kWh/day.user
0.25 kW peak per user

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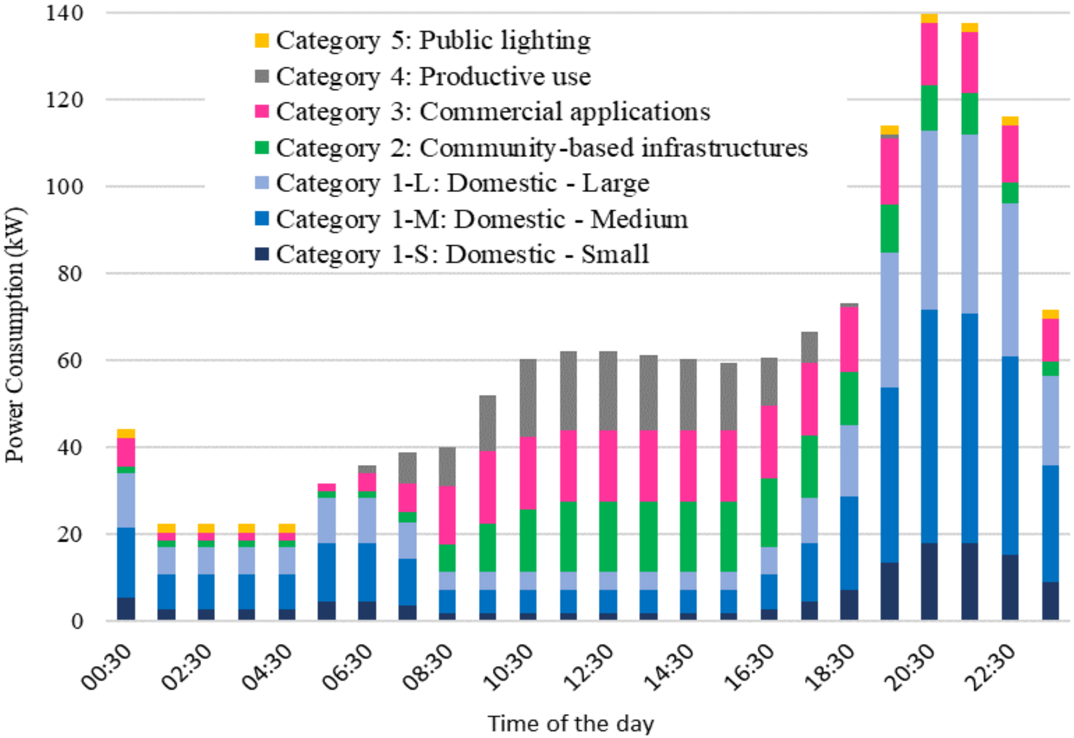

2.5 kWh/day.user
0.25 kW peak per user

Neighbouring village figures

2.8 kWh/day.user
0.23 kW peak per user

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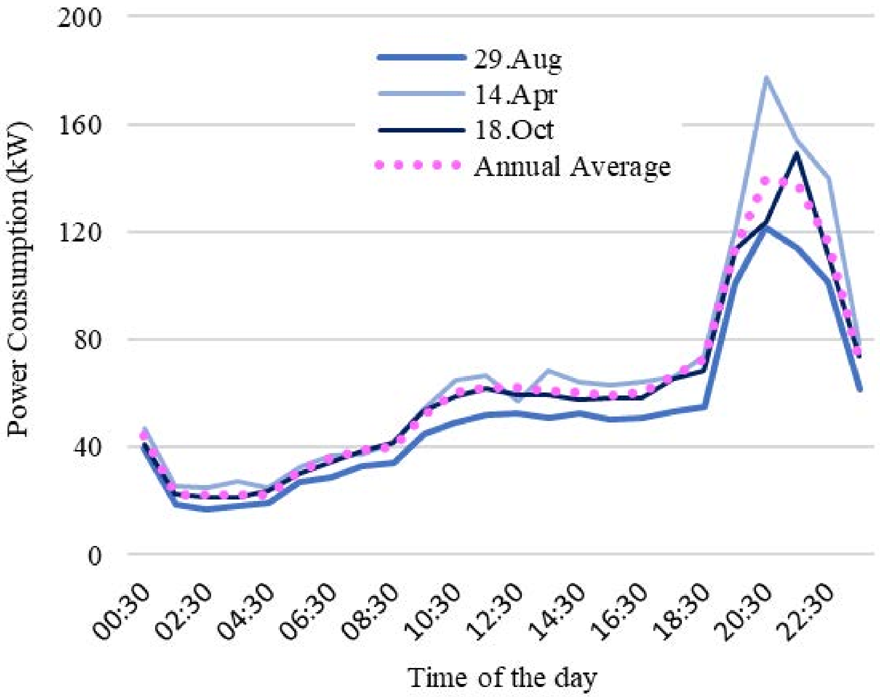
Addition of the variability factors

Case Study Results



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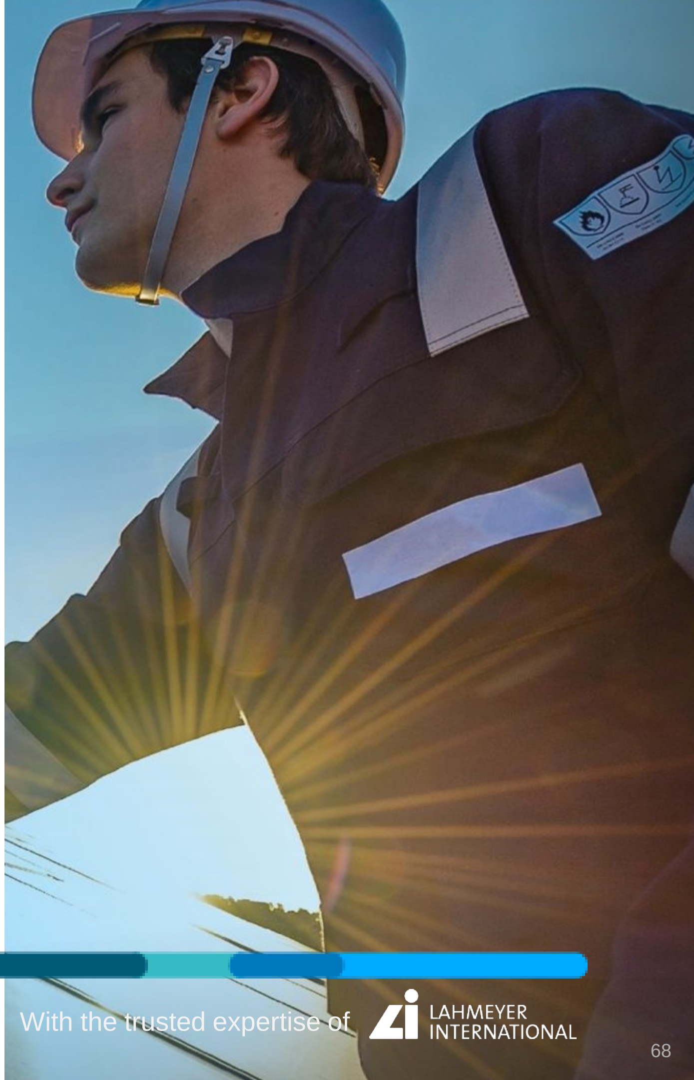
04

Conclusion



Conclusion

- Objective to reduce uncertainty on the load estimation with the use of adjustment factors

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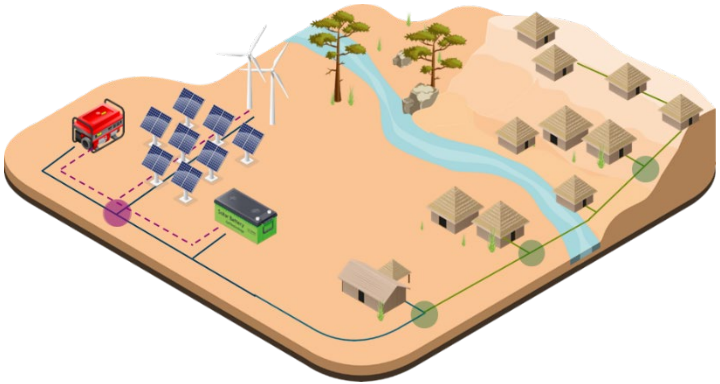
- However, preparing an **accurate** load profile in rural environments is **challenging**

Modular concept design of the hybrid power plant



Thank you very much for your attention

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