Remote Autonomous Energy Systems Design for Developing Countries

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1. Motivation and objectives

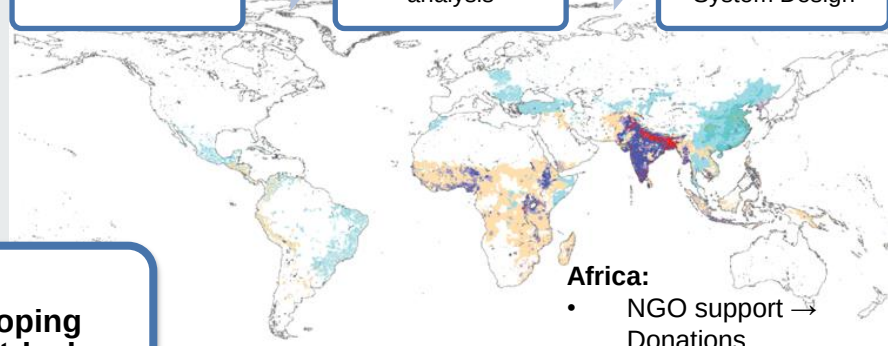
Overall Motivation

Global Status

Achieving universal access to modern energy remains imperative; fossil-fuel subsidies continue to distort energy markets.

In **2011**, nearly **1.3 billion** people worldwide **lacked access to electricity** and more than 2.6 billion relied on the traditional use of biomass for cooking. **Over 95% were located in Asia and sub-Saharan Africa.**

Site visits → Questionnaire analysis → Rural Electrification System Design



Global Awareness

United Nations
Millennium Development Goals

SE4ALL Initiative
2012 – **Year** of Sustainable Energy for All

2014-2024: **Decade** of Sustainable Energy for All

Developing Countries' Electrification Status

International milestones:
Millennium Development Goals, SE4ALL,…

Rural Electrification current approach

Sustainable Rural Electrification

Africa:
- NGO support → Donations
  - ↳ Small scale **collective** energy systems

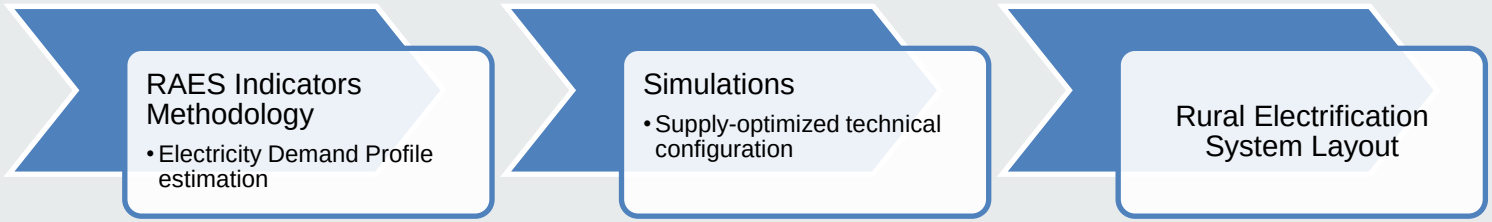
South Asia:
- Microcredit origin → private ownership
  - ↳ Small scale **individual** energy systems

How to design Remote Autonomous Energy Systems?

Research Outline

Phase 1:
Choice of the most suitable energy/ development indicators to "built" the demand estimation model

Phase 2:
Use case-studies from literature to test and validate/adjust the RAES Modeling Tool parameters



Step 1:
colect village's characteristics and development stage

Step 2:
Run that electricity demand profile

Step 3:
Select the best solution to implement the rural electrification project

Polygeneration Energy Container

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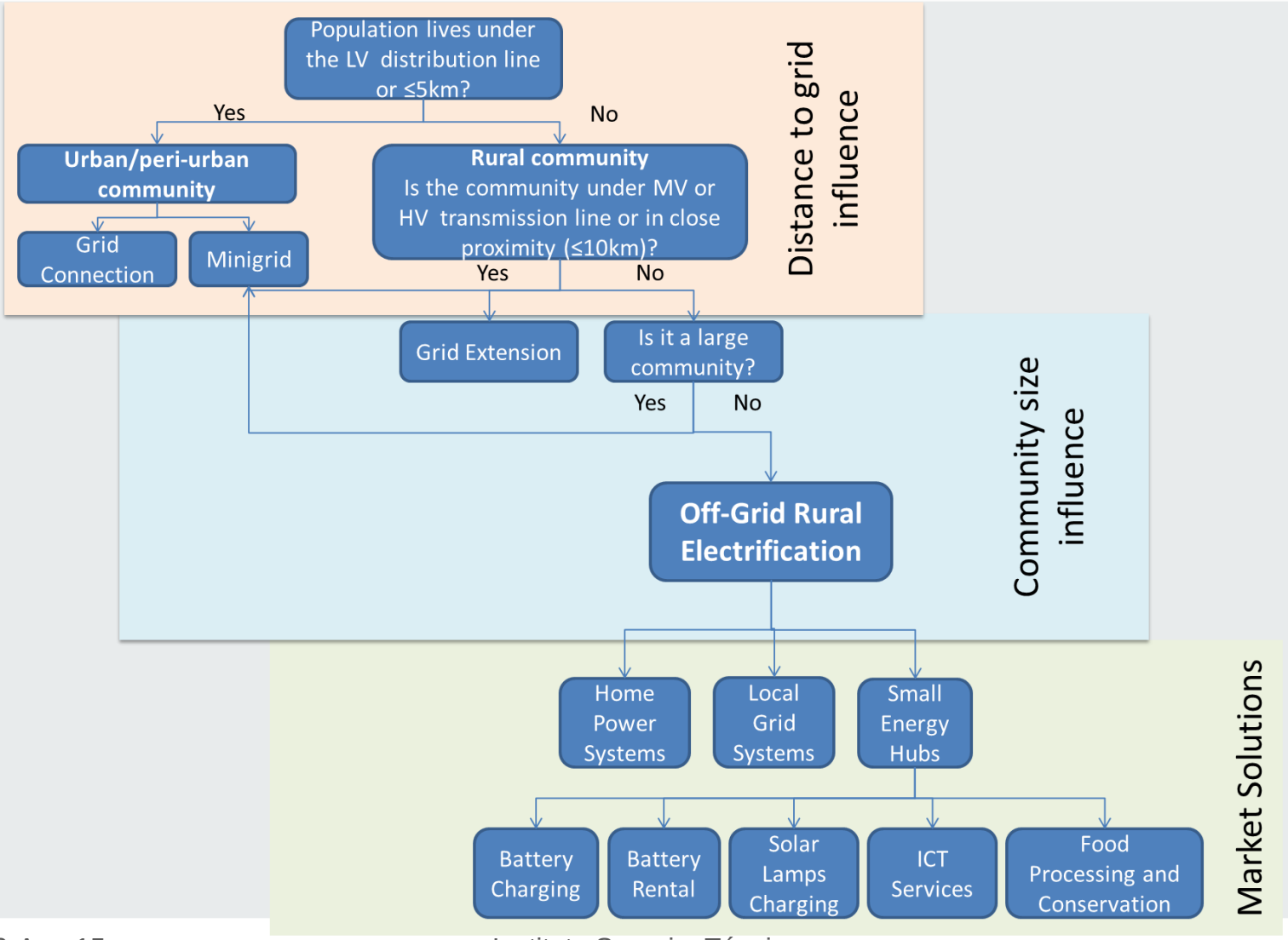
2. Current implementation of rural electrification

Rural Electrification Decision Tree



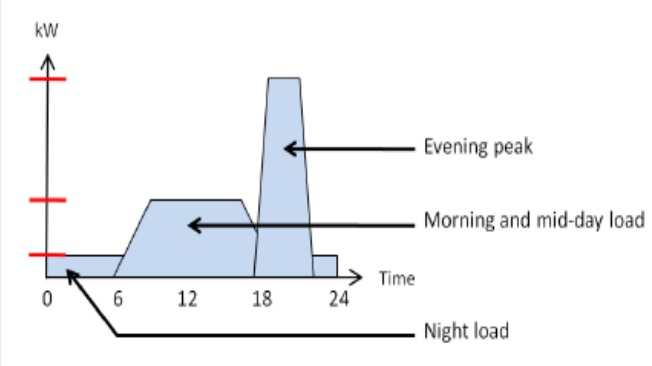
Forecasting energy demand: Planning approaches

- Energy needs obtained using questionnaires:

Country/ Region	Year	Aimed public	Study Focus
Ethiopia	2010	General Ethiopian citizens	Assess opinion towards sustainability of new proposed energy investments
Bangladesh	2013	Households	Evaluate the potential for using biogas in villages of Bangladesh
Uganda	2011	NGOs operating in remote villages	• Current Social View • Biomass Supply Potential • Energy Use: Household / Farming • Farming Activities / Current Machinery
Rwanda	07/2012 – 04/2013	Biogas sector	• assess the current biogas sector in Rwanda • make projections of biogas development by 2020 • analyze the socio-economic and environment benefits of biogas use to the Rwandan community
Asia Latin America	1999	Key persons in PV projects and commercial PV companies	Understand the potential impact and limitations of solar photovoltaic (PV) applications on sustainable agriculture and rural development, with a special attention to the effects on income generating activities and social welfare

- Appliances' profiles:

$$\sum energy\ uses$$



Forecasting energy demand: Energy Uses

Productive Uses	Agricultural activities Food processing Small businesses
Community Services	Education Health Care Community Services
Households	Lighting; Cooking; Radio and/or television; Cell phone charging; Fan; Refrigerator.

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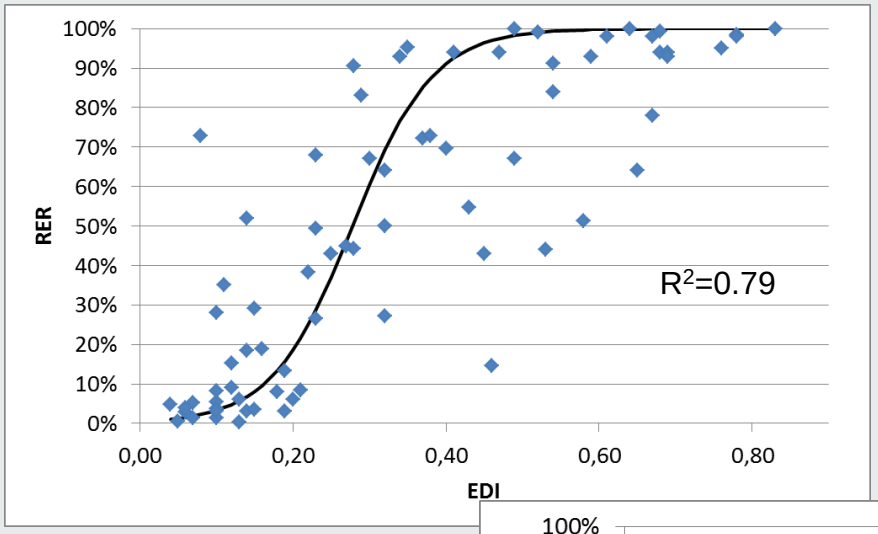
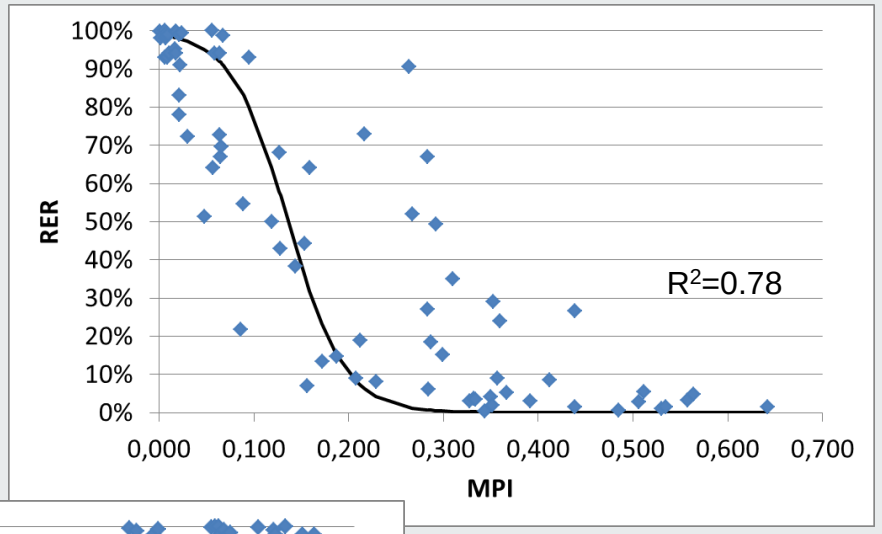
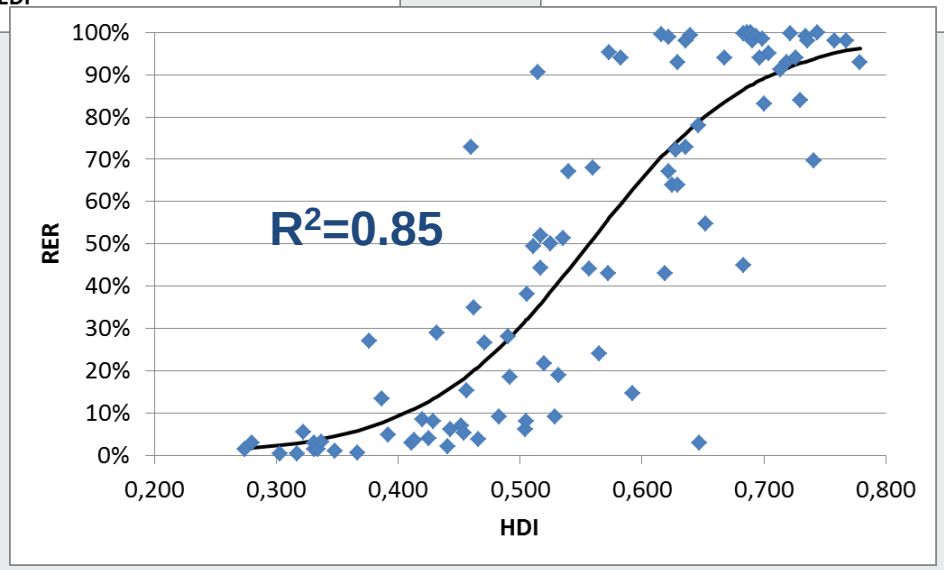
3. Remote Autonomous Energy Systems Methodology

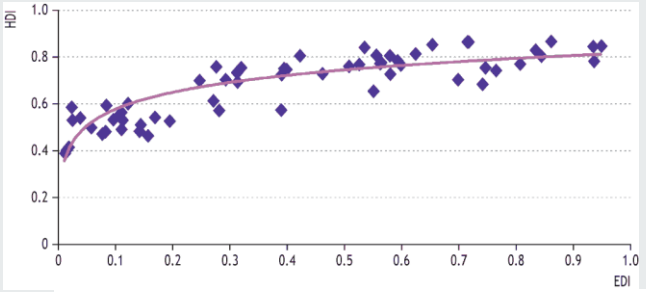
Choosing an index: Development Indexes versus Rural Electrification Rate

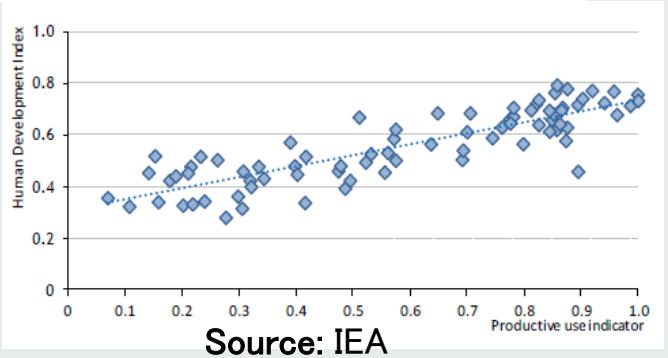




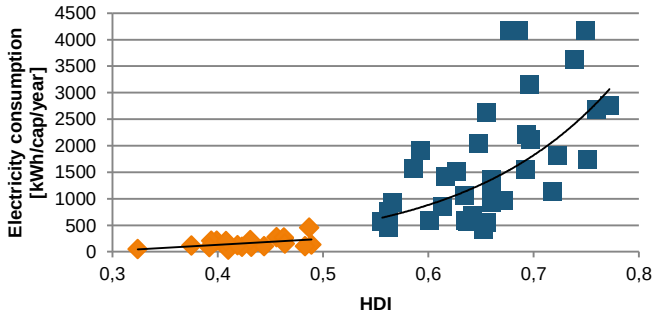


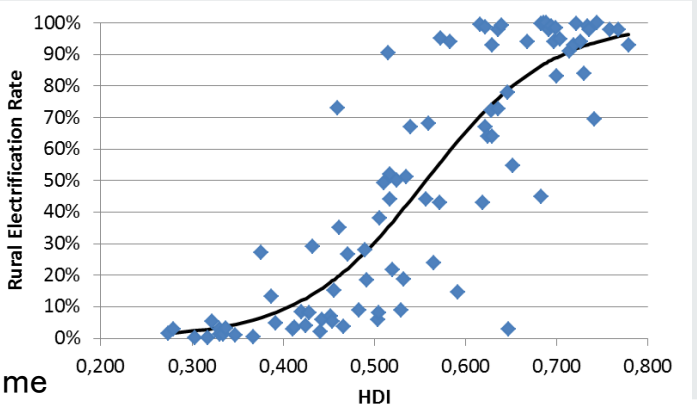
New approach: Development Indicators and Energy Availability





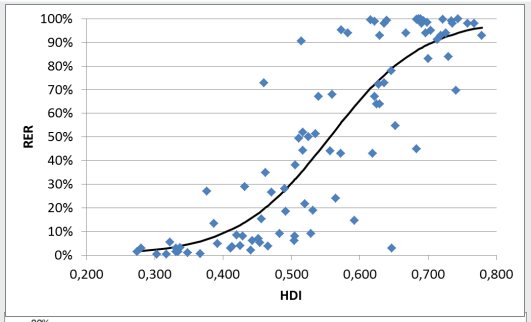
Source: IEA

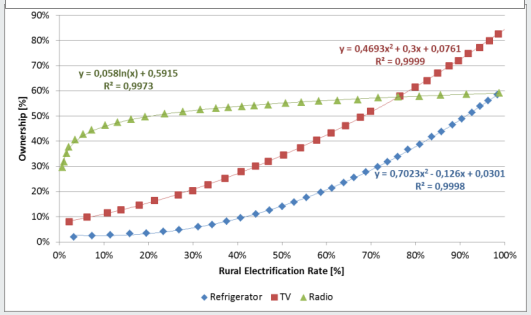




Data from World Bank and United Nations Development Programme

RAES - Planning methodology Summary

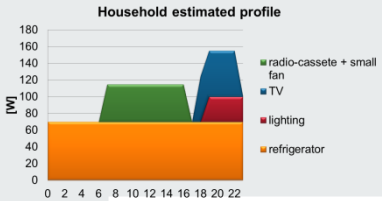


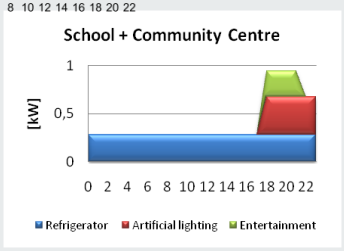


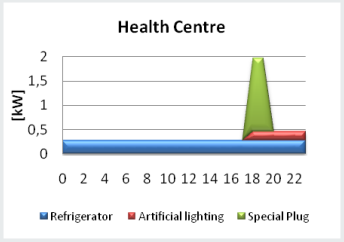
Indicators methodology

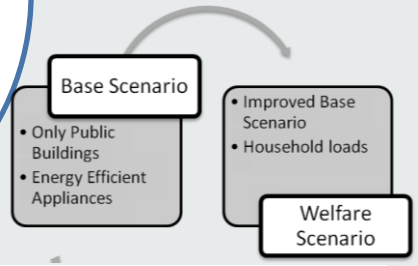
Individual energy profiles

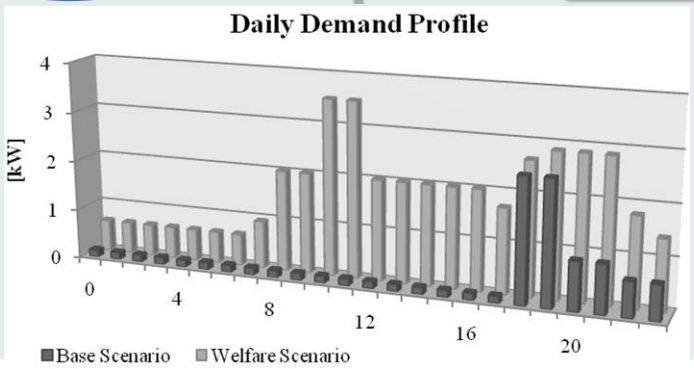
Village energy needs and demand profile







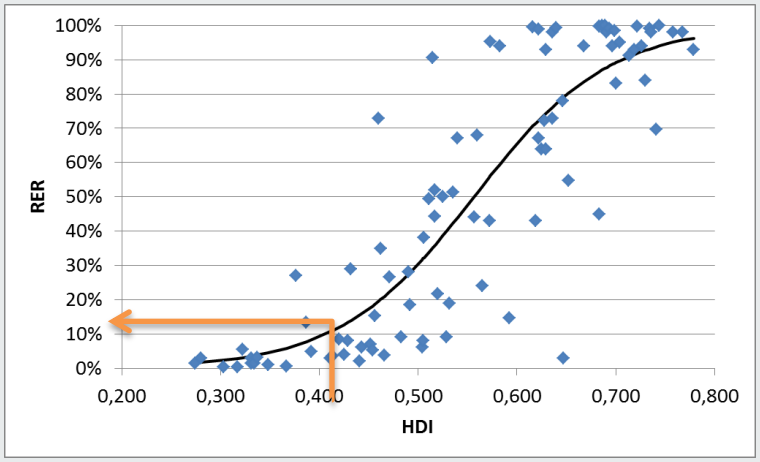


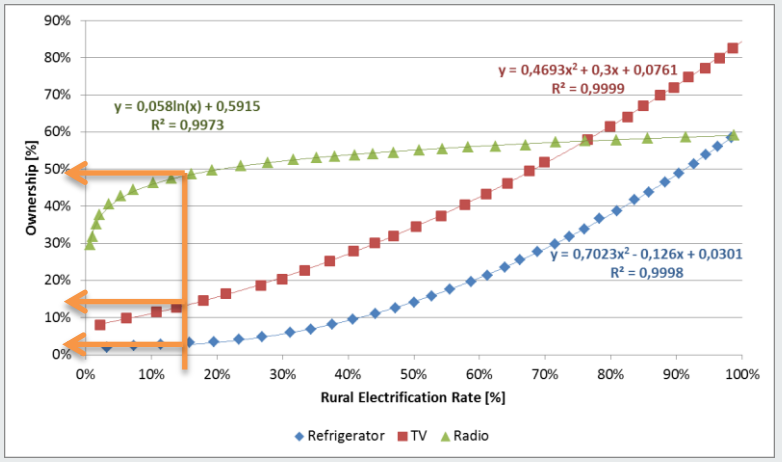


RAES - Planning methodology
Example: Kenya 2000

Kenya
Year 2000

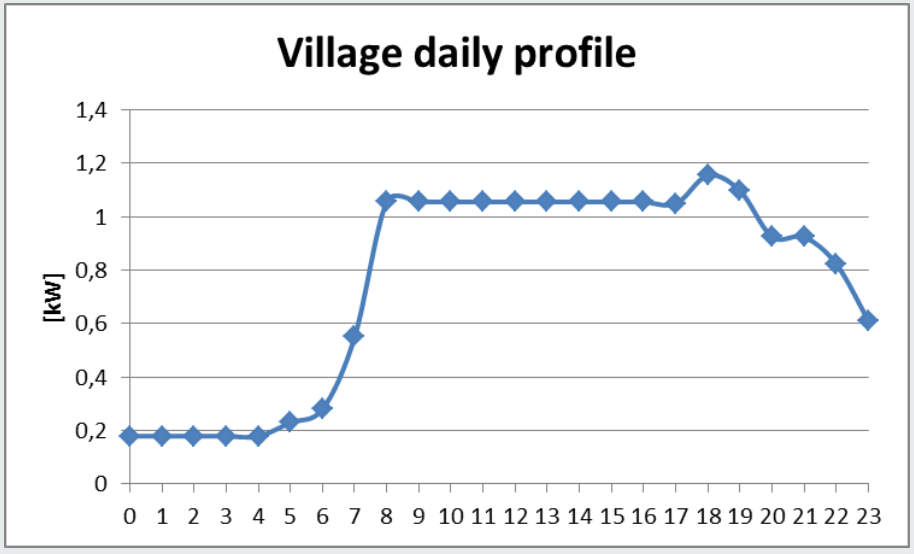
<u>Inputs:</u>
HDI=0.447
65 Households
1 School
1 Health Center





<u>Calculations:</u>

RER=0.168
11 Households
1 refrigerator
11 lighting
2 TV
6 radios



<u>Final Result:</u>
Village Energy Needs
18.04 kWh/day

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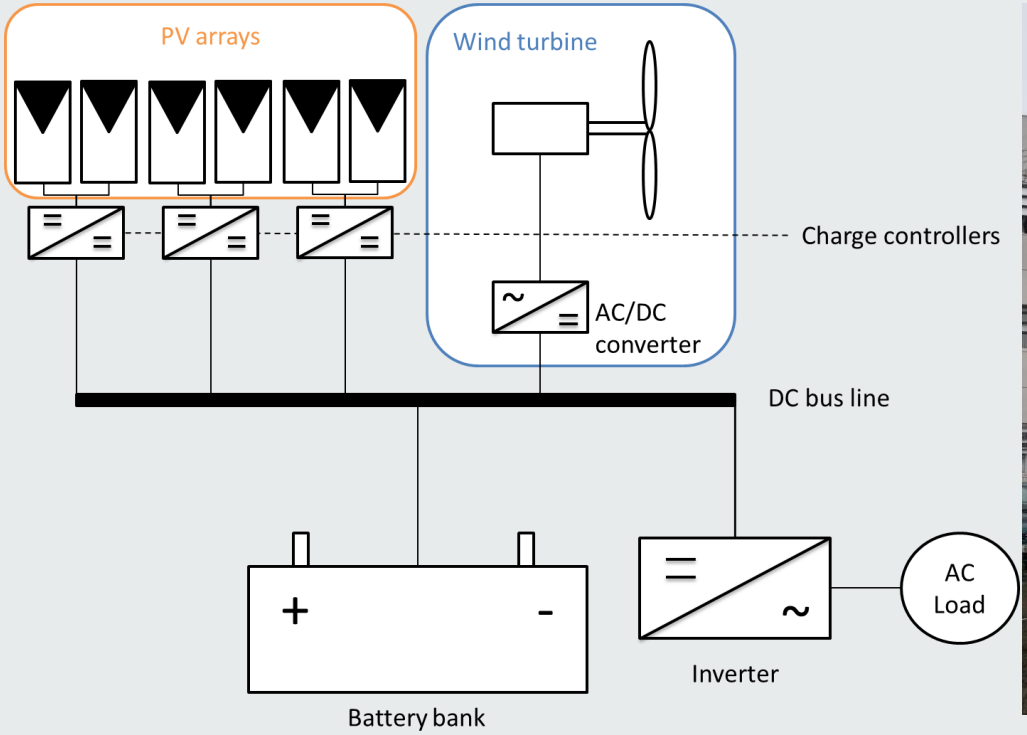
4. Polygeneration Energy Container

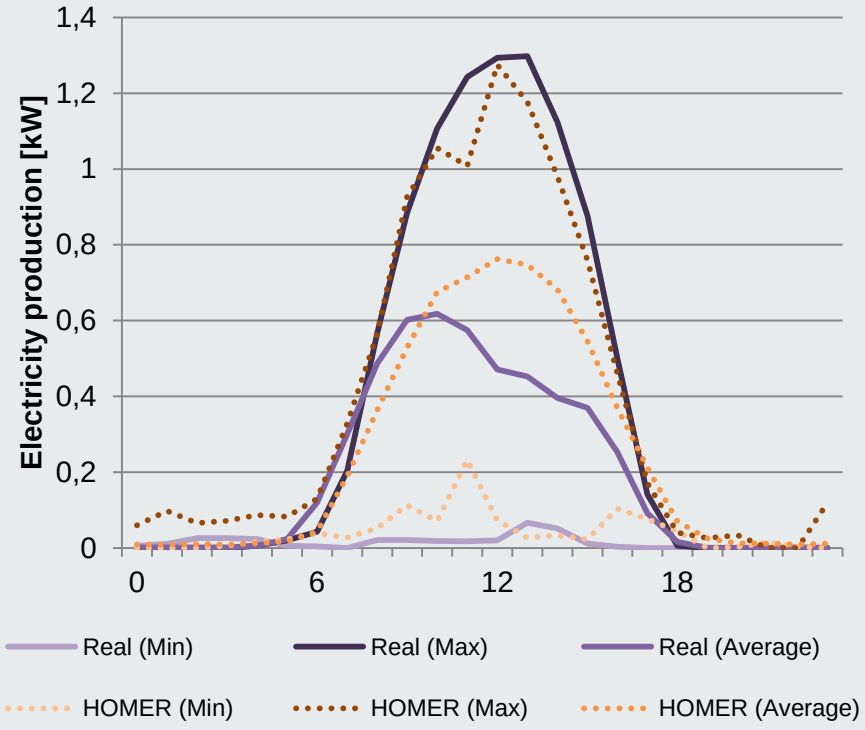
Polygeneration Energy Container @ IST-TagusPark, Portugal



- **Total capacity: 1.8 kW + 720Ah Battery bank**
- **Uninterrupted operation**: 2+ year
  - Total production (01/09/2012 - 21/08/2014): 3408 kWh;
- Testbed for:
  - Management system: PEC ↔ Energy Efficiency in Buildings Laboratory;
  - **installation, operation and maintenance challenges**;

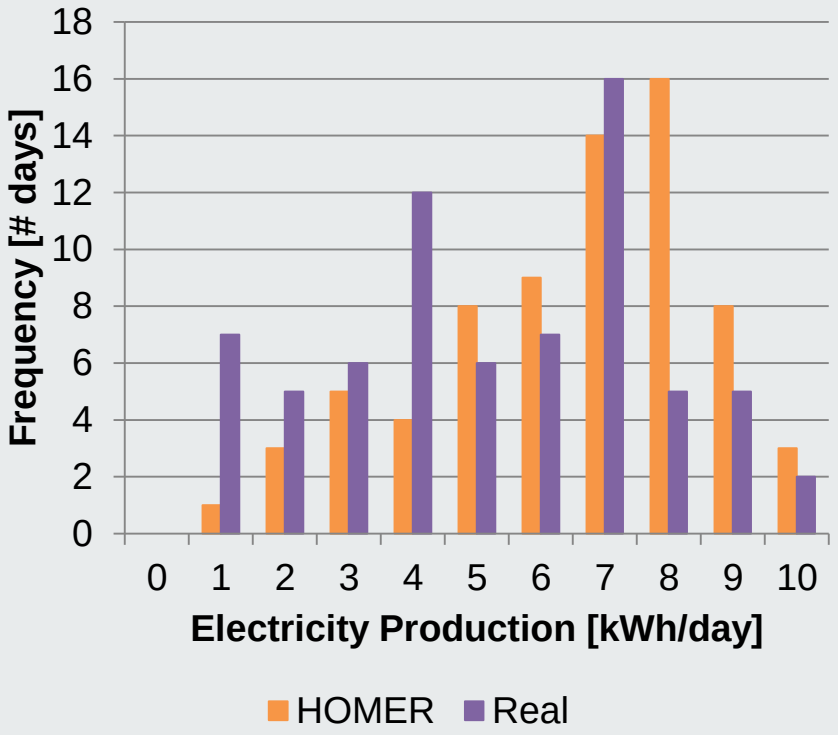
PEC operation results: Spring 2013

PEC Production daily profiles

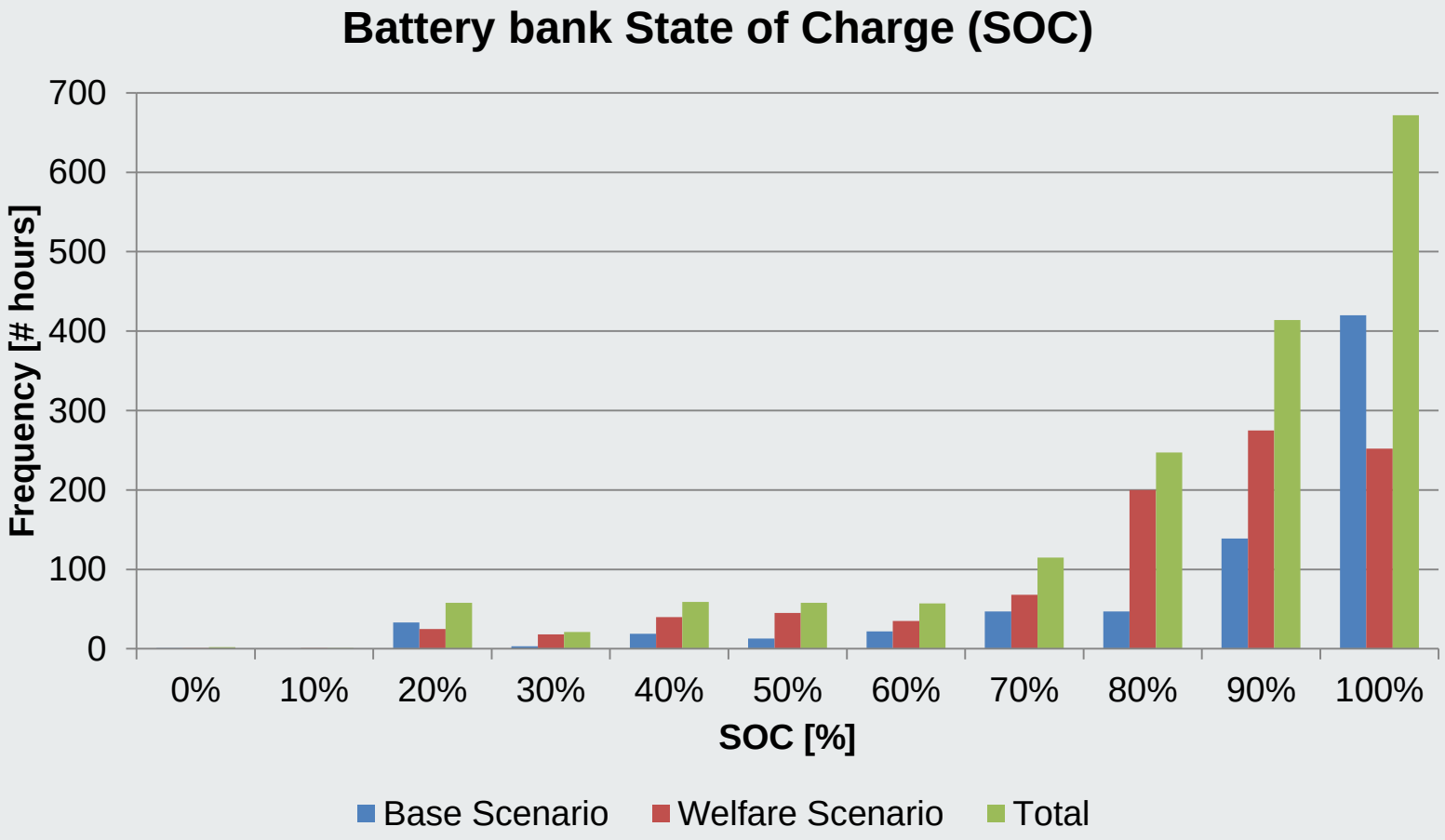


Electricity production histogram

comparison between real production data and forecasted production

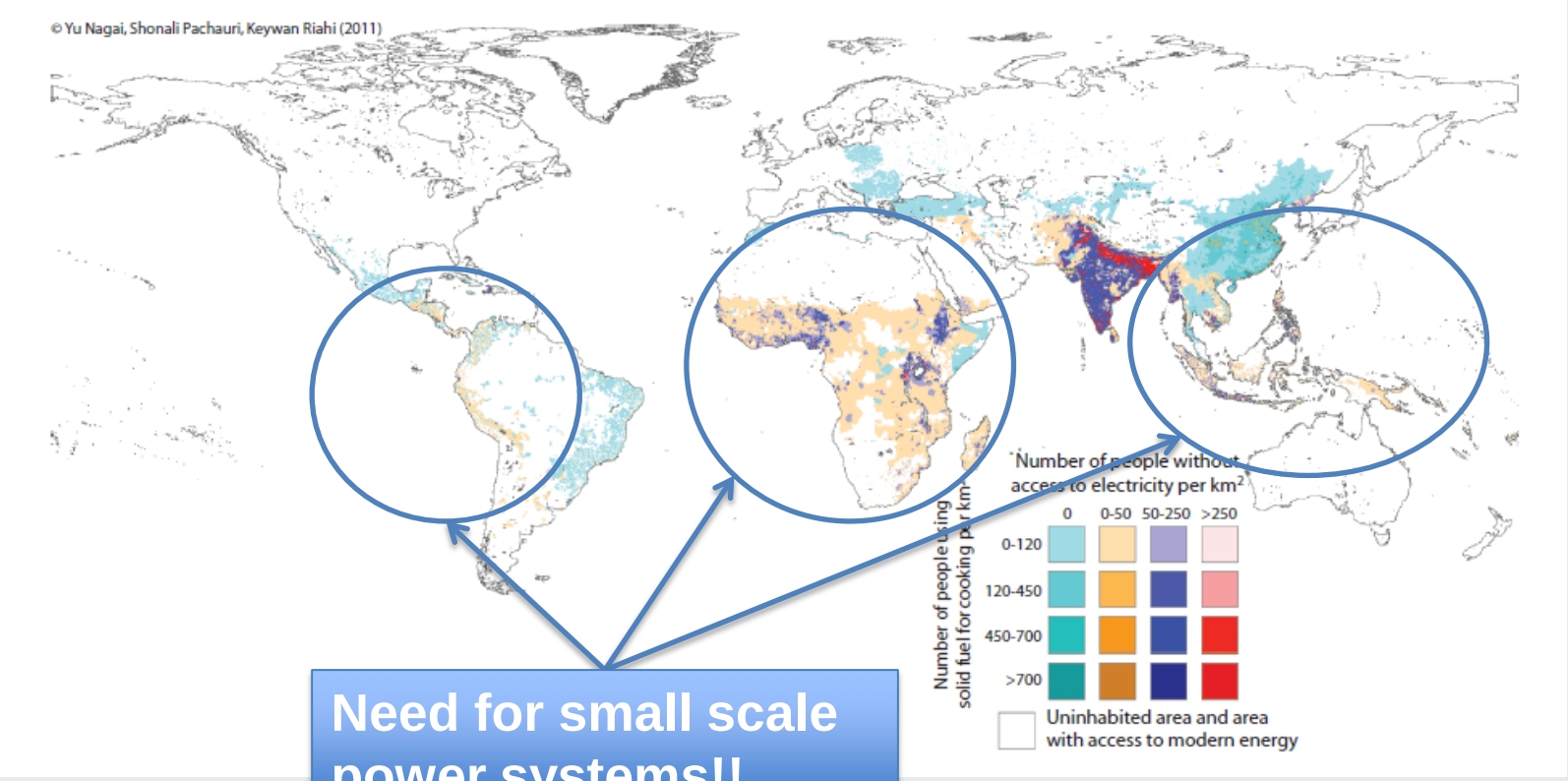


PEC operation results: Spring 2013



PEC – Further Business Models Analysis

Matching an existing need with a new product



Source: GEA, 2012: *Global Energy Assessment – Toward a Sustainable Future*, Cambridge University Press, Cambridge UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.

5. Conclusions and Future Work

- Rural Electrification **cannot** be “framed” into *One-size-fits-all* approach!
- Possible Follow-ups from the current work:
  - Rural Electrification Public Policies;
  - PEC Prototype “real conditions” field tests;
  - Business Models detailed analysis.

Publications:

- R. Paleta, A. Pina, C. A. Silva, Remote Autonomous Energy Systems Project: Towards sustainability in developing countries, Energy, Volume 48, Issue 1, December 2012, Pages 431-439 (Digital Object Identifier: dx.doi.org/10.1016/j.energy.2012.06.004)

- Rita Paleta, André Pina, Carlos A. Silva, Polygeneration Energy Container: Designing and testing energy services for remote developing communities, IEEE Transactions on Sustainable Energy, Volume 5, Issue 4, 2014 (Digital Object Identifier: 10.1109/TSTE.2014.2308017)

- Sara Ghaem Sigarchian, Rita Paleta, Anders Malmquist, André Pina, Feasibility study of using a biogas engine as backup in a decentralized hybrid (PV/wind/battery) power generation system – Case study Kenya, Energy, Available online 30 July 2015, (Digital Object Identifier:10.1016/j.energy.2015.07.008).

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