Energy access and off-grid electrification in sub-Saharan Africa: Challenges and Opportunities

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OVERVIEW

1. **The Research projects**
2. **Background: energy access & rural electrification in SSA**
3. **Off-grid electrification & systems**
4. **Community ecosystems & demand-side**
5. **Implications for business models**
6. **Policy level**
7. **Summary**
8. **Further Readings/Publications**
9. **Q&A**

1. THE RESEARCH PROJECTS

Project ‚RISE‘: Renewable, Innovative & Scalable Electrification

- GCRF-funded research project at SSEE & UCT
- Analysis of framework for rural electrification in Uganda & Zambia
- 3 levels: (1) Institutions (2) Community (3) Businesses

Project ‚Mumuni Singani‘

- RISE ‚Spin-off‘ supported by GCRF
- Development of a blueprint for integrated infrastructure solutions
- Multi-partner-concept & integrated approach

Project implementation (tbc)

- Integrated Infrastructure Concept - Implementation at 3-5 sites in Zambia
- Partnership with private sector & NGO
- Water-Energy-Food Nexus & demand side focus

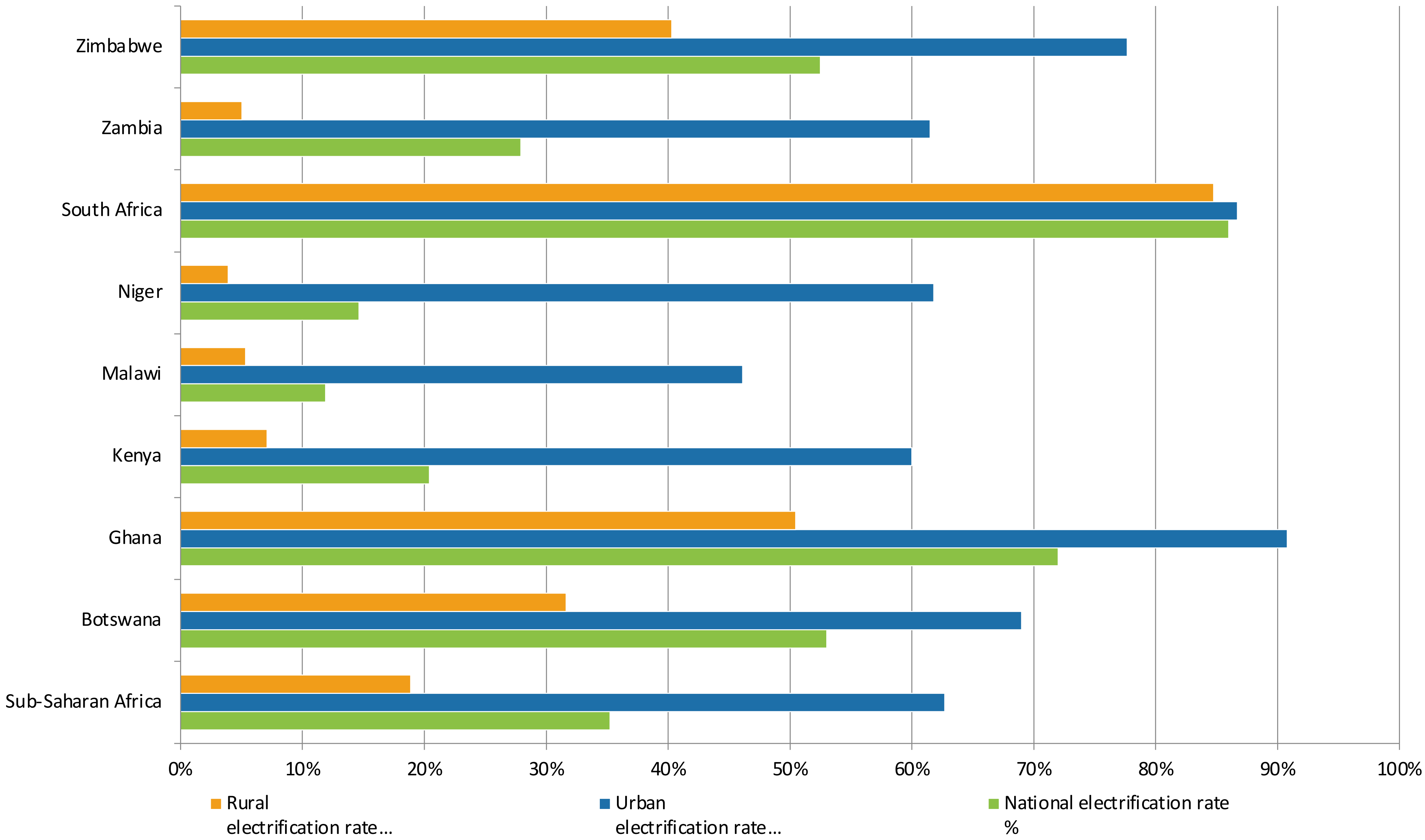
2. ENERGY-ACCESS IN SUB-SAHARAN AFRICA: URBAN VS. RURAL

78% Energy - Access Rate*

31% Energy - Access Rate*

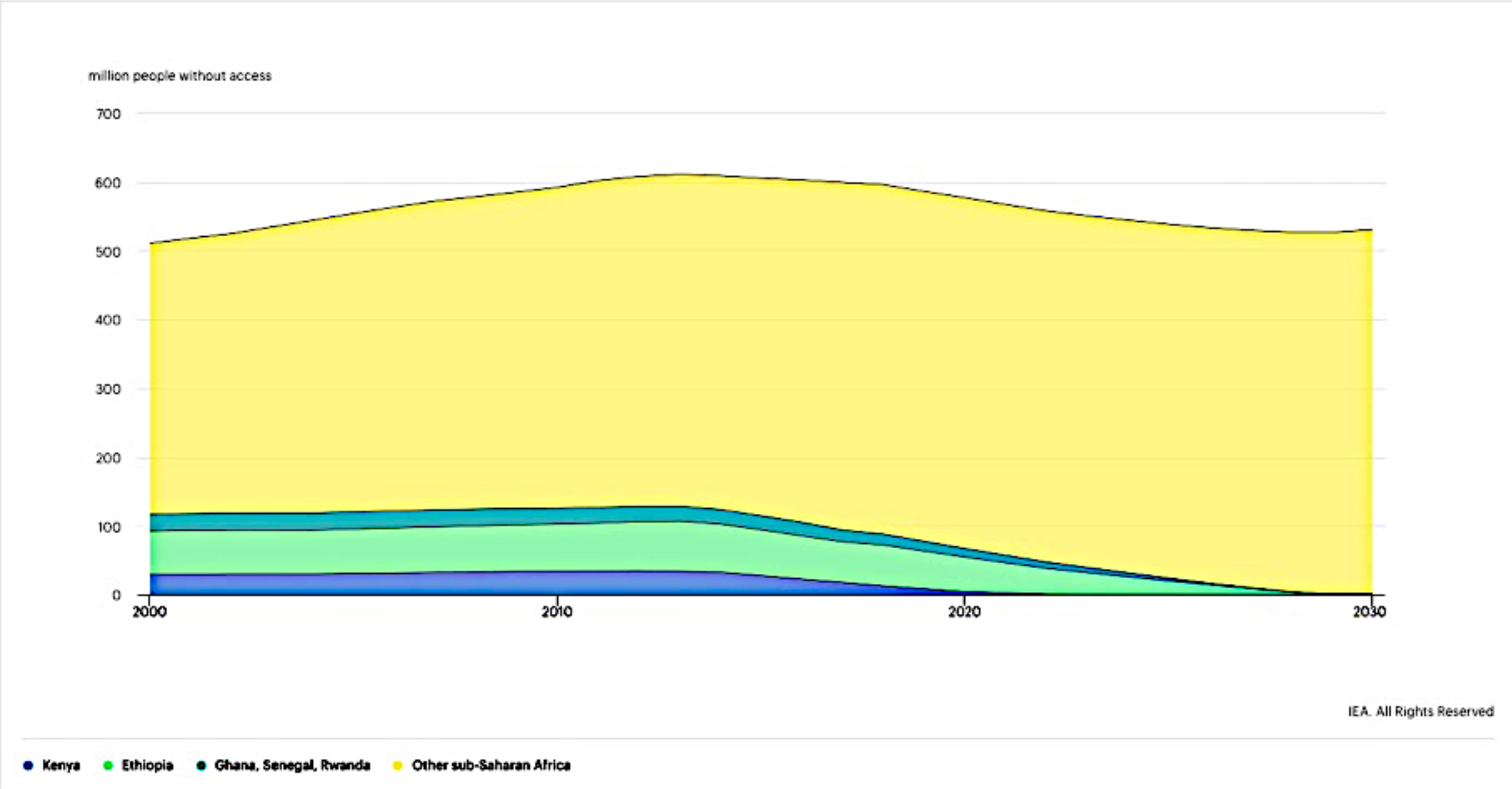
*Regional Average as of 2018 incl. South Africa; Source: http://data.worldbank.org

2. BACKGROUND: ENERGY-ACCESS IN SUB-SAHARAN AFRICA - NATIONAL VARIATIONS



http://www.worldenergyoutlook.org

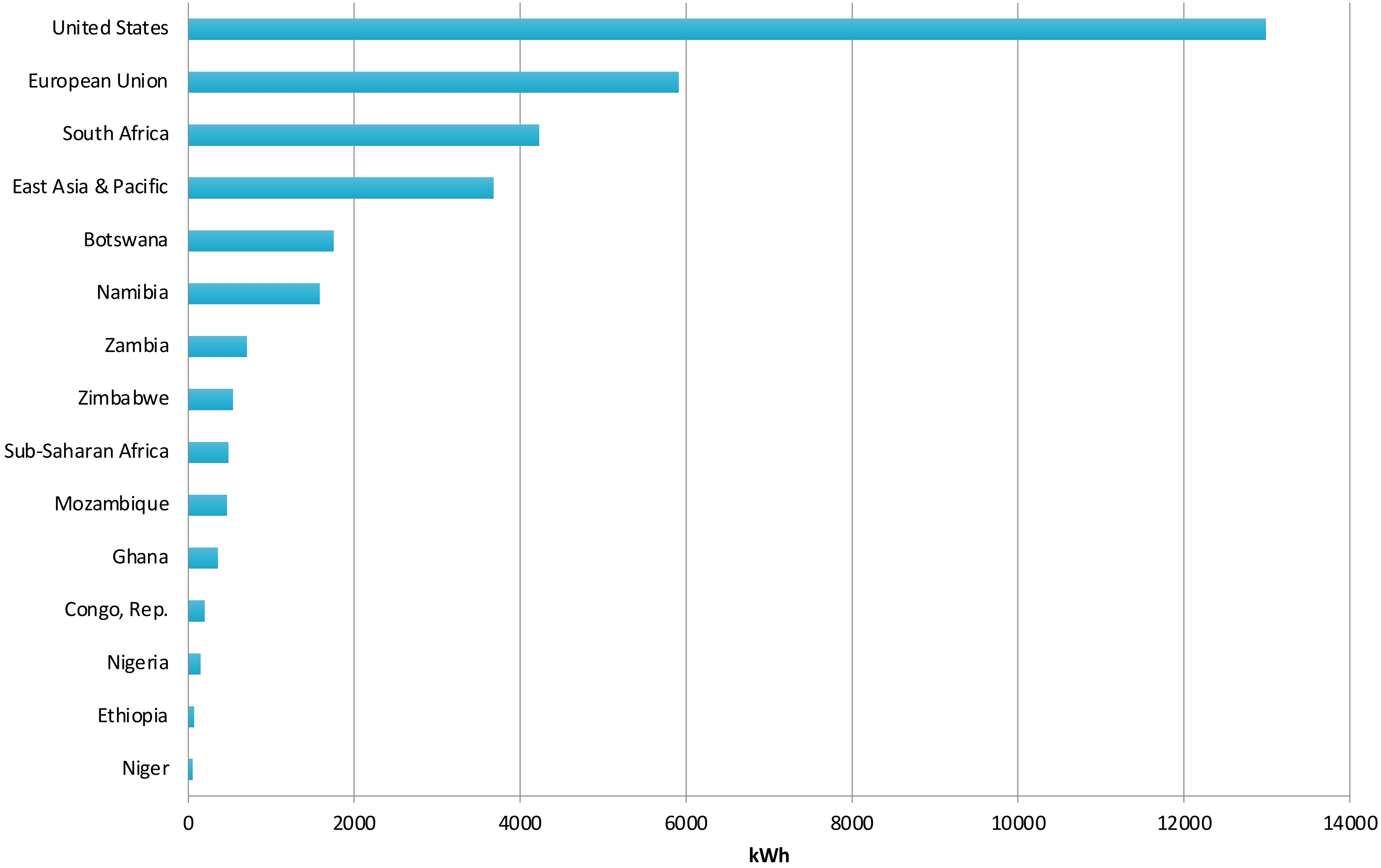
2. BACKGROUND: NUMBER OF PEOPLE WITHOUT ACCESS TO ELECTRICITY IN SSA



Last updated 12/2019

IEA, *Number of people without access to electricity in sub-Saharan Africa in the STEPS*, IEA, Paris https://www.iea.org/data-and-statistics/charts/number-of-people-without-access-to-electricity-in-sub-saharan-africa-in-the-steps

2. BACKGROUND: ELECTRIC POWER CONSUMPTION (KWH PER CAPITA)

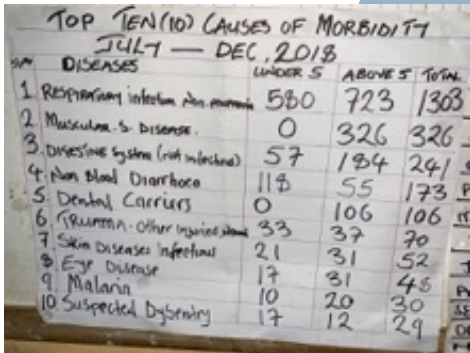


2014, http://data.worldbank.org


Education


Farming / Food Security


Local Business/Income Growth



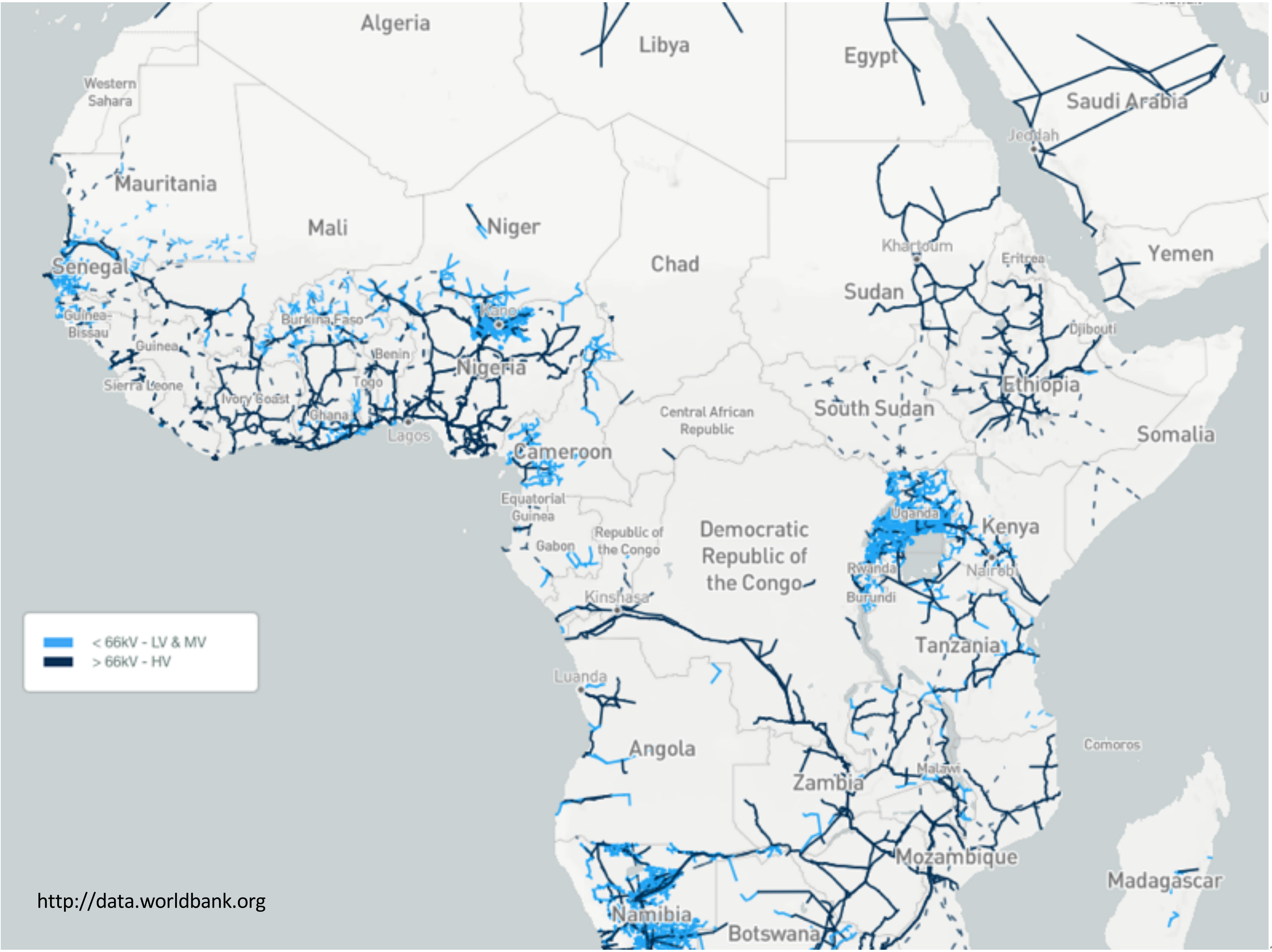
Health


Water supply


Environment/Climate Change


1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS
Direct/short-term impact
Indirect/long-term impact

3. OFF-GRID ELECTRIFICATION VS. TRANSMISSION GRID




Lake Mweru
Lake Rukwa
Moxico
Northern
North-Western
Luapula
Copperbelt
Zambia
Western
Central
Lake Malawi
Muchinga Mountains
Malawi
Eastern
Lusaka
Lusaka
Lilongwe
Caprivi
Southern
Lake Kariba
Lake Cahora Bassa
North West
Tete

3. OFF-GRID SYSTEMS MATRIX FOR RURAL ELECTRIFICATION[1]

OFF-GRID SYSTEMS MATRIX	DECENTRALIZED		DISTRIBUTED
Rural Energy Uses	**Stand-alone Systems**	**Micro-Grid Systems**	**Hybrid Micro-Grid Systems**
Household basic needs	Home-based Systems	Systems including a distribution grid	Systems including a distribution grid
Community services	Community-based Systems		
Productive uses	Productive-based Systems		
Consumer Number	Single	Multiple	Single OR Multiple
Energy Sources	Single		Multiple

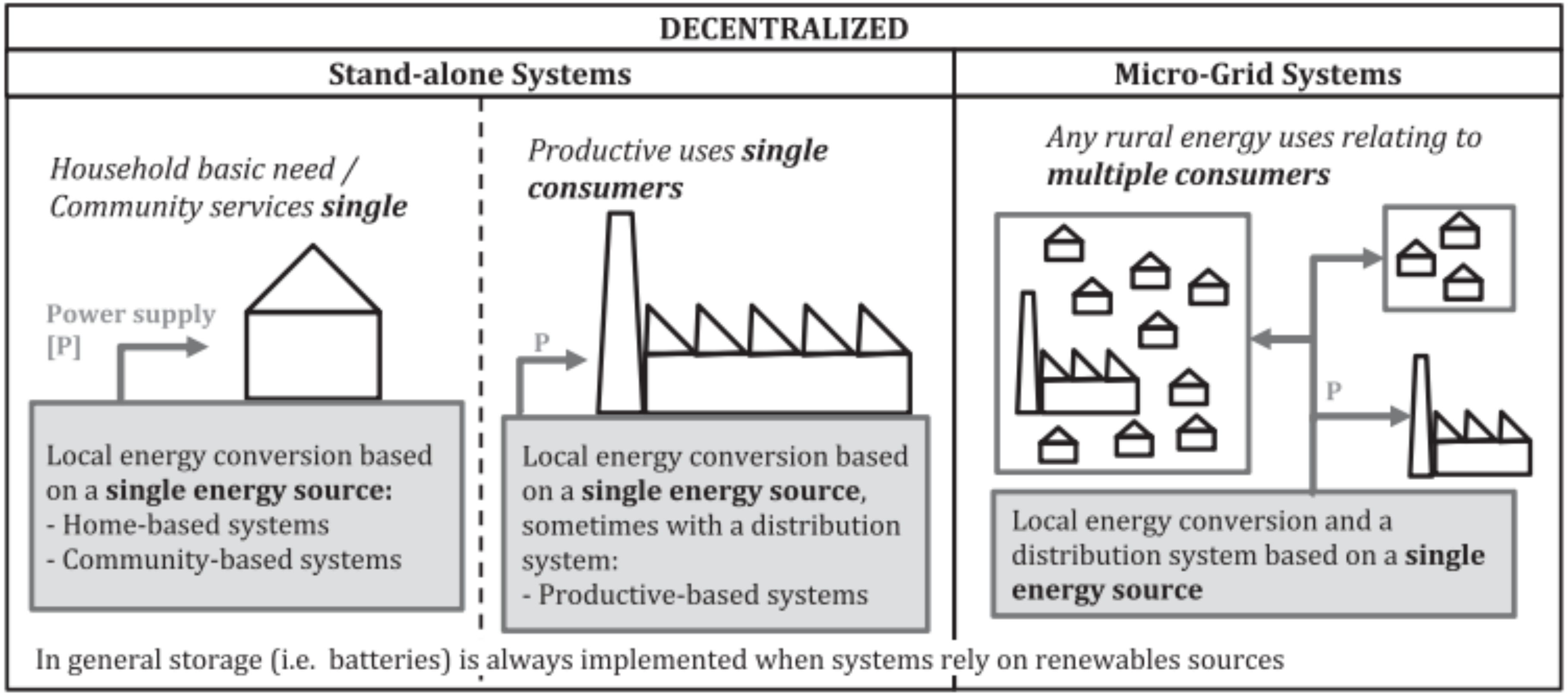
Home-based System, approx.200W, Zambia

Productive-based system: Solar-Hammer Mill, 12.5 kWp, DC,, Zambia

Community-based system, clinic, approx.400W, DC, Zambia

Mini-Grid system, Sinda, 30 kWp, AC, Zambia

[1] Mandelli, Stefano, Jacopo Barbieri, Riccardo Mereu, and Emanuela Colombo. 2016. "Off-Grid Systems for Rural Electrification in Developing Countries: Definitions, Classification and a Comprehensive Literature Review." Renewable and Sustainable Energy Reviews 58: 1621–46.

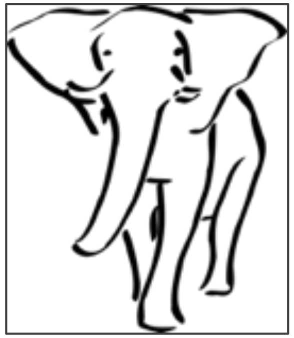


[1] Mandelli, Stefano, Jacopo Barbieri, Riccardo Mereu, and Emanuela Colombo. 2016. "Off-Grid Systems for Rural Electrification in Developing Countries: Definitions, Classification and a Comprehensive Literature Review." Renewable and Sustainable Energy Reviews 58: 1621–46.

How can we find sustainable energy solutions & scale them across the region?

How can we avoid ‚White Elephants‘?

How can we balance investment & benefit?



Vision	Reality
 *Source: Zambia Daily Mail, 01/07/2016 coverage of the Mpanta solar PV mini-grid with expected 480 connections	High investment costs (approx. USD 1,3 Mio total grant funding = USD 21 per W installed!) 45kW instead of 60KW operational (technical problems, lightning strikes) “Power is restricted to the above schedule because the inverters overheat” 168 customers instead of 480 High annual deficit (OPEX) Limited productive use of energy Low customer satisfaction, social tensions & imbalance* ** Muhoza, C., & Johnson, O. W. (2018). Exploring household energy transitions in rural Zambia from the user perspective. Energy Policy, 121, 25–34.*

Financial Sustainability (OPEX/CAPEX)

- Tariffs vs. affordability vs. income
- Utilization of energy generated; subsidies vs. cost reflective tariffs
- Revenue collection

Technical & Operational Sustainability

- Maintenance organisation
- Local technical/operational skills; life-cycle of components
- Downtime/technical faults/safety issues

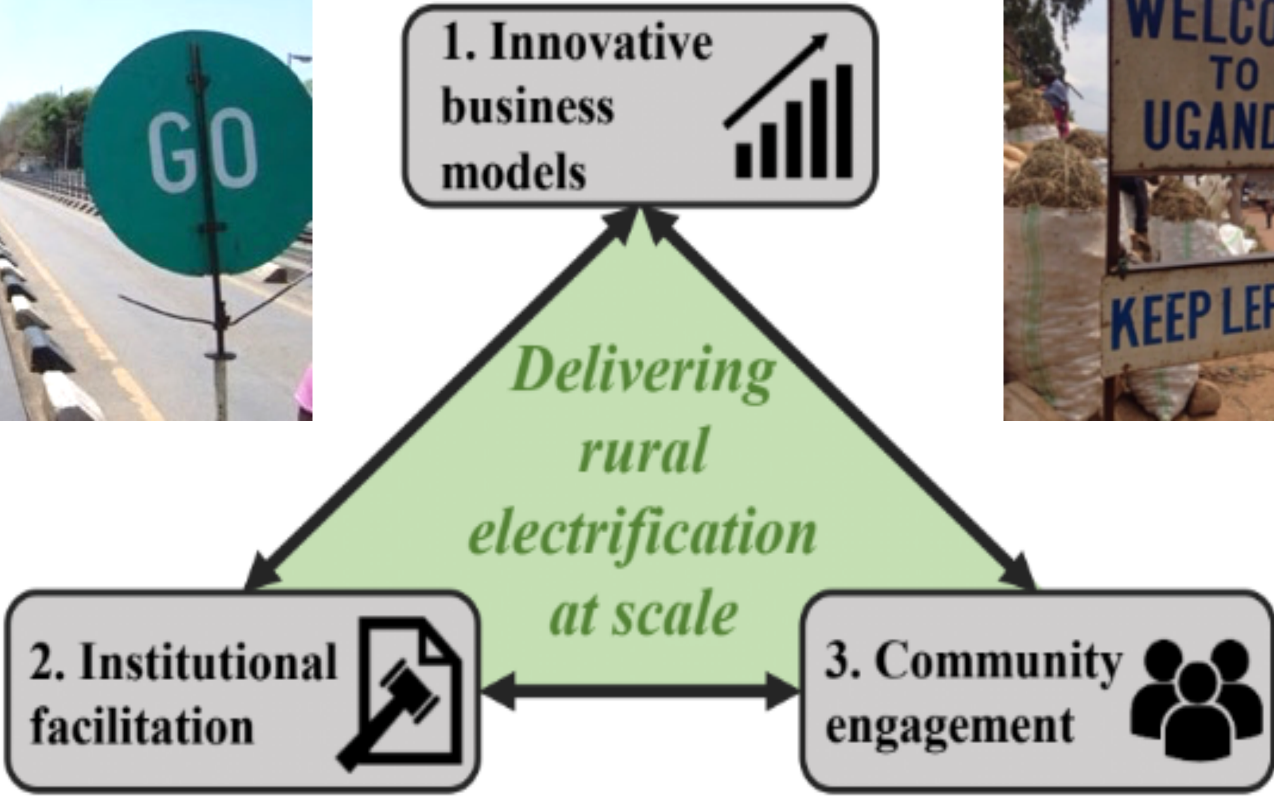
Social Sustainability

- Wider community impact /equal access
- Conflicts/socio-economic-development/gender equality
- Participation/management

Environmental Sustainability

- Land use/environmental impact/wildlife
- Waste management (system & appliances)
- Long-term vs. short.-term impacts

3. OFF-GRID SYSTEMS: RISE-RESEARCH DIMENSIONS & APPROACH



- Around 1800 Community surveys in rural Uganda & Zambia
- Over 50 structured & semi-structured stakeholder interviews (Businesses, Government, Traditional Leaders; NGOs; Donors)
- Focus group discussions; site-visits
- Comprehensive & qualitative document analysis (QDA)

COMMUNITY ECOSYSTEM

- The implementation and operation of any infrastructure solution, including RE-systems, must be seen in the context of its socio-economical environment.
- This environment establishes complex demands and creates opportunities that are substantial for the sustainability of the solution – especially in rural communities in sub-Saharan Africa
- Consequently planning and operation of decentralised energy systems such as solar PV mini-grids need to follow an interdisciplinary approach that takes into account technical, financial, socio-economical, cultural and environmental aspects - not only of the mini-grid itself - but the wider community that is expected to use the mini-grid and benefit from the provision of clean energy

Key finding 1: Energy is key to improving the quality of life in rural Uganda and Zambia, but is not seen as a top-priority purchase

- Many daily activities could benefit from electrification.
- 90% of electrified respondents indicated that electrification has a positive impact on both their personal and communal life.
- About 25% linked their frustrations directly to lack of access to modern energy services.
- However, energy is not a top priority purchase these pressing needs imply limited ability to pay for modern energy services
- But willingness to pay (WTP) for modern energy services is high,~86% WTP for a new or upgraded electricity connection.
- WTP higher for unelectrified respondents and uneducated– 96% of unelectrified WTP

Key finding 2: There is tremendous unmet demand for electricity-enabled cooling, cooking and productive use, but severe challenges remain to unlock it

- Current main electricity uses are lighting, charging devices, and entertainment
- There is a large gap between desired and current electricity use for cooling, cooking and productive uses
- there is a substantial and unserved potential for cooling, cooking and productive uses – up to 500% potential
- 97% are WTP for electricity for productive uses across sectors.
- Current electricity tariffs perceived to be too expensive by a majority (~60%)
- Community experience a range of challenges with electrification.
- Challenges include: - reliability, limited access options, insufficient capacity to meet needs, poor service, safety concerns, security of systems, bureaucracy in connection, technical problems with systems, and limited knowledge of technology and applications.

Key finding 3: Despite various information channels that exist, end-users are not yet well-informed enough about their energy choices

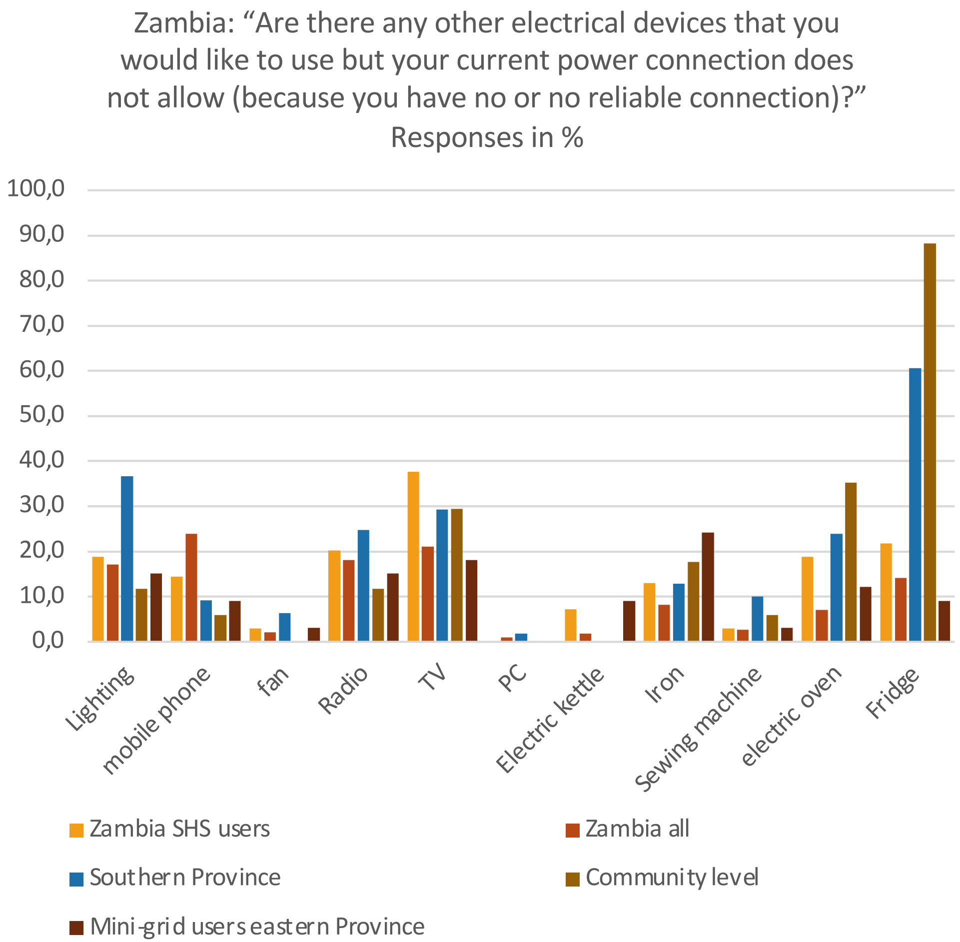
- Lack of information and knowledge is a key challenge of community interaction with energy providers.
- Reasons- inadequate outreach and visibility by service providers and key energy institutions.
- ~ 50% are unaware of energy service providers operating in their localities
- Community members face numerous challenges when interacting with energy businesses. - Only 43% are satisfied with energy services
- top challenges all feature knowledge gaps and understanding of business models
- This highlights the importance of relationship building and communication between any new potential energy provider and the target community.
- 5 main sources of information exist but none of them is outstanding → significant spread of information sources

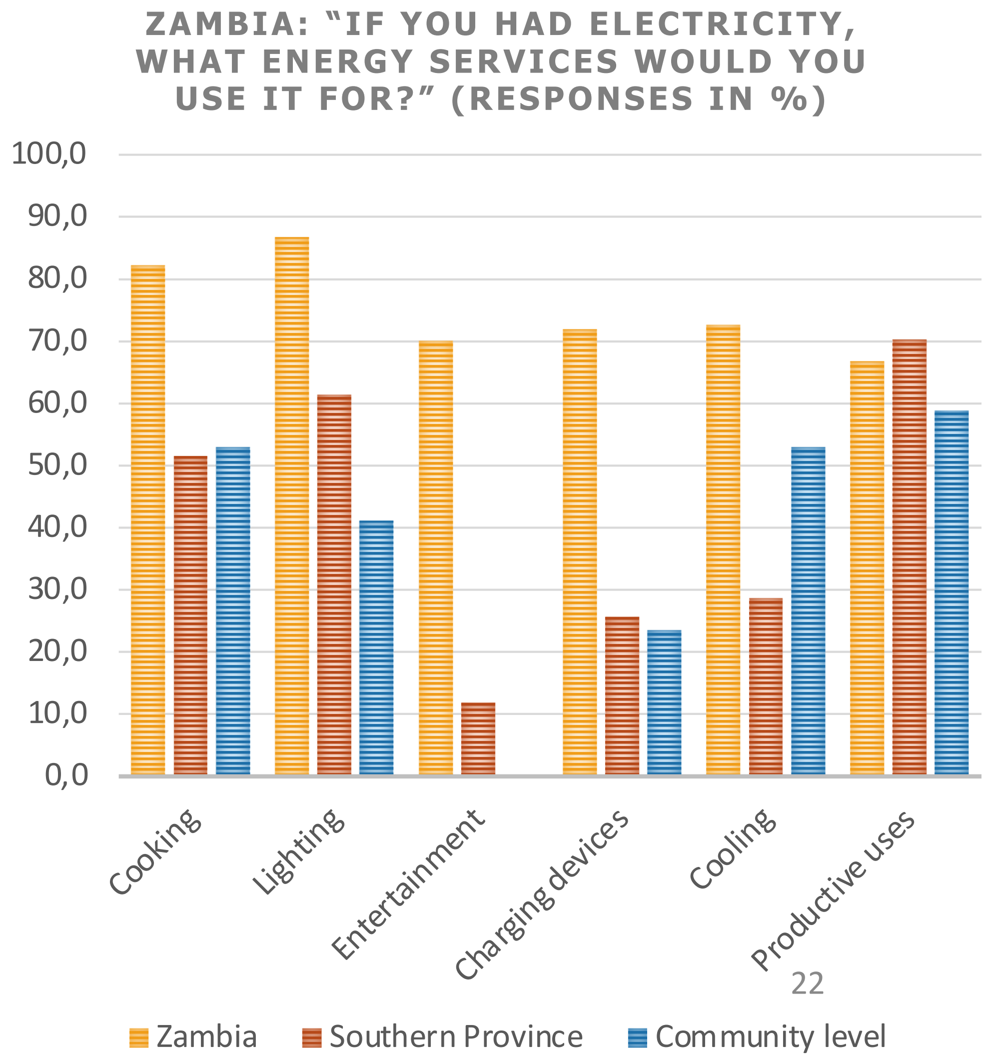
Key finding 4: Communities want to be more included in energy-related decision making using adequate and case-specific points of contact

- Current community involvement in electrification projects is 30%
- High desire for stronger involvement in energy project processes.
- There is no one-size-fits-all for community engagement →there are no clear preferences on involvement methods
- Need to identify individual community desires, to ensure adequate involvement through the relevant means
- Community engagement does not imply involving everyone in decision-making
- Some prefer other skilled community members, community leaders or, to a lesser extent, local authorities (e.g. MPs, councillors) negotiate on their behalf

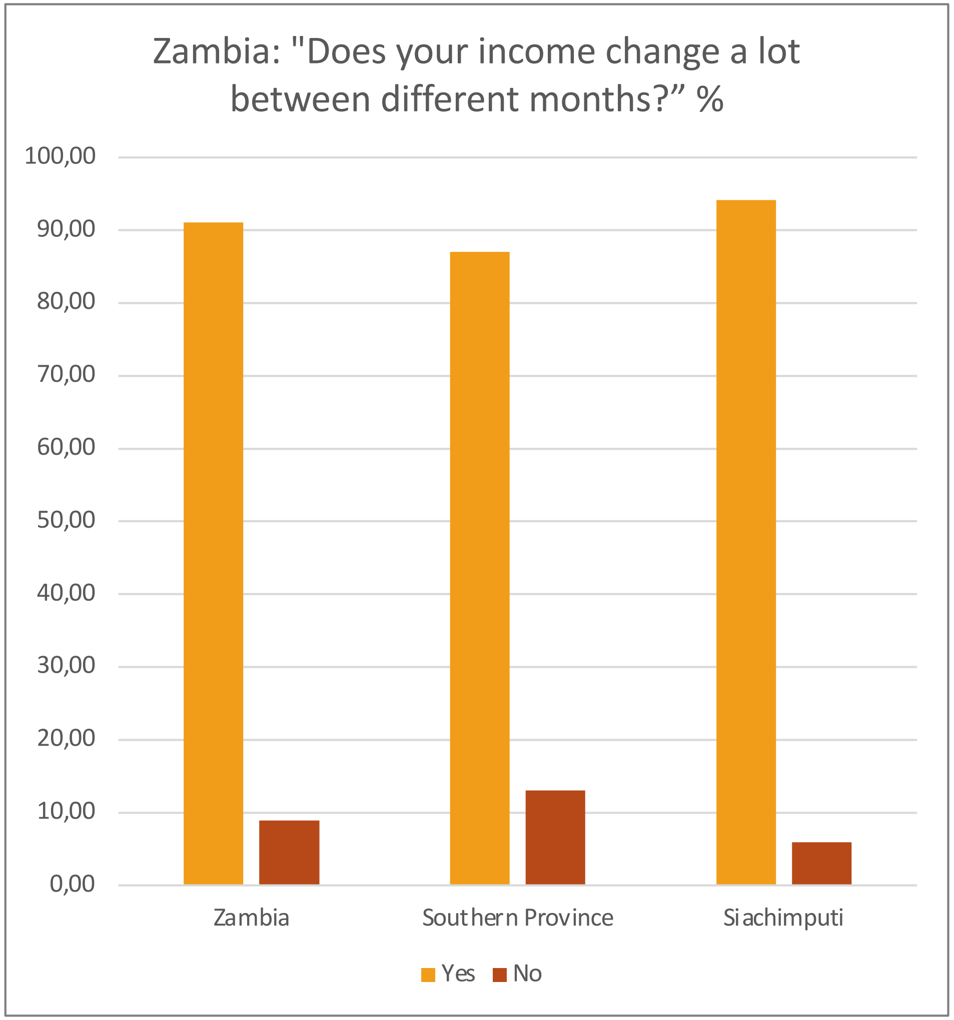
4: COMMUNITY LEVEL: DATA COLLECTION & NEEDS ASSESSMENT – ZAMBIA

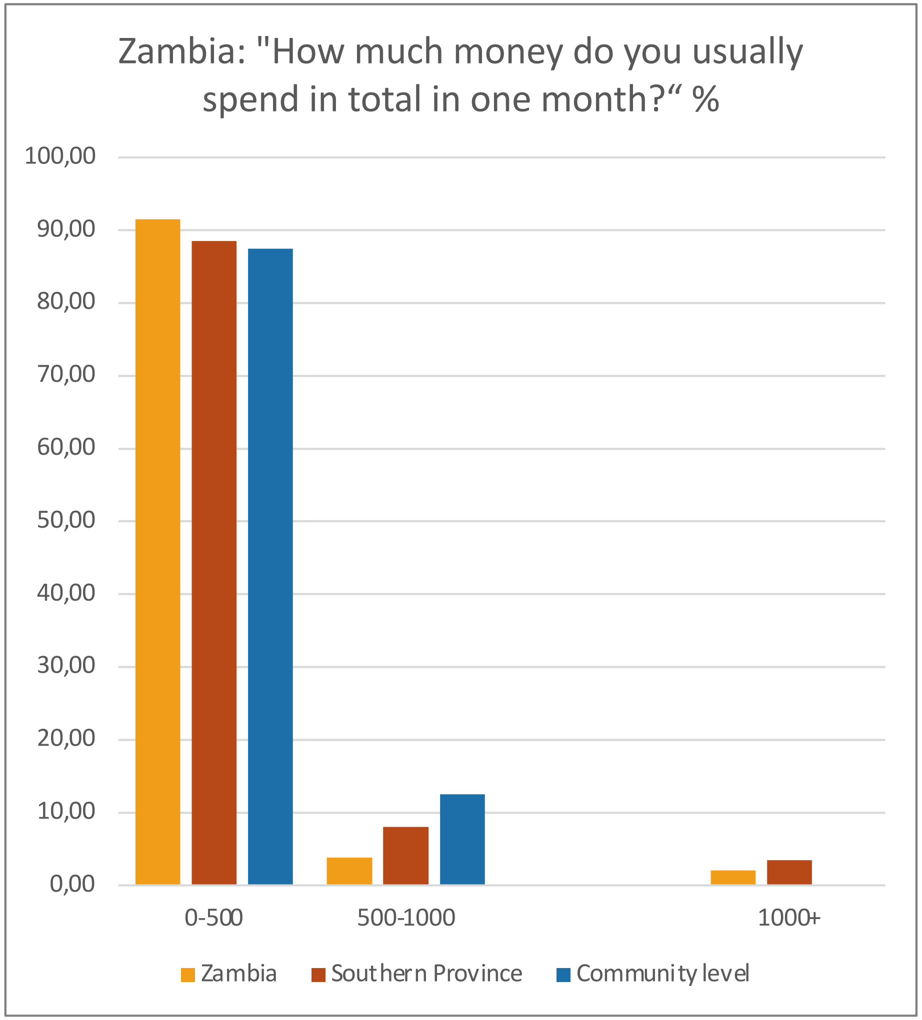
Current energy use	Income situation	Desired energy use	Affordability	No.& type of Businesses	Specific productive activities





Data from Project RISE*





Research Data from Project RISE*
500 ZMW ≈ 25 Eur

4. COMMUNITY LEVEL : COMPLEX & INTERRELATED CHALLENGES

Potential for more productive use of energy exist across all income-generating activities

- Productive uses can support a large range of income-generating activities across the agricultural, small-scale industry, retail and services sectors.
- ~ 15% use electricity for some form income-generating activity.
- main current PUE are cooling, battery charging, hair-dressing, entertainment and lighting.
- 'The value-add of 1 kWh can exceed 1 USD for different small businesses
- Large untapped potential exists across all sectors
- strong desire to provide cooling services, hairdressing, sewing, cooking in restaurants, welding and gadget repairing

5. IMPLICATIONS FOR OFF-GRID BUSINESS MODELS: UNDERSTANDING END-USER VALUE & DEMAND

Social/Cultural Barriers

- Understanding the adoption of Mini-Grid Services as Socio-Technical Change & understanding the Mini-Grid-User are important

Economic Barriers

- High Equipment costs
- High Electricity costs
- Low Availability of Equipment

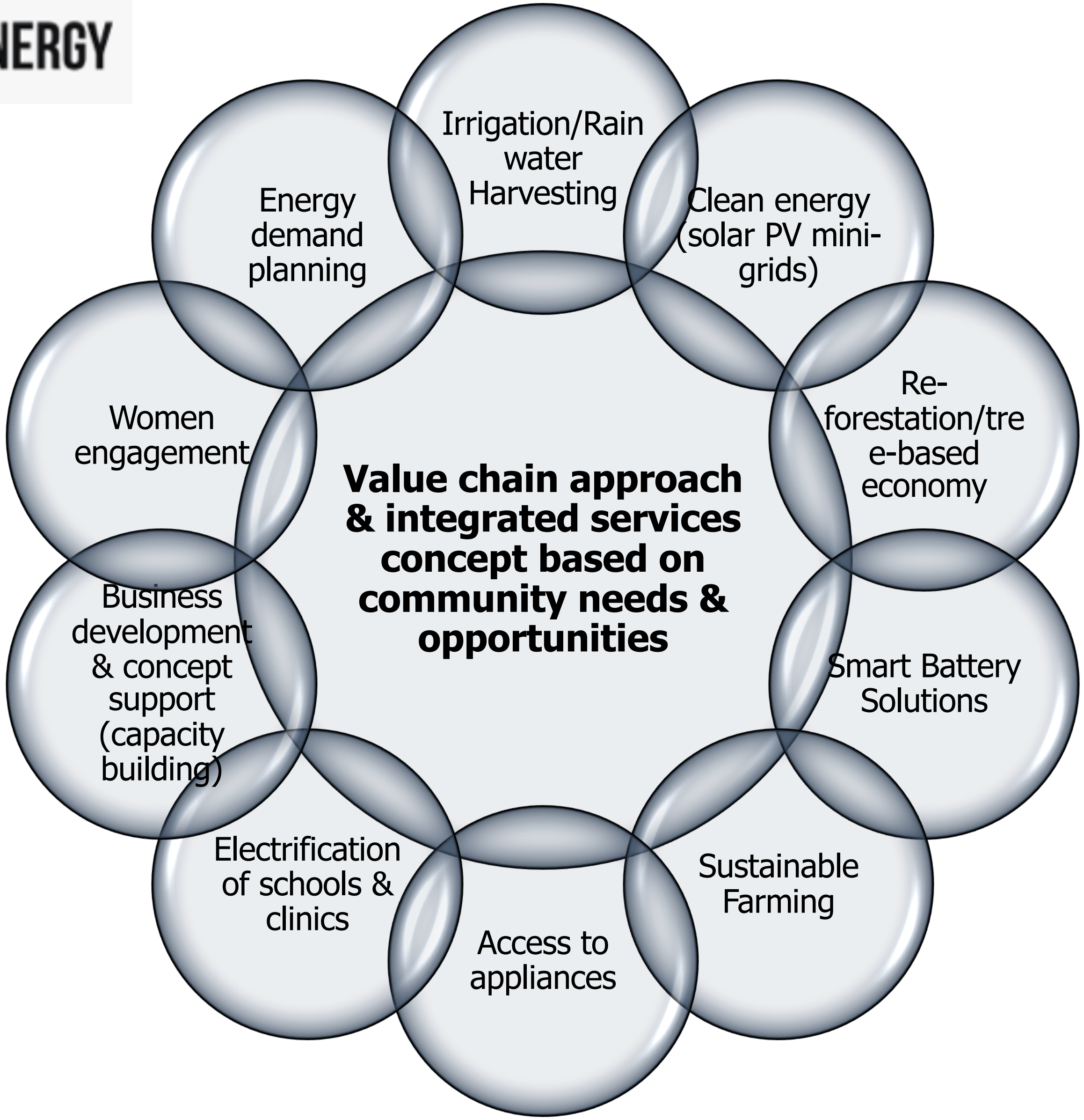
Management Barriers

- Overall business model
- Lack of aftersales services
- Technical capacity
- Customer (dis-)satisfaction

5. IMPLICATIONS FOR OFF-GRID BUSINESS MODELS: REALISTIC OPEX/CAPEX/REVENUE PLANNING

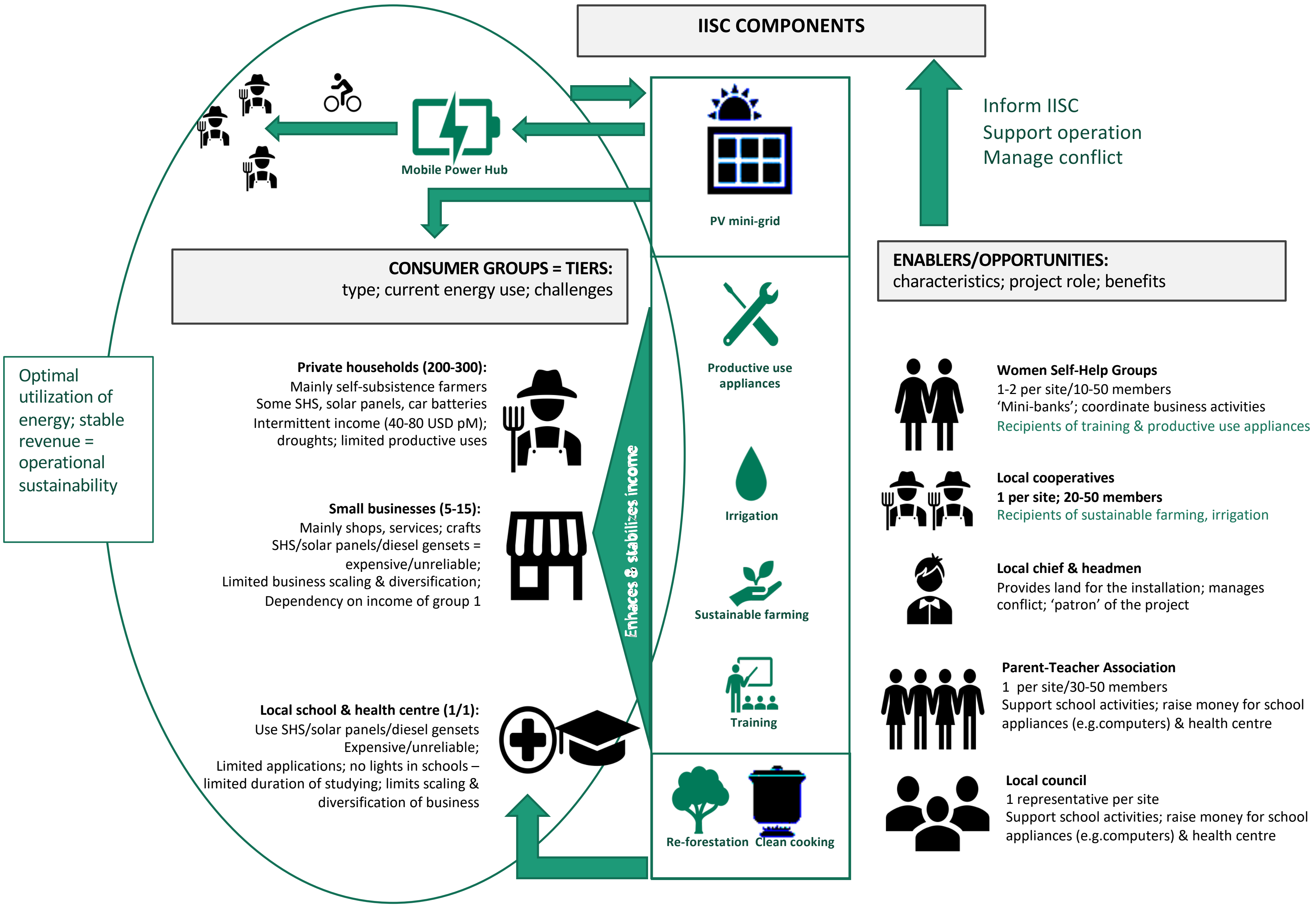
CAPEX	• Danger of "moon-pricing" – comparison of prices & costs; benchmarking of USD per kW installed • Long-term considerations (e.g. AGM vs. LI-ION Batteries?) & identify 'critical components' • High CAPEX = high energy tariffs = higher risk of affordability issues!
Stabilizing cash flow & adjust pricing	• Demand forecast; analysis of volatility, system downtime • High volatility > solutions to ‚stabilize' demand curve (e.g. by enhancing the customer base through portable storage solutions (e.g. Mobile Power) • Pricing structure that makes cash flows more resistant to low & volatile energy consumption (e.g. combination of basis fee + actual consumption charges) • ‚Balanced' grid (productive & household consumers)
OPEX	• Realistic calculation; revenue vs. **All** costs incl. reserves for components (inverters/batteries etc.) • Avoid common danger of OPEX exceeding revenues! • ‚Optimise' expenditures e.g. revenue collection; reduce component failure (e.g. conditioning of batteries); ‚bundle' project maintenance where possible
Added services & end-user stimulation	• Stimulate end-user demand e.g. through micro-financing approaches • End-user information & education • Warranty & Aftersales • Multi-Utility concept (selling services not only electricity: water/internet/cooling....)

5. IMPLICATIONS FOR OFF-GRID BUSINESS MODELS: COMPLEX PROBLEMS REQUIRE INNOVATIVE SOLUTIONS

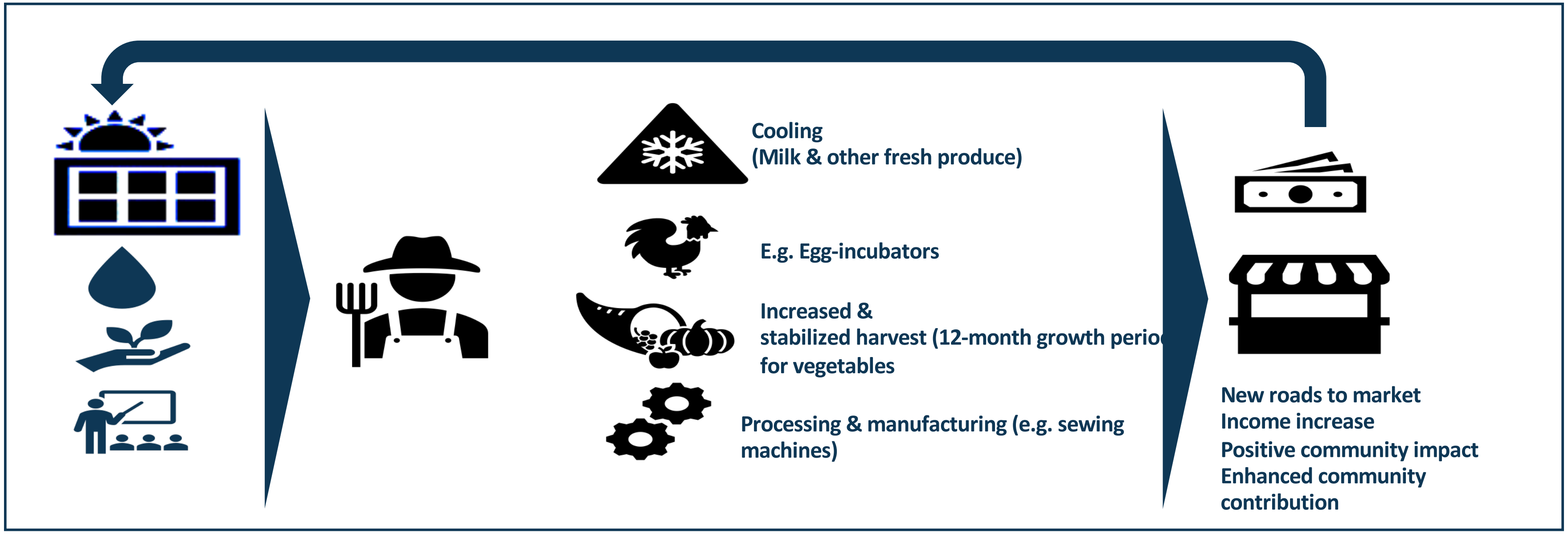


Project „Mumuni-Singani“

5. IMPLICATIONS FOR OFF-GRID BUSINESS MODELS: INNOVATIVE INTEGRATED SERVICES CONCEPT



5. OFF-GRID BUSINESS MODELS: IISC VALUE CHAIN & EXAMPLE BUSINESS CASE FOR EGG INCUBATION



VARIABLES	VALUES	UNITS
Size of incubator	100	eggs
Power rating of incubator	100	Watts (W)
Capital Cost	122	$
Amount of power consumed per day	2.4	kWh/day
Operational hours	24	hours/day
Operational days per month	21	days
Tariff	0.90	$/kWh
Cost of power	45	$/month
Avg. Expenses per month (including electricity)	83	$/month
Avg. Revenue of sales per month	125	$/month
Net profit	**42**	**$/month**
Profit Margin	**34%**	
Simple payback	**3**	**months**

Energy4Impact: https://www.energy4impact.org/file/2039/download?token=8ardN8he

5. IMPLICATIONS FOR OFF-GRID BUSINESS MODELS: IISC-SWOT ANALYSIS

Strengths

- Demand-side approach = stabilised MG revenue
- Community based approach: demands/needs captured; local buy-in
- Contributes to long-term MG sustainability
- Increased resilience of communities
- Addresses common challenges of rural SSA communities
- Lower MG investment risks

Weaknesses

- Increased development efforts (data collection/multi-partner approach)
- No 'one-size fits all' > scalability?
- Local footprint, cultural awareness & language skills required

Opportunities

- Facilitates local socio-economic growth, education & health
- Enhanced energy access
- New roads to markets for developer-partnerships
- Inclusion of Women entrepreneurs = gender equality
- Initiation of innovative financing schemes/less 'white elephants'
- Decrease rural/urban gap

Threats

- Discontinuity (new practices/operation model)
- Policy-framework & legal insecurities (e.g.Zambia: cost reflectiveness; grid-encroachment)
- Current grant financing schemes focused on OPEX
- Monocultures
- Climate change & market barriers

Theoretical model based on empirical research > practicality to be road-tested in pilot

6. POLICY LEVEL: RURAL ELECTRIFICATION – STATUS QUO AND SUGGESTED STRATEGY IN UGANDA & ZAMBIA

Findings

- No coherent strategy/electrification planning
- Interest-Influence GAP (many actors but local level not involved)
- Various electrification initiatives which are not integrated
- Overall financing GAPS given the ambitious targets of SDG 7
- Mainly donor- & private sector driven – no 'planning'
- Mainly CAPEX grant financing – solutions not sustainable
- Data gaps on various levels
- On-/off-grid-planning/implementation not aligned
- Regulatory gaps

Strategy

- An integrated roadmap (policy-framework) is needed that combines on- & off-grid planning and includes local stakeholder needs/advise
- Various existing initiatives & reform approaches (donor- & government driven) need to be integrated
- Clear roles & responsibilities to be defined
- Financing mechanisms developed that incentivize financial & operational sustainability
- Increase Monitoring & Evaluation

6. POLICY LEVEL: OPPORTUNITIES

- Private sector & donor driven programs can enhance no. of connections but the picture is uneven with regard to productive use & regional distribution – government driven strategic plans can complement private sector initiatives
- Greater coherence & integration of on- and off-grid planning can push rural electrification
- Effective monitoring and evaluation can provide important learning lessons
- More community involvement in energy policy-making can lead to electrification approaches that capture the needs of the consumers
- Greater regulatory certainty for grid-encroachment reduces financial risks for MG developers
- Foreign Donors have increased their focus on off-grid solutions, enhancing coordinated of efforts can reduce transaction costs and duplications of approaches

7. SUMMARY: THE TOP 10 OF SUSTAINABLE RURAL ELECTRIFICATION

1. Rural electrification remains low in most SSA countries despite increased donor donor efforts and cannot be solved through a ‘one-solution fits all’ approach.
2. Off-grid systems such as RE mini-grids (MGs) are the most favourable solution in most areas but face significant financial and operational challenges.
3. The community eco-system has decisive influence on the operational success of MGs but is often not a substantial part of the planning and implementation process.
4. In order to increase and ensure the long-term sustainability of MGs, solutions must focus on the various challenges for rural communities.
5. Local stakeholders must be closely involved in this process.
6. Business models for MGs must focus and enable the productive use of energy from the beginning.
7. MG Financing should include an OPEX component instead of pure CAPEX focus for grants. (‘Smart-Subsidy’)
8. MG planning needs to include realistic operation scenarios including ‘worst-case’ contingencies.
9. These measures should be flanked by policy approaches that integrate realistic on- & off-grid planning, coordinated donor approaches and legal securities for developers.
10. Women can be essential drivers of MG sustainability through their business activities and should be part of the planning, implementation and operation of MGs.

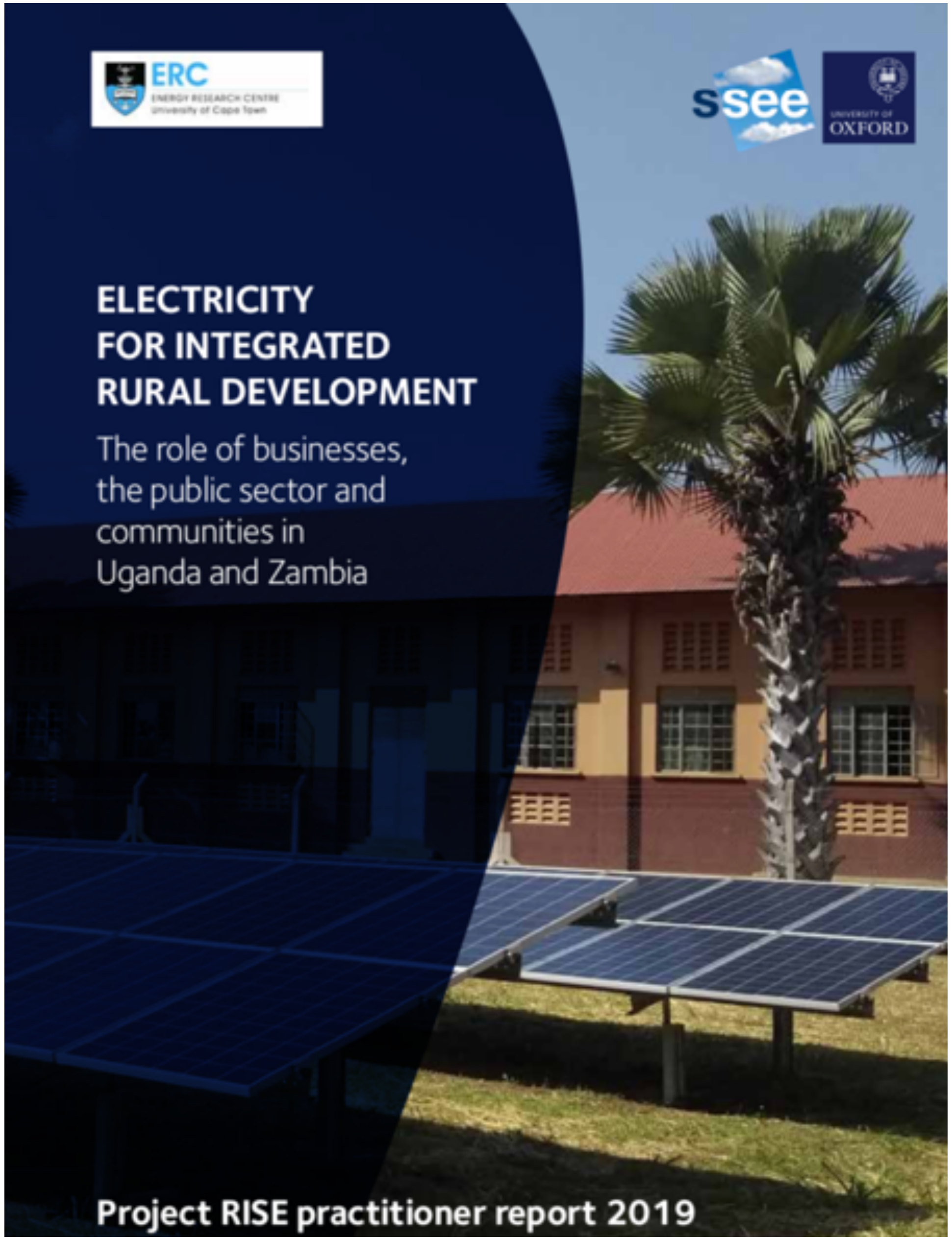
8. SELECTED READINGS & RECENT PUBLICATIONS

- Stritzke, S., Twesigye, P. & Trotter, P.A. 2021. “Towards responsive energy governance: Lessons from a holistic analysis of energy access in Uganda and Zambia.” Energy Policy 148,
- Adenle, A. 2020. “Assessment of Solar Energy Technologies in Africa-Opportunities and Challenges in Meeting the 2030 Agenda and Sustainable Development Goals.” Energy Policy 137
- Haney, A. et.al. 2019. “Electricity for integrated rural development. The role of businesses, the public sector and communities in Uganda and Zambia.” Project RISE practitioner report, University of Oxford, 2019: https://www.smithschool.ox.ac.uk/publications/reports/Smith-School-RISE-Report-final.pdf
- Peters, J., Sievert, M., & .Toman, M. A. 2019. „Rural electrification through mini-grids: Challenges ahead.“ Energy Policy 132
- Gollwitzer L., Cloke J. 2018. “Lesson from collective action for the local governance of mini-grids for pro-poor electricity access.” Briefing Paper 1, Low carbon energy for development network, Leicestershire
- Stritzke, S. (2018) On-Grid vs. off-grid; results from two research projects on RE implementation in SSA. In, Stritzke, S. (ed.) Practical Challenges of sustainable electrification, Workshop-Report.

Project websites:

- https://www.smithschool.ox.ac.uk/research/rise-renewable-energy-innovation-scale/index.html
- https://www.smithschool.ox.ac.uk/research/mumuni-singani/

Questions?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OXFORD
ELECTRICITY
FOR INTEGRATED
RURAL DEVELOPMENT
The role of businesses,
the public sector and
communities in
Uganda and Zambia
Project RISE practitioner report 2019

THANK YOU!

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