Solar Power and Off-Grid Electrification in Nigeria

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REINER LEMOINE INSTITUT

Reiner Lemoine Institut

Overview

- Not-for-profit research institute
- 100% owned by Reiner Lemoine Stiftung (RLS)
- Based in Berlin, established in 2010
- Managing director: Dr. Claus Beneking
- 25 research assistants + students
- Member of e.g. ARE, eurosolar, BNE

Alliance for Rural Electrification   EUROSOLAR Europäische Vereinigung für Erneuerbare Energien e.V.   BERLIN BRANDENBURG ENERGY NETWORK e.V.

Reiner Lemoine
Founder of the Reiner Lemoine Foundation

Mission

Scientific research for an energy transition towards **100 % renewable energies**

Research fields - RLI

Optim. Energy Systems and Transition	Off-Grid Systems	Mobility with Renewable Energies
▪ Simulation of integrated ▪ energy systems ▪ Modelling of energy supply including storage options (e.g. batteries, PtG) ▪ Feasibility studies for energy supply by GIS ▪ Energy transition and social acceptance	▪ Rural electrification planning ▪ Simulation of hybrid mini-grids ▪ Combination of GIS analyses and energy system simulations ▪ Market research and business strategies	▪ Mobility concepts with renewable energies ▪ Research on electrolyses and PtG ▪ Implementation of hybrid mini-grids and small wind turbines ▪ Hardware in the loop testing and measurements

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Agenda

- Introduction
- Methodology
- Results
- Conclusion

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Introduction

Policy Directive of the Federal Ministry of Power (FMP) of the Federal Government of Nigeria "**On the promotion of the use of energy from renewable sources and procurement of capacity"** will be created.

This study supports the Policy Directive by providing numbers on the potential of photovoltaic (PV) systems for rural electrification by Solar Home Systems (SHS) and hybrid Mini-Grids for whole Nigeria.

The attempt is complex because essential data on the current status of electricity supply and load demands in rural areas is lacking and profound work-arounds need to be established.

To do so, the team will use a GIS database and spatial modelling to

a) understand where the consumers are,
b) whether or not they are reached by the grid/electrified already
c) building priority areas for different electrification approaches
d) defining capacity needs in mini-grids and SHS and
e) modelling two different PV-shares in hybrid mini-grids

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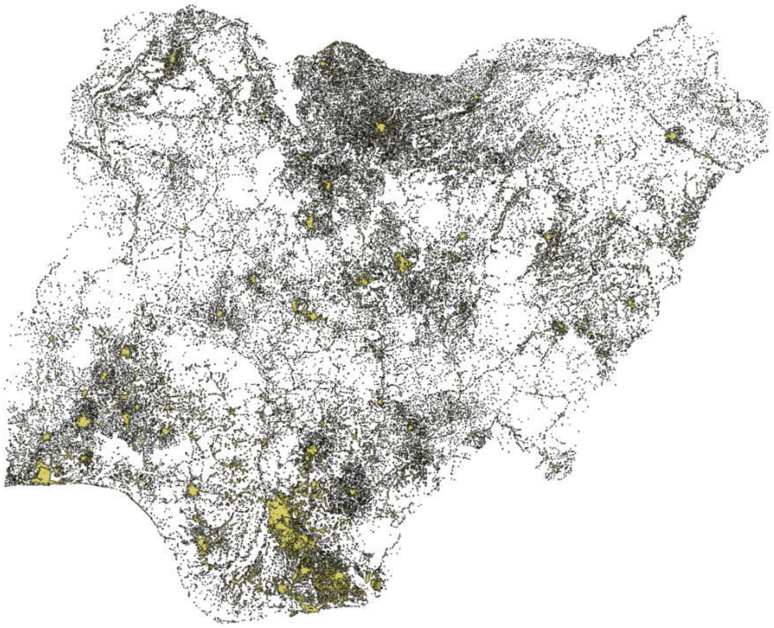
Methodology - Overview

For this analysis a combination of GIS tools, energy system simulations and literature analysis is chosen to derive an overview of the potential on SHS and PV hybrid Mini-Grids for rural electrification in whole Nigeria.

- GIS analyses by QGIS to
  - derive consumer cluster
  - identify status of electrification
  - define priority areas for electrification by grid extension, Mini-Grids, SHS
- Literature analyses
  - define loads and electricity consumption for Mini-Grids
  - define size of SHS for stand-alone electrification
- Energy system modelling to
  - derive shares of PV energy in one typical Mini-Grid as baseline for extrapolation of PV Mini-Grid potential

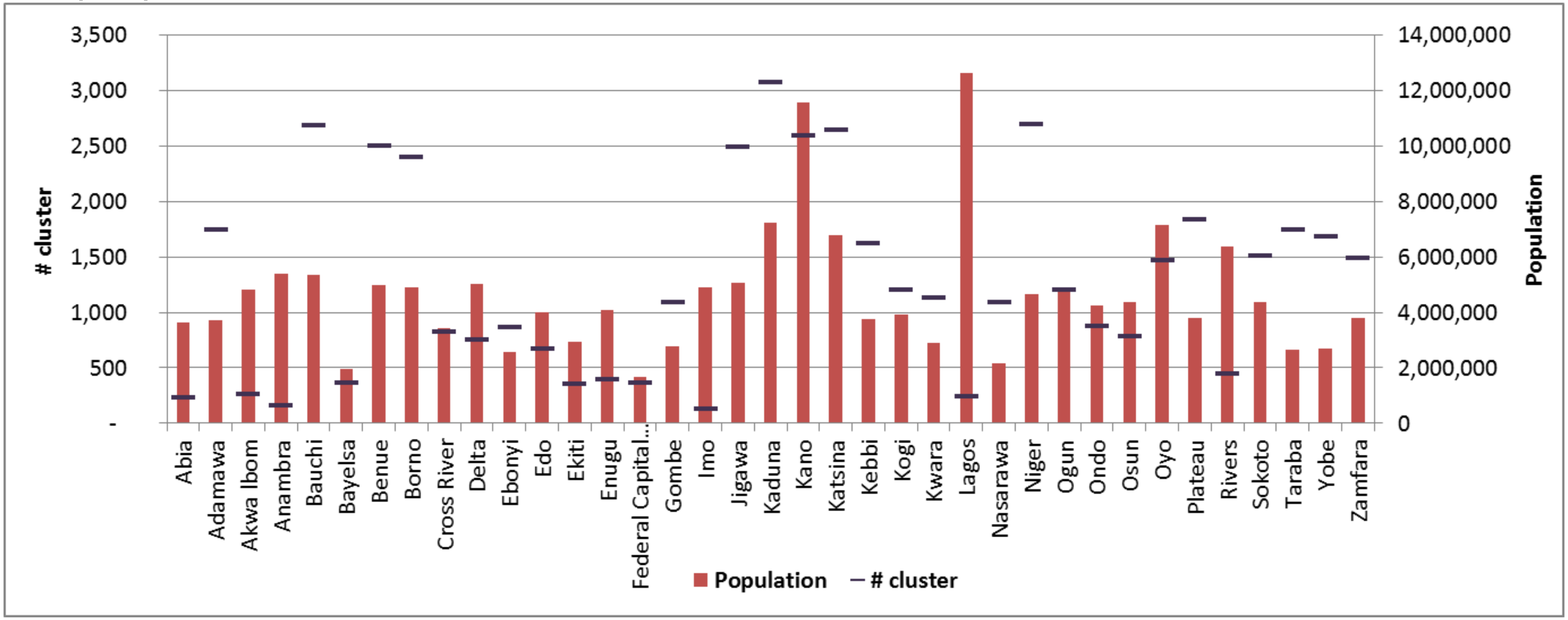
Consumer cluster are identified by global population data

- Consumer cluster are identified by global population data sets, NMIS school data, and polling units
- Results are validated and scaled by population figures from the National Bureau of Statistics



Consumer cluster - Results

- In total: 47,489 clusters including 171 of 181 million people of Nigeria (10 % of the rural population is assumed to live in very small rural settlements or have even no permanent settlement location so that they cannot be assigned to a certain consumer cluster) are identified
- The lower the number of clusters compared to the population of a state the more people live in urban areas



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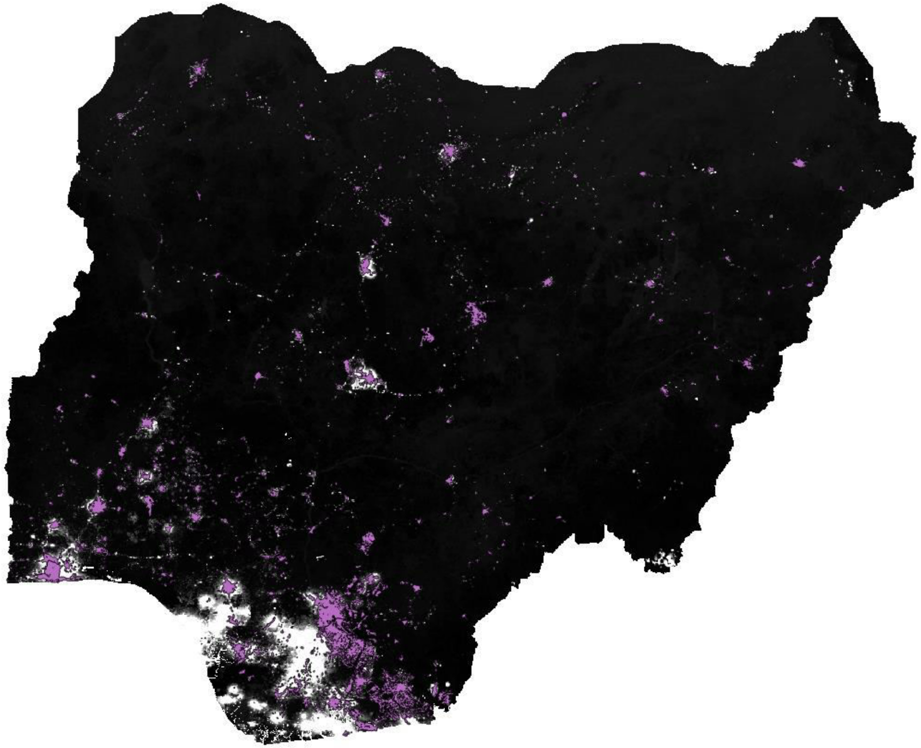
Status of Electrification - Methodology

- Consumer cluster which have nighlight emissions AND electrified schools are set as „electrified“



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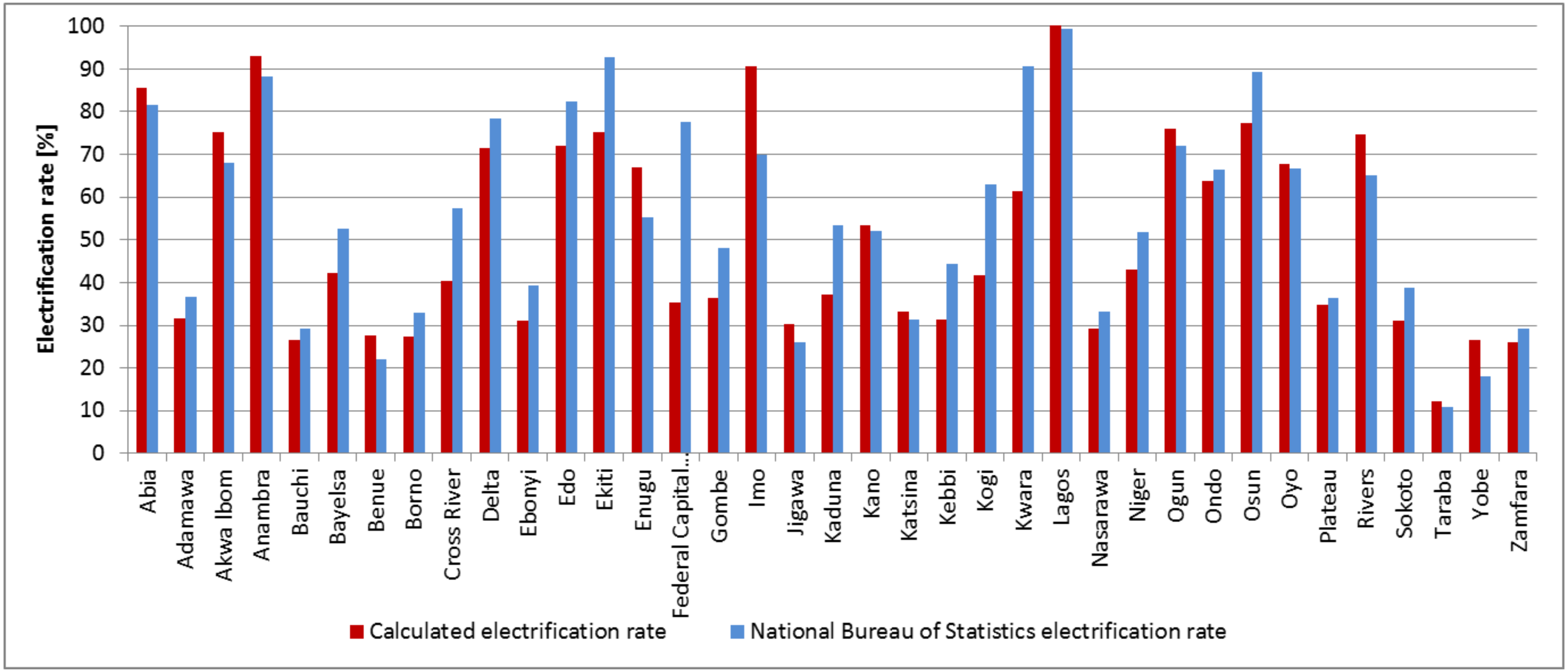
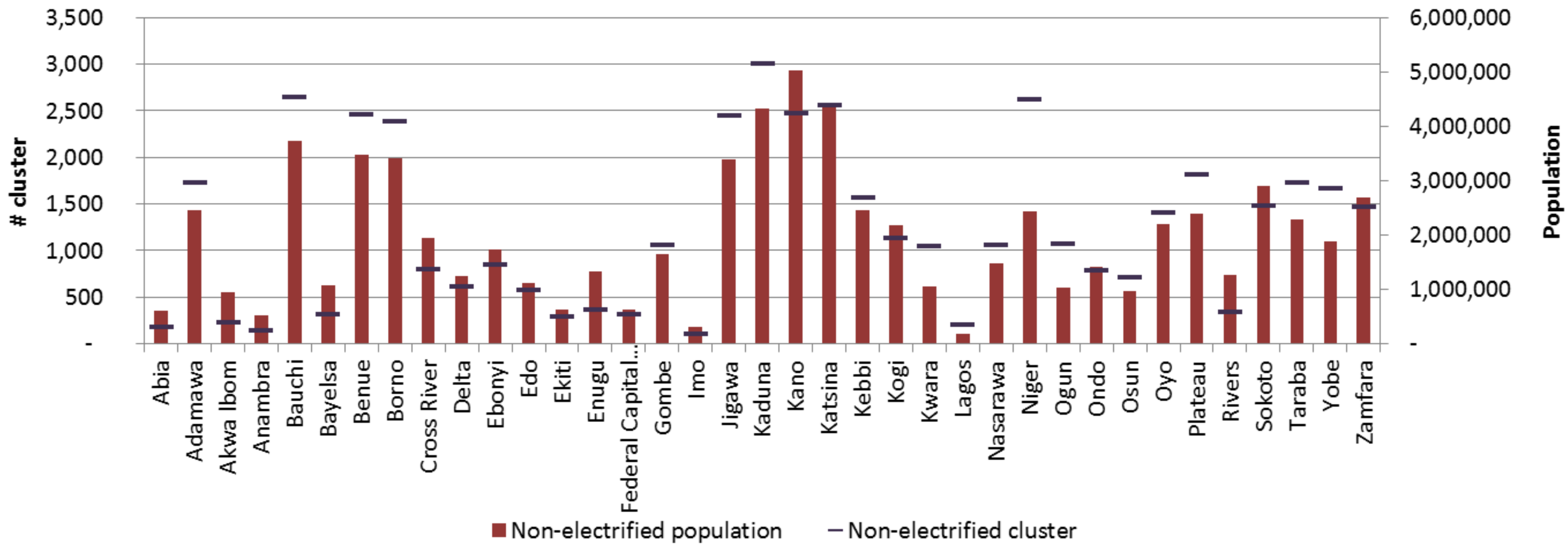
Status of Electrification – Results

- Results are validated with official rates from the National Bureau of Statistics and show very good match
- Total number of people living in electrified areas by GIS analyses: 54 % (98m people)
- Analysis allows to determine not only number but also location of non-electrified people



Status of Electrification – Results II

- In total 45,456 clusters are non-electrified (95 %)
- But only 83 out 181 million people living in the non-electrified area (46 %)
  - Including 10m people living outside clusters assumed to be non-electrified
  - The clusters with the largest number of people are all electrified



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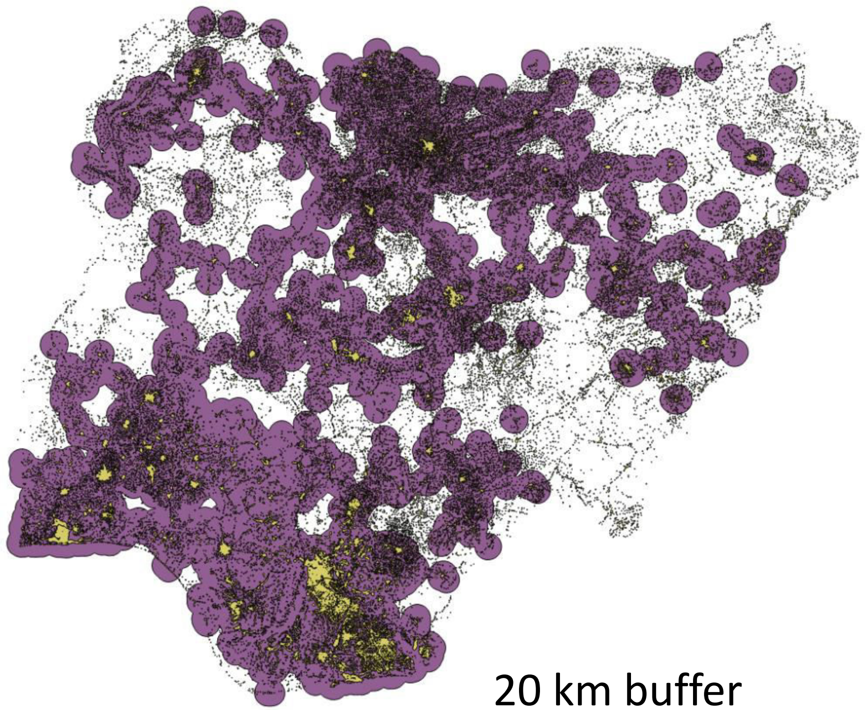
Electricity supply options - Methodology

- All clusters around 10 and 20 km buffer zone of electrified clusters (grid-clusters) are assumed to be electrified via grid connection
- All clusters outside the grid extension area below 1,000 ppl are assumed to be electrified by stand alone systems – SHS
- All remaining clusters are assumed to be electrified by PV Mini-Grids


20 km buffer

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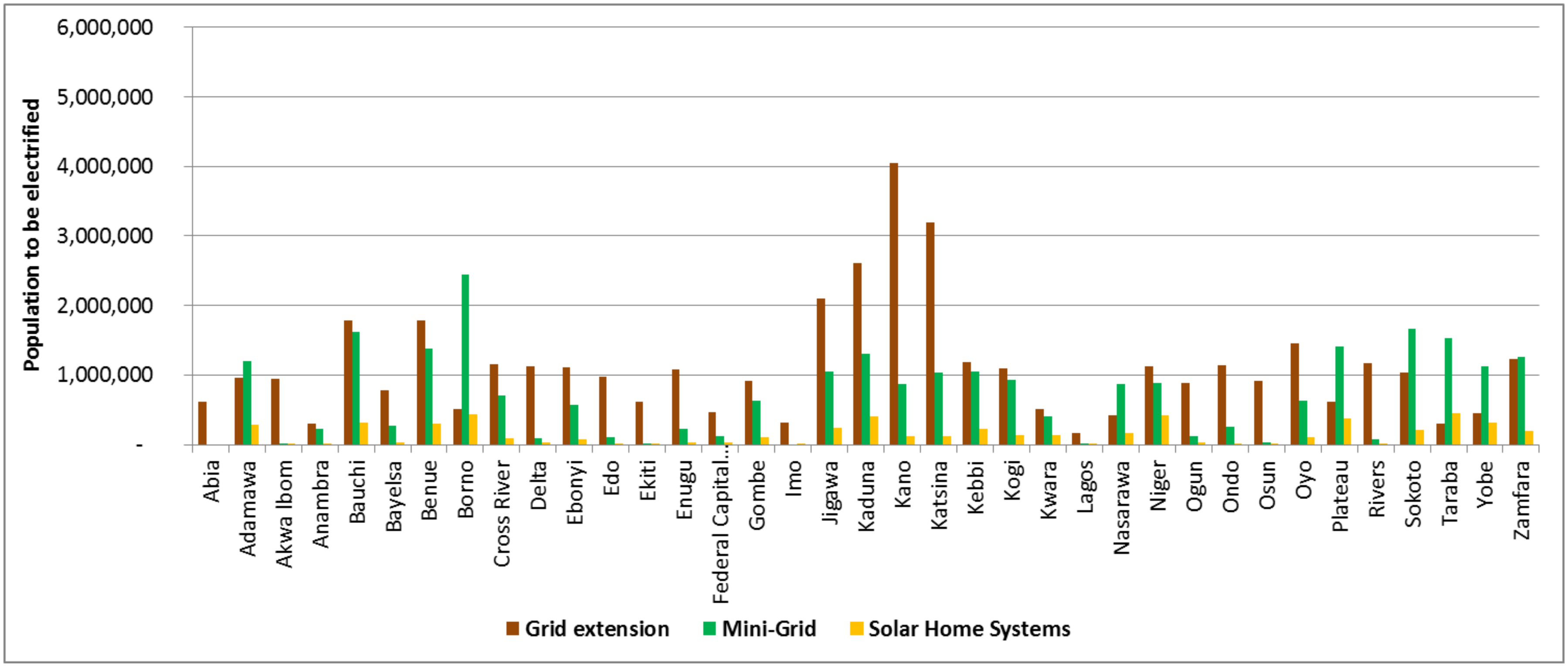
Electricity supply options – Results I – 10km grid buffer

- Total results
  - Grid electrification: 23,457 cluster 41.0 million ppl
  - Mini-Grid electrification: 7,882 cluster 26.2 million ppl
  - SHS electrification: 14,117 cluster 5.5 million ppl



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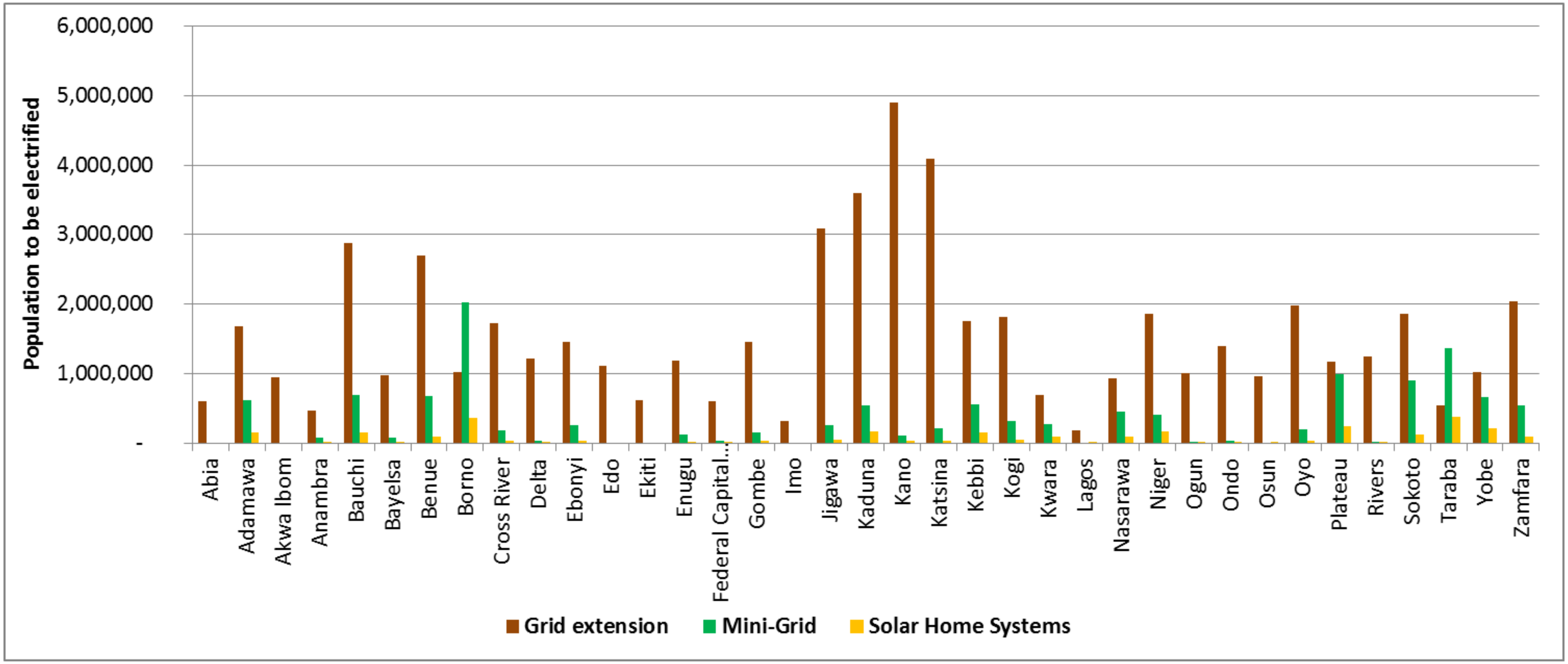
Electricity supply options – Results II – 20km grid buffer

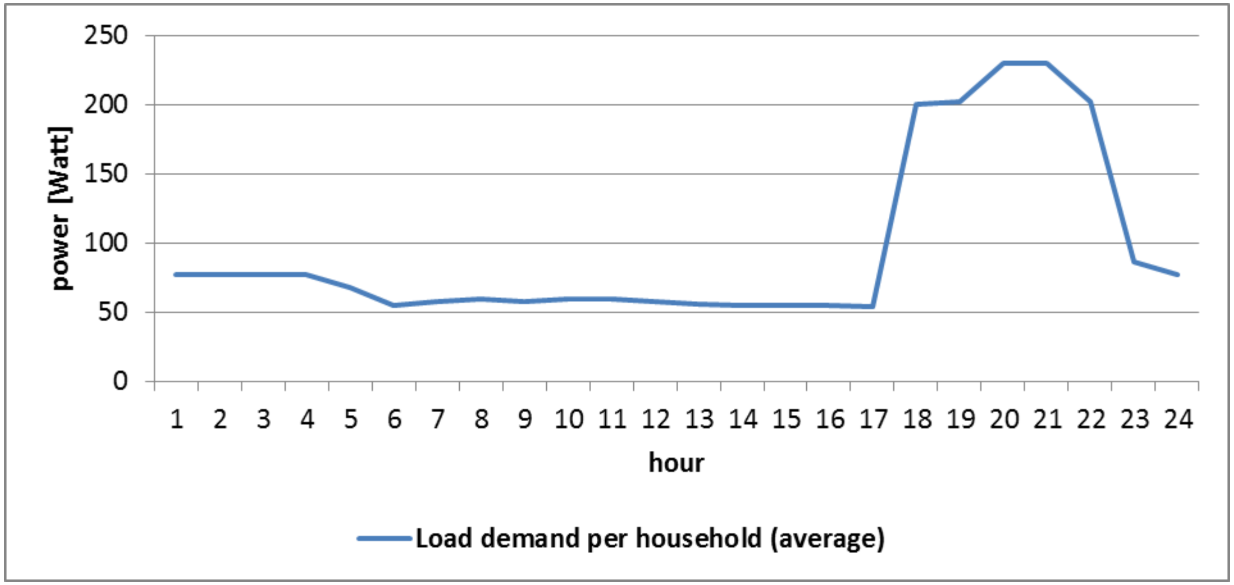
- Total results
  - Grid electrification: 34,446 cluster 57.1 million ppl
  - Mini-Grid electrification: 3,800 cluster 12.8 million ppl
  - SHS electrification: 7,210 cluster 2.8 million ppl



Details on Mini-Grids – Methodology Load Demand

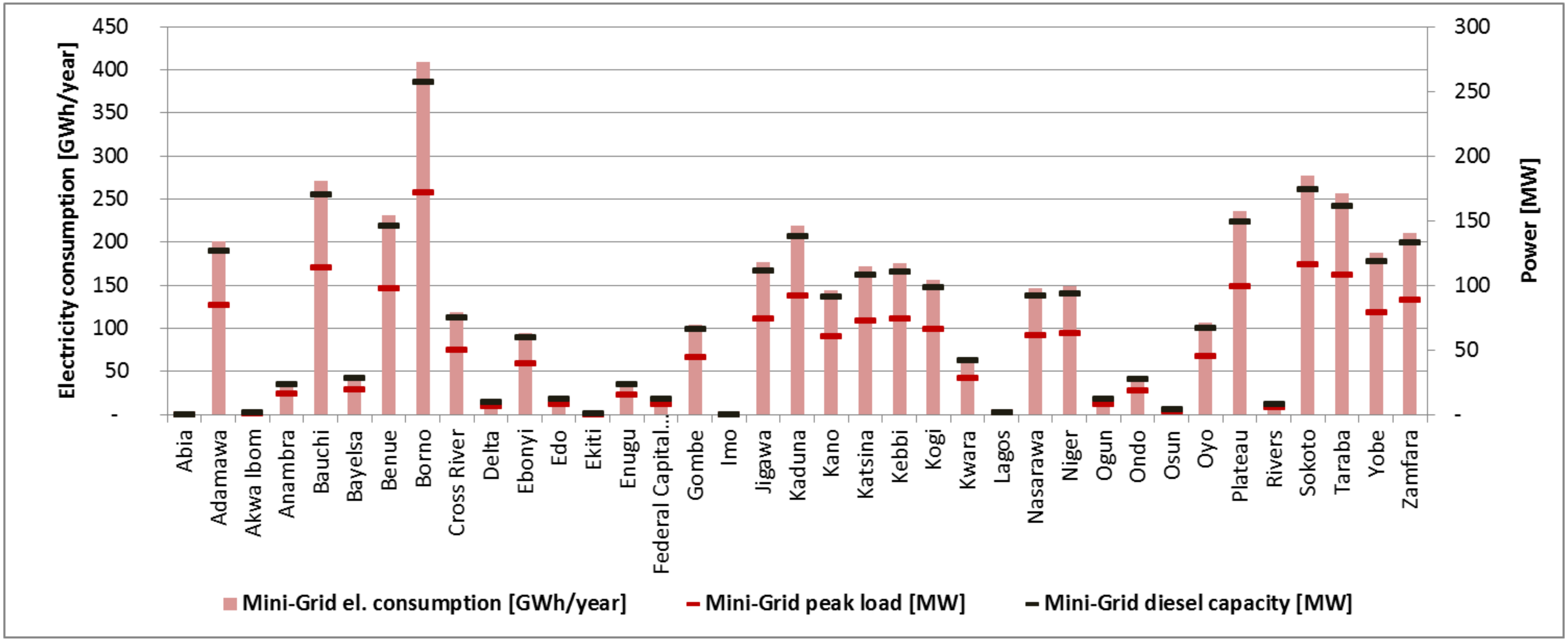
- Energy consumption
  - On average 5 persons per rural household are assumed
  - Number of households indicates a combined domestic and social infrastructure load for each consumer cluster prioritized for Mini-Grids
  - Per household a combined electricity consumption of 2.3 kWh/day (840 kWh/year) is assumed on average, annual peak load is appr. 250 W

Source: Economic evaluation of hybrid energy systems for rural electrification in six geo-political zones of Nigeria, by Olatomiwa et al. (2015)



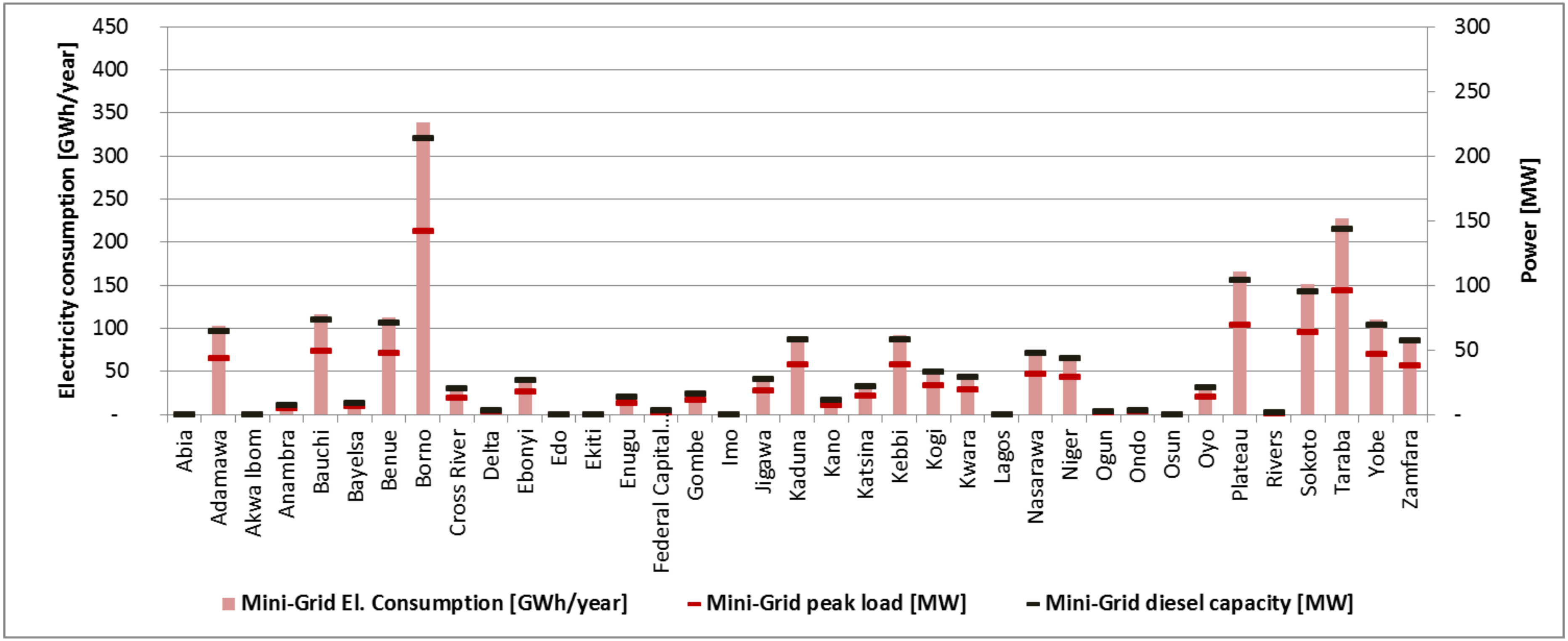
Details on Mini-Grids – Results Load Demand (10 km buffer)

- Energy consumption for Mini-Grid priority cluster in total
  - Electricity consumption per year: 4,370 GWh
  - Peak load: 1,830 MW
  - Required diesel capacities: 2,750 MW (1.5 times peak load)



Details on Mini-Grids – Results Load Demand (20 km buffer)

- Energy consumption for Mini-Grid priority cluster in total
  - Electricity consumption per year: 2,135 GWh
  - Peak load: 895 MW
  - Required diesel capacities: 1,345 MW (1.5 times peak load)



PV potential Mini-Grids - Methodology

- One showcase is simulated
- Showcase village: 5,000 ppl (1,000 households)
- Simulation of one reference year
  - Self-developed simulation tools in Matlab
  - Individual set-up of components and loads
  - LCOE optimizations

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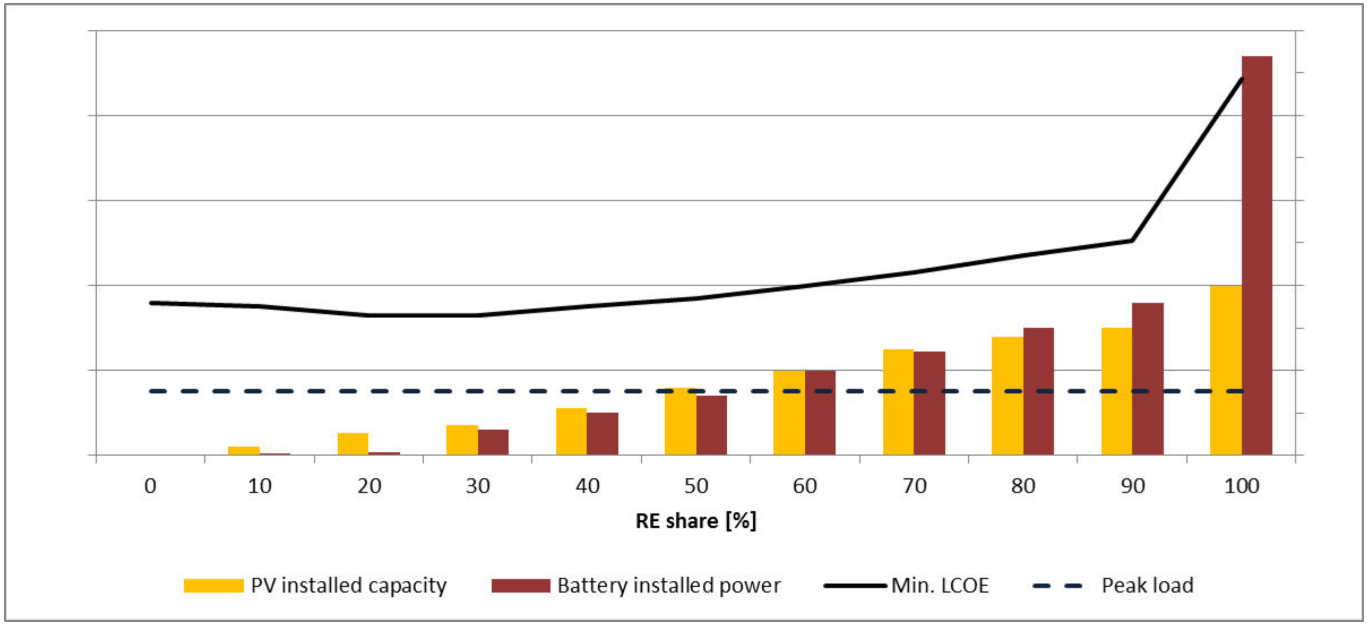
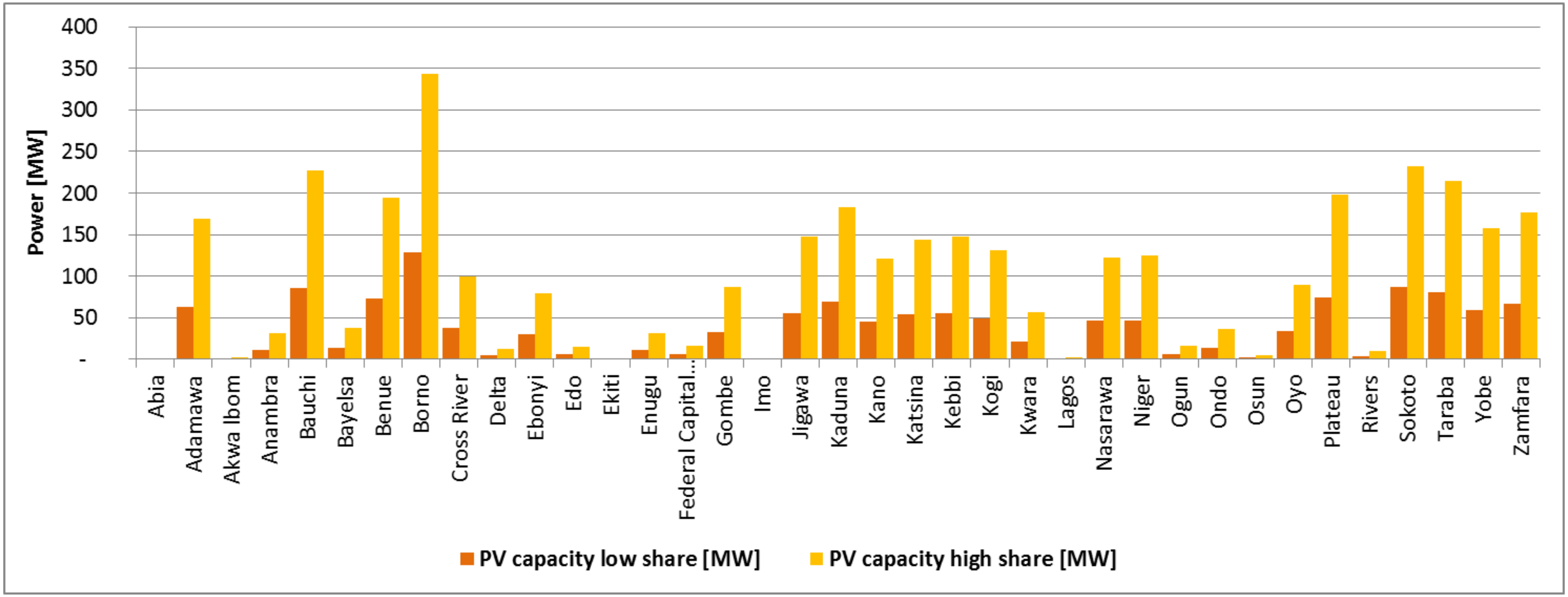
PV potential Mini-Grids – Results Showcase

- Only qualitative results are shown
- Load profile has high evening peaks and low demand during the day
  - Batteries are necessary even for low shares of renewable energies (high power batteries)
  - Cost increase for high RE share as PV production is only during the day (storage necessary)
- Suggested PV capacities for further analysis
  - Low share system: 0.75 times peak load
  - High share system: 2 times peak load



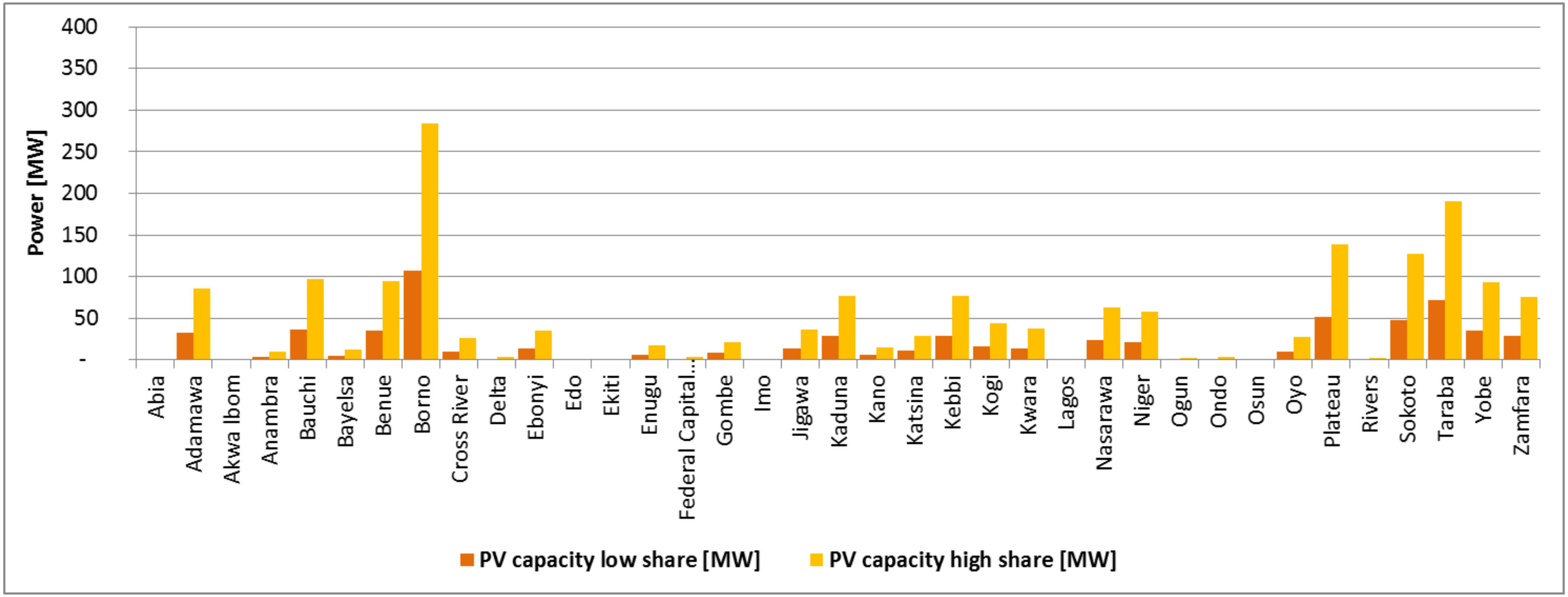
PV potential Mini-Grids – Results (10 km buffer)

- Per Mini-Grid priority cluster 263 Wp PV (low share RE) and 700 Wp (high share RE) capacities are assumed for each household
- Total capacity: 1,380 MW (low share); 3,660 MW (high share)
- Per Mini-Grid cluster only one PV hybrid Mini-Grid is assumed
  - Total number: appr. 8,000



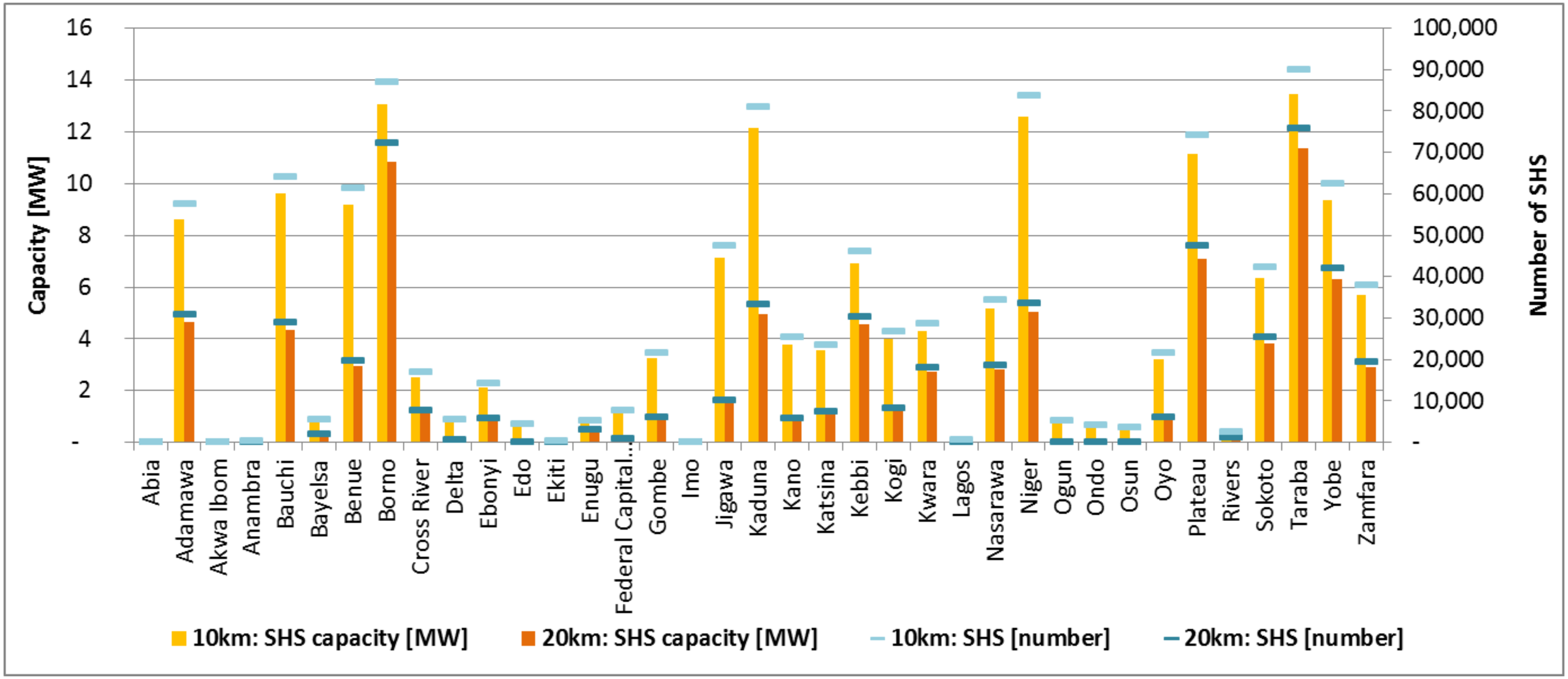
PV potential Mini-Grids – Results (20 km buffer)

- Per Mini-Grid priority cluster 263 Wp PV (low share RE) and 700 Wp (high share RE) capacities are assumed for each household
- Total capacity: 671 MW (low share); 1,790 MW (high share)
- Per Mini-Grid cluster only one PV hybrid Mini-Grid is assumed
  - Total number: appr. 3,800



Solar Home Systems – Methodology / Results

- Per SHS priority cluster 150 Wp SHS capacities are assumed for each household
- Total capacity: 164 MW (10 km buffer); 84 MW (20 km buffer)
- Total number: 1.1m (10 km buffer); 0.6 m (20 km buffer)



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Conclusion

- Number of Mini-Grids and SHS depends upon the intensity of electrification by extension of the central grid
  - 10 and 20 km buffers are applied to show different grid electrification ranges
    - (10 km = low grid electrification; 20 km = high grid electrification)

- **PV potential for hybrid Mini-Grid** electrification ranges from **671 to 3,660 MW**
  - Two scenarios for low and high share RE systems
  - Low share RE: 671 MW (high grid electrif.) to 1,380 MW (low grid electrif.)
  - High share RE: 1,790 MW (high grid electrif.) to 3,660 MW (low grid electrif.)

- **SHS PV potential** for stand alone electrification ranges from **84 to 164 MW**
  - 84 MW (high grid electrification)
  - 164 MW (low grid electrification)

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Limitations

- No detailed simulation for grid extension costs was performed
- No detailed energy system modelling for each cluster was performed
- No specific regional input parameter could be applied

⇒ Results show a preliminary possible range of PV potential for Mini-Grid and SHS electrification

⇒ Detailed simulation will give more clearity

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Thank you!

Working group on rural electrification planning, Abuja, November 2015.