REINER LEMOINE INSTITUT

Ländliche Elektrifizierung mit PV-Mini-Grids

Fallbeispiel Nigeria

31. PV-Symposium

10. März 2016 in Kloster Banz, Bad Staffelstein

Dr. Philipp Blechinger

Das Reiner Lemoine Institut (RLI)

Überblick

- Gemeinnütziges Forschungsinstitut
- 100 % Tochter der Reiner Lemoine-Stiftung (RLS)
- Gegründet 2010 in Berlin
- Mitglied u.a. bei: ARE, eurosolar, BNE, dena, EEA
- Geschäftsführung: Dr. Kathrin Goldammer

Reiner Lemoine
Gründer der Reiner Lemoine-Stiftung

Forschungsfelder

Transformation von Energiesystemen

Wir erforschen stabile und realisierbare Systeme für eine globale Erneuerbare Energieversorgung.

- Begleitung der Energiewende – national, regional und EU-weit
- Simulation und Optimierung sektorübergreifender Energiesysteme
- Analyse einzelner Technologien im Gesamtsystem (Speicher, PTG, PTH, KWK, WP, u.a.)
- Transformationsforschung

Mobilität mit Erneuerbaren Energien

Wir untersuchen Energie- und Mobilitätssysteme, um Synergien zu identifizieren und zu entwickeln.

- Batterieelektrische Mobilität: Versorgung der Fahrzeuge mit Strom aus Erneuerbaren Energien
- Wasserstoffelektrische Mobilität: Erzeugung des Wasserstoffs mittels Elektrolyse und Erneuerbarer Energien
- Auf synthetischem Methan basierende Mobilität: Erzeugung des Methans mittels Elektrolyse, Erneuerbarer Energien und Methanisierung

Off-Grid Systeme

Wir unterstützen die Entwicklung nachhaltiger Energieversorgung in abgelegenen Regionen.

- Ländliche Elektrifizierungsplanung
- Simulation und Optimierung hybrider Mini-Grids
- Kombination aus GIS Analysen und Energiesystemmodellierung
- Marktanalysen und Geschäftsstrategien

Agenda

- Übersicht ländliche Elektrifizierung
- Fallbeispiel Nigeria
- Zusammenfassung

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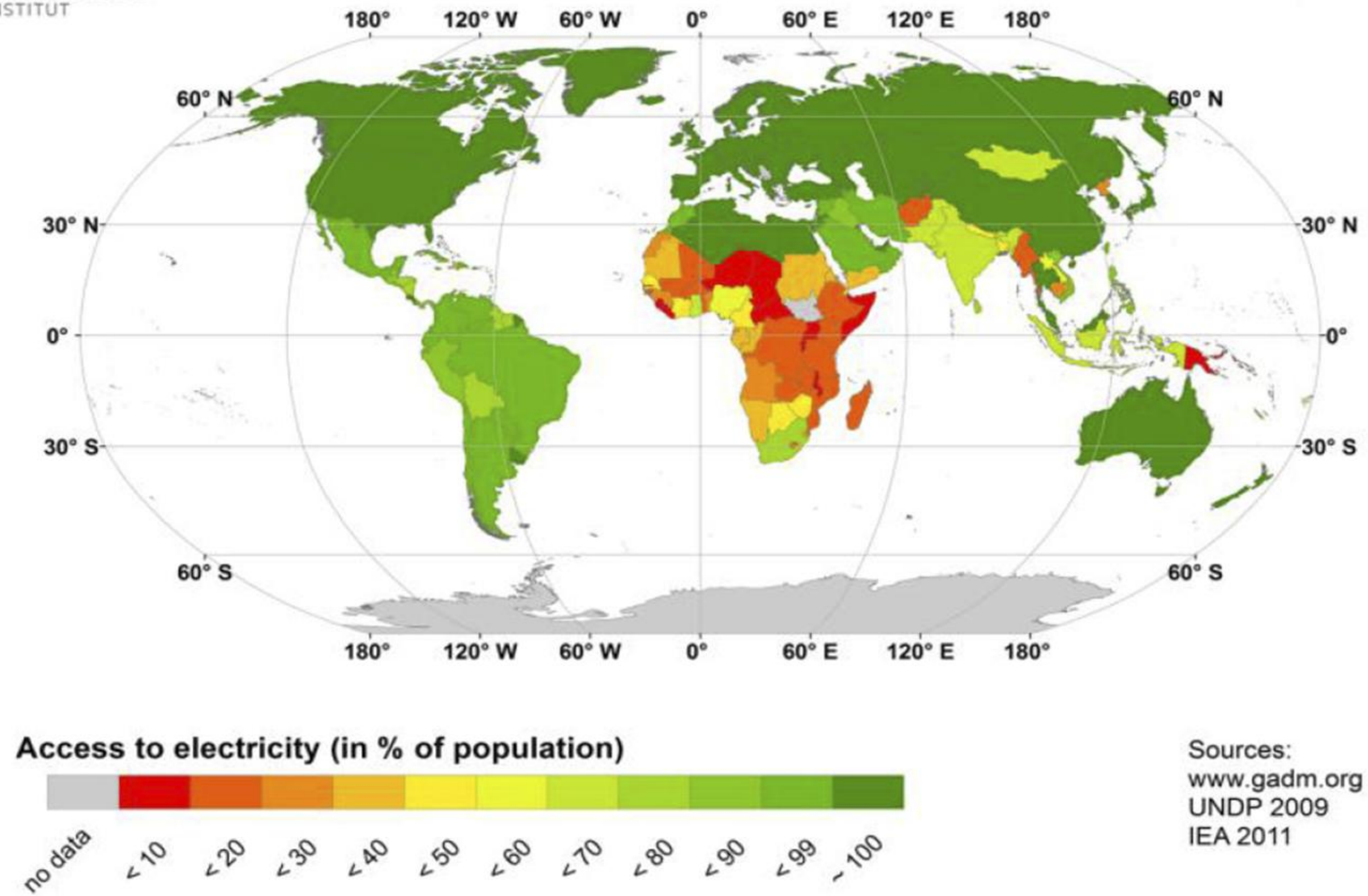
Ländliche Elektrifizierung - Weltkarte



Cader, C. et al. (2015) **Global cost advantages of autonomous solar-battery-diesel systems compared to diesel-only systems.** Energy for Sustainable Development, 2015.

Ländliche Elektrifizierung – Aggregierte Ergebnisse

SOURCE: IEA, World Energy Outlook 2015

Electricity access in 2013 - Regional aggregates

Region	Population without electricity (millions)	Electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
Developing countries	1,200	78%	92%	66%
Africa	635	43%	68%	26%
North Africa	*1*	*99%*	*100%*	*99%*
Sub-Saharan Africa	*634*	*32%*	*59%*	*17%*
Developing Asia	526	86%	96%	78%
China	*1*	*100%*	*100%*	*100%*
India	*237*	*81%*	*96%*	*74%*
Latin America	22	95%	98%	84%
Middle East	17	92%	98%	78%
Transition economies & OECD	1	100%	100%	100%
WORLD	1,201	83%	95%	70%

Größter Anteil an Menschen ohne Zugang zu Elektrizität lebt in sub-Sahara Afrika oder in Süd-Ost Asien.

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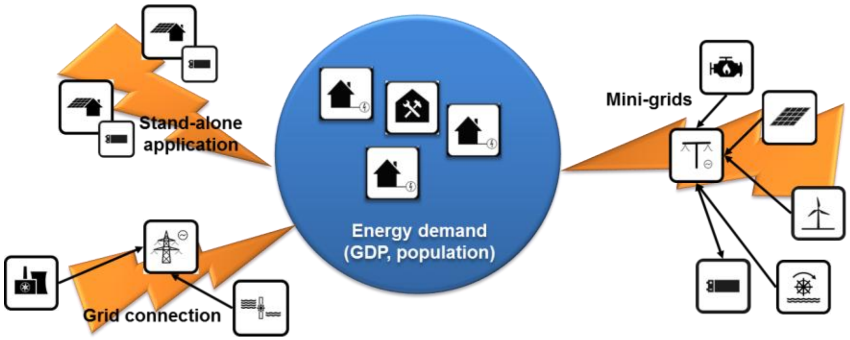
Ländliche Elektrifizierung und Mini-Grids

Potential:

- 1,2 Milliarden Menschen weltweit haben keinen Zugang zu Stromversorgung
- Aber: Elektrifizierung hauptsächlich durch Netzerweiterung
- Aber: Geringe Kaufkraft der lokalen Bevölkerung



Implementierung von Mini-Grids:

- Alternative zu langsamen und unwirtschaftlichem Netzausbau
- Schwieriges Geschäftsmodell, da Umsätze pro Kunde/in gering sind
- Neu Elektrifizierung, reine PV-Batterie Projekte sind möglich (ohne Diesel)
- Oft Spenden-finanzierte Projekte

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Agenda

- Übersicht ländliche Elektrifizierung
- Fallbeispiel Nigeria
- Zusammenfassung

Nigerian Energy Support Programme (NESP) –
Component III: Rural Electrification

Rural electrification planning

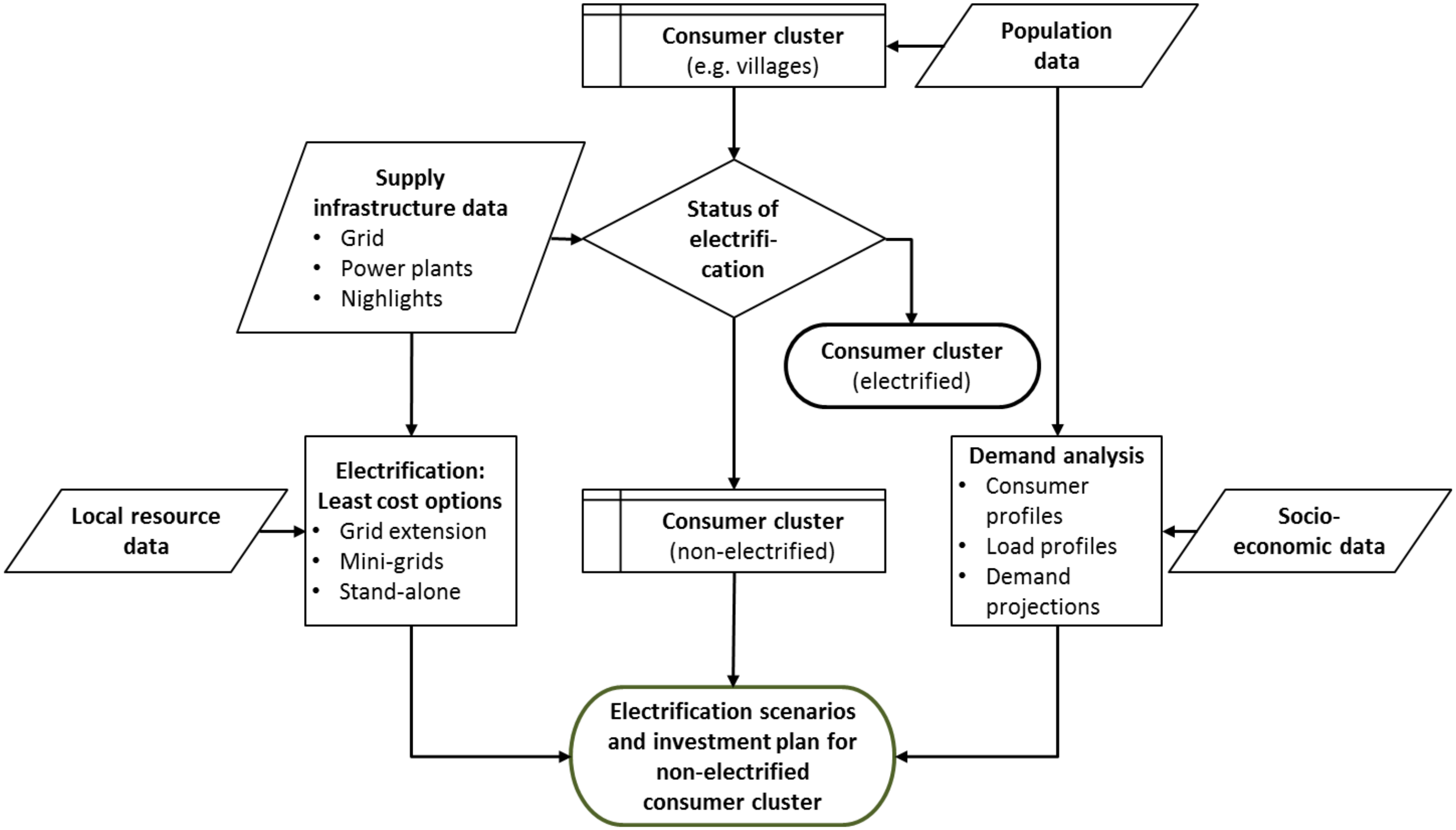
- GIS analyses
- Evaluation of on- and off-grid supply options
- Local capacity development

INTEGRATION

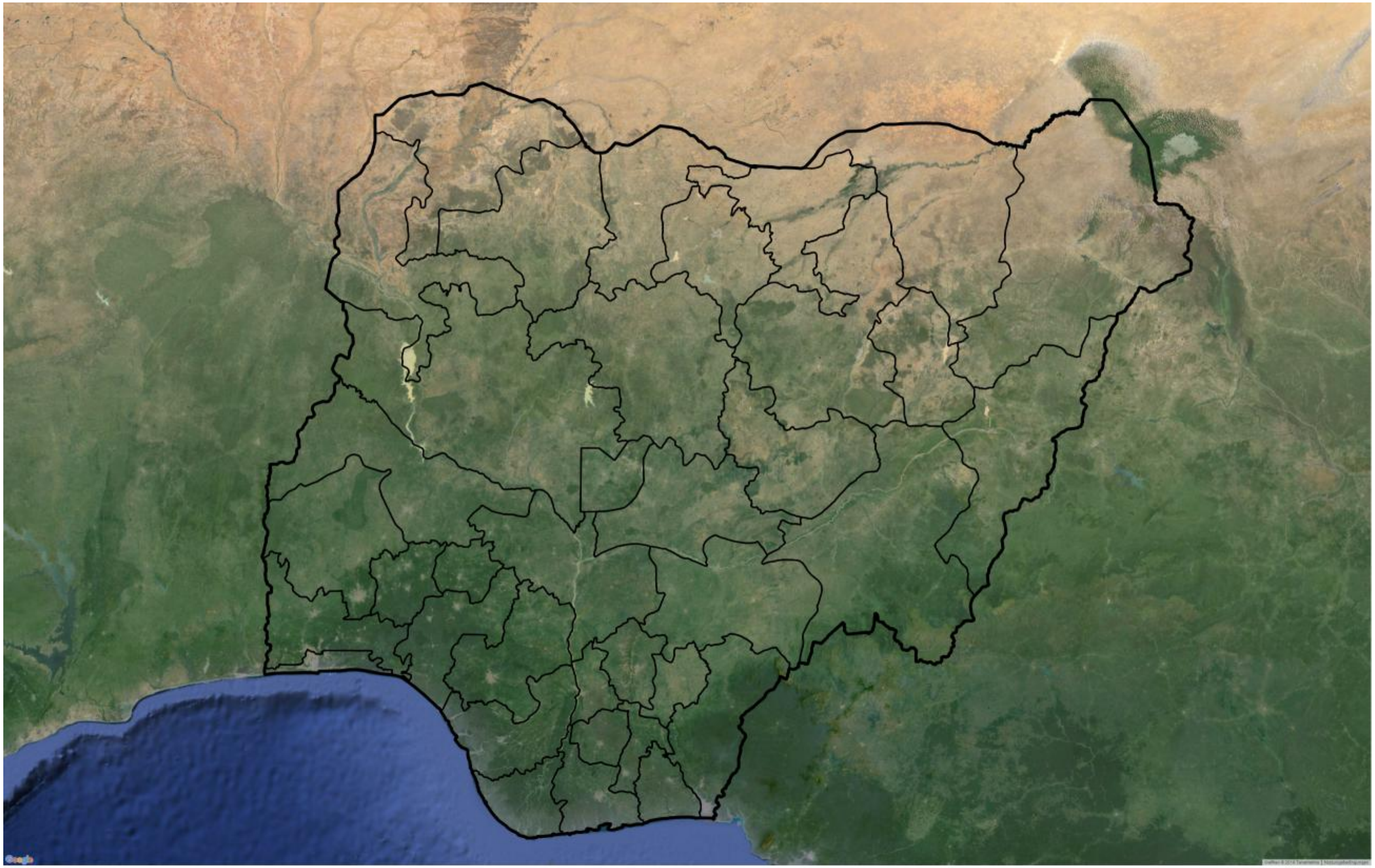
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Dynamic electrification modelling - Showcase

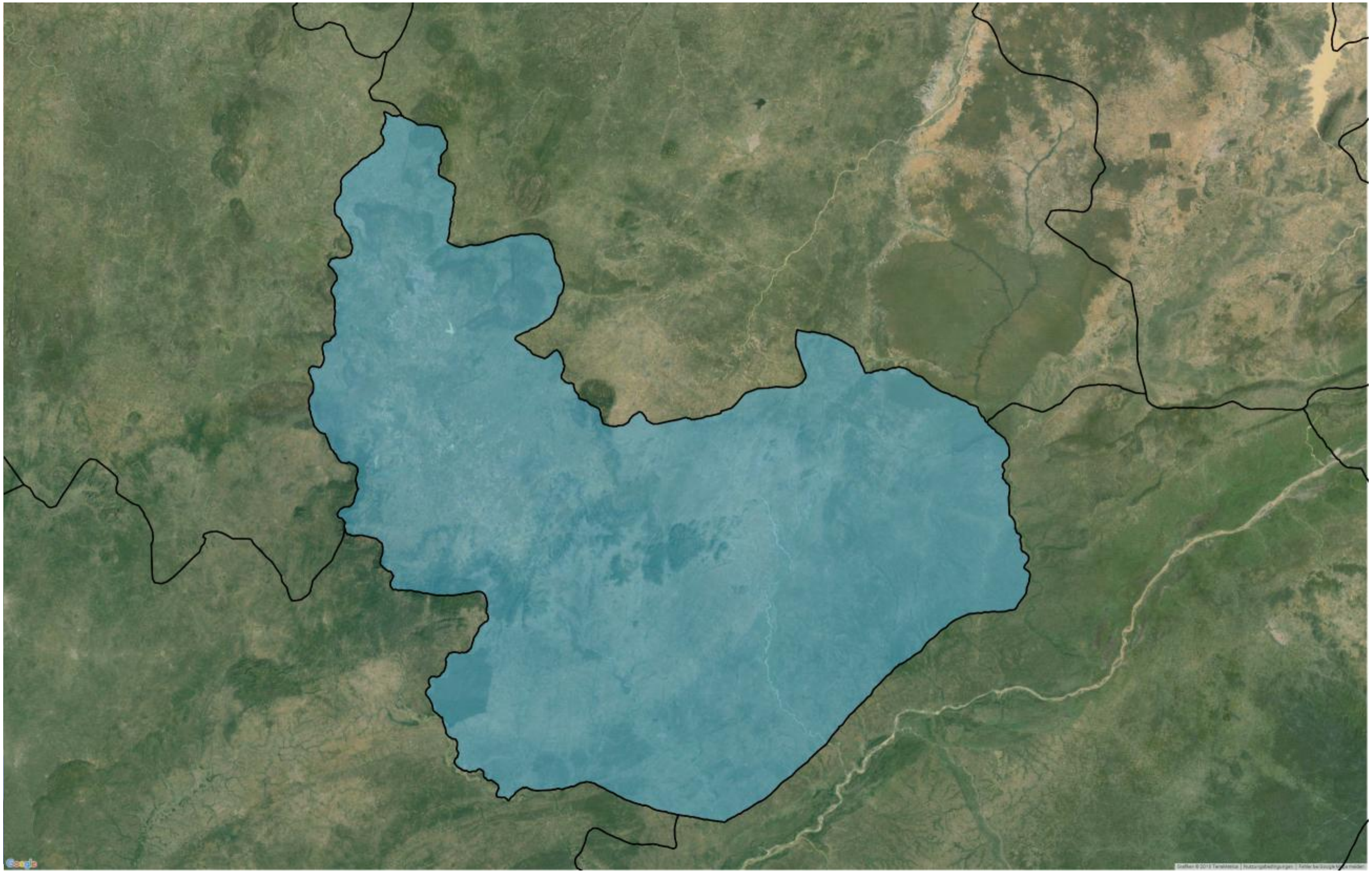
- Electrification modelling along the example of Plateau State



Map of Nigeria

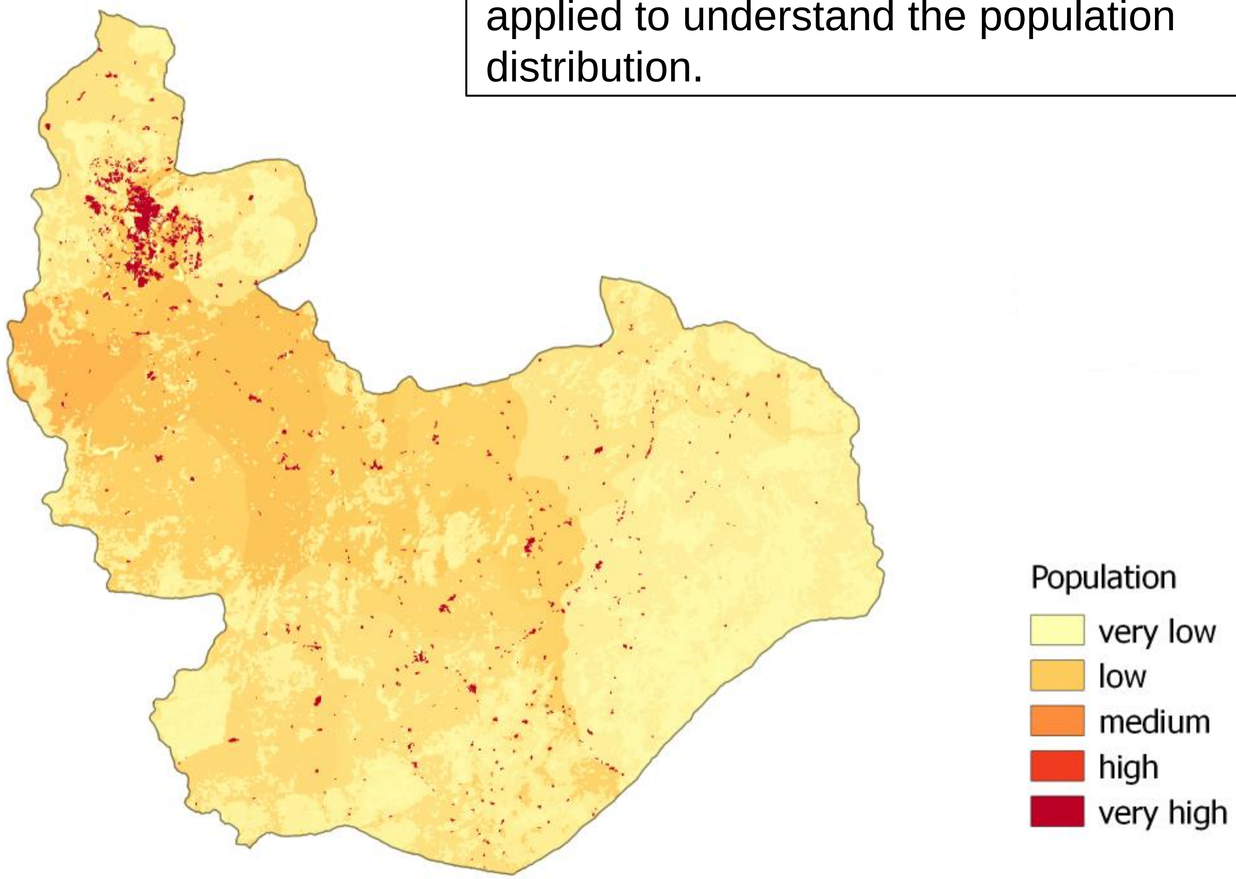


Map of Nigeria – Plateau zoom



Step 1a: Identification of consumer cluster - population

Consumer cluster build the baseline of electrification modelling. Global data sets are applied to understand the population distribution.



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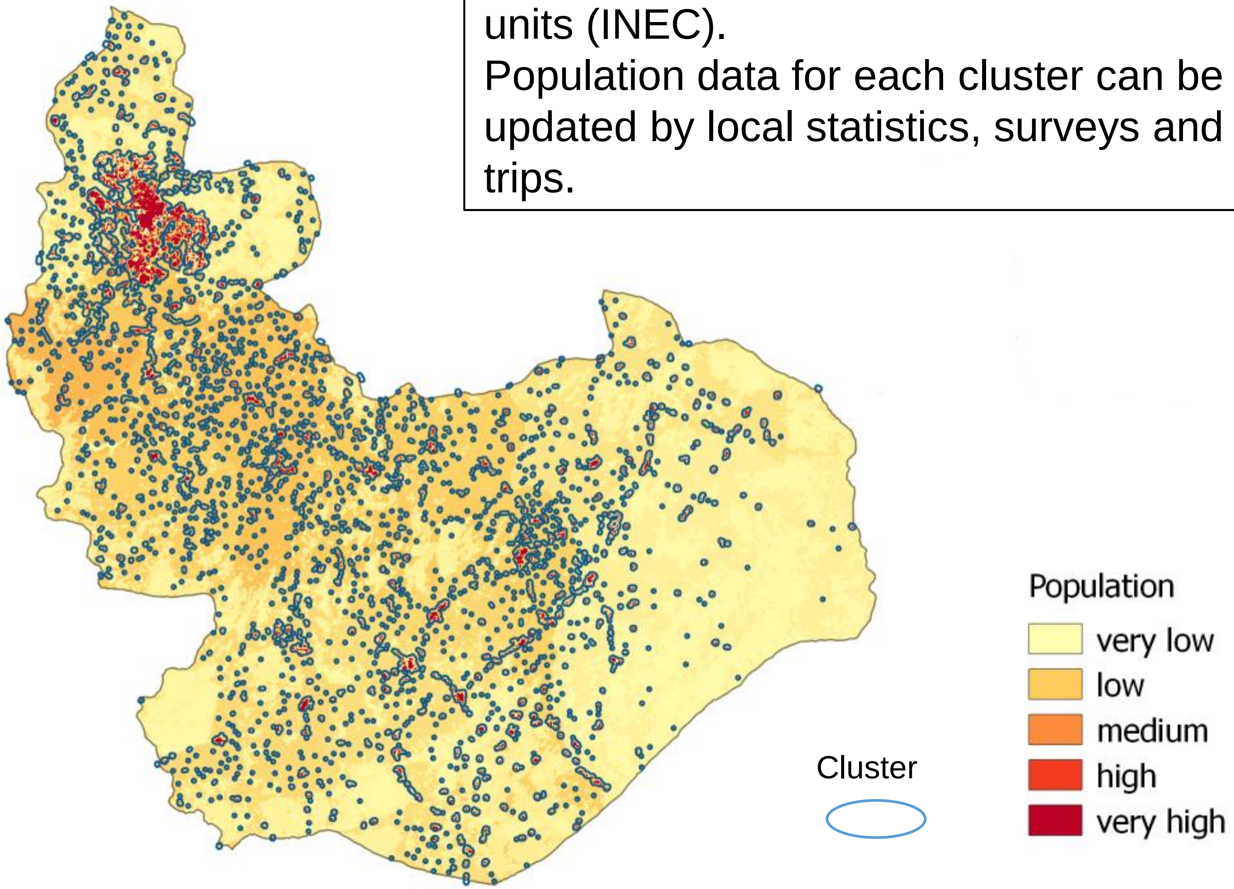
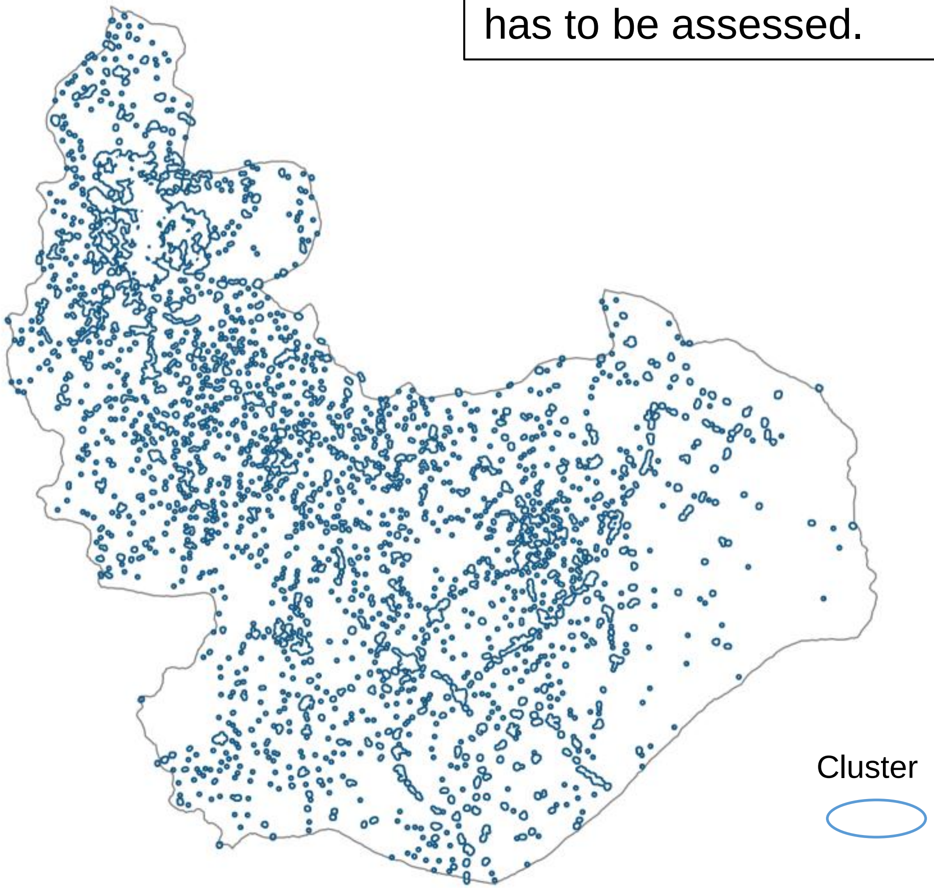
Step 1a: Identification of consumer cluster - location

Consumer cluster are derived based on population density, school data and polling units (INEC).
Population data for each cluster can be updated by local statistics, surveys and field-trips.



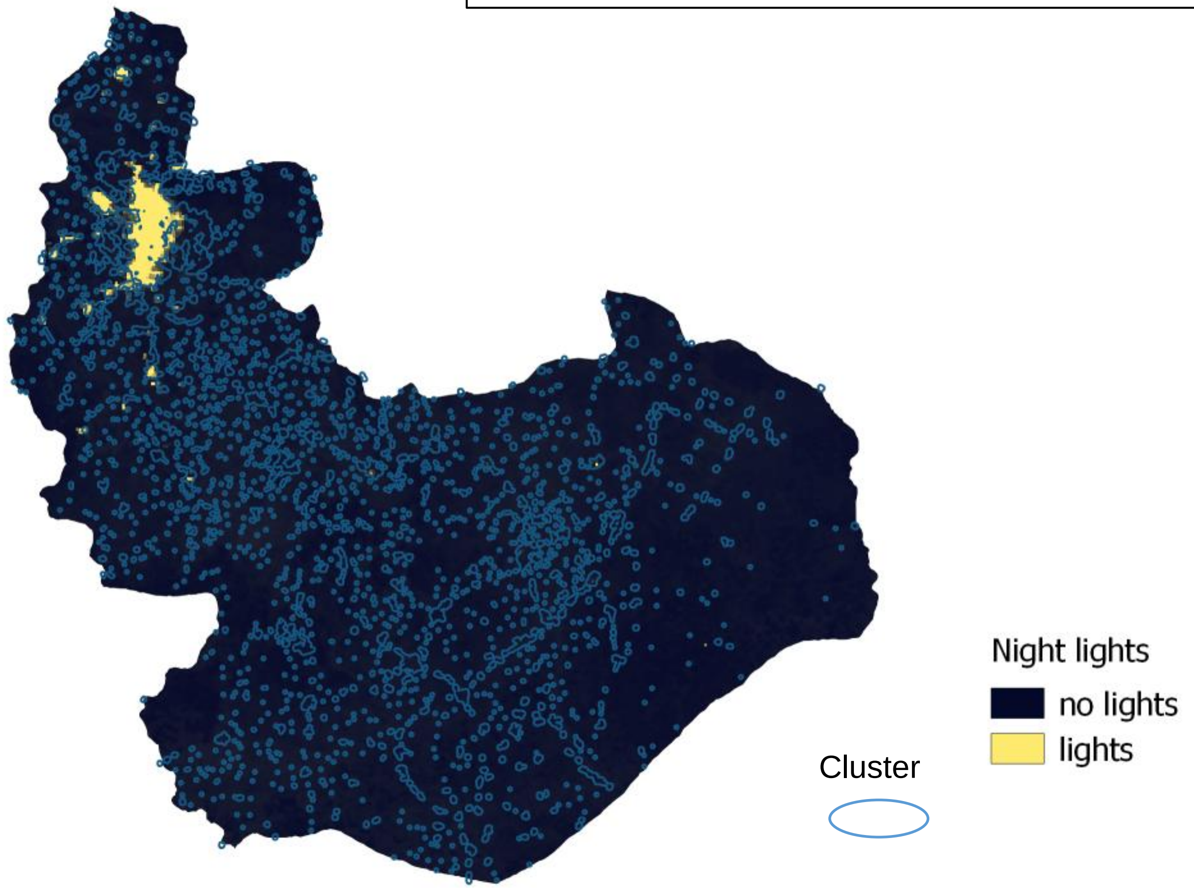
Step 1b: Assessment of status of electrification

Consumer clusters and their population data are identified. Now the status of electrification has to be assessed.



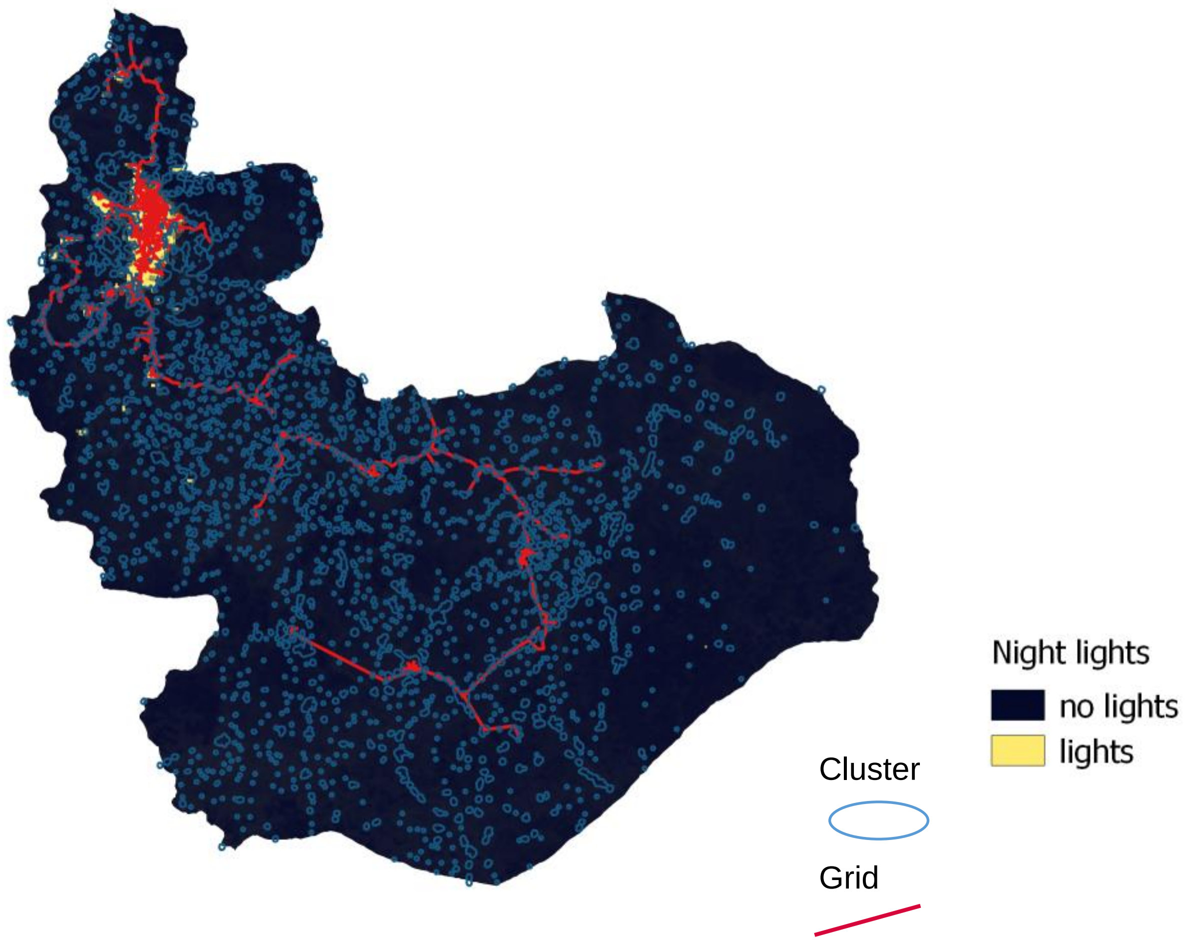
Step 1b: Night light imageries

Light emissions during night indicate availabilty of electricity



Step 1b: Grid data

Grid-connection indicates access to electricity.



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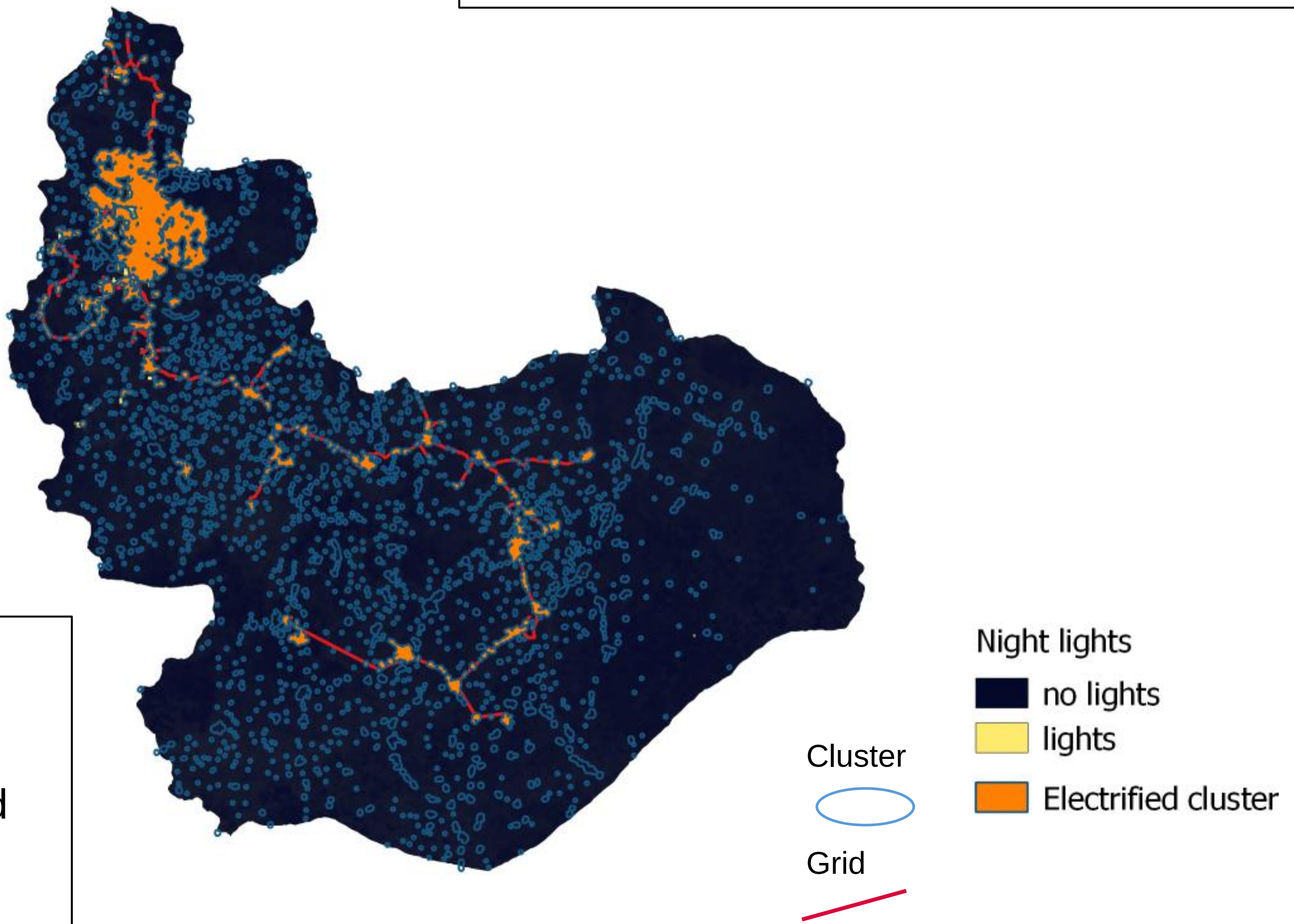
Step 1b: Final identification of status of electrification

Combination of night ligths and grid data shows electrified clusters.



Results
Clusters electrified:
26; 1 %
People living in electrified clusters:
1.4 mill.; 34 %

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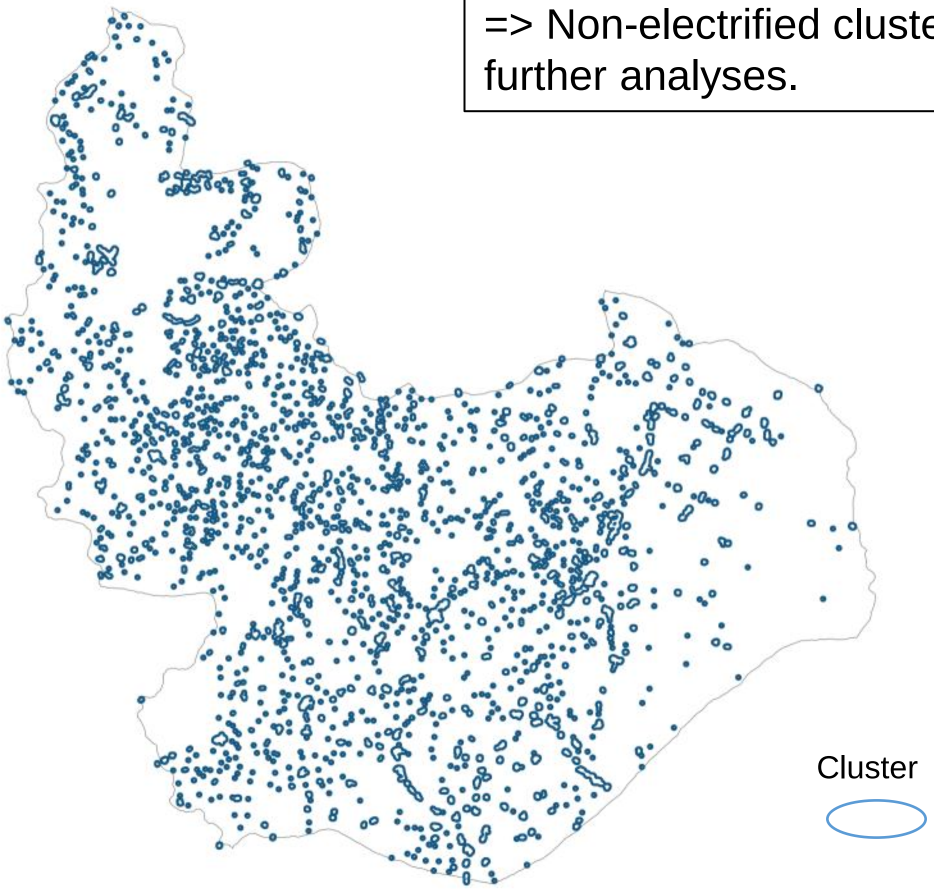
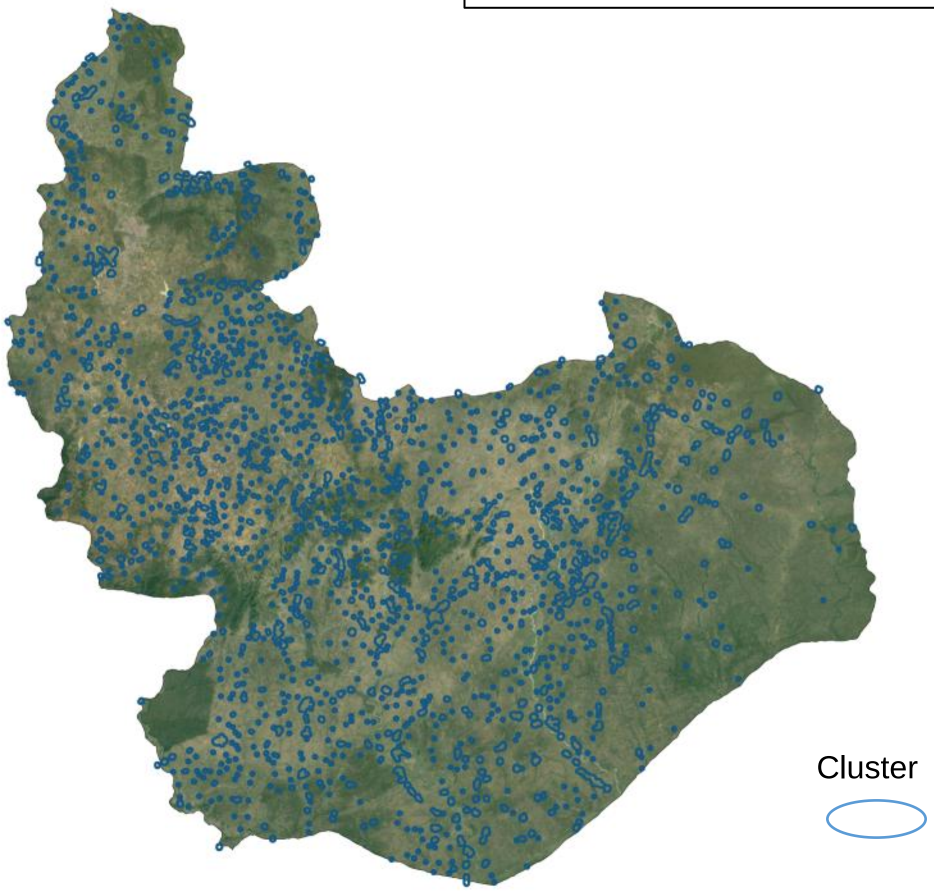
Step 1b: Non-electrified clusters

Combination of night ligths and grid data shows electrified clusters.
=> Non-electrified clusters can be derived for further analyses.



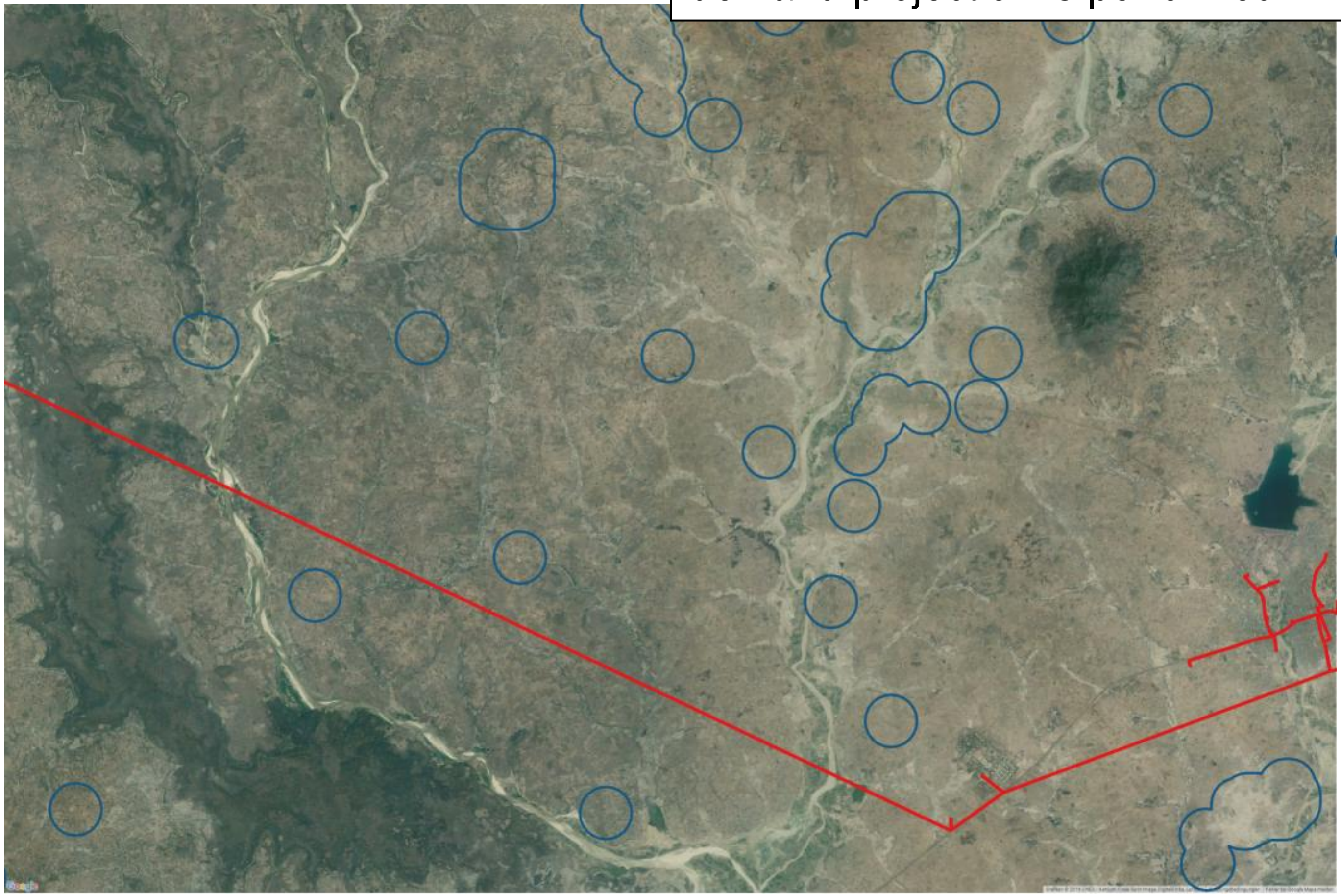
Step 2: Demand analysis for each non-electrified cluster

For each non-electrified cluster an individual demand projection is performed.

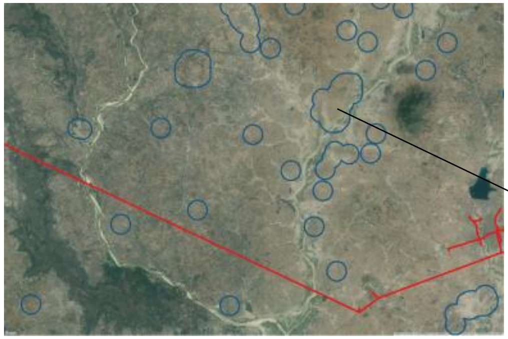


Step 2: Demand analysis - Zoom

For each non-electrified cluster an individual demand projection is performed.



Step 2: Demand analysis - Input

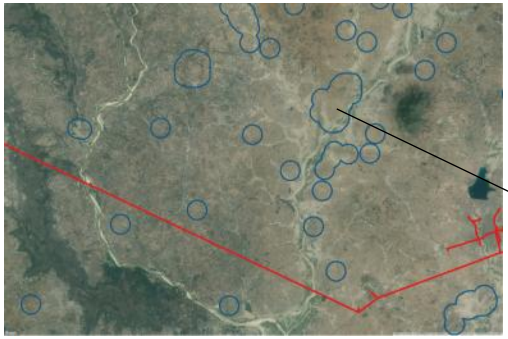


For each non-electrified cluster an individual demand projection is performed.
Socio-economic and infrastructural data are collected and processed.

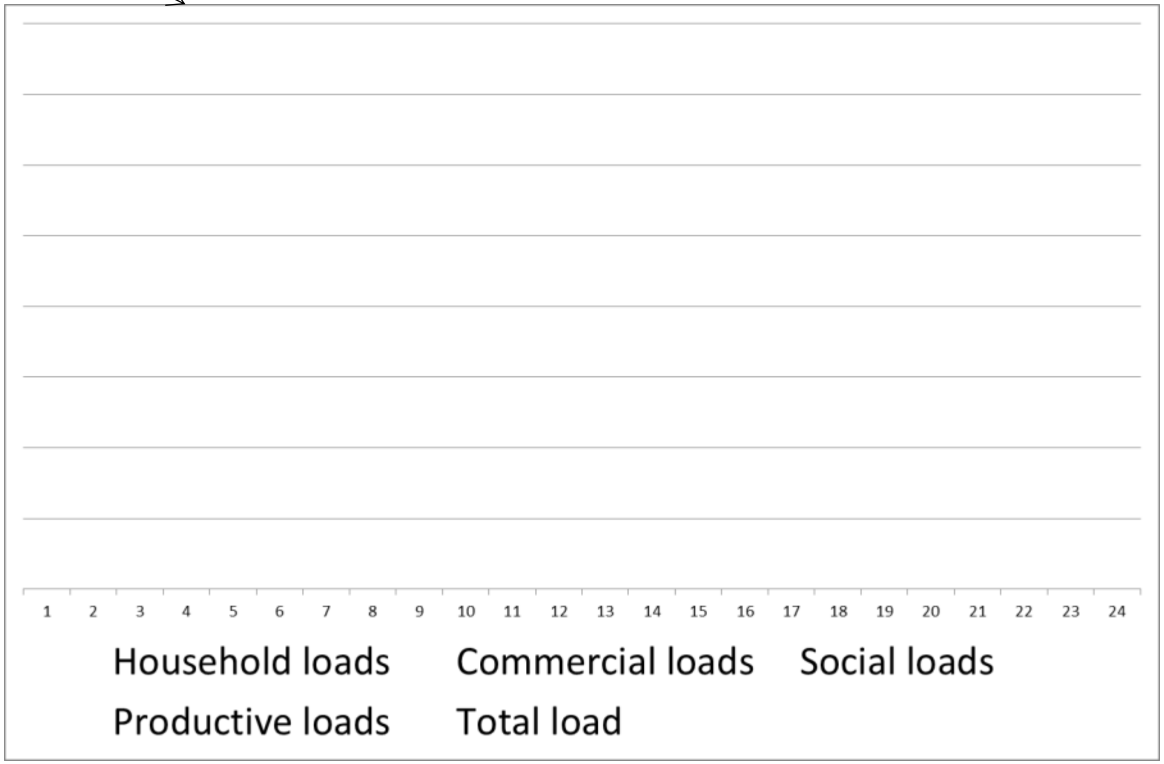
Results – Example village
Population: appr. 1,600 (equals 320 households)
Commercial consumers: 20 (small shops and enterprises)
Social loads: 5 (schools, health station and community buildings)
Productive loads: 4 (mills, car shops and welders)

Cluster information → **Daily load curve** → **Annual load curve (incl. random variability)** → **Individual profile per cluster**

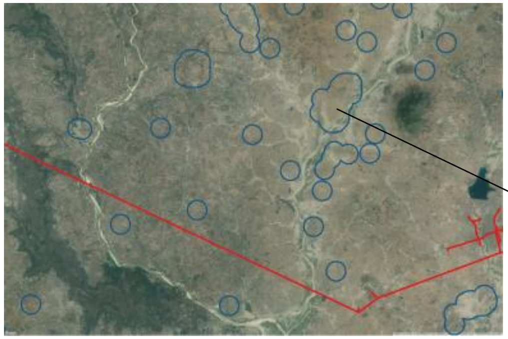
Step 2: Demand analysis



Socio-economic and infrastructural data feed into automatized load projection model.



Step 2: Demand analysis – Household loads



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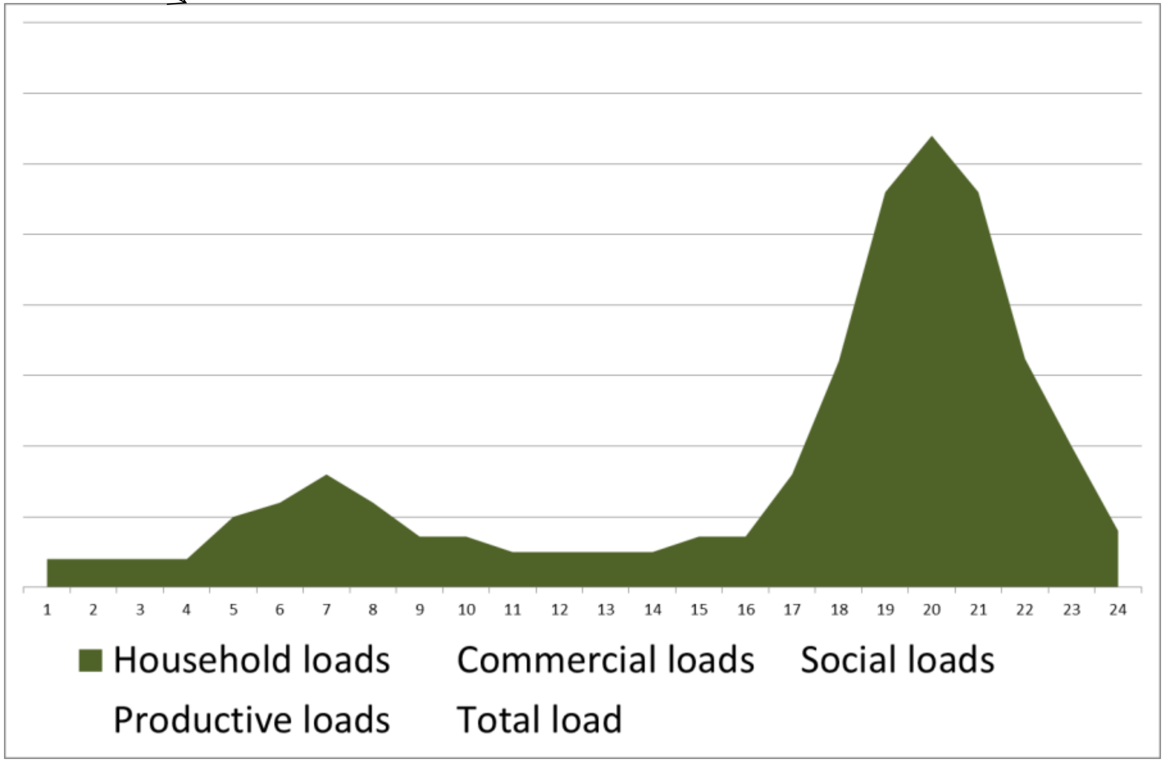
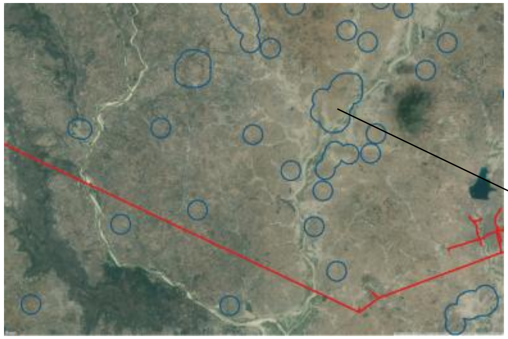
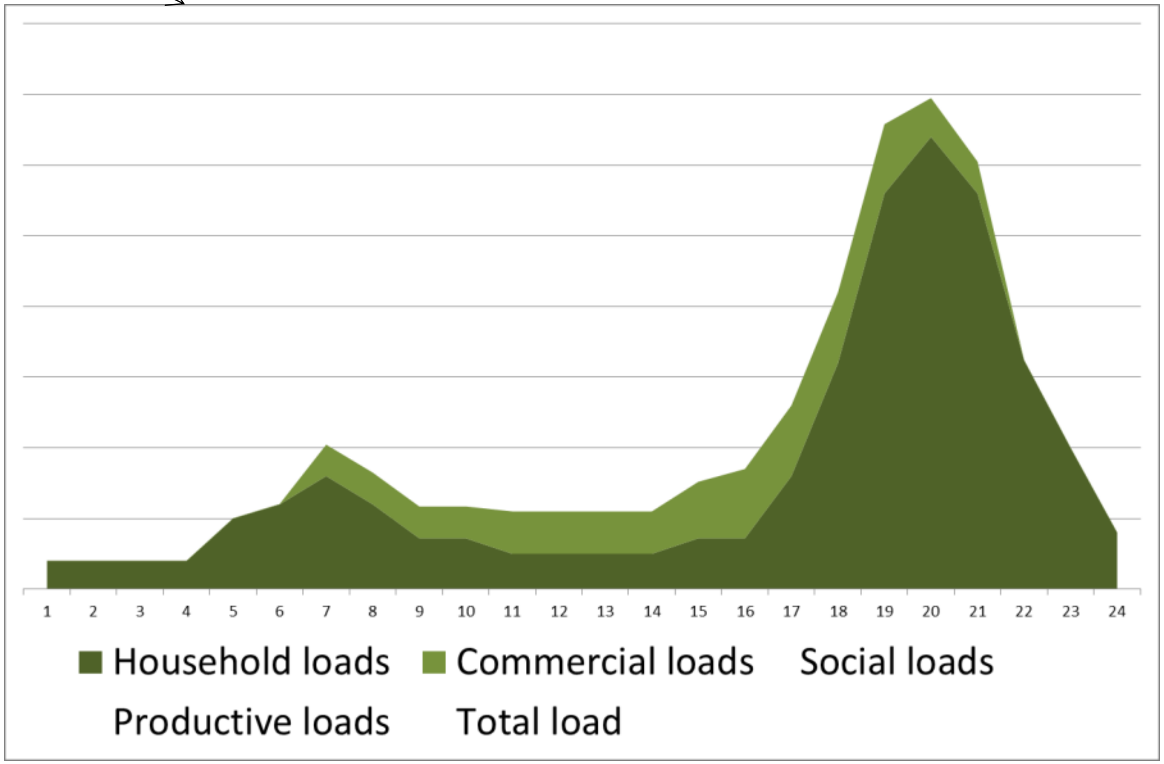


Assumptions
- High evening peak
- Mixture of different household types

Step 2: Demand analysis – Commercial loads



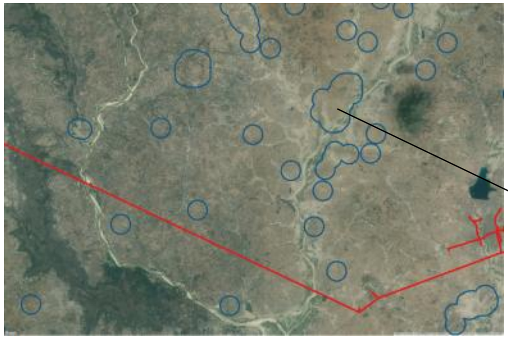
Socio-economic and infrastructural data feed into automatized load projection model.



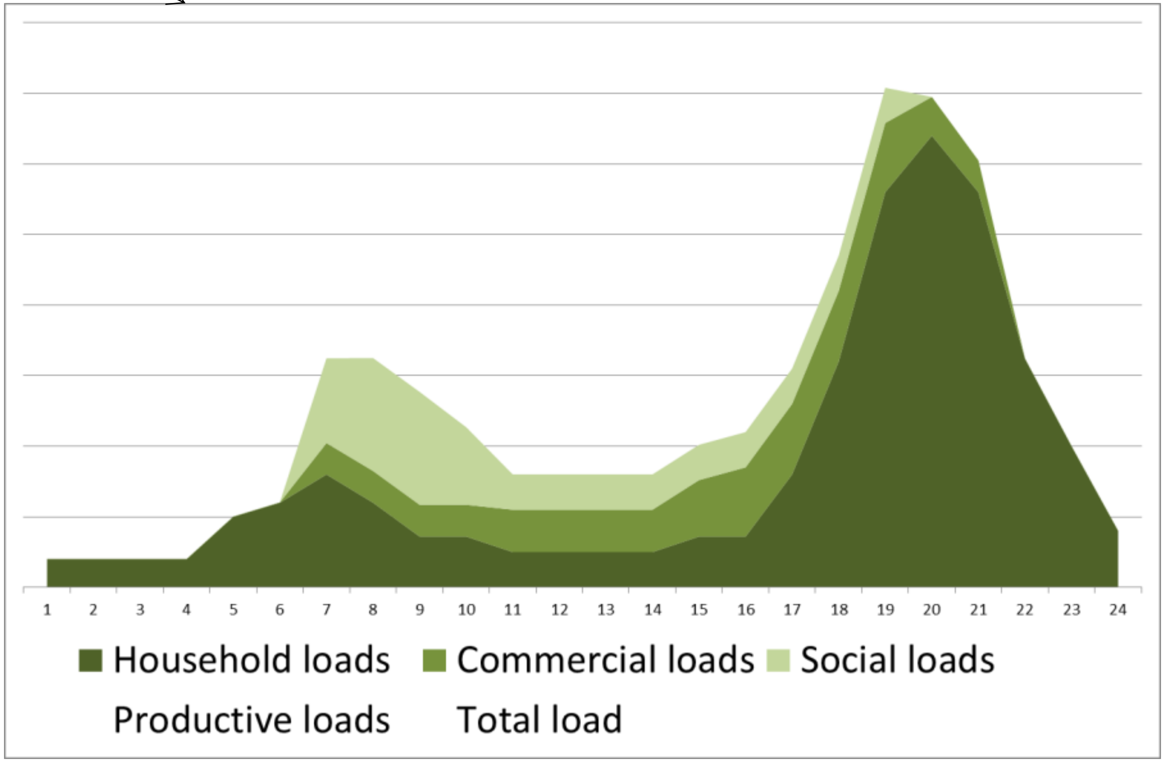
Assumptions

- Small shops and enterprises
- Main load during daytime and evening

Step 2: Demand analysis – Social loads



Socio-economic and infrastructural data feed into automatized load projection model.



Assumptions
- Schools, health station and community buildings
- Main load before noon and during the day

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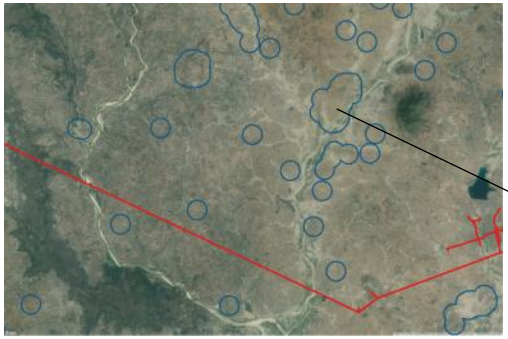
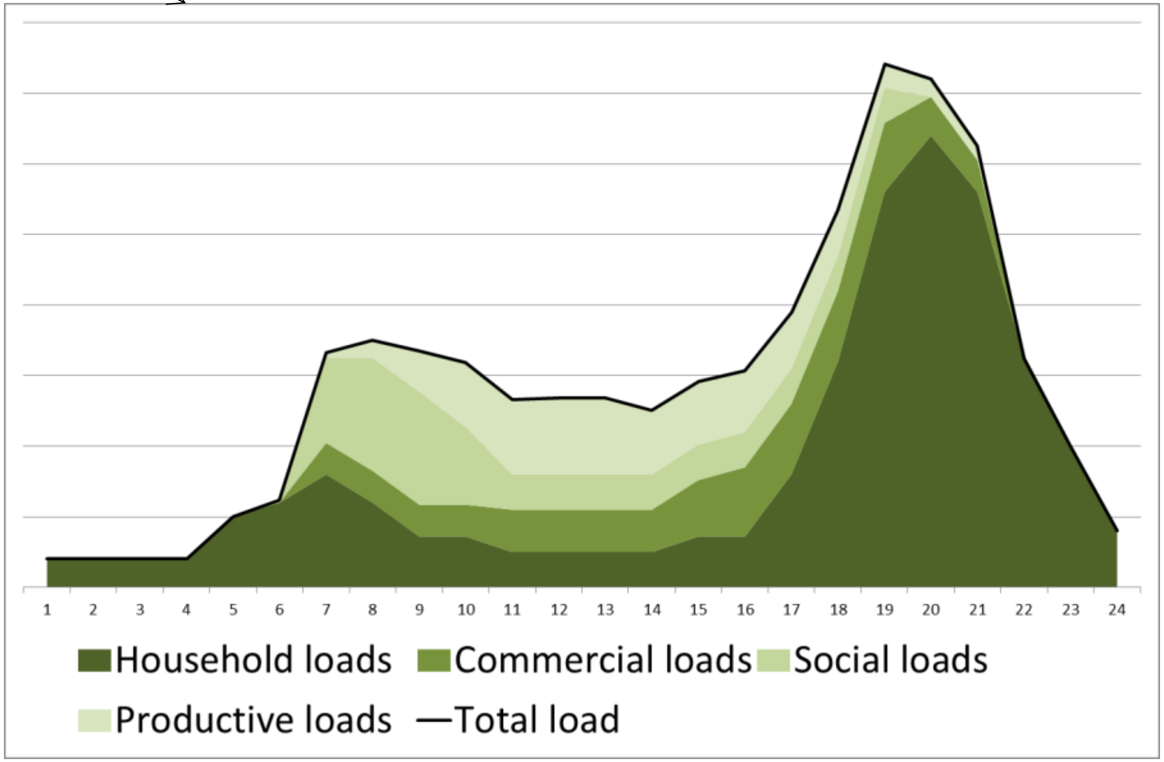
Step 2: Demand analysis – Productive loads

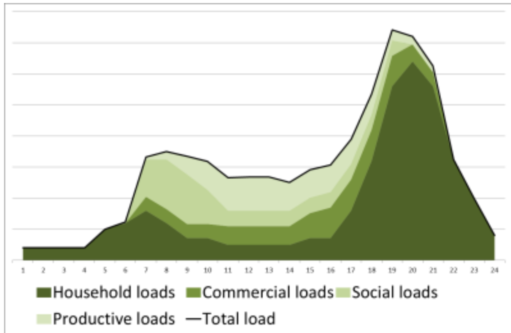


Socio-economic and infrastructural data feed into automatized load projection model.

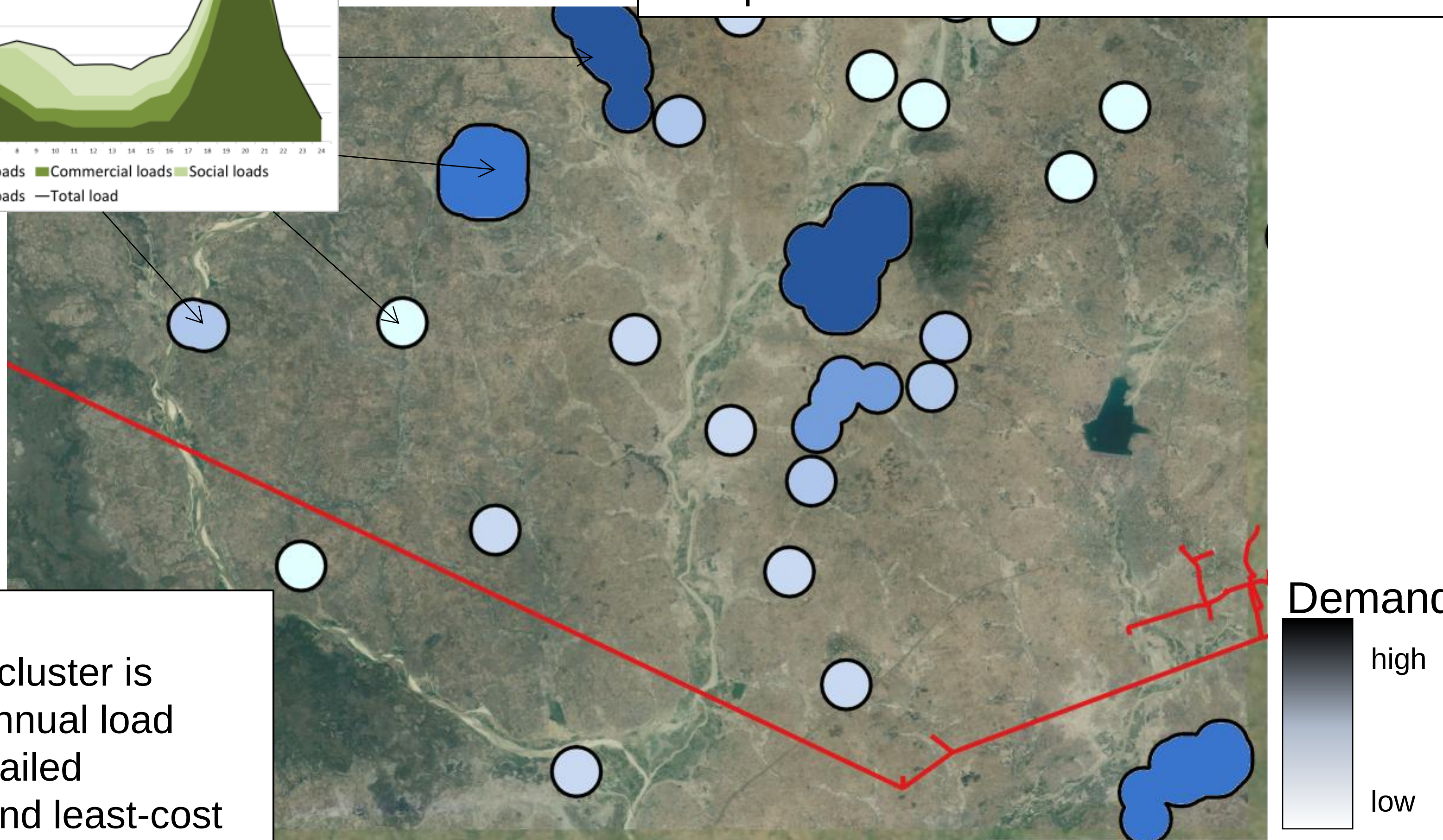


Assumptions
- Mills, car shops and welders
- Main load during the day

Step 2: Demand analysis – Dynamic extrapolation



Load analysis routine is fed back into GIS for extrapolation of results.



Results
Demand per cluster is calculated. Annual load profile for detailed simulations and least-cost analysis.

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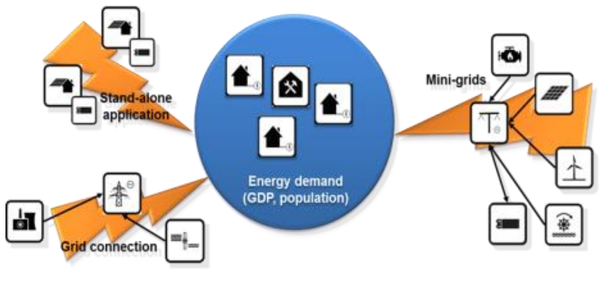
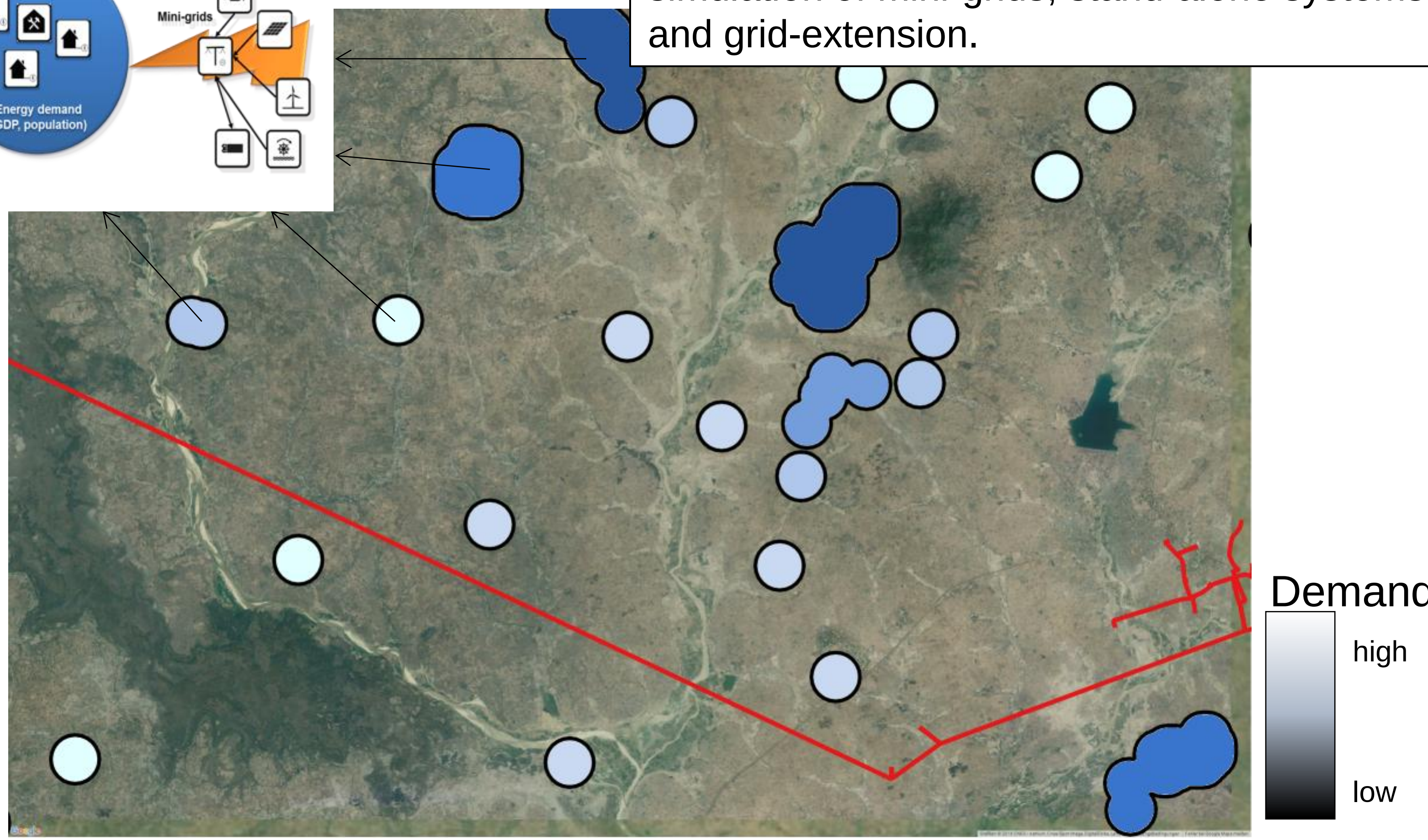
Step 3: Least-cost analysis – Input data: load

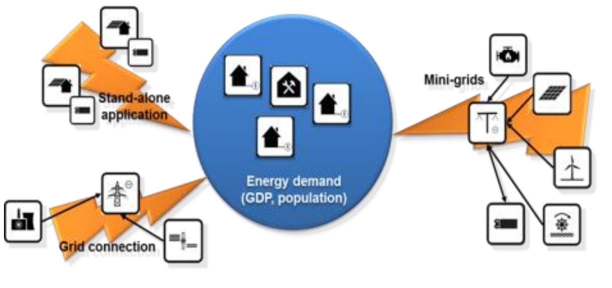
Load demand is fed into least-cost model for simulation of mini-grids, stand-alone systems and grid-extension.

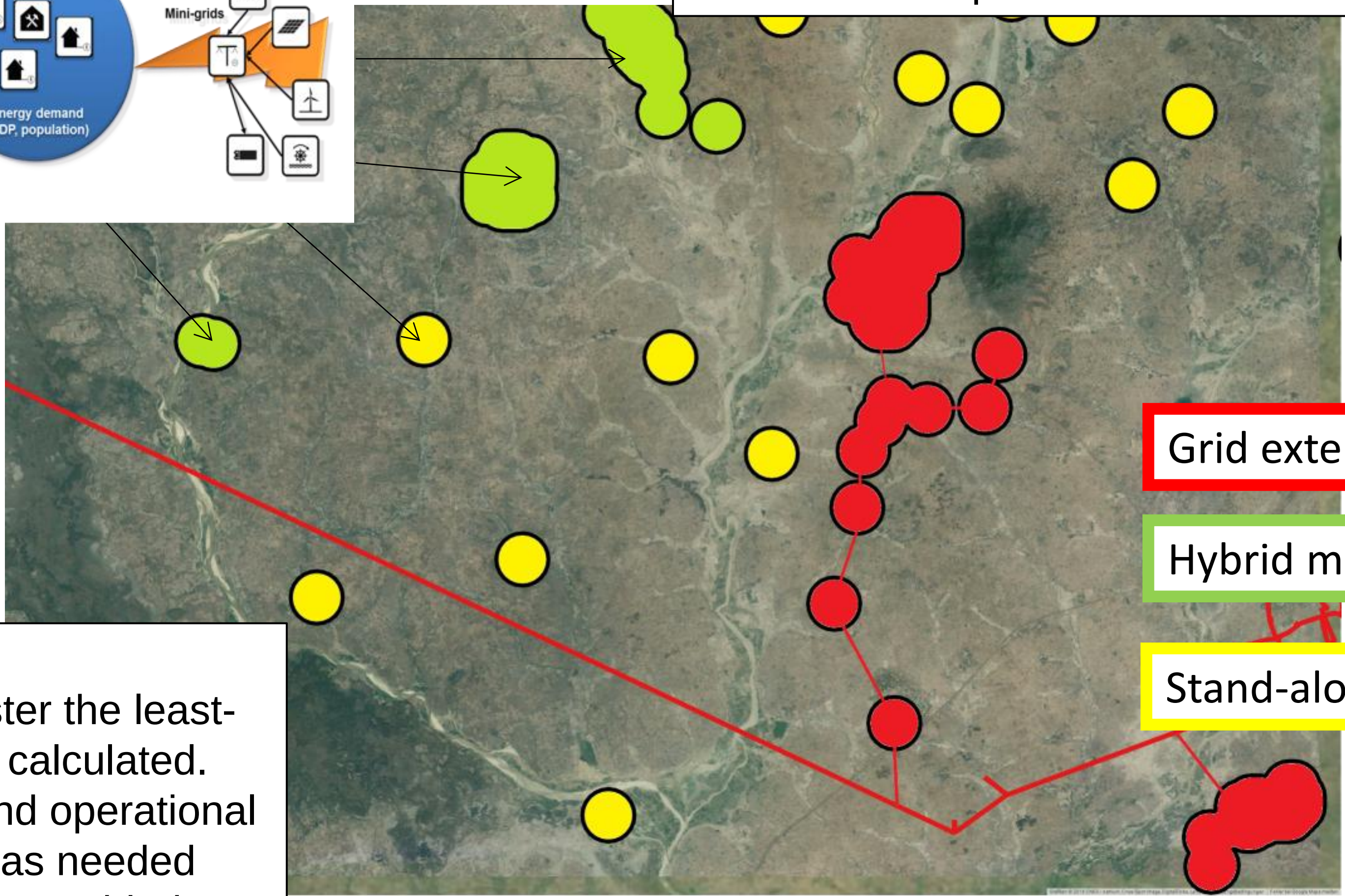




Step 4: Investment plan

Results for each cluster show least-cost electrification option.





Grid extension

Hybrid mini-grids

Stand-alone

Results
For each cluster the least-cost option is calculated. Investment and operational costs as well as needed capacities are provided.

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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 project 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

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

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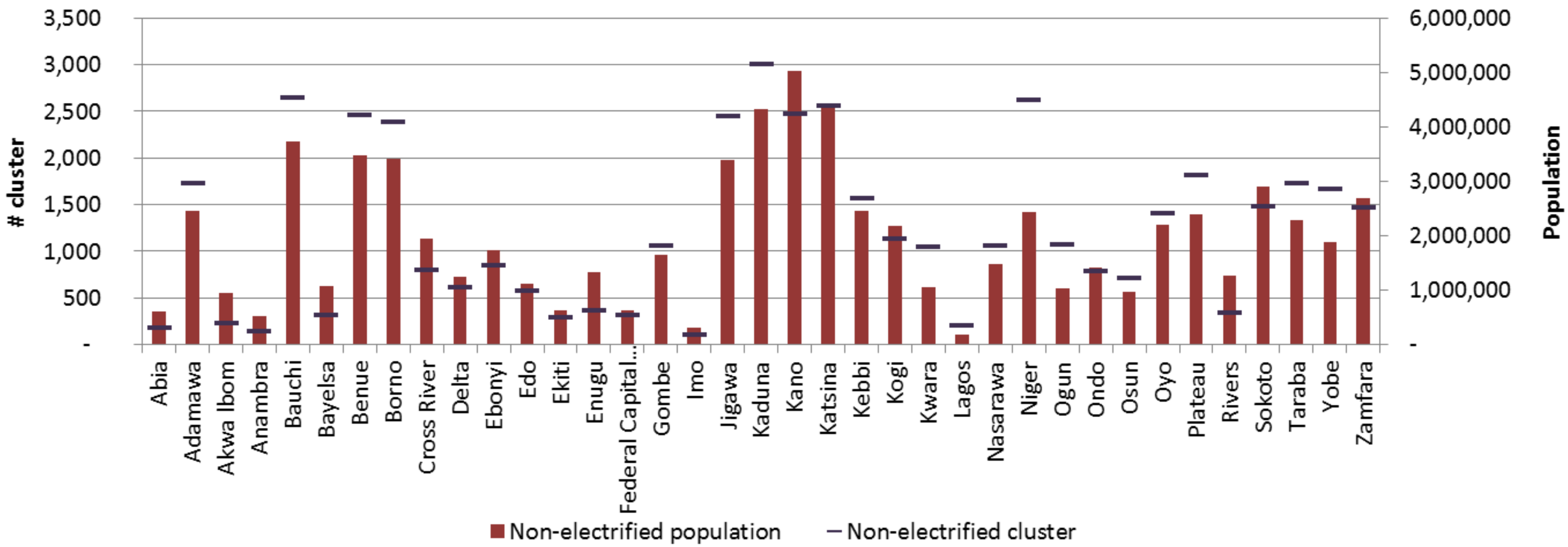
Status of Electrification – Results

- 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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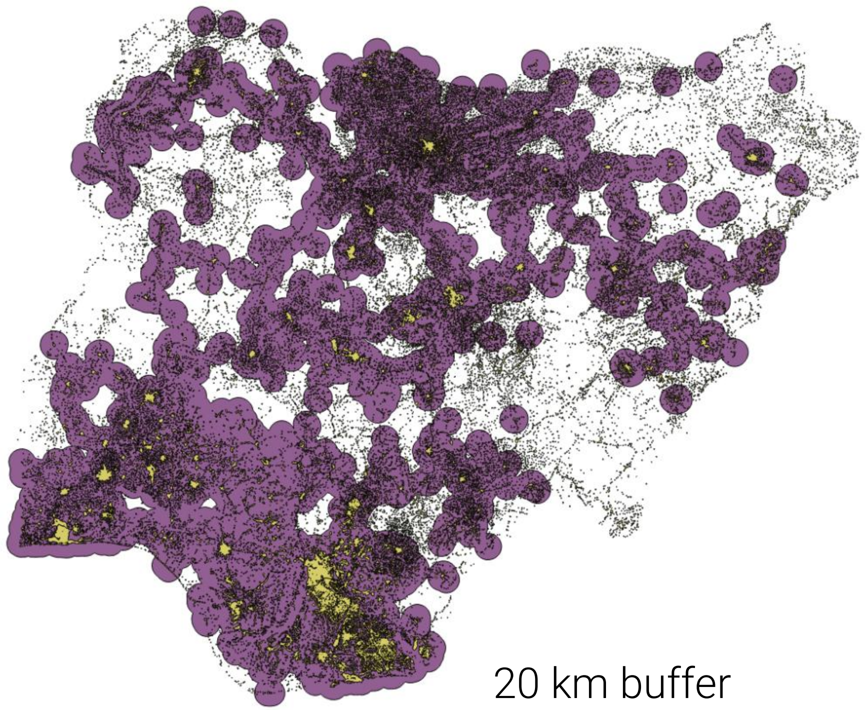
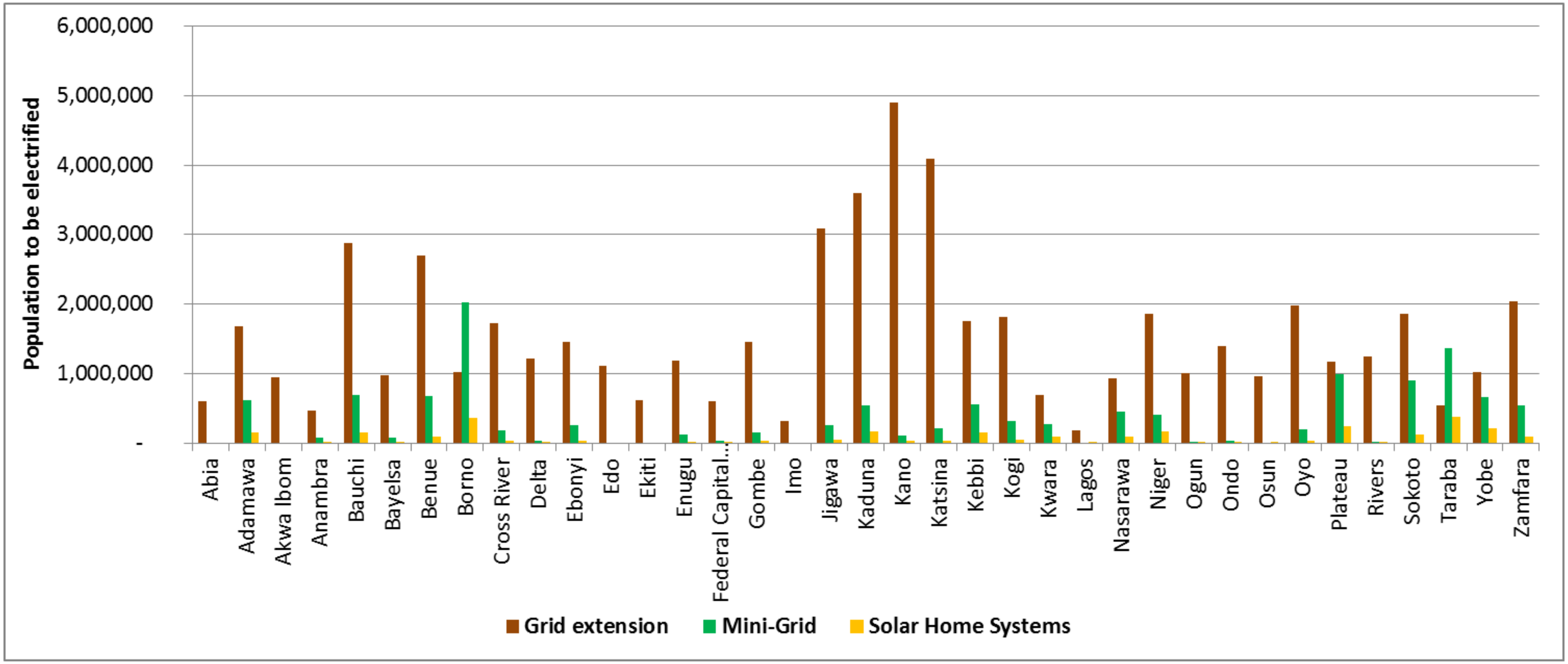
Electricity supply options – Preliminary approach

- All clusters around 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



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



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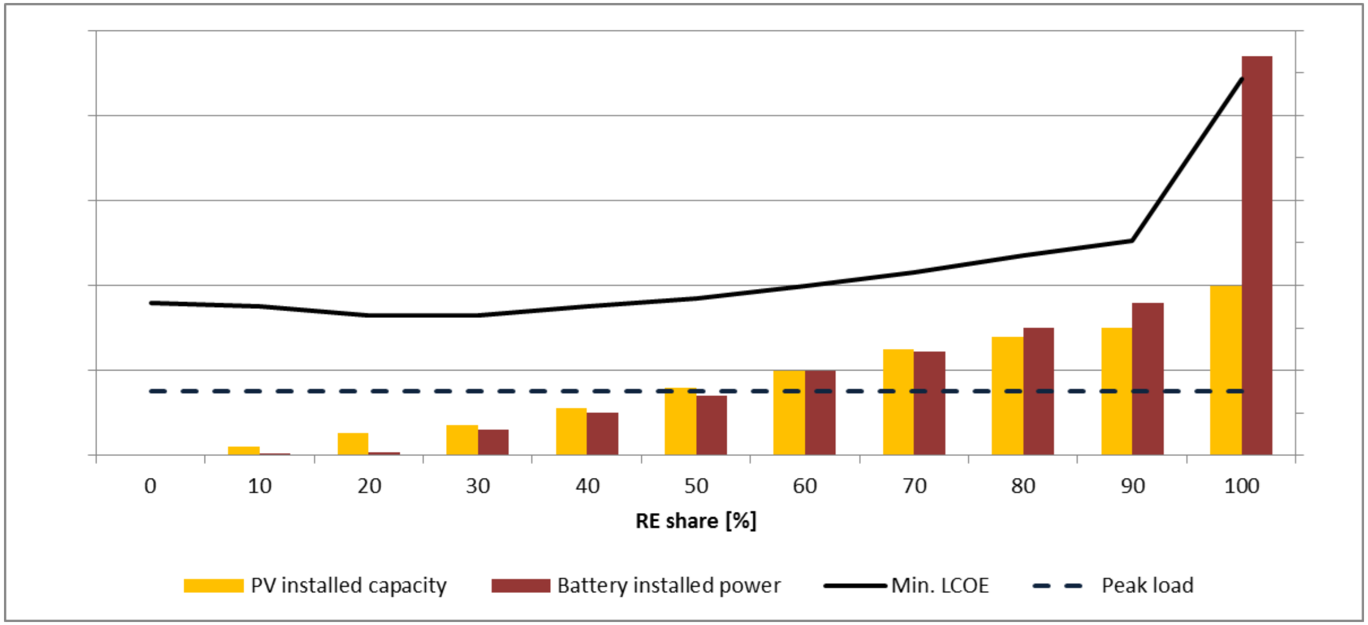
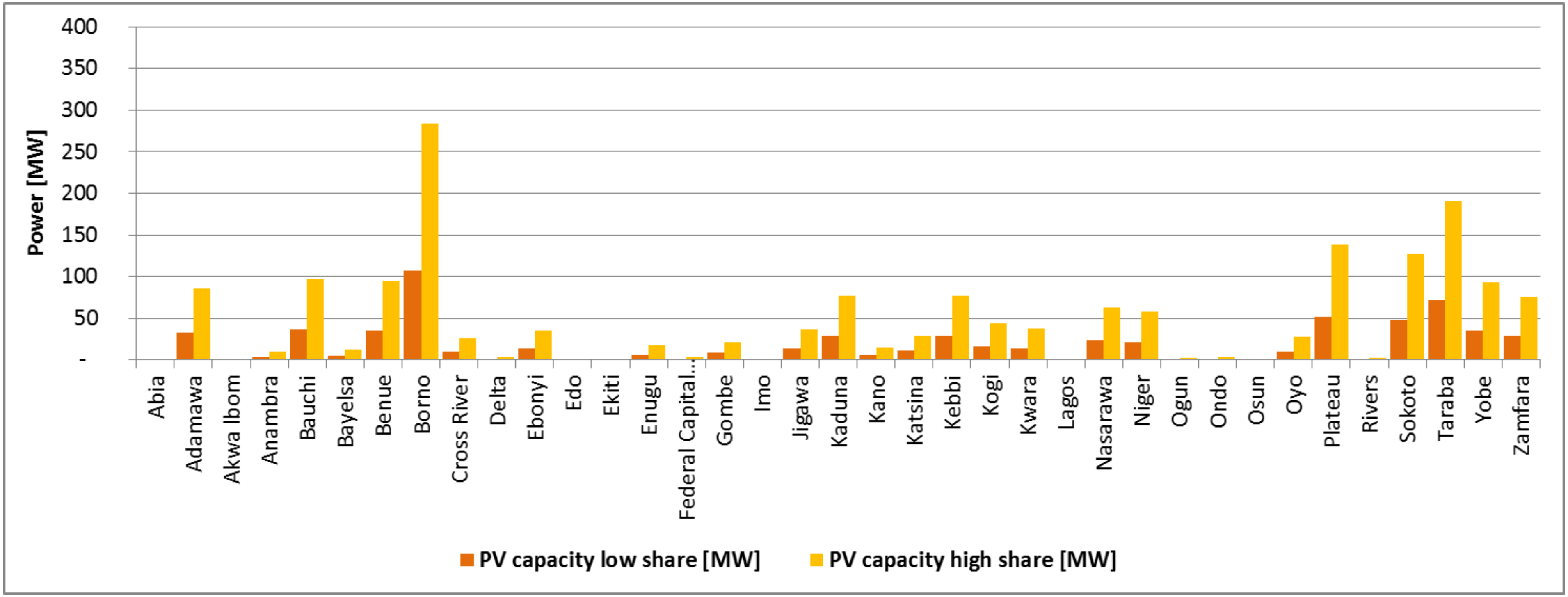
PV potential Mini-Grids – Results Showcase

- Only qualitative results are shown (as cost parameter are not approved)
- 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 (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



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Agenda

- Übersicht Hybridisierung
- Marktpotentiale
    - Inseln
    - Remote Industries
    - Ländliche Elektrifizierung
- Fallbeispiel Nigeria
- Zusammenfassung

Zusammenfassung – Ländliche Elektrifizierung

- PV hybrid Mini-Grids werden mehr und mehr als Alternative zur Netzerweiterung akzeptiert und sogar gefördert.

- Eine umfassende Planung und Modellierung ist notwendig um die attraktivsten Standorte zu identifizieren.

- Nigeria:
  - Vorläufiges Potential zur Elektrifizierung von ca. 13 Millionen Menschen durch PV hybrid Mini-Grids
  - Regulierung wird erarbeitet die wettbewerbsfähige Tarife für private Mini-Grid Betreiber erlaubt (> 50 ctEUR/kWh)

Ländliche Elektrifizierung durch PV hybrid Mini-Grids:
Ein interessanter Markt der gleichzeitig die Verbesserung der lokalen Lebensbedingungen in Entwicklungsländern ermöglicht!

Vielen Dank für Ihre Aufmerksamkeit

SPRECHEN SIE UNS AN FÜR

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- Auftragsforschung

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