KTH Department of Energy Technology
Division of Energy Systems Analysis

LIGHTING UP THE WORLD
THE FIRST GLOBAL APPLICATION OF THE OPEN SOURCE, SPATIAL ELECTRIFICATION TOOL (ONSSET)

Researchers:

Dimitris Mentis
Alexandros Korkovelos
Shahid Hussain Siyal
Paritosh Deshpante
Oliver Broad
Mark Howells
Holger Rogner

Presentation:

Alexandros Korkovelos

2015 INTERNATIONAL WORKSHOP ON ENVIRONMENT AND ALTERNATIVE ENERGY
November 13th 2015
ESAC, Madrid, Spain

A research initiative funded by:

Introduction

Nowadays:

- ❖ About 2.7 billion people have no access to modern energy services.
- ❖ Over 1.3 billion people do not have access to electricity.
- ❖ The majority live mainly in rural areas of developing Asia and sub-Saharan Africa.
- ❖ Access to energy is crucial for human well-being & a country's economic development.

Sustainable Development Goals

- Agenda 2030 for Sustainable Development by United Nations.
- There are **17 SDGs** that are intended as universal goals aiming to develop people, economy and society and to sustain nature, life support and community.
- **7th SDG: Ensure access to affordable, reliable, sustainable and modern energy for all by 2030.**

Objective

The main objectives of our research are:

- To develop a methodology to approach the **UN 7th Sustainable Development Goal** in a comprehensive and quantitative way.
- To introduce a toolkit in order to come up with the **optimal infrastructure and generation mix** for electrification.
- To apply this tool in all countries that do not have 100% access to electricity (i.e. developing Africa, Asia, Latin America and middle East).
- Support the energy planning for sustainable transition in these counties.

Importance of energy planning

- Energy planning is essential in order to match demand and supply.
- Cost minimization is a primary objective.
- Considerable modifications in the energy infrastructure are needed.

However…

- These modifications are inherently motivated by geospatial questions.
- Ground level geospatial data are of key importance to help identify the most effective electrification strategy.
- In developing countries, there is a lack of reliable energy-related data.

Why Geographic Information Systems?

The use of GIS serves multiple purposes:

Location based assessments: GIS tools enable assessments to analyse energy related geospatial information.

Remote sensing: The use of GIS tools facilitates the integration of remote sensing techniques to derive resource availability & energy potentials in cases where such data are not (publically) available.

Illustration of results: GIS is used to illustrate results in interactive maps, providing an effective science – policy interface.

The integration of GIS in energy system models is still in its infancy.

OpeN Source Spatial Electrification Toolkit

ONSSET Toolkit for:

✓ Identification of most economic electrification mix (technology type)

✓Quantification of investment

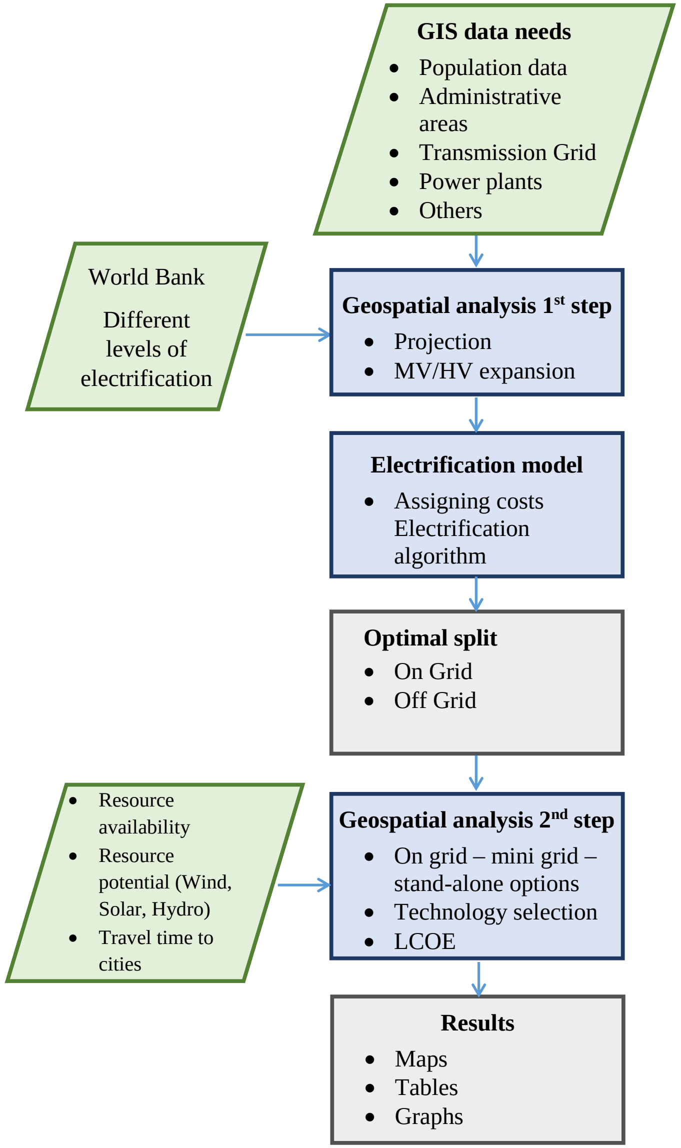
✓Geospatial illustration of national electrification targets

Methodology

1st step

- Population projection
- Distance for existing/planned grid
- Cost assumptions

On Vs Off Grid spit



Cost based electrification model

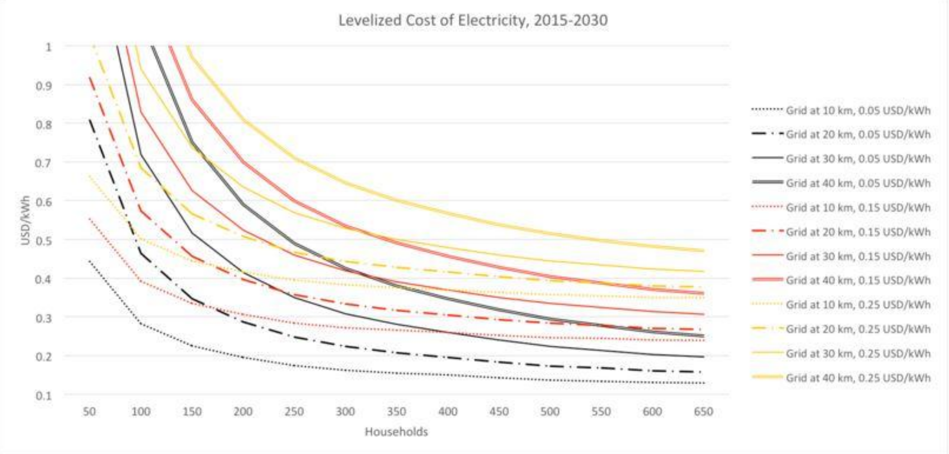
World Bank tiers of electrification:

The analysis is carried out for all the 5 levels of electricity access in order to compare how the optimal electrification mix alters with different energy rates.

Level of access	Tier-0	Tier-1	Tier-2	Tier-3	Tier-4	Tier-5
Indicative appliances powered	*Torch and Radio*	*Task lighting + Phone charging or Radio*	*General lighting + Air circulation + Television; Computing; printing*	*Tier 2 + Small appliances (i.e. General food processing and Washing Machine)*	*Tier 3 + Medium or continuous appliances (i.e. Water heating; Ironing; Water Pumping; Rice cooking, Refrigeration; Miniwave)*	*Tier 4 + Heavy or continuous appliances (i.e. Air Conditioning)*
Consumption (kWh) per household per year (recommended from the WB framework)	*<3*	*3–66*	*67–321*	*322–1,318*	*1,319 –2,121*	*>2,121*
Consumption (kWh) per household per year – As calculated in [17]	-	*22*	*224*	*695*	*1800*	*2195*

Technologies compared for energy access:

For each GIS settlement, the cost of each electrification technology is evaluated with a cost model, calculating the LCOEs of the compared technologies.



For the **LCOE calculations**, four parameters are considered and connected to costs:

- Population density
- Target level and quality of energy access
- Local grid connection characteristics and the national cost of grid electricity

Methodology

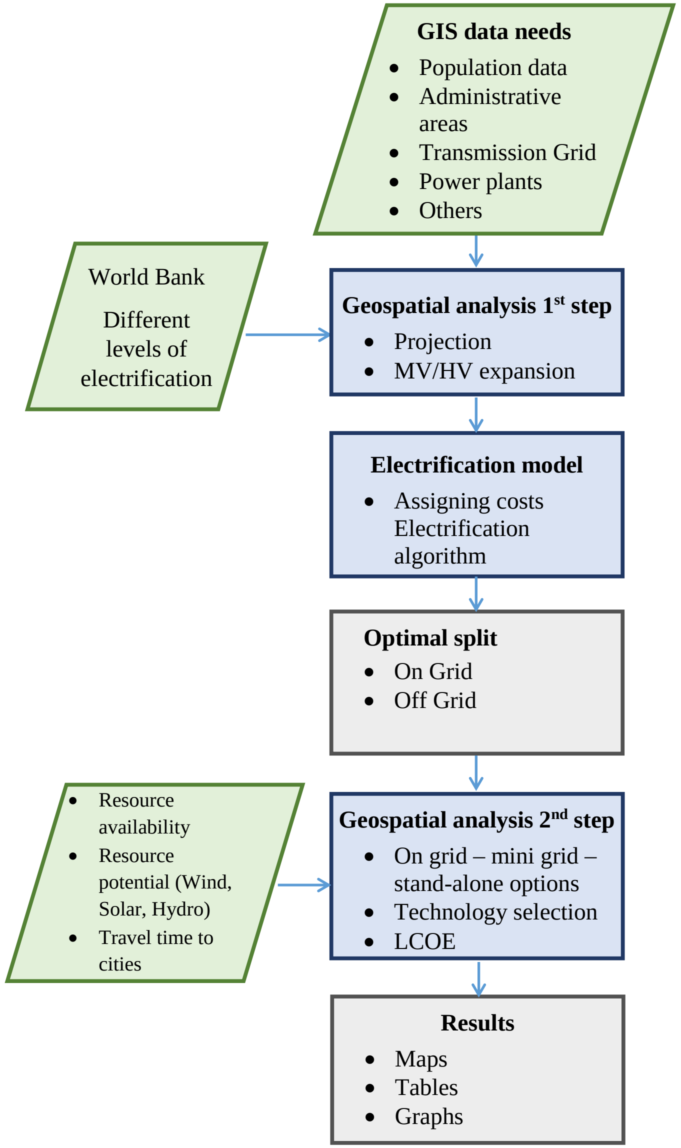
1st step

- Cost assumptions
- Population projection
- Distance for existing/planned grid

On vs Off Grid spit

2st step

- Renewable resources availability
- Diesel cost estimations

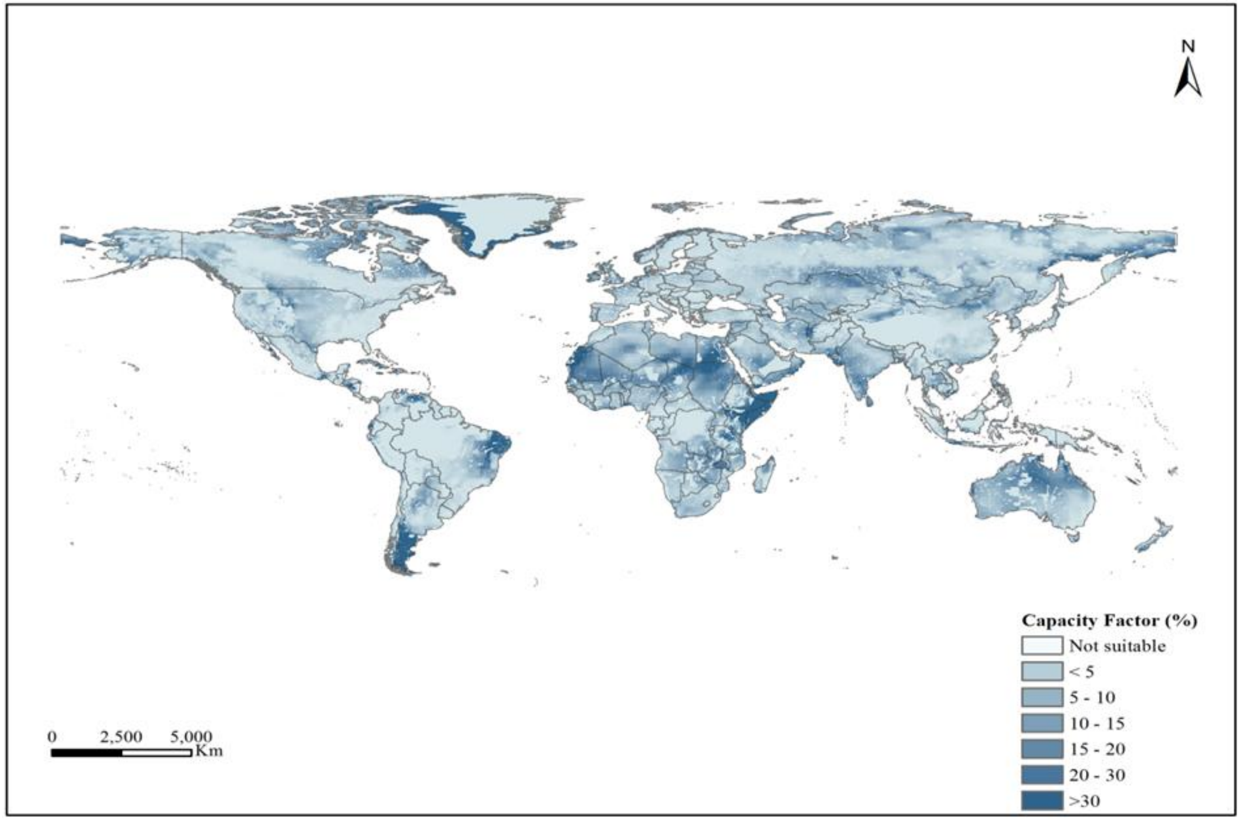


Geospatial resources assessment (1/4)

Spatial wind power mapping

- Global wind power capacity factor
- 20 year average wind speed data
- 0.5 degrees spatial resolution
- Source: NASA - GES DISC

Global Wind Capacity Factor

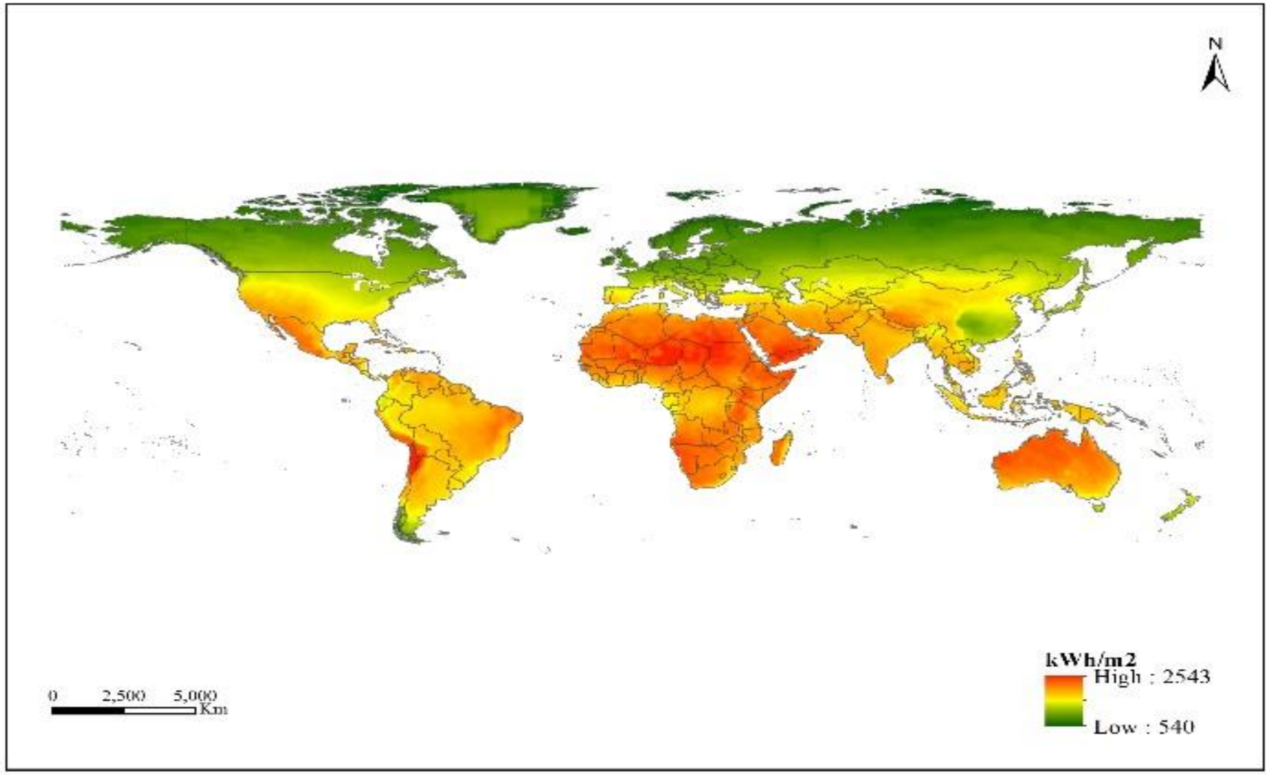


Geospatial resources assessment (2/4)

Spatial solar availability

- Global Horizontal Irradiation
- 20 year average data
- 1 degree spatial resolution
- Source: Langley Atmospheric Science Research Center (SSE – NASA LaRC POWER Project)

Global Solar Energy Availability

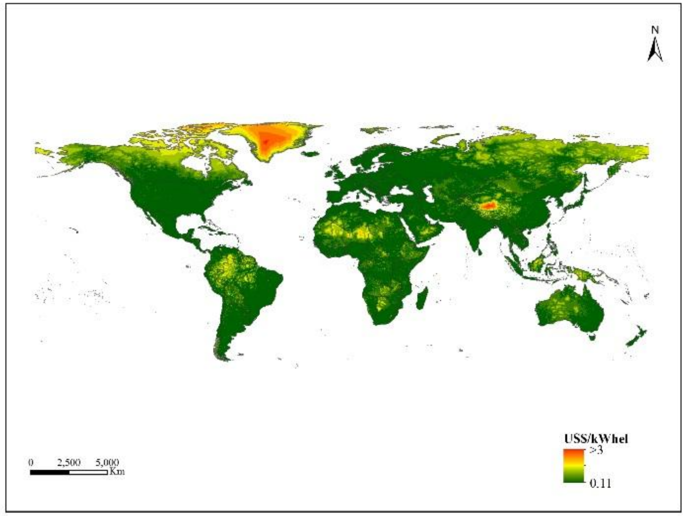


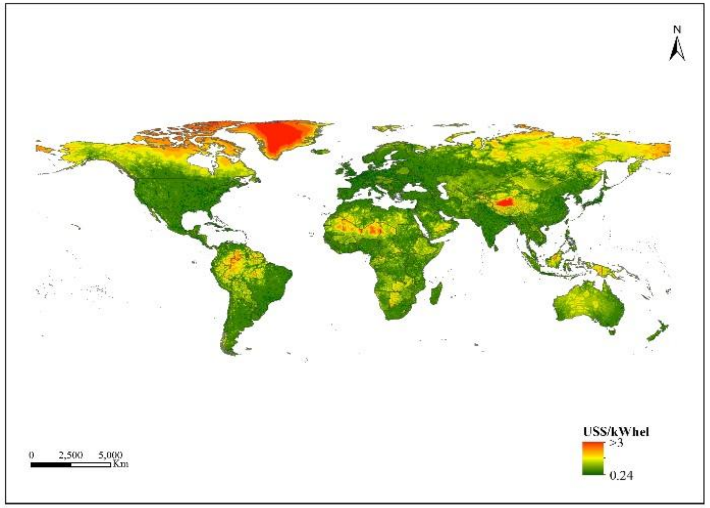
Geospatial resources assessment (3/4)

Spatial LCOE for Diesel gensets

- Global coastlines
- Characterization of a country as landlocked or coastal
- Travel distance to major cities
- International diesel price (current and projected)

LCoE for Diesel generators (Current)





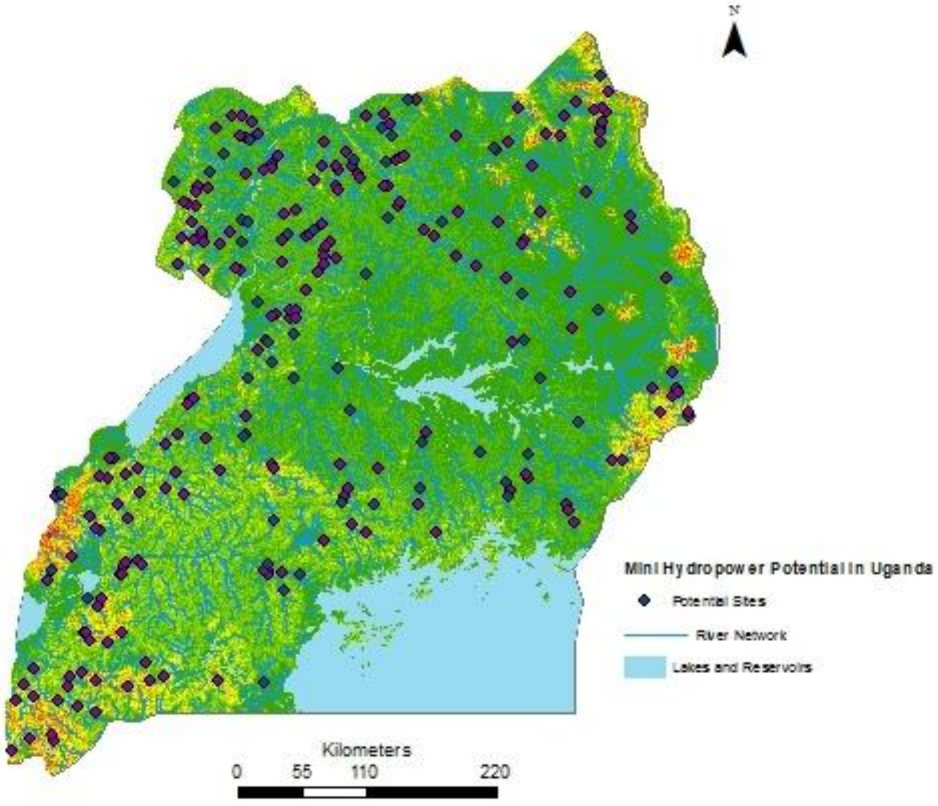
LCoE for Diesel generators (Projected)

Geospatial resources assessment (4/4)

Spatial Mini Hydropower potential

- Global Runnoff data (GSCD – EU JRC)
- Global River Network (HydroSHEDS)
- Global Digital Elevation Maps (USGS/NASA SRTM)
- 0.5 degrees spatial resolution
- Sources: EU JRC, WWF, CGIAR-CSI

Mini Hydro Power Potential



Methodology

1st step

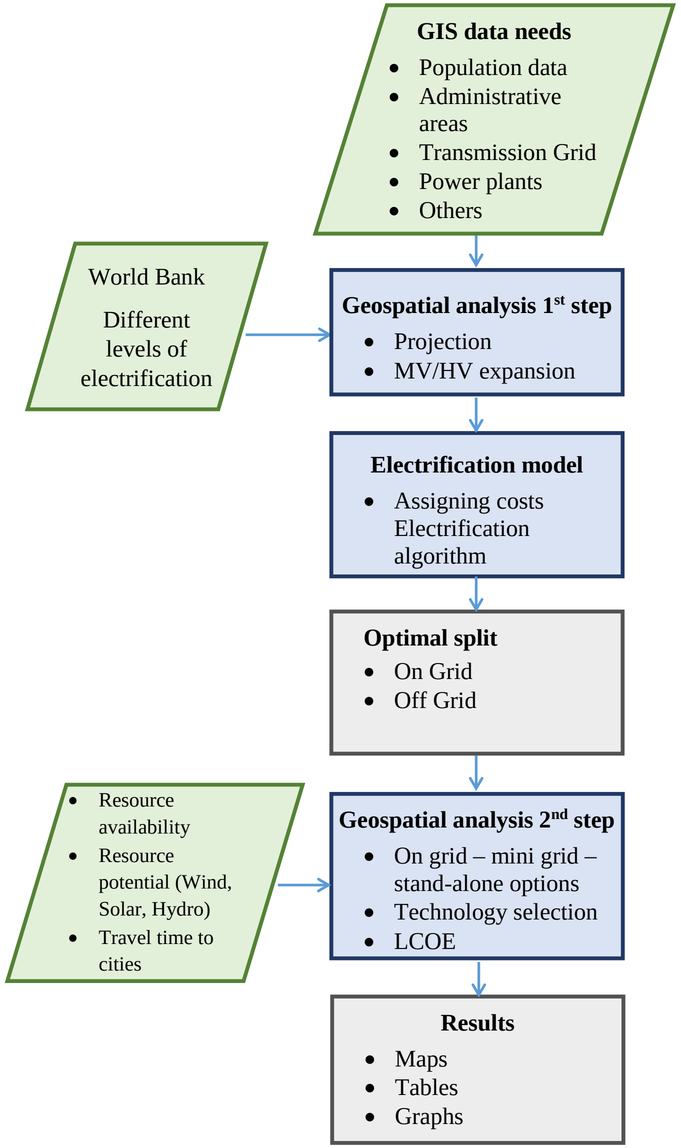
- Cost assumptions
- Population projection
- Distance for existing/planned grid

On vs Off Grid spit

2st step

- Renewable resources availability
- Diesel cost estimations
- LCoE for each technology

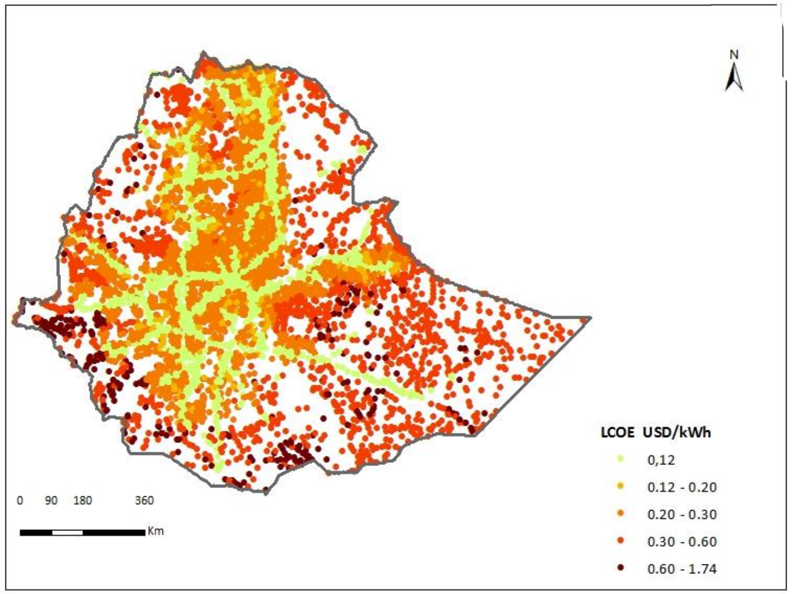
Most economic electrification option



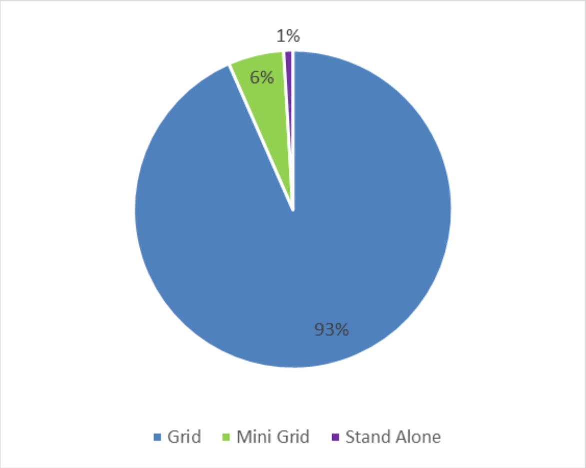
Results-Graphical Representation

- Administrative areas
- Population data/Demand
- Existing Transmission Network
- Power plants & Mines
- Expansion of HV/MV lines
- Resources potentials
- Optimal Split
- LCoE

Ethiopia - Case Study



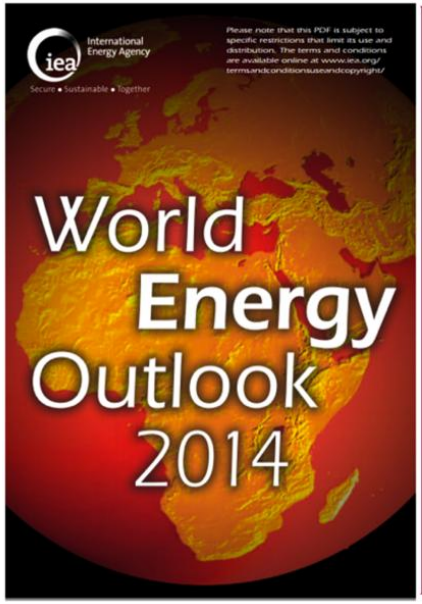
Results – Tabular representation

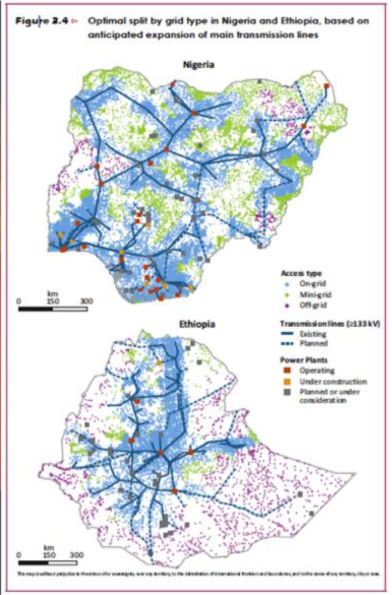


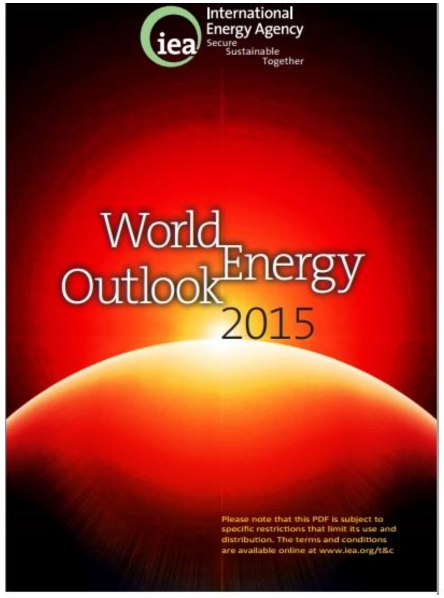
Item	Related physical unit	*Unit*
Rural access target	150	kWh/capita/year
Urban access target	300	kWh/capita/year
Grid distribution	7,844	*Settlements*
Grid distribution	25,424,842	*Households*
Grid distribution	127,124,209	People
Planned grid expansion (Transmission with HV lines)	5,431	*km*
Grid extensions for those gaining access (Transmission with MV lines)	36,343	*km*
Grid extensions for those gaining access (Distribution with MV & LV lines)	513,407	*km*
Mini grids distribution	915	*Settlements*
Mini grids distribution	791,739	*Households*
Mini grids distribution	3,958,695	People
Mini grids power generation capacity	0.34	*GW*
Mini grids power generation	0.84	*TWh*
Stand alone systems	1060	*Settlements*
Stand alone systems	131,353	*Households*
Stand alone systems	656,767	People
Stand alone systems power generation capacity	0.032	*GW*
Stand alone systems power generation	0.086	*TWh*

Publications

- IEA World Energy Outlook 2014 (Nigeria, Ethiopia)
- IEA World Energy Outlook 2015 (India)







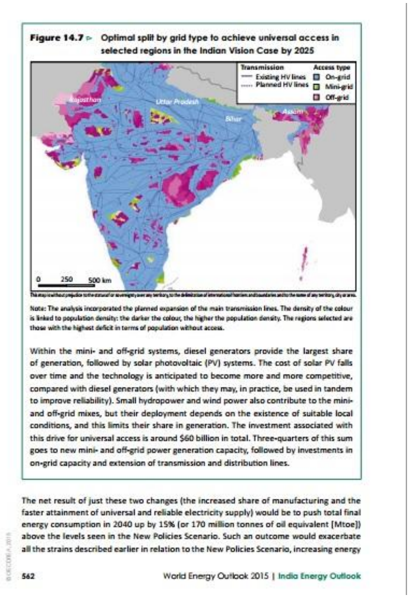


Figure 14.7 ▷ Optimal split by grid type to achieve universal access in selected regions in the Indian Vision Case by 2025

Note: The analysis incorporated the planned expansion of the main transmission lines. The density of the colour is linked to population density: the darker the colour, the higher the population density. The regions selected are those with the highest deficit in terms of population without access.

Within the mini- and off-grid systems, diesel generators provide the largest share of generation, followed by solar photovoltaic (PV) systems. The cost of solar PV falls over time and the technology is anticipated to become more and more competitive, compared with diesel generators (with which they may, in practice, be used in tandem to improve reliability). Small hydropower and wind power also contribute to the mini- and off-grid mixes, but their deployment depends on the existence of suitable local conditions, and this limits their share in generation. The investment associated with this drive for universal access is around $60 billion in total. Three-quarters of this sum goes to new mini- and off-grid power generation capacity, followed by investments in on-grid capacity and extension of transmission and distribution lines.

The net result of just these two changes (the increased share of manufacturing and the faster attainment of universal and reliable electricity supply) would be to push total final energy consumption in 2040 up by 15% (or 170 million tonnes of oil equivalent [Mtoe]) above the levels seen in the New Policies Scenario. Such an outcome would exacerbate all the strains described earlier in relation to the New Policies Scenario, increasing energy

562 World Energy Outlook 2015 | India Energy Outlook

- Elsevier Energy for Sustainable Development : ”A GIS based approach for electrification planning – A case study on Nigeria”.
- Elsevier Energy: ”A Cost Comparison Of Technology Approaches for Improving Access to Electricity Services”.

Conclusions

- The 7th Sustainable Development Goal mandates an electrification expansion in many countries.
- The proposed methodology is an attempt to optimize various electrification efforts in the targeted countries with a spatial reference.
- This is a complementary approach to already existing energy planning models that do not consider geospatial characteristics.

Future work

- Carry out country specific case studies according to national targets.
- Perform the analysis considering higher resolution maps, in order to achieve more representative results.
- Make use of additional geospatial data to identify energy related characteristics (NASA Nighttime light maps).
- Launch an interactive and online database with data for all the unelectrified countries (available in February 2016).

For further questions please refer to

Alexandros Korkovelos – alekor@desa.kth.se

Dimitrios Mentis – dimitris.mentis@desa.kth.se

Mark Howells – mark.howells@energy.kth.se

Thank you