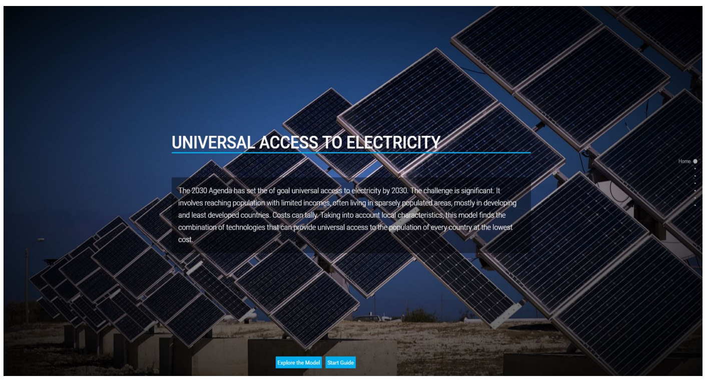


Understanding Modelling Tools for Sustainable Development

MODULE: MODELLING UNIVERSAL ACCESS TO ELECTRICITY: A Hands-on Exercise

TABLE OF CONTENTS

INTRODUCTION

This exercise illustrates how to find the lowest-cost option to provide access to electricity. The exercise uses the ONSSET electrification tool to explore how the distance to a grid and markets, local biophysical conditions, international fuel prices and national energy costs can influence the choice of technology to provide access to electricity at the lowest cost.

LEARNING OBJECTIVE

- Perform an electrification analysis and identify the overall lowest-cost option for a given region using the ONSSET standalone interface.

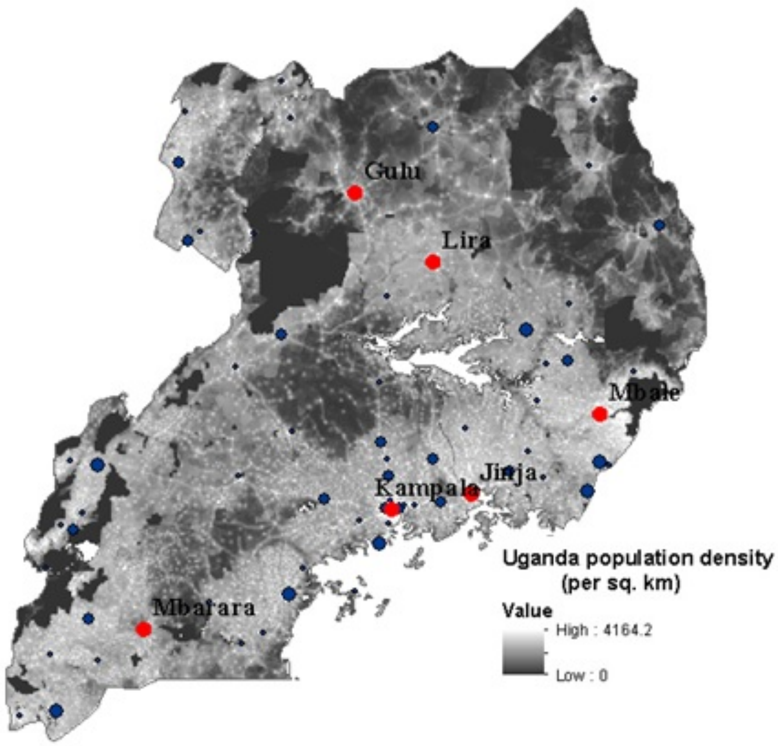
CASE STUDY BACKGROUND: UGANDA

Uganda is a landlocked country located in Eastern Africa with 39 million people. Its total land area is 241,038 square kilometres. Most Ugandans (84 per cent) live in rural areas; approximately 6 million people live in urban settings. The capital city is Kampala with a population of approximately 2 million people; other big cities are Gulu, Lira and Mbarara (Figure 1).

Access to electricity is low, covering approximately 18 per cent of the population. People living in big urban areas are more likely to have electricity services. The total electricity demand in the residential sector is about 500 GWh/year (2013). With an average 4.5 persons per household, Uganda's residential electricity consumption for the population with electricity amounts to approximately 320 kWh/hh/year, between Tier 2 and Tier 3.

The current installed capacity for electricity generation in Uganda is 821.5 MW, primarily coming from several large hydropower plants (Kiira, Nalubaale and Bujagali). Thermal power plants and cogeneration (bagasse) also contribute to the power generation mix. Transmission and distribution losses are relatively high (28 per cent in 2013) but are expected to drop to 18 per cent over the next few years due to improvements in power transmission infrastructure. The current grid electricity cost is approximately $0.051 per kWh (2015).

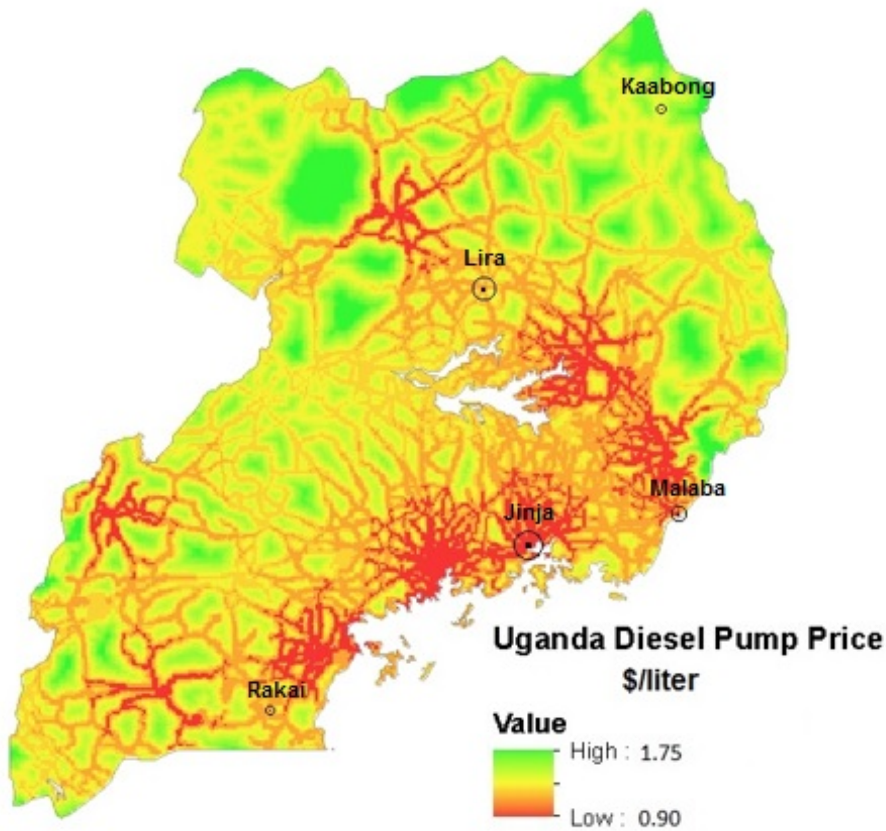
FIGURE 1. POPULATION DENSITY IN URBAN SETTLEMENTS IN UGANDA (2010)



Increased access to electricity for households would require additional generating capacity. The country's future plans include the construction of three large hydropower plants (Karuma Dam, Ayago and Murchison Falls) with a combined capacity of 1,900 MW, a geothermal plant (Namugoga) of 150 MW, and a solar plant (Namugoga) of 50 to 100 MW, as well as increased capacity in existing biomass power plants (Kakira II and Kinyara) to 60 MW. According to the projected generating costs, future grid electricity will drop to $0.029 per kWh by 2030 (value adopted from the TEMBA model).

As a landlocked country with no refining infrastructure, Uganda faces high costs for imported oil products (gasoline and diesel). The current diesel pump price (July 2016) in big cities is $0.72 per liter, with the price fluctuating between $0.90 and $1.30 per liter over the past three years. Smaller cities and remote villages experience higher diesel costs due to additional transportation costs. Figure 2 shows the diesel price variation as a correlation with distance from the nearest urban centre. Diesel prices may decrease slightly after 2020 upon the commission of Uganda's oil refinery, currently being constructed in the Hoima district.

FIGURE 2. DIESEL PRICE VARIATION PER DISTANCE FROM NEAREST URBAN CENTRE



Uganda is endowed with substantial renewable energy resources such as solar, wind and hydro. Their dispersed nature favours off-grid technologies that utilize resources available locally. Average solar irradiation is 2,000 kWh/m^2/year with higher values observed in the north (figure 3). The north-eastern part of the country (Kaabong, Kitgum and Kotido) shows high suitability for wind projects (CF around 20 per cent) (figure 4). Moreover, 43 potential sites have been identified for mini/small hydro electricity generation with a total estimated capacity of 49.8 MW and expected generation of 175 to 262[1] GWh/year.

As per SDG 7, all Ugandans should have access to affordable, reliable, sustainable and modern energy services by 2030. That will require a significant increase in the provision of electricity. The objective of this exercise is to identify the optimal electrification mix that would enable Uganda to meet this goal.

[1] Estimated electricity generation was calculated assuming a capacity factor range of 0.4 to 0.6.

FIGURE 3. SOLAR AVAILABILITY IN UGANDA

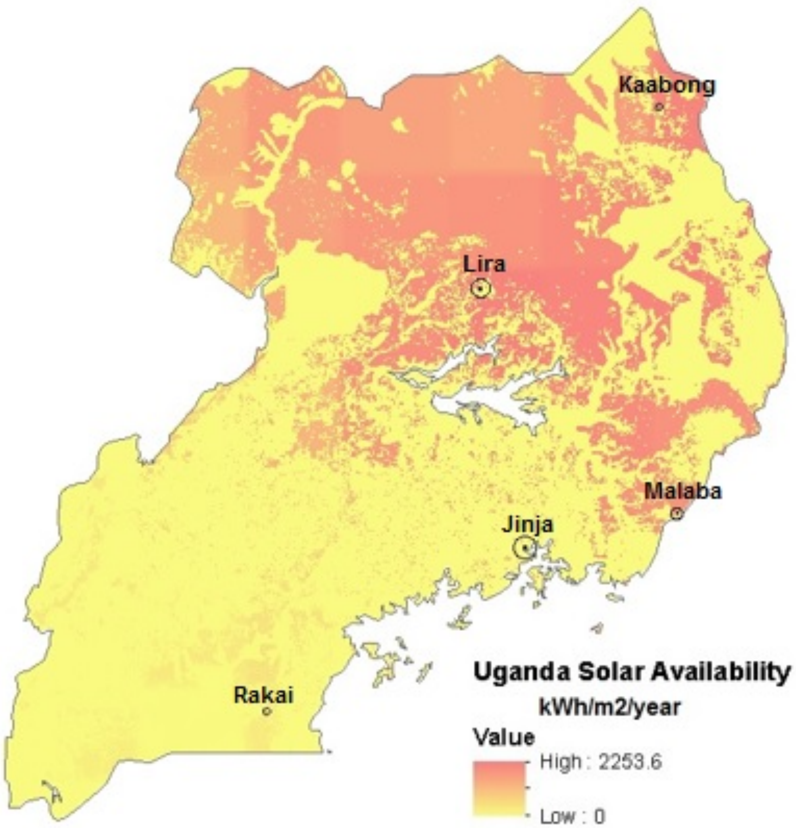


FIGURE 4. WIND CAPACITY FACTOR IN UGANDA

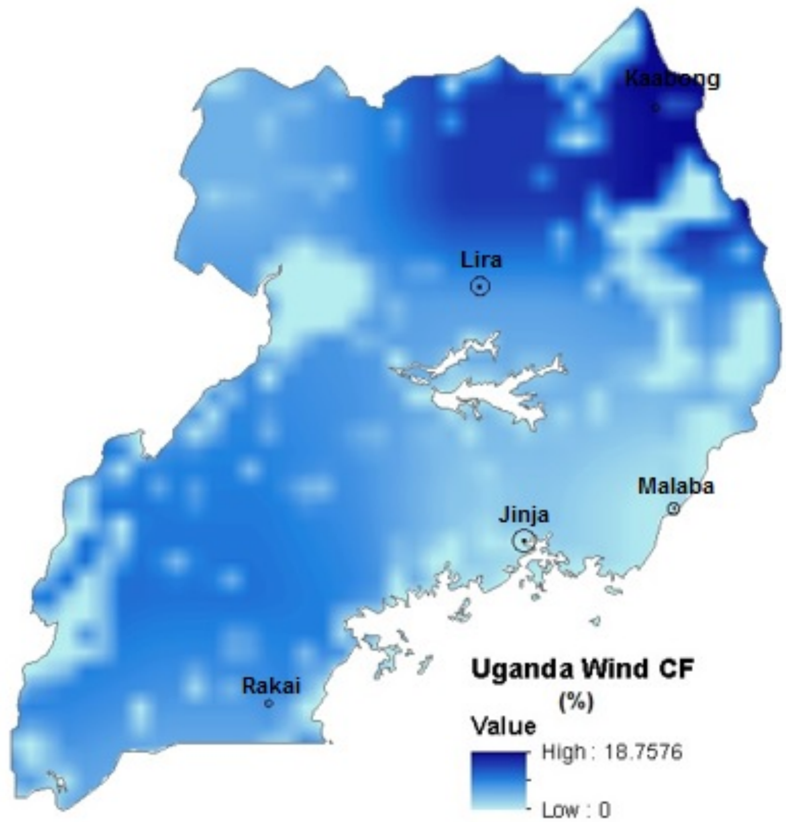
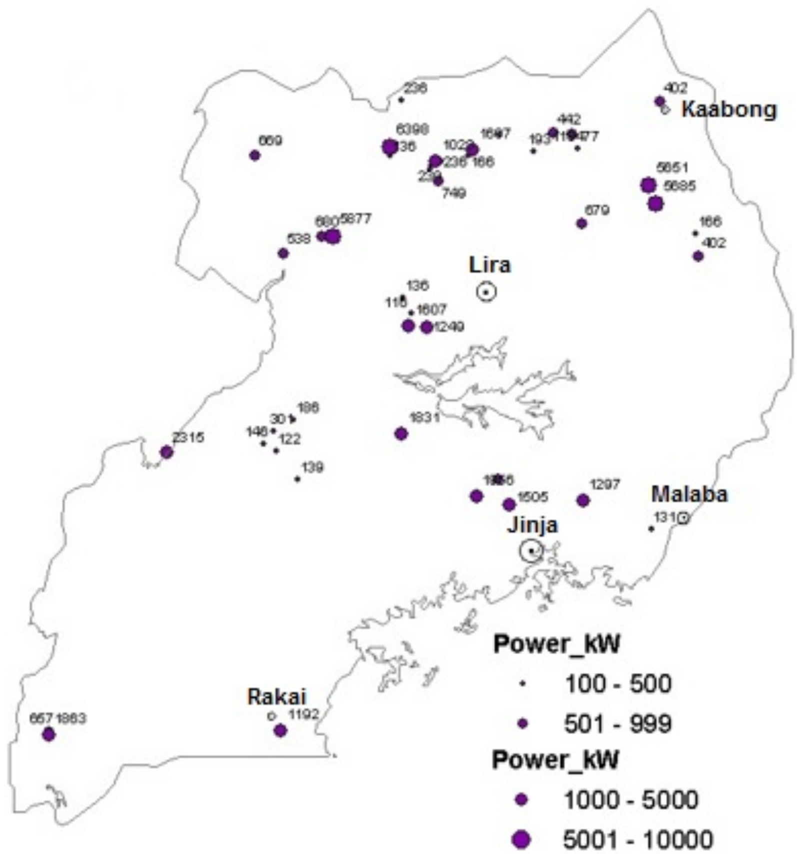


FIGURE 5. MINI/SMALL HYDROPOWER POTENTIAL SITES IN UGANDA



HANDS-ON SESSION

For this exercise, participants shall be divided in two groups, A and B. Participants of Group A will write a policy note based on the online electrification interface. Participants of Group B will provide suggestions for electrification planning in Uganda using the online version of ONSSET.

GROUP A: WRITING POLICY NOTES BASED ON THE ONLINE ELECTRIFICATION RESULTS

The objective of this group is to practice interpreting model results to formulate policies or inform investment decisions. The point of departure is the online interface. By changing the pre-defined parameters (e.g., diesel price, grid LCOE, electricity access target) the group should simulate the anticipated future conditions in the electricity sector of Uganda.

Furthermore, by using the results of the least-cost electrification analysis (acquired from the online interface), the group should identify the best solution in different regions, quantify the investment requirements, design an electrification plan and formulate policy notes to facilitate the plan's implementation. The following tasks should be performed.

TASK 1

Describe in 5 to 10 bullet points the most important obstacles to full energy access in the country.

TASK 2

Explain what the electricity system (demand and supply) will most probably look like in 15 years. Answer the following guiding questions:

- What is access to electricity expected to be?
- Which energy resources are expected to be used to achieve full access to electricity?

TASK 3

Simulate the scenario in the following link:

http://un-desa-modelling.github.io/electrification-paths-visualisation/

TASK 4

Identify the optimal electrification mix per region as well as the total investment requirements for full access to electricity. Answer the following guiding questions:

- Do the solutions reflect the country's vision?
- Is the country able to afford this transition?
- If not, what about reconsidering the scenario parameters?

TASK 5

Design an electrification strategy per region. Answer the following guiding questions:

- Where should the transmission network be expanded?

- Which areas are more favourable for mini-grids and which for standalone systems?
- Which resources are primarily utilized?
- What is the penetration of renewables (in terms of mini-grid and standalone systems) in the electrification mix?
- How is that penetration affected by diesel price fluctuations?

TASK 6

Formulate policy notes that would help facilitate the implementation of the electrification strategy. Introduce subsidies, or other measures, to support the deployment of certain technologies.

GROUP B: PROVIDE SUGGESTIONS FOR ELECTRIFICATION PLANNING BASED ON THE ONLINE VERSION OF ONSSET

Group B has as a starting point the online version of ONSSET. Based on the given set of characteristics describing the existing conditions of Uganda (e.g., population, electricity access target, resources availability, techno-economic data for the technology options), the objective of the group is to identify the least-cost electrification mix, and determine capacity additions by technology and total investment requirements for providing electricity to all unserved areas.

The following tasks should be performed.

TASK 1

Read “The case study of Uganda – Country review”. Determine and list the data requirements to build the model.

TASK 2

Start data collection. The summary of the data required for the exercise is provided in the appendix. No further information is required, unless the participants want to look for more updated data.

TASK 3

Use the simplified online version of ONSSET to insert the findings into the model.

TASK 4

Identify the optimal (least-cost) electrification option for Uganda for different scenarios, varying a number of factors such as electrification tier and diesel price.

TASK 5

Based on the results, write notes that will support policymakers in developing electrification strategies. Answer the following guiding question:

- Do the solutions reflect the country's vision for electrification?

GROUP DISCUSSION

In this section, each group should select a representative who will summarize the respective group's approach and findings.

Group A will present solutions for meeting the electrification target at the national/regional level. The groups should be able to answer the following questions:

- What are the most important hindrances to full electrification of Uganda?
- What is the electrification strategy that Uganda should follow in order to achieve this goal by 2030?
- What is the suggested energy policy that could facilitate the implementation of the electrification strategy?

Group B will highlight electrification challenges/options in the studied area. The group should be able to answer the following questions:

- What are the main electrification challenges in the country?
- What is the optimal electrification option identified for various scenarios?
- Is the policy proposed by Group A consistent with the findings here?

The two groups shall compare their findings, analyse and discuss potential differences, and collaboratively suggest improvements in electrification planning.

For further clarifications please refer to the instructors.

Good luck!

APPENDIX

TABLE 1. EXAMPLE OF MAPPING OF TIERS OF ELECTRICITY TO INDICATIVE SERVICES AND ANNUAL ELECTRICITY DEMAND

Level of access	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**
Indicative appliances powered	*Task lighting + phone charging or radio*	*General lighting + fan + television*	*Tier 2 + medium power appliances (i.e., general food processing, refrigeration)*	*Tier 3 + medium or continuous appliances (i.e., water heating, ironing, water pumping, rice cooking, microwave)*	*Tier 4 + high power and continuous appliances (i.e., air conditioning)*
Consumption per household and year (kWh)	22	224	695	1800	2195

Source: Adapted from World Bank 2015.

TABLE 2.SOCIAL AND TECHNO-ECONOMIC DATA FOR GROUP B

Population (2015)	39,032,380
Population (2030)	61,929,170
Urban population ratio (2015)	16%
Urban population ratio (2030)	22%
Household price (ppl/hh)	4.5
Current price of diesel ($/litre)	0.72
Low estimate for diesel price ($/litre)	0.34
High estimate for diesel price ($/litre)	1.30
Grid electricity cost ($/kWh)	0.051
Investment cost for additional capacity to the national grid ($/kW)	1,593
Grid losses	28%
Base-to-peak ratio (grid)	39%
Grid cost ratio	10%
Access to electricity (2015)	18%

Mini/small hydro capital cost ($/kW)	3,000
Wind turbines capital cost ($/kW)	3,000
Mini-grid solar PV capital cost ($/kW)	4,300
Mini-grid diesel capital cost ($/kW)	721
Stand-alone solar PV capital cost ($/kW)	5,000
Stand-alone diesel capital cost ($/kW)	938

REFERENCES

Mentis, D., M. Andersson, M. Howells, H. Rogner, S. Siyal, O. Broad, A. Korkovelos and M. Bazilian (2016). "The benefits of geospatial planning in energy access – A case study on Ethiopia." *Applied Geography* 72: 1–13.

Mentis, D., M. Welsch, F. Fuso Nerini, O. Broad, M. Howells, M. Bazilian and H. Rogner (2015). "A GIS based approach for electrification planning – A case study on Nigeria." *Energy for Sustainable Development*.

Nerini, F. F., O. Broad, D. Mentis, M. Welsch, M. Bazilian and M. Howells (2016). "A cost comparison of technology approaches for improving access to electricity services." *Energy* 95: 255–265.

Taliotis, C., A. Shivakumar, E. Ramos, D. Mentis, V. Sridharan, O. Broad and L. Mofor (2016). "An indicative analysis of investment opportunities in the African electricity supply sector – Using TEMBA (The Electricity Model Base for Africa)." *Energy for Sustainable Development* 31: 50–66.