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Brief

A New Approach for Mapping Electricity Access in Sub-Saharan Africa with Satellite Data

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Abstract

FEEM Policy Brief

A study carried out as part of the FEP research program (Future Energy Program) has developed an online interface that combines satellite, geographical and demographic data to represent the progress of electrification in Sub-Saharan Africa from 2014 to date. Through satellite data it is possible to observe lighting during daylight hours, and especially at night, and to identify the areas where populations without access to the electricity grid or to autonomous generation solutions are concentrated. Since the satellite data are constantly updated over time, the interface allows tracking of the evolution of the electrification process, including the demographic dynamics. The high resolution of the data makes it possible to understand more effectively the geographical areas with or without access to electricity in the Sub-Saharan area. The dataset supports the policymakers involved in energy planning aimed at achieving the *Sustainable Development Goal 7* of the 2030 Agenda for universal access to modern and sustainable energy.

01 Project concept and development

The project to develop a dataset and a dynamic interface stems from the necessity of studying access to electricity in more detail than the usual territorial surveys. Most of the public statistics currently available on access to electricity in Sub-Saharan Africa are at national level (IEA, 2017b; World Bank, 2018) and are collected through field work and surveys that are costly and time-consuming, Moreover, the quality of the data collected is sometimes an issue (e.g. USAID, 2018).

The study used the lighting data of the electric sources observed by the satellites during the day and above all during the night. These data were combined with data regarding the population density and the geographical areas, either urban or rural. The work was validated using the data received from the available surveys. In particular, an estimate was produced and compared with the data provided by the World Bank and the International Energy Agency on access to electricity, finding excellent consistency, both nationally and at the province-level.

Six months of preparatory work were needed to become familiar with the methodology and architecture of the project and an additional six months to implement and refine the interface. The study was developed in partnership with the IIASA Energy Program, i.e. the International Institute for Applied Systems Analysis based in Laxenburg, Vienna, where several researchers have been working on issues related to access to electricity for years.

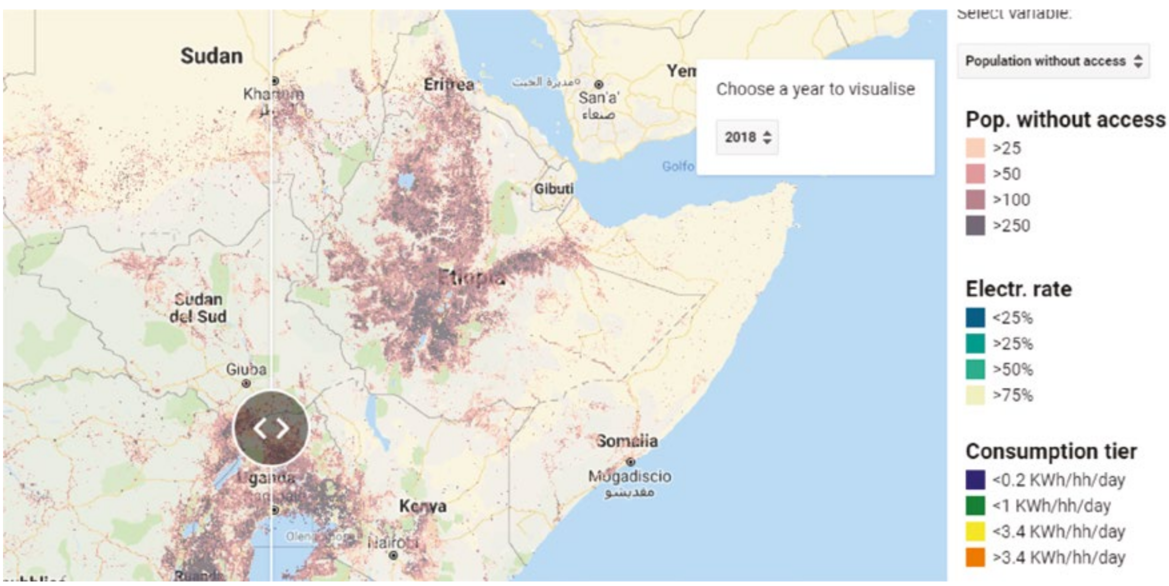

Figura 1. *Screenshot of the online interface developed to explore the electrification dataset*

The interface (Figure 1), based on Google Earth Engine, is accessible via the link **https://www.feem.it/gdessa** and is hosted by the FEEM website. It allows comparing the diffusion of electrification and the density of people without access to electricity in each year between 2014 and 2018. It is also possible to visualize an estimate of the average level of consumption in all of the areas where the population has access to electricity.

02 Potential uses of the dataset

The *dataset* can potentially be used in many areas, i.e. to identify the most efficient technologies and ways to improve access to electricity, or to better understand how to direct investments for development or to keep track of SDG 7 of the 2030 Agenda (to guarantee universal access to sustainable and modern energy) for potential future productive uses.

The main advantage of the new *dataset* is that it provides more information than the national statistics. For example, the access rate to electricity in South Africa is around 85-90%, while in Malawi it is around 12%. These data are readily available in the archives of international cooperation and development organizations or local energy ministries. On the other hand, it is difficult to identify – for example in South Africa - where the remaining 15% of the population that does not have access to electricity is located. This figure is very important, as it concerns several million people. Thanks to satellite mapping, it is possible to have a much better idea.

High resolution mapping benefits a variety of users, starting from local *policymakers* involved in the electrification planning process, researchers involved in understanding the causes and effects of access to the electricity grid, and the general public that wants to understand the energy access issue.

03 Advantages

The main merit of this work is that it offers a *user-friendly* interface that allows anyone to browse and analyze the electrification situation. The mapping is made within the framework of Google Earth Engine, a powerful, detailed and efficient tool that allows processing and visualizing the satellite data.

The type, quality and resolution of the main satellite data used have been public since 2014, the year in which the NASA satellite, which is the main source of these data, was launched and entered into operation. In the coming months of 2019 it will be possible to expand the estimate and continue with the mapping. As the satellite data are constantly updated over time, through the interface it will be possible to keep track of electrification development and to have a clearer idea of the evolution and weaknesses of the process. The demographic and migration trends are also tracked thanks to constant updates on the geographical data on the population.

04 Surveys

The mapping has shown that some countries have experienced amazing growth processes, in particular Kenya, Ghana and Benin, in the 5 years from 2014 to 2018. This result was consistent with the literature on electrification.

The main reasons for this progress were national and private financing, but also international financing as a result of effective *policies*. On the contrary, in other areas the situation is unchanged or has only slightly improved. These areas are - for example - Malawi, Burundi, Zambia, but also Ethiopia, which is a special case. In Ethiopia there has been a significant increase of the so-called *stand-alone*, private solar panels, which are not part of the electricity grid.

The great distances, the lack of public policies and international interests limit the development of electrification in several African countries, including Ethiopia. Satellite mapping contextualizes the process, i.e. it shows where the population without access to energy is concentrated in space; in the case of Ethiopia, the population without access to energy was observed to increase as the distance from the capital Addis Ababa increased.

05 Stumbling blocks in the expansion of the electricity access in sub-Saharan Africa

There main roadblocks limit the expansion of the electricity access in sub-Saharan Africa: the first depends on the land's geographical characteristics and on the distances involved. The net generally unfolds only partially in the area, but other important inhabited centers remain excluded. Moreover, countries like the Democratic Republic of the Congo, which have very extensive forests, have to cut down the trees in order to get the network through; at the same time, even desert or rocky areas contribute to increasing difficulties. The continent is therefore dotted with strong infrastructure barriers.

The second concerns the costs: a kilometer of high voltage electricity transmission network generally costs at least $30,000 (The World Bank, 2017), and therefore there is an increasing debate between the *trade- offs* of the network and decentralized structures, mini *grids* or *stand-alone* solar panels, but these solutions are not always comparable to the access to the main network (Bhatia & Angelou, 2015). The international community favors these solutions, because they are a way to push towards the development goals set by the 2030 Agenda.

The last issue, which concerns families and rural businesses, is the fact that the costs for connecting to the electricity grid are very high even when it is in close proximity (Bonan, Pareglio, & Tavoni, 2017). Political support is needed to effectively plan the spread of the grid, but political interests do not always coincide with the objectives of fair development and the reduction of inequalities.

06 Potential and future uses

Several models have been developed and released, for example by the KTH in Stockholm (Mentis et al., 2017) and by the PBL in the Hague (PBL Netherlands Environmental Assessment Agency, 2017), which allow us to evaluate which are the most efficient options to guarantee access to electricity at the local level, estimating the investments required over time, and assessing what impacts this would have on both emissions and costs. It would be very interesting to use this *dataset* for these purposes. Such uses would probably contribute to the accuracy of existing estimates. Moreover, they would allow a more widespread use, as it can also be used by non-experts. This can significantly raise greater awareness of the problem, not only to address it firsthand, but to provide cultural insights through an indirect impact.

This resource can also be useful for local African authorities. Due to the rise of *stand-alone* solutions, the authorities are not always able to keep track of the people who have access to electricity. In particular, it is challenging to keep track of how these solutions spread, since they depend largely on private companies and not on the national network managed by the State (Mazzoni, 2019). A project similar to the mapping model that keeps track of indipendent electrification could therefore be developed for each of these countries.

Policy conclusions

The *dataset* and interface presented here are an innovative tool to improve the understanding of the electrification challenge, its geographical characteristics and planning. However, some important issues must be addressed by policy makers aiming at supporting the process of electrification in Sub-Saharan African countries.

One of the main problems is the high percentage of the population - in almost all Sub-Saharan countries -which lives below the poverty line and which is largely equivalent to the population that currently does not have energy access. This is where the most significant support, not only from national governments, but also from international financial institutions, must be directed. Although major efforts are already under way, more needs to be done if the ambitious goals are to be achieved without unduly burdening public finances, thus putting a brake on investment and growth in other sectors.

- The optimal balance between electrification by connection to the network, *mini-grid*, and autonomous solutions such as *solar home systems* must be carefully evaluated, taking into account a number of local conditions, the impacts of each technology, and uncertainties related to future developments (Deichmann, Meisner, Murray, & Wheeler, 2011). For example, clear legislation regarding potential future interconnections must be established, so as to provide greater certainty about the long-term prospects of *mini-grid* investments, and thus encourage private participation. The spread of digital technologies can play an important role in this sense (IEA, 2017a; Mazzoni, 2019). Multidisciplinary and interregional studies are thus of vital importance (Hafner, Tagliapietra, Falchetta, & Occhiali, 2019).

- The billing systems of public and private electricity suppliers must be more flexible to meet the needs of families with credit constraints in order to encourage them to gain access to electricity, and to trigger an advantageous process for both the supplier and the consumer. Behavioral considerations (such as how information and tariffs are presented) and the type of default contract can play a role in this regard, particularly in the emerging context of mobile-based solutions and smart payment schemes.

- *Feed-in-tariffs* (economic incentives for production through renewable energies) can encourage both private individuals and companies to invest in infrastructure and to have a guaranteed return in the future. In the case of private electricity producers that install medium and large-scale power plants, the *feed-in-tariffs* guarantee certainty in economic returns. In turn, long-term public-private contracts stimulate and help finance investments.

- *Feed-in-tariffs* are a burdensome political tool for public finances, so they must be designed in a way that does not to distort the market, is flexible in relation to the different technologies and conditions, and is supplemented by procurement processes, as in the case of South Africa (Eberhard & Kåberger, 2016).

- Satisfying the growing demand from already electrified consumers and an emerging industrial sector seems more feasible without significant public or international subsidies. In this case, the budget constraints of already electrified consumers are much less. Here, the real challenge is to create an adequate investment framework to allow independent energy producers to operate in a competitive market (Eberhard, Gratwick, Morella, & Antmann, 2017) and rapidly expand the national installed capacity, while the public services can focus on the infrastructure of the planning and expansion network.

- Independent electricity producers must therefore be encouraged to enter the market with competitive procurement procedures that follow the principles of efficiency and economy, rather than being requested to negotiate directly with government actors (Ackah, Opoku, & Suleman, 2017). Offering long-term standardized electricity purchase agreements and transparent rules is essential.

- Government *master-plans* must look ahead. They must adopt the most effective strategies in terms of infrastructure development, market and contract design, international politics, and the import-export dynamics of energy resources. The potential effects of intra-sectoral cooperation must be identified and exploited.

- Besides increasing generation capacity, the promotion of regional interconnections will maximize the national energy potential and add more generation capacity to the system, while ensuring its robustness and the efficient management of renewable energy intermittency.

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