

Comprehensive Country Ranking for Renewable Energy Based Mini-Grids Providing Rural Off-Grid Electrification

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Abstract

Access to electricity is a matter of course to most people on earth. Still there are far too many people that do not have the possibility to use electricity neither private nor for working. Renewable energy based mini-grids can be a solution for electrifying rural areas. Sustainable business models are needed and places for starting them. A worldwide country ranking for that issue shall help finding adequate countries. Top ten countries are presented and the top country, Rwanda is pictured in further detail.

Keywords: mini-grid, rural electrification, Rwanda.

Introduction

There are 1.3 billion people without electricity worldwide (International Energy Agency [IEA], 2011). Especially in Africa and South-East-Asia there are countries with high population but only few people have access to electrical energy. Electricity is the essential basis for the improvement of elementary needs, like light, communication, education, health and safety. Further, electricity is often the first step leading to commercial and industrial activities. Several Photovoltaic (PV)-based off-grid systems are available on the market (Breyer, Werner, Rolland, & Adelman, 2011) but due to the additional focus on commercial and industrial activities, in this work mini-grids are emphasized. An overview of literature reports on mainly PV-based mini-grids can be found at Werner and Breyer (2012). Self-sustaining island systems are mostly the only possibility to bring electricity to people living in rural areas and to grow local economy. In consequence of rising fuel prices, renewable energies become more and more interesting and especially photovoltaic (PV) systems are an adequate technology for mini-grids since they are easy to install and to maintain while solar energy is available everywhere for free. The technics of self-sufficient mini-grids do work properly and are sufficiently tested. Nonetheless there seems to be no public mini-grid which works without subsidies, yet.

Research Objectives

The aim is to bring electricity to not electrified people not only by providing them the system, but by establishing sustainable business models which work on a long-term and might be reproducible. This requires a project development including sustainable financing and system operation (Breyer et al., 2012). Pure economics emphasize that stable PV-based mini-grid business models are possible (Cader, Hlusiak, & Breyer, 2013).

Still, not every country with non-electrified regions is predestined to be among the first ones for implementing business models of mini-grids. Political and economic instability can be criteria for exclusion or high subsidized diesel fuel can make a renewable energy-based mini-grid completely uneconomic compared to a diesel generator. It is important to start with an overview on all countries to find out which are adequate for developing a business plan. A comparison of all countries regarding relevant characteristics shall lead to a country ranking concerning the implementation of business models for mini-grids and finally to possible target countries.

Methods

For filtering and ranking those countries that are interesting for business models of mini-grids, different characteristics of countries have to be compared and rated. These are chosen by their relevance for starting a business of electricity supply. There have been identified two main criteria regarding starting a business. The first one is the market potential and the second one is the political and financial environment. Both criteria are based on several indicators giving country specific information.

To realize the ranking a comprehensive spreadsheet has been created. It is included to use the option to choose exclusion criteria and weighting factors. The factors presented in this paper are those which were finally considered as the best.

Relevant countries

For comparison of the countries it is reasonable to exclude nations which are definitely not relevant for this study. Otherwise they might distort the results of ratings. Countries that are already electrified sufficiently do not need electrification activities and do not need to be regarded in the further process. Countries have been excluded by this criterion in case of having electrification rates over 95 % and less than 200,000 people in rural areas without electricity (data from (United Nations [UNDP], 2007; IEA, 2004, 2010; UNDP & World Health Organization [WHO], 2009; World Bank, 2010a). Most of industrialized nations are excluded that way.

Next step is to exclude countries which are definitely unsuitable for starting a business: countries with high political instability or very low diesel prices. Nations that belong to the 5 % of lowest political stability worldwide (World Bank, 2010b) are excluded as well as countries for which existed a travel warning from the German Ministry

of Foreign Affairs in April 2012 (German Federal Foreign Office, 2012). Renewable mini-grids have to compete with low diesel prices. Thus countries with a pump price for diesel of less than 0.25 USD/l are excluded from the ranking (Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ], 2012; World Bank, 2010c). 89 remaining nations have been evaluated with the following criteria.

Market potential

The market potential index is based on three criteria and amounts to 40 % of the total ranking. The absolute amount of rural people who are without access to electricity (*rpwoe*) and thus potential users of mini-grids is calculated by the rural population (World Bank, 2010a) multiplied by one minus the rate of rural electrification (UNDP & WHO, 2009). It represents 50 % of the market potential. For not neglecting nations with little population, the electrification rate (*er*) of the whole country is also included in the market potential with 30 % (UNDP, 2007; IEA, 2004, 2010; UNDP & WHO, 2009). As pure diesel grids are direct competitors to renewable mini-grids, pump price for diesel (*ppd*) is included with 20 % in the market potential, too (GIZ, 2012; World Bank, 2010c).

Political and financial environment

Focusing on starting a business, political and financial environment represents the major part of the final ranking with 60 %. It is composed of political stability (*ps*) (World Bank, 2010b) and inflation (*if*) (World Bank, 2009/2010) with each 15 %, corruption perception index (*cpi*) (Transparency International [TI], 2011) with 20 % and finally the ease of doing business index of the World Bank (*dbi*), which is a combination of 10 different criteria itself and influences not only political and financial environment with 50 % the most, but also the final ranking with 30 % (World Bank & International Finance Corporation [IFC], 2011). Country specific information like governmental attitude towards renewable energies would have been desirable for the ranking as well, but as there are no quantifiable numbers it has to be regarded for each interesting country itself like it is shown further down on the example of Rwanda. Different weightings of the criteria are demonstrated in Figure 1.

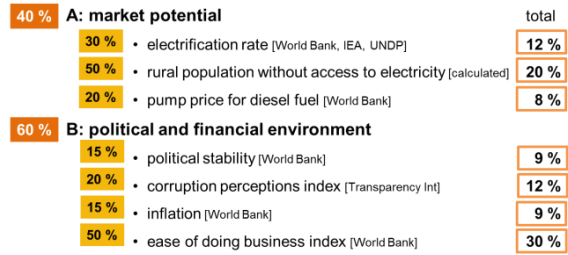


Figure 1: Weighting of criteria for country ranking.

Scoring

The ranking itself works by a scoring of each criterion. Countries can gain 1 to 10 points for each attribute, whereas 1 is worst and 10 shows best preconditions for renewable mini-grids. Scores are given in different ways depending on the data basis. For criteria like “electrification rate”, “pump price for diesel”, “political stability”, “corruption perceptions index” and “inflation”, which are in linear proportions, the ten scores have been evenly spread to the countries. For “rural population” and for the “ease of doing business rank” has been done a spreading on percentiles.

Using the described weighting, which is demonstrated in Figure 1, the final scoring of one country (*fs*) is reached with the following calculation:

$$fs = 0.4 * (0.3er + 0.5rp + 0.2ppd) + 0.6 * (0.15ps + 0.2cpi + 0.15if + 0.5dbi)$$

Results

From scoring the countries, weighting different criteria and finally ranking all nations, results a ranking of all countries worldwide. This shows their applicability for starting business models of mini-grids compared to the other countries. Top 20 of the final ranking are presented in Figure 2.

Rwanda is on the top of the list followed by other African states like Zambia, South Africa and Botswana. There is only one country on the top 10 list which does not belong to Africa. This is Peru on the 10th position. Rwanda as an example how to look more intense on a target country shall be presented more detailed later. Regarding results of the two main criteria separately, top 10 lists look very different.

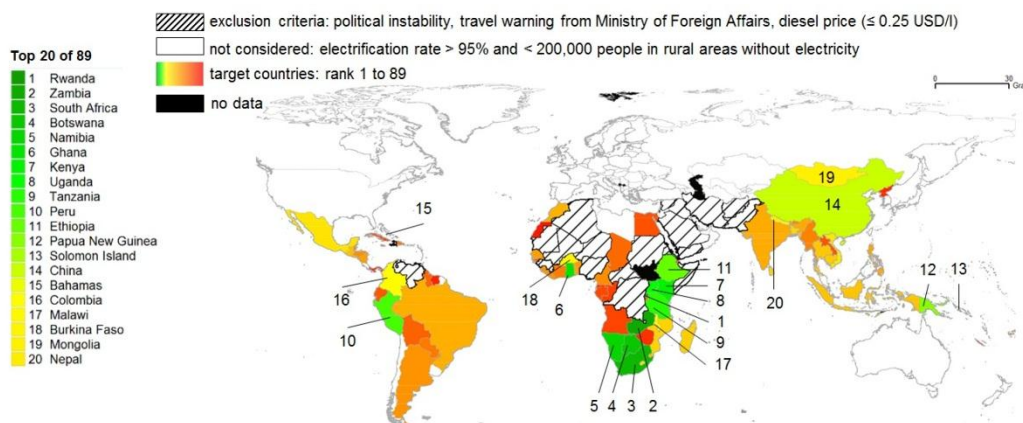


Figure 2: Result of Country Ranking: Top 20.

This is visible in Table 1 and Table 2. Top countries of the market potential criterion are countries with low electrification rates and many people without access to electricity. Top ten countries are all from Africa. Top countries are Malawi, Uganda, Kenya and Tanzania.

Table 1: Ranking of market potential. Data are taken from (UNDP, 2007; IEA, 2004, 2010; UNDP & WHO, 2009; World Bank, 2010a/c; GIZ, 2012).

rank	country	electrification rate [%]
1	Malawi	9
2	Uganda	9
3	Kenya	16
3	United Rep. of Tanzania	14
5	Rwanda	5
6	Burkina Faso	15
6	Madagascar	19
6	Burundi	3
6	Chad	4
10	Zambia	19

Being under the top 10 of “economic and financial environment”, means that the country offers good conditions for starting a business. Here are also countries with higher electrification rates as the potential users are not considered yet. Top countries are The Bahamas, Botswana and Rwanda.

Table 2: Ranking political and financial environment.

Data are taken from (UNDP, 2007; IEA, 2004, 2010; UNDP & WHO, 2009; World Bank, 2010a/c; GIZ, 2012).

rank	country	electrification rate [%]
1	The Bahamas	87
2	Botswana	45
3	Rwanda	5
4	South Africa	75
4	Namibia	34
6	Antigua and Barbuda	95
7	Peru	86
8	Solomon Island	14
9	Colombia	94
9	Mexico	99

Country profile Rwanda

To get an insight into the top country of the ranking, Rwanda has been analyzed in more detail. Information which are interesting for sustainable business models of mini-grids shall be offered here

The east African state has been in civil war in the early 1990s and started rehabilitation in the end of the 1990s. Economy and income for people had to be recreated. Meanwhile there is a very good economic environment in Rwanda. The state systematically fights corruption and got a World Bank’s doing business rank of 45, out of 183, in 2011 (TI, 2011; (World Bank & IFC, 2011). Especially rank 8 in getting credit and starting a business are excellent results in terms of thinking about business models focusing mini-grids.

Still there is a rural electrification rate of only 1 % which means that there is a rural population of 8.5 million people having no access to electricity. Figure 3 shows the population density in Rwanda and the transmission lines crossing the country. It is visible that there is a high population density but only few transmission lines. This is confirmed by Figure 4 which shows the nightlights in Rwanda. Only those people who have access to electricity can use it for lighting at night.

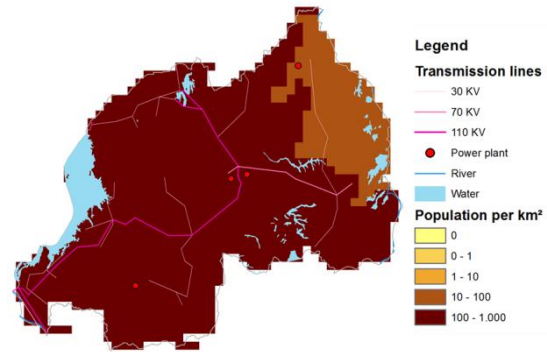


Figure 3: Transmission lines, power plants and population in Rwanda. Data are taken from Hijmans; National Geospatial Intelligence Agency; African Development Bank Group, 2012; Platts, 2009; Balk & Yetman, 2005.

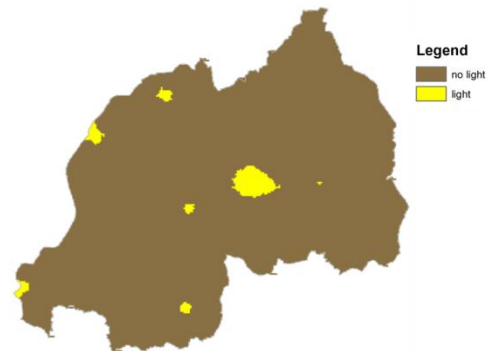


Figure 4: Nightlights at Rwanda. Data are taken from Hijmans; NOAA National Geophysical Data Center, 2007.

In Rwanda there are only some bigger cities like Kigali the capital, Gisenyi or Butare having light at nights. The rest of the country is dark as soon as the sun goes down although there are lots of people living in the dark areas.

Additionally Rwanda only produces half of its consumed electricity itself. Thus the country has urgent needs to expand its capacities. There are targets for electrification in Rwanda which say that there shall be 1,000 MW electric power capacities in 2017 while there were 90 MW in 2011. Conventional energy resources are very expensive for Rwanda as they do not have any resources themselves. There are investments in energy production with methane gas, hydro power, geothermal and solar power (German Trade & Invest [GTAI], 2011; Wilhelmi, 2011).

Regarding all these conditions Rwanda seems to be rightly on the first place of the ranking. It offers a good environment for implementing a sustainable business

model of renewable mini-grids. Only one thing could be a barrier for that intention. This is that rural people are not living in settlements but have their farms spread on the hills (Wilhelmi, 2011). This situation would not be economic for a mini-grid because of long and expensive cables. This is something not considered in the ranking and has to be checked for each country separately. Still, as the general set-up is so positive, it might be worth to look for places in Rwanda where people live close to each other or are willing to move for electricity. Industry can be established and poverty can be fought that way.

Discussion

According to this work it can be stated that there are several countries which offer good preconditions for starting a sustainable business of electrifying rural people with renewable energy based mini-grids. The results show countries which seem to be on good way concerning sustainable development and can help entrepreneurs focusing on countries being adequate for starting a business. Adequate countries are different countries from southern and eastern Africa and Peru as a South American state. However, while working with the subject it became obvious that still every country has to be checked in detail like it has been done on the example of Rwanda in this paper.

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