SOLAR THERMAL POWER PLANTS IN WEST AFRICA: SITE SELECTION AND POTENTIAL ASSESSMENT

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1. Introduction

West Africa has some of the lowest modern energy consumption rates in the world with average electricity consumption of 88 kWh/capita compared to the continental and global averages of 563 and 2596 kWh/capita respectively. Direct Normal Irradiation (DNI) which is the 'fuel' for Concentrating Solar Power (CSP) is relatively high in some part of region. Hence CSP presents better opportunities for increasing access to electricity and for diversifying sources of energy in West Africa; however, to date no CSP plant has been installed in the region and none is under construction. Moreover, except for Burkina Faso, no site evaluation in West Africa has ever been performed for CSP. This study aims at filling that gap by evaluating and ranking suitable sites for large-scale CSP projects. It further computes the potential nominal power for different technologies with many scenarios.

2. Literature review

Selecting an appropriate site for concentrating power plant has been the subject of many studies. Azoumah et al., (2010) provided technical guidelines for selecting a suitable site for CSP projects in the Sahel. The guidelines were applied in selecting a candidate site in Burkina Faso. Broesamle et al., (2001) made use of satellite data and Geographic Information System (GIS) to rank potential sites for CSP in North Africa. Bravo et al., (2007) in considering parabolic trough plants with 6 hours thermal storage, used GIS and found a generation ceiling of 9,897 TWh/y for Spain; After taking just 1% of the whole wasteland in China as potential site for solar thermal power plant and assuming a land area requirement of 20,234 m²/MW of installed capacity for power tower technology, Hang et al., (2008) showed that 1,300 GW of electricity generation capacity could be installed. Fluri, (2009) also used GIS to identify potential areas for the implementation of large scale CSP plant in South Africa; assuming parabolic trough technology with an average capacity factor of 38.8 %, he found that the identified areas could yield a total nominal capacity of 547.6 GW corresponding to a net annual energy generation of 1,861 TWh. Charabi and Gastli, (2010) used GIS tools to first evaluate the solar resource and to select a candidate site for large CSP plants for Duqum in the Sultanate of Oman; they also calculated the electricity generation potential for different CSP technologies and for concentrated PV (CPV). The same methodology was used by Clifton and Boruff, (2010) in order to classify potential CSP sites in the Wheatbelt region of Western Australia.

Criteria used in these studies include sufficient DNI, suitable land use profile, availability of water, closeness to transmission lines, proximity to pipelines, low slope value, access to highways for maintenance and repair, population density etc.

3. Methodology

Overlaying is the method used in this study. It is an important procedure in GIS analysis. It involves superimposing two or more map layers to produce a new map layer by combining diverse data sets; Overlay analysis is used to investigate geographic patterns and to determine locations that meet specific criteria. Criteria used in this study are sufficient DNI, proximity to transmission lines, low slope value. This approach was previously used by Charabi and Gastli, (2010), Fluri, (2009) and Hang et al., (2008). Three maps of

West Africa were developed; they illustrate spatial distribution of solar radiation resources (DNI), land slope and transmissions lines respectively; the maps were subsequently laid over each other with restricted criteria. The intersected area is assumed to be suitable area for CSP implementation. Based on the obtained land surface and using performance characteristics of commercially matured plants such as SEGS IX, PS 10 and PE I, the nominal capacities were then estimated.

4. Results and discussion

Figure 1 illustrates suitable areas for large-scale concentrating solar power plants in West Africa; Criteria used in this map were DNI greater than 4.5, land slope less than 3% and distance to transmission lines less than 20 km.

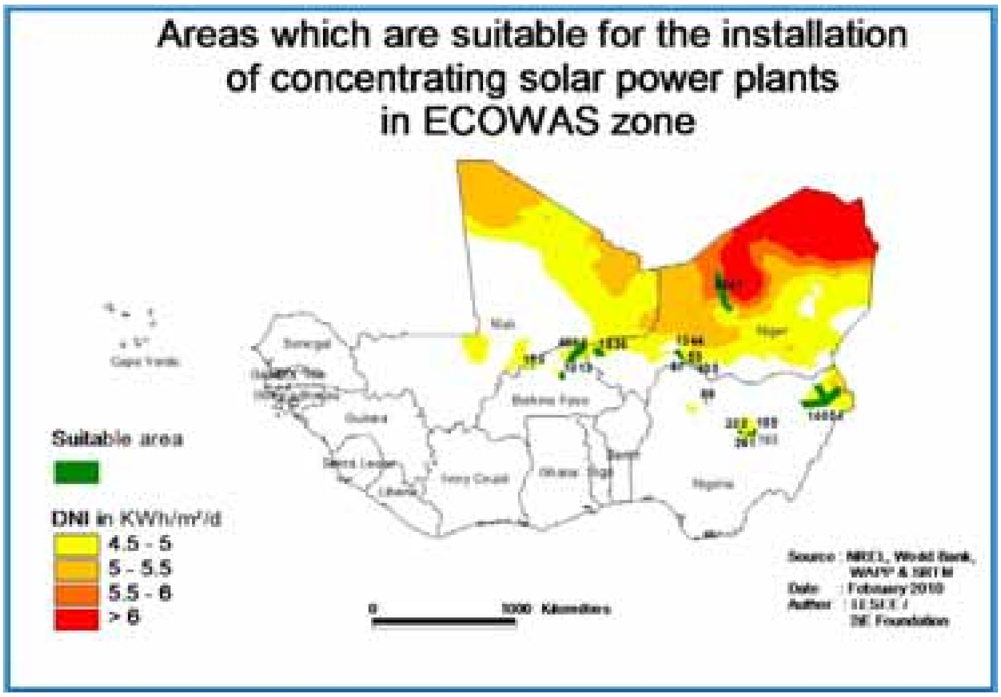

Fig. 1: Suitable areas for large-scale concentrating solar power plants in West Africa

Land use pattern and availability of water were not taken into account in this map; however they can be extrapolated from the results of the study conducted by Azoumah et al., (2010) in Burkina Faso since there is a strong climate similarity between the designated area and Burkina Faso. From the study, only 36 % of the land in the Sahel is occupied by housing, forest, rivers and agricultural farms with housing accounting for 0.04 %. There is no competition in land use in the region as shown in the previous study in Burkina Faso. Water resources were assumed to be scarce from the same study conducted in Burkina Faso.

While Figure 1 represents only one scenario, Table 1 computes the potential land area and the associated nominal capacity yield for the three main large CSP technologies in West Africa in many scenarios; the technologies are Parabolic Trough (PT), Central receiver (CR) and Linear Fresnel (LF). Computations were inspired by performance characteristics of SEGS IX in California, PS10 and PE1 in Spain.

Tab. 1: Scenarios for potential CSP nominal power in West Africa

DNI kWh/m2.day	Land slope %	Distance to transmission lines	Suitable land area km²	DNI on Suitable land area kWh/m2.day	Nominal Capacity for PT GW	Nominal Capacity for CR GW	Nominal Capacity for LF GW
≥ 5	≤1	≤20	1149	5.514	40.14	22.99	27.21
		≤60	10840	5.554	381.44	218.44	258.53
		≤100	20068	5.603	712.38	407.96	482.83
	≤3	≤20	8914	5.393	304.57	174.42	206.43
		≤60	29143	5.616	1036.93	593.82	702.81
		≤100	55155	5.772	2016.97	1155.06	1367.05
	≤5	≤20	9595	5.421	329.54	188.72	223.36
		≤60	32115	5.527	1124.57	644.01	762.20
		≤100	61483	5.69	2216.43	1269.29	1502.25

PT: Parabolic trough; CR: Central receiver; LF: Linear Fresnel

The potential nominal capacity for large-scale concentrating solar power is huge in West Africa. To illustrate this, let's consider only 1 % of the suitable land area with daily DNI greater or equal to 5 kWh/m2.day, land slope less or equal to 3 % and distance to transmission line not more than 100 km, Table 1 shows that West Africa has a potential nominal capacity of 20.16 GW for Parabolic trough technology.

5. Conclusion

Solar Thermal Power (STP) Plants appear to be good candidate for increasing access to electricity in Africa; however, with the exception of Northern Africa where extensive work is being conducted, potential assessment of Solar Thermal Power Plant in West Africa is yet to be done. This paper presented results of the potential assessment of STP for electricity generation in West Africa. The study considered only 1 % of the suitable land area which meet certain criteria and found that West Africa has a potential nominal capacity of 20.16 GW for Parabolic trough technology. Further studies need to be conducted to ascertain the economic viability of such plants in the region.

6. References

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