SOLAR THERMAL GENERATION: A SUSTAINABLE INTERVENTION TO IMPROVE SAPP'S DIMINISHING GENERATION SURPLUS CAPACITY

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ABSTRACT

The threat of diminishing electricity generation surplus capacity within the Southern African Power Pool (SAPP) is explained. The global discourse on the long-term environmental impact and sustainability of conventional energy sources is highlighted against the backdrop of the prospect and potential of Solar Thermal Power Generation (STG). The latter is illustrated in terms of both a detailed discussion of various STG technologies suitable for the SAPP region and an analysis of their attendant levelized costs of energy (COE). Implications and conclusions are then drawn for the SAPP region.

1. INTRODUCTION

The Southern African Power Pool (SAPP) is a consortium of countries in Southern Africa represented by their National Power Utility Companies, with a regional development goal of linking SADC member states into a single electricity grid for cost effective power and resources sharing. The organisation was formed in 1995 and the its member countries with respective Power Utility Companies are: Angola-ENE, Botswana-BPC, DRC-SNEL, Lesotho-LEC, Malawi-ESCOM, Mozambique-EDM, Namibia-NamPower, South Africa-ESKOM, Swaziland-SEB, Tanzania-TANESCO, Zambia-ZESCO, and Zimbabwe-ZESA [1, 2]. SAPP has in been in operation for just over a decade1995 since its creation in 1995.

Reference to SAPP's electricity demand projections reveals the need to boost the region's electricity generation capacity and reduce demand. It is estimated that based on the region's present electricity consumption trends, the regional demand on electricity cannot be met beyond 2010. A country-by-country analysis within SAPP also reveals a parallel trend: Botswana for instance imports more than 70% of its electricity mainly, from South Africa. The contractual electricity import agreement between Botswana and South Africa will need to be renegotiated at the end of 2007 due to electricity bottlenecks felt domestically within South Africa itself.

Remedial measures by SAPP have in pragmatic terms been directed primarily to efforts geared towards increased generation levels. Only a few individual countries' utility companies, notably ESKOM in South Africa, have embarked on a two-prong solution that integrates electricity conservation through energy efficiency measures and Demand-Side Management (DSM) programmes in their generation expansion portfolio. However, the choice for a suitable primary source of energy to generate electricity is not arbitrary.

In a carbon-constrained world, the primary energy source for use in electricity generation is no longer dictated by economics alone. A choice of sustainable energy alternative ought to balance environmental, economic as well as technological concerns. This paper argues that there is sufficient evidence in terms of proven and mature STG technology diffusion, acceptable economic indices, and environmental correctness to warrant solar as the sustainable energy source of choice in circumventing SAPP's diminishing generation surplus. In this paper electricity, a sub sector of the energy sector shall be used interchangeably to connote "energy" and vice versa.

2. SAPP GENERATION PROJECTIONS

"In 2007 the net SAPP generation capacity is expected to reach 45GW against peak demand of well over 45GW. In the past 10 years, electricity generation surplus capacity within the member utility companies has been declining. The region has currently a combined total installed generation of 52.743 GW but the net generation output is around 45GW. By 2010, it is projected that the combined total SAPP member countries' demand shall reach 47.626GW [2]. It is alleged, that to operate optimally, SAPP must ensure it maintains a generation reserve level of 10.2 percent or higher at all times. It is projected also that at current demand growth rates, the region could exhaust its reserve capacity by 2007 and would not be able to meet further increases in demand for power which will lead to power outages with severe economic, political and social consequences. This has prompted member states, through SAPP, to embark on a number of short and long-term projects to bolster its power generation capacity by more than 42GW by either constructing new power stations or enhancing the performance of existing facilities [2]. Table 1 shows the SAPP's electricity demand projections.

Table 1: SAPP electricity demand projections [2]

Year	Total (MW) Interconnected	Total (MW) SAPP Demand	Status
1998	32,699	33,466	←HISTORIC→
1999	32,771	33,676	
2000	34,229	35,110	
2001	35,781	36,749	
2002	36,981	38,021	
2003	35,694	36,803	
2004	37,780	38,890	
2005	39,341	40,511	
2006	41,479	43,290	←FORECAST→
2007	42,788	44,689	
2008	43,832	45,827	
2009	45,209	47,290	
2010	46,576	48,795	
2011	47,986	50,291	
2012	49,426	51,800	

Ten years after its inception, SAPP identified in 2005 priority projects aimed at reversing the diminishing generation surplus capacity [2]. These projects involve rehabilitation of the existing infrastructure, short-term generation projects, and transmission projects to interconnect non-operating members of the SAPP such as the Mozambique-Malawi, Zambia-Tanzania-Kenya interconnections and the Western Power Corridor (Westcor). The initiative also includes plans to relieve congestion on the SAPP grid and to evacuate power to the load centres."

SAPP may be accused of being seemingly oblivious to the current discourse on the electricity sustainability agenda mainly due to its apparent lack of assertiveness in prioritising renewable energy projects. Instead SAPP seems to pronounce solutions that default to the electricity-business-as-usual scenario where coal is assumed to be the primary source to bolster generation capacity. Using SAPP's operational statistics and planning data from 1996 up to 2014 [2], 24 of the 45 power stations that have been or are yet to be built are thermal power stations with the remaining 21 being either hydro pumped storage power stations. None is envisaged to be solar. Individual government interventions aimed also at curbing their generation deficits seem to corroborate the perceived electricity-business-as-usual scenario [3].

The New Vision, 12th December 2006 reports that "Israeli investors yesterday met President Yoweri Museveni and proposed provision of 100 MW of fuel oil generated electricity*",* whereas the Solar equipment suppliers in Kampala appeal to the government to "boost the capacity of solar power providers to provide power to communities" *African News Dimension, 26th December 2006.*

In Tanzania, "The Tanzania Electricity Supply Company (TANESCO) guarantees only 347 MW of electricity generation against a country maximum demand of 550 MW. The company's six hydropower stations with a total output of 561 MW, now yield a paltry 50 MW, which has necessitated the day-long power shedding. The long term plan is to use thermal, natural gas and coal to generate 500 MW that would completely end power outages."

In Zimbabwe, "The Zambezi River Authority (ZRA) has failed to attract investors for the construction of the giant US$1.5 billion Batoka hydroelectric power station, a joint project between Zimbabwe and Zambia. Sources within the ZRA said a number of enquiries from potential investors have been coming in but not a single one of them had materialised "for unspecified reasons". The timely implementation of the project was critical in light of the projected regional power deficit in 2007. *The Herald, 25th December 2006*".

In this snapshot headline news on energy matters, only Kenya is different in that the "Great Wall Drilling Company" has clinched a deal to drill geothermal wells for KenGen. The firm's work early next year will begin with the construction of a new 70 MW power plant, Olkaria IV, in Naivasha. The drilling would accelerate geothermal development, which is expected to reduce dependence on hydropower generation. The Government has identified geothermal power generation as the cheapest option for the next 20 years. Research shows there is potential of more than 2GW of geothermal energy in the Rift Valley. Kenya has an effective capacity of 130 MW making it the leading geothermal power producing country in Africa. *The Standard, 20th December 2006*"

Hence in SAPP's agenda on corrective interventions, as do individual government's intentions, both measures meant to ameliorate diminishing electricity generation capacity are still dominated by an over-reliance on coal. Given the huge hydro-potential within some SAPP member states, the development of hydro power generation could suffice to avert the diminishing surplus capacity. However there may be justifiable disquiet on entrusting the region's electricity security of supply to water-endowed countries whose political stability may not be guaranteed. SAPP's silence on the potential of renewable electricity generation options needs redressing by creating awareness for the viability of the solar thermal power generation potential in the region.

3. THE SUSTAINABLE RENEWABLE SOLAR THERMAL GENERATION

In a carbon-constrained world of our times, a long-term energy vision for SAPP would be expected to be pragmatic on sustainable electricity supply. Using Bruntland's definition of sustainable development and recasting it to apply to sustainable electricity development, "Sustainable *Electricity* Development is *electricity* development that meets the *electricity* needs of the present without compromising the ability of future generations to meet their own *electricity* needs" [4].

SAPP's projected $8Billion investments on transmission infrastructure and the erection of new coal-fired power stations does not include arguments on sustainable electricity development:

First, the transmission infrastructure is a dominant cost factor in the electricity demand-supply industry mainly due to the length of the electrical energy supply chains involved [5]. To mitigate such huge capital investments one strives to reduce the supply chain for instance by blending alternative sources of electricity generation with the conventional sources of generation and locating the new generation sites near the anticipated loads i.e. distributed electricity supply. In their summary findings, Mapako and Mbewe [6] note, "Centralized dissemination of modern energy (*electricity*) (*in sub Saharan Africa*) is found to have an urban focus and to be associated with centralized production of (*electrical*) energy". Taking stock of the scattered distribution of the load amongst rural communities, solar electricity could be supplied to SAPP rural communities through the distributed generation mode.

Secondly, the identification of new plant capacities is an imprecise science that assumes a predictable rate of growth in demand. In most cases, new plants cannot be utilised immediately to their fullest capacity because the assumed demand will not have materialised at the time of plant commissioning. Hence the investment on unrealistic plant capacities is tantamount to sunken investment. Sustainable electricity investment argue instead for incremental capital expenditure on smaller distributed plants that grow with time as justified by a demand that is borne out of short-term forecasting. Such distributed generation accelerates Return on Investment [7].

Thirdly SAPP needs to be emphatic on reflecting the real cost of using coal-generated electricity. So far that cost has been held artificially low. As a result, the traditional argument against solar electricity has been that it is not economical vis-à-vis coal-based electricity. This argument must be qualified by taking into consideration, the cost of environmental damage that has all along been neglected in electricity bills. In recognition of the long-term global environmental damage due to Green House Gas (GHG) emissions when coal is used as the primary source of electricity, signatories of the Kyoto Protocol have made commitments to mitigate the environmental deterioration. According to the recent conclusions by the UK Stern report on Climate Change [8]:

- If climate change continues unabated, average temperatures could rise by more than 5^{o}C from pre-industrial levels,

  Mike Hulme [9] quoting the Intergovernmental Panel on Climate Change (IPCC) states that, "the estimated increases in temperature is expected to lie between 1.4^{o}C and 5.8^{o}C by 2100".

  The IPCC [11], the world authority on global warming, estimates that for the southern African region, an increase in average temperatures of between 2^{o}C and 5^{o}C is to be expected over the coming century [9].

- The physical and human geography of the planet will be profoundly affected: 300 million people could become refugees as their homes succumb to drought or flood. Poorer countries will be among the worst affected.

- The world's economic growth will be cut by 20 per cent or more. Each tonne of carbon dioxide that we emit now is causing damage valued at $85 or more.

- The cost of action to reduce GHG to avoid the worst impacts of climate change can be limited to around one per cent of global GDP each year.

Countries are likely to be able to meet their Kyoto Protocol targets only through actions in which electricity conservation programmes (viz. Energy efficiency and Demand-Side Management (DSM) are combined with alternative renewable sources of electricity generation; the most attractive of which seems at least for SAPP to be solar thermal electricity generation (STG) because solar energy is abundant within the SAPP region and because solar does not result in GHG emissions.

STG is economic only for countries endowed with high levels of solar insolation. Figure 1 is a reproduction of the global climatic regions following the Koppen Climate classification [10]. According to this taxonomy most of the SAPP region climate is a dry, high daily temperature climate (B) that subdivides into two sub-climates: The steppe or semi-arid (S) and desert or arid (W) hence the acronyms BS, BW in most Koppen classification maps. BS and BW climates are typically found between 18° to 28° in both hemispheres and therefore SAPP shares the same climatic conditions as those predominant in the south-western United States (notably, California) and northern Mexico, Argentina, north Africa, and the central part of Australia. According to Quaschning [12], "Just 1 % of the available Sahara desert area alone would theoretically suffice to provide the total global electricity demand through STG Plants". Therefore, in the medium and long-terms, the potential of electricity provision through STG for SAPP must be assessed on the basis of the technological, economic and environmental practices, availability of human capacity and experiences of countries having comparable climatic belts as that in the SAPP.

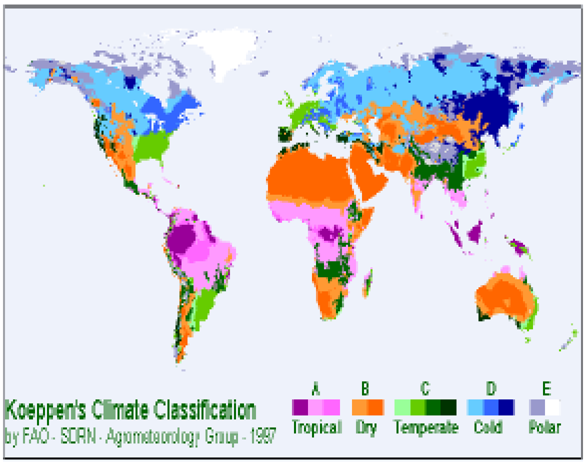

Figure 1: The Koppen Global Climate Classification [10]

The amount of annual solar irradiation decides whether a region is or is not suited for their installation [12]. The solar irradiation depends on the latitude as given in Figure 1

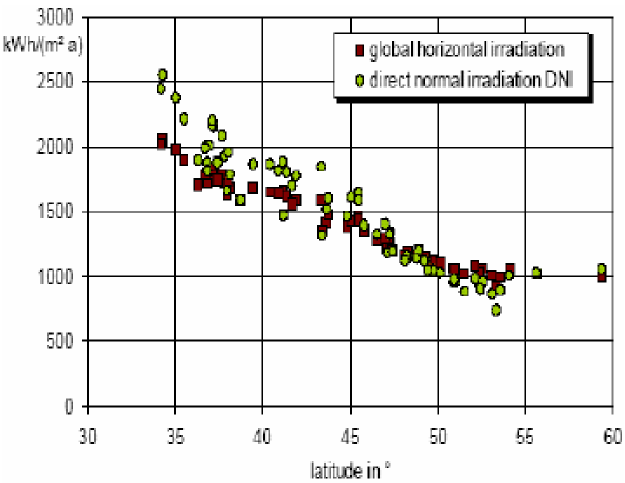

Figure 2: Solar irradiation Vs latitudinal position [12].

Figure 2 underpins the suitability of STG for the SAPP region where the low latitudinal position lends the region potentially higher levels of Direct Normal Solar Irradiation (DNI) than the maximum value shown in Fig. 2. In Botswana for instance the monthly average of the daily radiation received on a horizontal surface in the case of absence of the atmosphere can be as high as $43MJ/m^2/day$ which translates to $5733\ kWh/m^2/a$ [13]. It is considered that annual global horizontal irradiation values above 1800 kWh/m²/a offer nearly perfect conditions [14]

The utilisation of solar radiation for electricity generation can be achieved through Photovoltaic systems (PV) or using STG systems. In the low kW power range, both PV and STG systems could be used where both technologies are suitable for distributed generation and supply of electricity to loads for instance in the rural communities. PV can utilize and operate on the diffused part of the total incident solar radiation. Dish/Stirling and Trough/Tower STG Systems on the other hand depend entirely on DNI for their operation. Research shows that for higher MW-range plant sizes where high DNI values are necessary, only Solar Thermal Trough and Tower Systems are convenient. High-end MW STG plants could be located near existing conventional power plants to bolster the capacities of existing (coal-fired) power plants and thereby reduce costs by sharing infrastructural costs with investments already made on existing coal-fired plants.

Electricity generation through STG started in the California's Mojave desert in 1984 where a stage-wise incremental development resulted in the 354MW STG plant now operational for over 10 years since its completion in 1991 and supplying the Grid with an annual average of over 800 GWh. The Mojave plant demonstrates the feasibility of the STG in terms of the technology, its economics, and answers environmental concerns.

4. JUSTIFYING THE SUSTAINABILITY OF STG ELECTRICITY

Firstly on the STG technology: The principle and operation of STG technology is widely reported in the literature [13, 15, 16, and 17]. STG uses focusing thermal collectors to operate solar furnaces at high temperatures. The high temperatures are used to generate superheated steam in the furnace, which in turn is pumped to a turbine to generate electricity. This basic technology has been refined over time and shown to work satisfactorily as illustrated in the case of the Mojave plant. There are several plants in construction. Spain has already commissioned a 20MW plant. In California bigger plants of up 900MW are envisaged. The STG technology is therefore tested and reliable.

Secondly, the economics of STG need to be substantiated. The economics of STG can be assessed by considering the development of its levelized costs. Concretely, the statistics for the Mojave SEGS plant shown in table 2 can be used for illustration.

Table 2. Data for the 354MW Mojave plant in California

California Solar Electric Generation Systems - SEGS	
Data	Value
Year installed	1984 - 1991
Capacity	354MW
Total parabolic mirrors	9.0
Total Aperture area of reflectors	2.3 Mi m^2
Total ground area	Over 7 km^2
Total Yearly Energy produced	0.6TWh
Cumulative energy produced so far	Over 8 Billion kWh
Initial Levelized COE	0.27$/kWh
Levelized COE at commissioning	0.12 ... 0.14$/kWh

Table 2 shows that the levelized cost of energy (COE) was 27 cents/kWh at the beginning. At its completion in 1991, the COE had dropped to between 12 up to 14 cents/kWh. Quaschning [15] asserts that the levelized COE will decrease to reasonable levels with time as the efficiency of the components used in the STG technology improves and as the technology diffusion penetrates more markets. Figure 3 shows the development of the COE over the years.

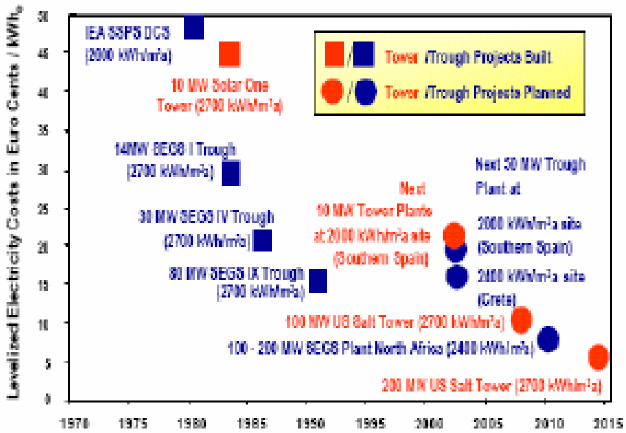

Figure 3: Historical development of the levelized COE [15]

STG plants are much more economic than photovoltaic systems [14]. The levelized COE for solar systems decrease with decreasing latitude as is shown in figure 3. The figure implies, that for the SAPP countries where the latitudes are lower than those indicated, one can assume further reductions in the levelized COE.

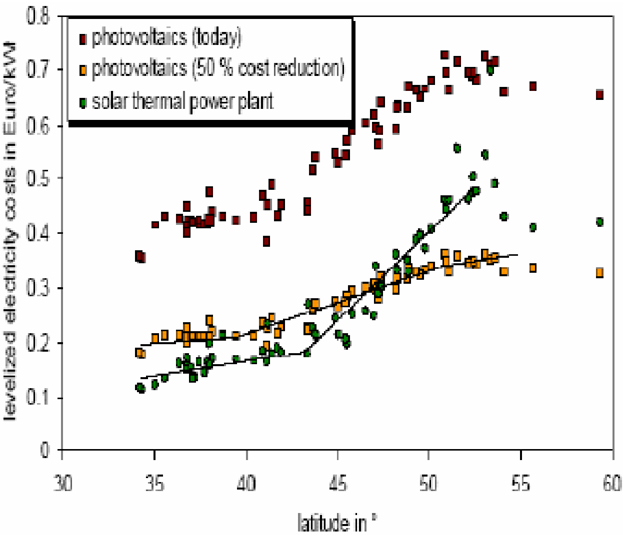

Figure 4: The levelized COE against latitude [12]

A study on large STG plants [18] indicates that the COE decrease with plant size and type as shown in Figure 5. The same study reveals that STG is more economic when STG plants are aggregated in multiples of smaller units to form the aggregate plant as illustrated by the cost savings summarised in Table 3. Thus better economies of scale are achieved by incremental development of an STG plant over time to a bigger aggregate unit. For instance the 354MW plant in California was built with 9 basic parabolic mirror units.

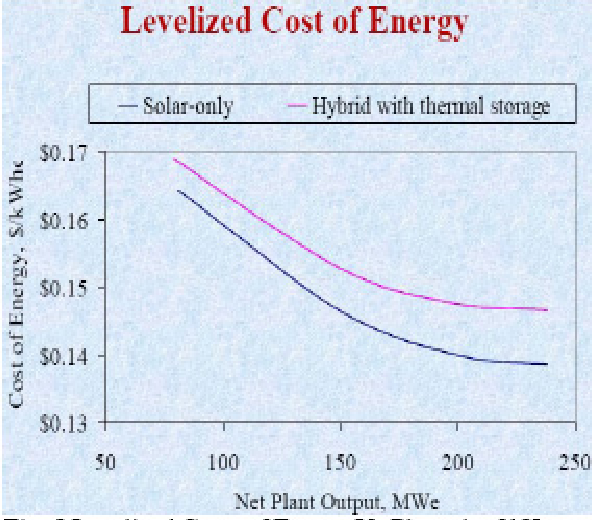

Fig. 5 Levelized Costs of Energy Vs Plant size [18]

The development of STG technology has taken a global scale. More plants are being built and an increasing number of countries are adopting the technology as illustrated by the sample plants in table 4

Table 3 Illustrating Economies of Scale for STG [18]

COST OF SUMMARY			
	One 250 MWe	Four 250 MWe Separated power blocks	Four 250 MWe Adjacent Power blocks
Equivalent annual capital cost in $1000	111,496	404,333	413,900
Annual operation and maintenance cost in $ 1,000	11,780	38,300	35,950
Annual energy production in MWe	740,980	2,963,920	3,098,532
Levelized energy cost in $/kWhe	0.166	0.149	0.145
Savings due to multiple plants	Base	-10.20%	-12.70%

Table 4 Development and operation of the STG plants

Country	Size	Notes	Status
USA, CA	354MW	9 standalone STG	Operational
USA, CA	64 MW	Largest standalone STG yet	Started being built Feb 2006
USA, CA	500MW	To Covers 4 square miles	Approved in October 2006
USA, CA	300MW	For expansion to 900MW	Awaiting approval
SPAIN	200MW	Europe's 1st Large STG plant	Started being built June 2006

Information on STG is wide-spread with the notable research contributions made by Quaschning at the website, http://www.volker-quaschning.de/downloads/index_e.html. Notable sources of general information on STG and research are the US Department of Energy-DOE through its sister organisations, the Energy Renewable Laboratory-NREL, the Energy Efficiency and Renewable Energy Network-EREN, the European Renewable Energy Council-

EREC, and the European Photovoltaic Industry Association-EPIA. Most documentation point towards diminishing levelized COE for STG and thereby justifies the long term economic prospects of the technology. But a significant impediment towards STG development is the argument levelled against STG by many traditional economists, that STG electricity is not economic since it is not competitive against coal-generated electricity. It can be counter-argued, that STG may appear overly uneconomic only because the real cost of using coal for electricity generation has for a long time been camouflaged. Were the costs of environmental damage (currently standing at $85 or more in the UK [8]) to be included into the electricity bills, comparisons would at least convince the sceptics about the economic worth of STG.

A study [17] to provide an assessment of the potential economic impact of developing Nevada's solar power resource compared the economic benefits of three levels of. Investments on STG: "In a one-off investment on a single 100MW plant, the income for Nevada, discounted over the construction phase in 2004-2007, through the operation and maintenance phase starting 2007 to 2035, was estimated to be $1.15 billion. In a different scenario where the investment on STG was to sustain only two-thirds of Nevada's total demand, additional personal income and Gross Social Product (GSP) for Nevada of $3.41 and $3.47 respectively were to be expected. Where an aggressive STG investment involved the constructing of ten 100-MW plant each, direct, induced, and indirect benefits in terms of personal income and GSP would reach $9.37 and $9.85, respectively"

We limited this study to an examination of the tangible benefits of moving toward renewable-power generation. Nevertheless, the intangible benefits of improving air quality and reducing the threat of global warming are certainly important. Taken together, the tangible and intangible benefits to the state make CSP generation an attractive option.

Thirdly and finally, the social and environmental merits of STG need to be highlighted. In the same study, "Potential Economic Impact of Constructing and Operating Solar Thermal Power Generation Facilities in Nevada" [17], Schwer and Riddel conclude that besides the economic aspects, "There were other additional intangible benefits related to improving air quality and reducing the threat of global warming. Taken together, the tangible and intangible benefits to the state of Nevada made Concentrated Solar Power generation an attractive option.

An additional social aspects revealed by the study was "the regional economic development potential of rural Nevada. The STG industry could support sustainable economic development in places that are currently seeking opportunities for economic development. New jobs in the relatively highly paid utility industry could provide a core of income for counties that are fast losing traditional income sources such as mining." A similar case could therefore be made for isolated SAPP communities that, the latter would have their social well-being improved by virtue of new economic opportunities that come along with STG development.

5. DISCUSSION

Having made a case in favour of why STG in SAPP, this paper ought to provoke an even bigger questions: Why not STG in SAPP *now*? Why Procrastinate? Is the region's climate not conducive for STG? Has the STG technology not been tested? Are its economics still questionable? Can't SAPP be proactive in combating GHG emissions now ahead of their imminent prevalence? What if the equivalence of $8 Billion was invested by SAPP on distributed STG development?

6. CONCLUSION

In conclusion we have underpinned the long-held view of an imminent electricity generation capacity deficit within SAPP that needs redressing. We have highlighted the focal projects that SAPP has prioritised to ameliorate the generation capacity deficit. The paper has noted that SAPP measures are traditional leaning on non-sustainable electricity generation that relies on coal. The paper has argued for a case of exploring in an assertive manner, the potential of solar thermal generation within SAPP. The arguments advanced are based on the evidence in research and the experiences accumulated over more than a decade of operating practical STG plants in a region (Nevada, California) whose climatic conditions according to the Koppen Climate classification scheme, are the same as those within the SAPP region. The paper has concluded from the advanced arguments that the conditions and timing of the introduction of the STG technology within SAPP are both more favourable than they were a decade ago when the STG became first fully functional in California. This is because the SAPP region may count on higher DNI levels due to their more favourable geographical positioning, the levelized costs of energy may be today much lower for SAPP than those stated in the case studies done since the STG has matured over the years and since the diffusion of the STG technology is now widespread. In addition, STG is ideal for SAPP whose dispersed communities in the rural areas cannot always rely on the Grid for their electricity supply. STG therefore is a sustainable intervention to boost their economic and social status. In the process, SAPP also makes cost savings on its transmission infrastructure outlay on account of distributed STG. The discussion has provoked a number of questions, whose answers demand the collective effort of different stakeholders in electricity demand-supply chain. These stakeholders are likely to make balanced views that take into consideration the three pillars of any sustainable (electricity) development, namely the technological, the economic, and the socio-environmental aspects.

However, reliance alone on bolstering generation capacity through renewable solar thermal technology is not sufficient. The extra surplus generation efforts must be complementary to aggressive energy conservation strategies implemented through Energy efficiency and Demand-Side Management Programmes.

7. REFERENCES

[1] Desk Study Report – "Issues and Options for Rural Electrification in SAPP Member Countries and Rural Electrification Planning in Lesotho", March 2003 http://pdf.usaid.gov/pdf_docs/PNADD466.pdf

[2] Southern African Power Pool official Website, http://www.sapp.co.zw/viewinfo.cfm?linkid=9&siteid=1

[3] The esi-africa bulletin website, http://www.esi-africa.com

[4] Bruntland G. H., "Our Common Future -The Bruntland Report", http://www.re-set.it/documenti/1000/1800/1850/1856/brundtland_reportpdf.pdf , 1987

[5] Scheer H., The Solar Economy- Renewable Energy for a Sustainable Global Future', Verlag Antje Kunstmann GmbH, Munich, 1999, ISBN 1-85383-835-7, Chapters 1, 2 and 8

[6] Mapako M & Mbewe A., Renewables and Energy for Rural Development in Sub-Saharan Africa, AFREPREN, Zed Books Ltd 2004, ISBN Hb 1 84277 518 9 Page 1-8

[7] Edinger R., Kaul S., Renewable Sources for Electric Power: Prospects and Challenges, Quorum Books, 2000 ISBN 1-56720-233-0, Pages 75-80

[8] The UK Stern Report on "The Economics of Climate Change". http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

[9] Hulme M., "Director, Tyndall Centre for Climate Change Research, in "Chaotic World of Truth–Viewpoint", http://news.bbc.co.uk/2/hi/science/nature/6115644.stm

[10] "World Climates" http://www.blueplanetbiomes.org/climate.htm/

[11] "The Intergovernmental Panel on Climate Change (IPCC); http://www.ipcc.ch/ Report" http://www.celcias.com/blog/2007/02/ipcc-report-released/

[12] Volker Quaschning V., Muriel M.B., "Photovoltaics or Solar Thermal Power Plants?" VBG Congress on Power Plants, Brussels October 10-12-2001, http://www.volker-quaschning.de/downloads/VGB2001.pdf

[13] Andringa J., The Sun In Botswana, Turbo-Print, Tlokweng, Gaborone, 1992, ISBN 99912-0-071-1, Pg 111

[14] Quaschning V., Geuderl N., Richter C., "Contribution of Concentrated Solar Thermal Power for a competitive Sustainable Energy Supply", CleanAir2003Conference http://www.volker-quaschning.de/downloads/CleanAir2003.pdf

[15] Quaschning, "The seamless solar link to the conventional power world", Renewable Energy World July-August 2000 Pg 184-191 http://www.volker-quaschning.de/downloads/rew2000.pdf

[16] Quaschning V., "Specific Cost Development of Photovoltaic and Concentrated Solar Thermal Systems Depending on the Global Irradiation – A Study Performed with the Simulation environment, GREENIUS", ISES Solar World Congress, Goteborg Sweden June 14-19 2003 http://www.volker-quaschning.de/downloads/ISES2003.pdf

[17] Brown G.C., Skipsey E., Energy Resources – Geology, Supply and Demand, Open University, 1986, ISBN 0 335 15200 7, Page 144-148

[18] Kelly B., Large Plant Studies, "Parabolic Trough Meeting", February 14 2006

[19] Schwer R. K. and Riddel M., "The Potential Economic Impact of Constructing and Operating Solar Power Generation Facilities in Nevada", Centre for Business and Economic Research University of Nevada Las Vegas, Nevada. http://www.osti.gov/bridge

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