Energetic and Economic Potential of Solar Thermal Energy in the Sub Saharan Africa

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ABSTRACT

Sub Saharan Africa is facing a crisis evidenced by rolling electricity blackouts. These shortcomings in the power sector threaten Africa's long term economic growth and competitiveness. A significant contribution to reducing the stress on the electricity supply could be made by large-scale utilization of solar thermal systems for domestic hot water, heating and cooling demand for hospitals, hotels but also for industrial process heat.

Introduction

Around 2.4 billion people in developing and transition countries are currently deprived of access to modern energy services. Energy poverty affects negatively the situation of large numbers of people and the economy in Sub-Saharan Africa.
There are close links between energy supply and practically all aspects of sustainable development such as access to water, agricultural and industrial productivity, health care, education, job creation, environmental pollution and climate change.

According to the World Bank[1] today some 25 countries in sub-Saharan Africa are facing a crisis evidenced by rolling electricity blackouts.

Key Issues in Africa's Power Sector:

- **Low access and insufficient capacity - Some 24% of the population of sub-Saharan Africa has access to electricity versus 40% in other low income countries. Excluding South Africa, the entire installed generation capacity of sub-Saharan Africa is only 28 GW, equivalent to that of Argentina.**

- **Poor reliability - African manufacturing enterprises experience power outages on average 56 days per year. As a result, firms lose 6% of sales revenues in the informal sector. Where back-up generation is limited, losses can be as high as 20%.**

- **High costs - Power tariffs in most parts of the developing world fall in the range of US$0.04 to US$0.08 per kilowatt-hour. However, in Sub-Saharan Africa, the average tariff is US$0.13 per kilowatt-hour. In countries dependent on diesel-based systems, tariffs are higher still. Given poor reliability, many firms operate their own diesel generators at two to three times the cost with attendant environmental costs.**

Shortcomings in the power sector threaten Africa's long term economic growth and competitiveness. The cost to the economy of load-shedding is equivalent to 2.1 % of GDP on average.

In South Africa for instance, the pressure on energy efficiency measures to contribute to mitigating the supply challenge has steadily mounted. After the extended period of excess generation capacity, South Africa ran into electricity supply constraints in 2007 (Figure 1) when the growing need for electricity outpaced the rate at which power stations were being

[1] Fact Sheet: The World Bank and Energy in Africa, http://web.worldbank.org

built. As a result the country experienced repeat power outages from late 2007, continuing into the first quarter of 2008. The ability to supply in South Africa's electricity needs has remained a challenge ever since and electricity supply is likely to remain vulnerable into the foreseeable future.

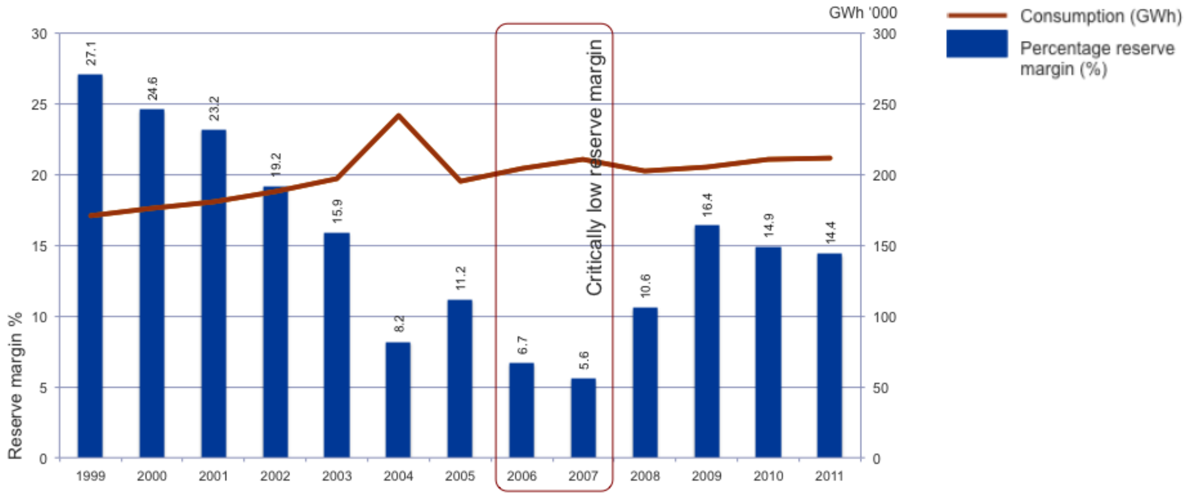

Figure 1: Percentage reserve margin
% buffer between the available supply and projected demand on the electricity system
Source: Source: ISGAN, http://amicasebook.org/?p=1515

The global economic recession in 2008 slowed economic activity and electricity consumption, offering the overloaded electricity network some reprieve. Now, along with the slow economic recovery, the reserve margin is again diminishing, leaving the power system at risk.

The Role of Heat in Africa

It has to be mentioned here that policies usually just focus on electricity when talking about energy and energy policy measures.
With this approach, more than 50% of the final energy consumption in Sub-Saharan African counties which is heat is neglected. This leads to the fact that high value energy like electricity is used for low temperature heat applications. This is a waste of resources and very inefficient from an energetic and sustainable development point of view.

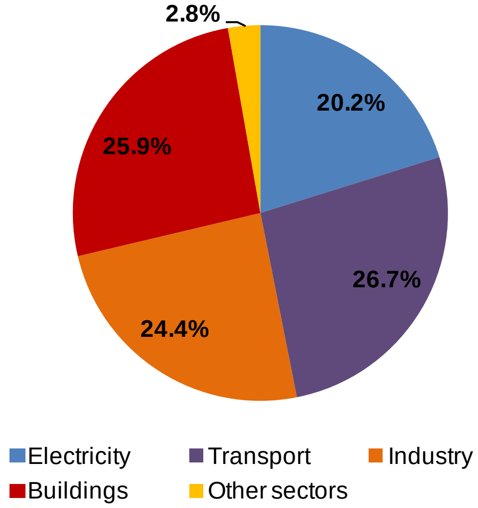

Figure 2: World total final energy consumption, 2011 (322 EJ)
Source: Paolo Frankl, IEA, Paris

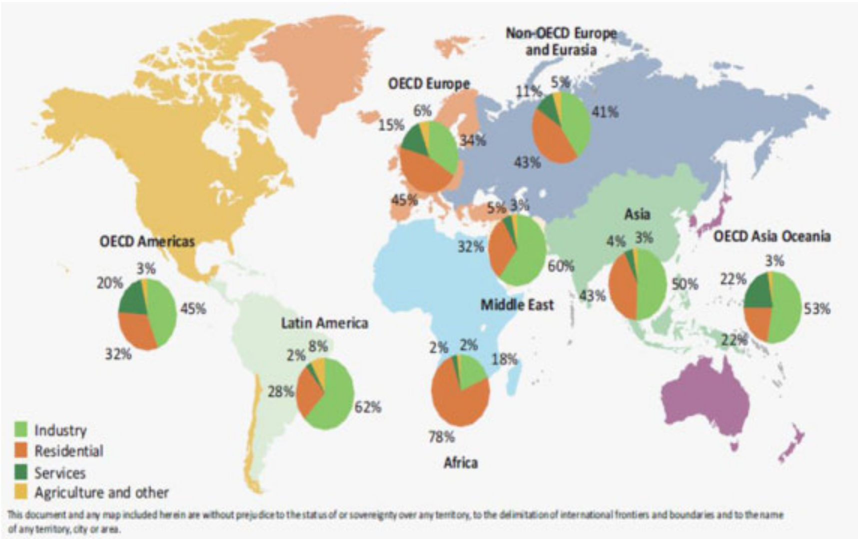

Figure 3: Use of heat in different regions and sectors worldwide.
Source: IEA Energy Technology Perspectives 2012

Since about 40 - 50% of the electricity in the residential sector is used for hot water preparation as soon as people have access to electricity, solar water heaters would be one of the major options in order to reduce the electricity demand and thus the environmental effects like CO_2 emissions caused by fossil power plants.

According to the Integrated Demand Side Management Program of the South African power utility ESCOM besides other technologies and measures Solar Water heating Systems for domestic uses but also for heating and cooling of hospitals, hotels, student hostels and also for providing heat for industrial processes could play a major role in reducing the stress on the security of electricity supply (see figure below).

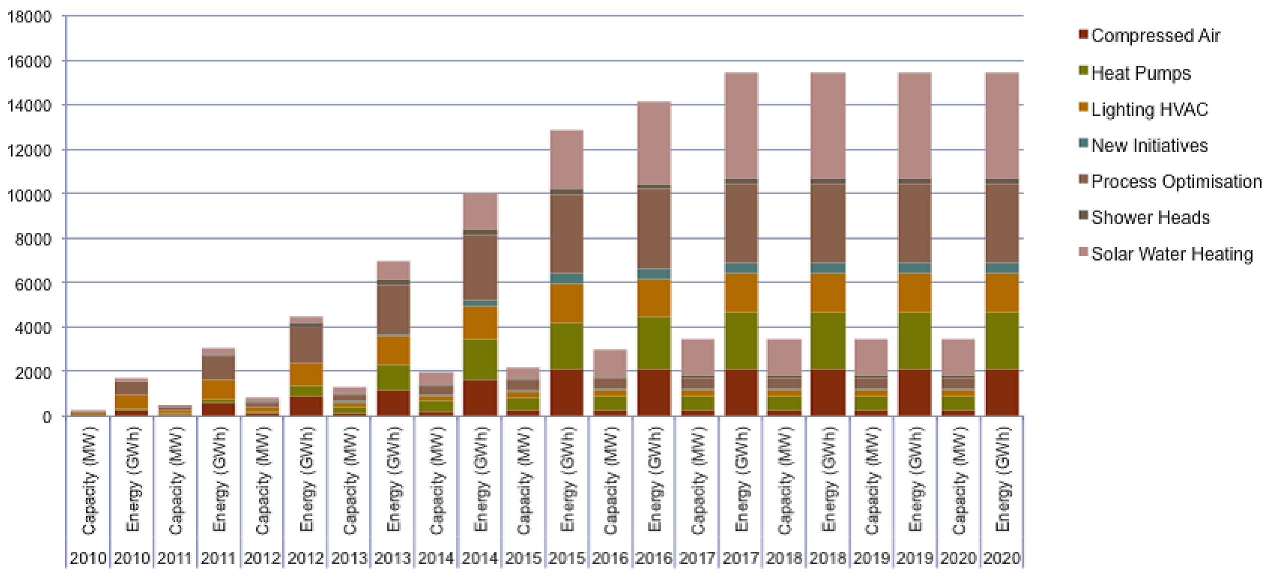

Figure 4: IDM component as included in the Integrated Resource Plan 2010. The anticipated contribution from IDM interventions to the national electricity plan in South Africa. Solar Water heating could play a significant role.
Source: ISGAN IDM Case Study South Africa

Current Status of Solar Thermal Utilization in Sub-Sahara Africa

African countries have an excellent solar irradiation between 1800 kWh and 2400 kWh annual radiation and estimates from the International Energy Agency (IEA) suggest that solar thermal systems could meet about 70 – 80% of the regions low temperature heating and cooling demand.

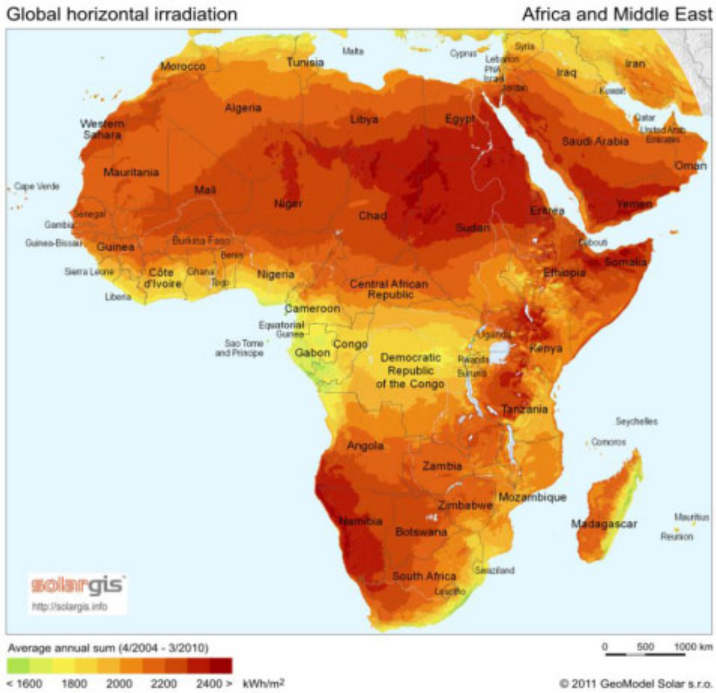

Figure 5: Global solar radiation in Africa (Source: Solargis)

In comparison with other regions of the world, the use of solar thermal energy in African countries is still on a very low level, even if the resource – the availability of solar radiation – is one of the highest worldwide and available in all African countries. In 2013 the share of the capacity installed in Sub Saharan Africa was 0.3% of the total capacity worldwide. Nearly 82% of the world-wide capacity of 406 GW_{th} was installed in China and Europe, with comparable low solar radiation.

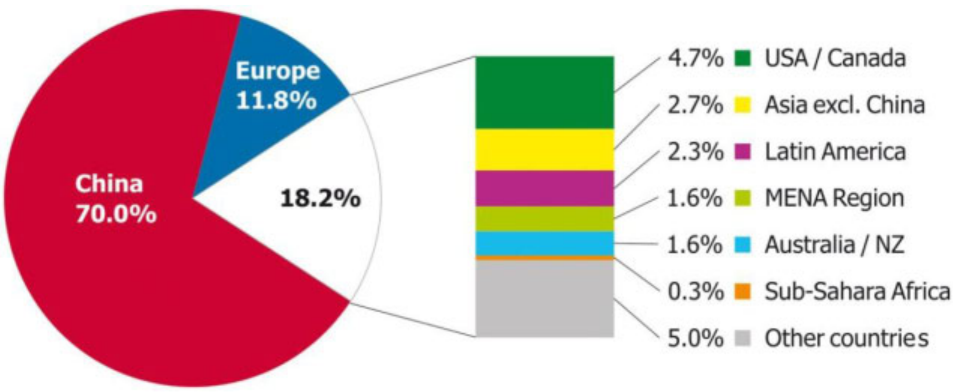

Figure 6: Share of total installed capacity in operation by economic region at the end of 2013
Source: Mauthner, F., Weiss, W. (2015) Solar Heat Worldwide

Even if the total installed capacity in Sub Saharan Africa is on a low level a positive market trend was observed in recent years. Sub-Saharan Africa showed the second largest market growth between 2012 and 2013 behind the MENA region.

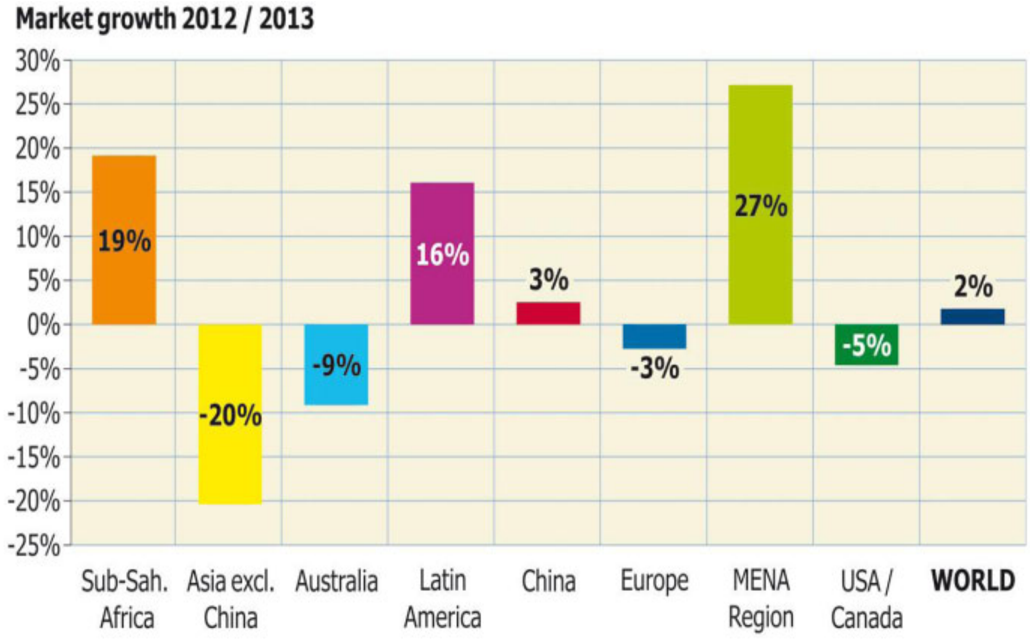

Figure 7: Market growth of newly installed capacity 2012/2013 by economic region and world-wide. Source: Mauthner, F., Weiss, W. (2015) Solar Heat Worldwide

Market Potential

The significant amount of electricity, which is needed for hot water preparation, is given below in an example for the West African ECOWAS region:

By increasing the standard of living and with access to electricity also the hot water consumption will rise in future in the residential sector, in hotels, hospitals and in industry.

Assuming that the ECOWAS region would have the same hot water consumption as the countries with the highest solar thermal market penetration (Cyprus and Israel) an annual electricity demand of about 285.000 GWh would be needed to prepare the hot water. The daily hot water consumption in Cyprus and Israel is about 35 liter/person.

If we also assume that the ECOWAS region would have the same solar thermal market penetration like the two leading countries had already reached in 2012 (466 kW_{th}/1000 inhabitants) it turns out that the electricity saved annually with solar thermal systems would be 252.768 GWh. This avoided electricity consumption equals to the amount of basic electricity for almost half of the population of the ECOWAS countries. Basic annual electricity demand for a household is assumed with 2,000 kWh/year.

In other words:
"By investing in solar thermal systems the countries could avoid significant investment and running cost for power plants as well as for fuel imports."

The figures for all ECOWAS countries are given in the table below.

Table 1: Annual electricity savings and avoided CO_2 emissions due to the installation of solar thermal systems

Country	Population	Installed capacity	Annual Electricity savings	Basic electricity for	Annual CO2 avoidance
		kWth	GWh	number of households	Million Tons
Benin	10.161.000	4.740.107	7.674	3.837.229	5
Burkina Faso	18.365.000	8.567.273	13.871	6.935.411	9
Cabo Verde	539.000	251.444	407	203.550	0
Côte d'Ivoire	22.849.000	10.659.059	17.258	8.628.762	12
The Gambia	1.926.000	898.479	1.455	727.340	1
Ghana	25.758.000	12.016.107	19.455	9.727.325	13
Guinea	11.474.000	5.352.621	8.666	4.333.074	6
Guinea Bissau	1.693.000	789.785	1.279	639.349	1
Liberia	4.092.000	1.908.918	3.091	1.545.315	2
Mali	16.456.000	7.676.724	12.429	6.214.491	8
Niger	17.466.000	8.147.889	13.192	6.595.910	9
Nigeria	177.156.000	82.643.274	133.803	66.901.698	91
Senegal	13.636.000	6.361.194	10.299	5.149.538	7
Sierra Leone	5.744.000	2.679.576	4.338	2.169.181	3
Togo	7.351.000	3.429.242	5.552	2.776.053	4
ECAWAS	334.666.000	156.121.689	252.768	126.384.224	171

The following figures show the potential for solar heating in cooling in different economic regions world-wide. As can be seen in these figures there is a significant potential for Africa in solar water and space heating as well as for solar process heat for low temp industrial heat

IEA Roadmap vision for solar water and space heating

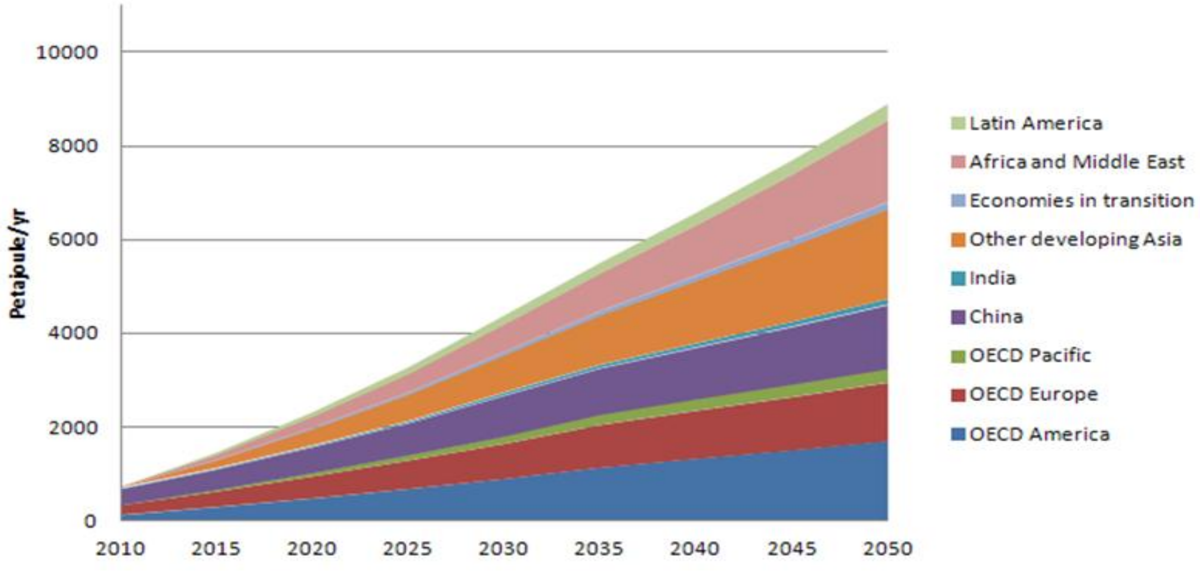

Figure 8: IEA Roadmap vision for solar water and space heating by economic region (PJ/yr)
Source: IEA SHC Technology Roadmap Solar heating and Cooling, 2012

In this vision, solar hot water and space heating in buildings will increase by 7.1% annually between 2010 and 2050, while the total energy used for water and space heating increases only 1.3% (or 0.8 EJ). By 2050, solar hot water accounts for 25% of water heating energy use, while solar space heating will have a 7% share.

Roadmap vision of solar process heat for low temp industrial heat (EJ/yr)

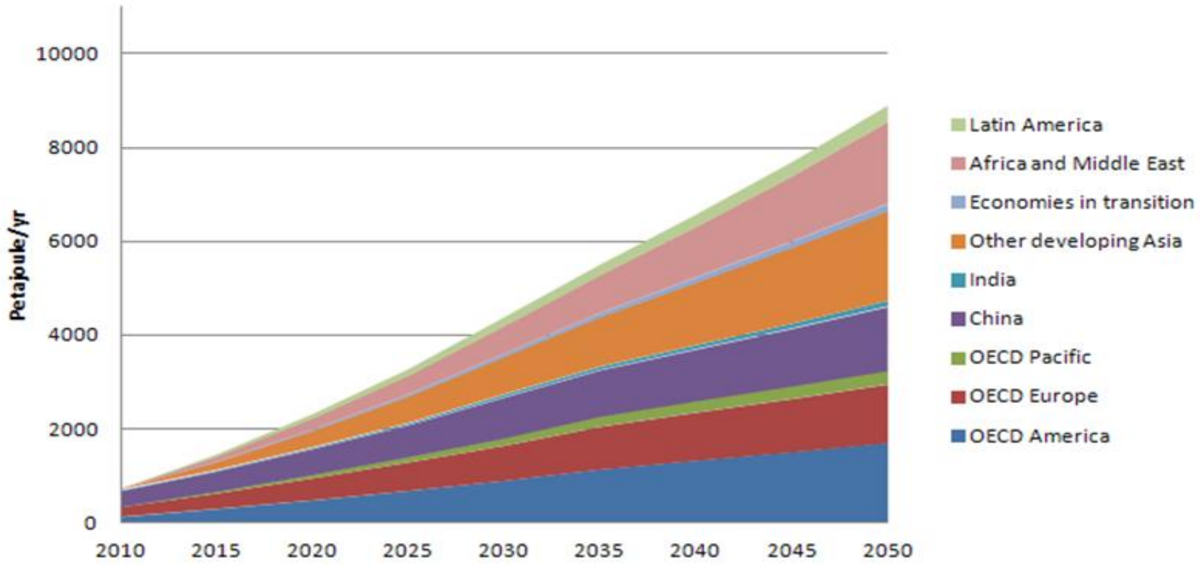

Figure 9: IEA Roadmap vision of solar process heat for low temp industrial heat (EJ/yr)
Source: IEA SHC Technology Roadmap Solar heating and Cooling, 2012

Solar heat has a significant role to play in the industrial sector. By 2050, the *ETP 2012* 2DS scenario estimates the potential for solar heat in industrial applications to contribute up to 7 200 PJ per year (7.2 EJ/yr), on the basis of an installed capacity of over 3200 GW_{th}, in industrial low-temperature applications up to 120^0C

Barriers to Implementation

Smart implementation of Solar Thermal Programs can play an important role in providing the energy needs of a country and can do so at a comparatively low cost. It furthermore presents an opportunity to create and protect employment and contribute to the environmental aspirations of the country.

Barriers to implementation

- **required upfront capital investment**
- **long payback periods**
- **low levels of awareness and**
- **low confidence in projected energy and cost savings that will be achieved**

The most critical mitigation of barriers is a policy, regulatory and funding framework that promotes and supports solar thermal implementation and creates an appropriate and stable enabling environment.

A range of funding models, effective pricing structures and levels, channels to market and technology options assist to make incentives accessible to more consumers.

Effective communication is another critical aspect of successful implementation.

Conclusions

There is a significant market potential for solar thermal systems in Sub-Saharan countries. The solar thermal systems could significantly reduce the stress on the electricity supply and could at the same time create a significant amount of jobs in local production.

References

Mauthner, F., Weiss, W.: Solar Heat Worldwide – Markets and Contribution to the Energy Supply 2013, IEA, Paris 2015

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