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The Sun Rises in the East (of Africa): A Comparison of the Development and Status of the Solar Energy Markets in Kenya and Tanzania

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Abstract

This paper describes and analyses the historical development and current status of the solar energy markets in Kenya and Tanzania. It examines the development of both the Kenyan and the Tanzanian solar energy markets since their beginnings in the 1970s, their current size and structure and it presents forecasts for their future development. In addition, it highlights and explains similarities and differences between the solar energy markets of the two East African countries. The paper is based on an extensive literature survey that takes account of academic as well as 'grey' literature. The literature review has been complemented by 25 personal in-depth interviews with leading experts on the East African solar energy market. In the paper it is shown that the solar market of Kenya is one of the world's leading markets for off-grid solar uses, with an installed capacity of around 10 MWp and over 300,000 solar home systems. The Tanzanian solar market is found to have developed much later than the Kenyan market and to remain smaller than its neighbour, with an installed capacity of around 4 MWp and 40,000 solar home systems. In addition to solar home systems, other segments for uses of solar energy in social institutions, telecoms and tourism are also covered. The paper draws some initial policy conclusions regarding the regulation and promotion of solar energy in East Africa. Awareness, availability and affordability are found to be major drivers that all need to be present to enable the widespread uptake of off-grid solar technologies in emerging markets.

Keywords: Solar energy; Photovoltaic energy; Market development; East Africa; Kenya; Tanzania

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List of Abbreviations and Acronyms

AC	alternating current
a-Si	amorphous silicon
BBS	battery-based systems
BOS	balance of system
c-Si	crystalline silicon
CSP	concentrated solar power
DC	direct current
EAC	East African Community
ERC	Energy Regulatory Commission (Kenya)
GDP	gross domestic product
GNP	gross national product
GW	Gigawatt
ICT	information and communication technology
IEA	International Energy Agency
IFC	International Finance Corporation
IPTL	Independent Power Tanzania Ltd.
GEF	Global Environment Facility
GWh	gigawatt hour
KenGen	Kenya Electricity Generating Company Ltd.
KES	Kenyan shilling
MW	megawatt
MWp	megawatt peak
NGO	non-governmental organisation
PSMP	Power System Master Plan (Tanzania)
PV	photovoltaic
REA	Rural Energy Agency (Tanzania)
REF	Rural Electrification Fund (Tanzania)
RES	renewable energy source/sources
RET	renewables energy technologies
SHS	solar home system
SIDA	Swedish International Development Cooperation Agency
SUDERETA	Sustainable Development through Renewable Energy in Tanzania
SSMP	Sustainable Solar Market Packages
SWH	solar water heater
TANESCO	Tanzania Electric Supply Company Ltd.
TAREA	Tanzania Renewable Energy Association
TASEA	Tanzania Solar Energy Association
TaTEDO	Tanzania Traditional Energy Development and Environment Organisation
TAZARA	Tanzania Zambia Railway Authority
TEDAP	Tanzania Energy Development and Access Project

kgoe	kilograms of oil equivalent
KPLC	Kenya Power & Lighting Company Ltd.
ktoe	kilotons of oil equivalent
kWh	kilowatt hour
kWp	kilowatt peak
LCPDP	Least Cost Power Development Plan (Kenya)
LED	light emitting diode
LPG	liquefied petroleum gas
MEM	Ministry of Energy and Minerals (Tanzania)
MoE	Ministry of Energy (Kenya)
TRA	Tanzania Revenue Authority
TTCL	Tanzania Telecommunications Company Ltd.
TZS	Tanzanian shilling
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
UTC	Coordinated Universal Time
WHO	World Health Organisation
Wp	watt peak

Exchange rates

KES 100.0 = US$ 1.2399

TZS 1,000.0 = US$ 0.6678

EUR 1.0 = US$ 1.3628

All exchange rates current as of 30 September 2010 (Source: www.xe.com).

1. Introduction

The world's energy markets are currently facing tremendous structural change as countries around the world attempt to reduce the carbon intensity of their economies. The increased exploitation of renewable energy sources (RES) such as wind, biomass and solar energy is among the technological solutions that are currently being pursued on all continents. As a result, solar energy markets have been booming during the past decade, with particularly strong industry growth in the US, Europe and China. At the same time, more than two billion people in developing countries are still lacking access to modern energy services, such as clean cooking fuels and electricity. Many of these people live in sub-Saharan Africa, where the electrification rate was only 25.9% in 2005 (IEA, 2006) and where traditional biomass for cooking and heating still contributes a very high share to the primary energy supply of most nations.

More than any other continent, Africa therefore faces the double challenge of improving the living conditions of its populations by sharply increasing energy access, while at the same time developing its energy sector in a way that is sustainable. This long term sustainability in itself has at least two dimensions. Firstly, the development paths of individual nations should ensure that their development does not have negative economic, social or ecological impacts on the livelihoods of present and future generations. Secondly, African nations will almost certainly have to contribute to efforts that aim to maintain the long-term health of the planet, even though under current international agreements they are largely exempt from binding measures to curb carbon emissions. These concurrent developments therefore present sub-Saharan Africa with two challenges that will need to be tackled at the same time: increasing energy access while at the same time ensuring that the energy supply is economically, socially and ecologically sustainable.

Renewable energy sources are frequently presented as a possible solution to all of Africa's energy problems and in some cases it almost seems as if renewable energies in general, and solar energy in particular, could serve as a panacea for many of Africa's ills. Such claims are probably too optimistic, but a valid question remains: what contribution can renewable energies make in solving Africa's energy challenge? This working paper is an attempt at a partial answer to this very comprehensive question by looking at the role renewable energies play in two of Africa's most dynamic solar energy markets, namely Kenya and Tanzania. This paper focuses on solar energy because this renewable energy source is most commonly cited as *the* answer to Africa's energy challenge and because it has been a particular favourite of donors and the development community for almost four decades.

The East African nations of Kenya and Tanzania are two examples of countries that face the challenges just described. Both countries have quickly growing populations and population and economic growth has led to rising prosperity and increased energy demand. Currently, the electrification rates in Kenya and Tanzania are among the lowest in the world, with 14% and 11% respectively in 2005 (IEA, 2006). At the same time, both Kenya and Tanzania continue to rely heavily on traditional biomass for most of their primary energy needs, while undergoing structural changes in their power sectors that used to be dominated by clean and abundant hydro power as the primary source of electricity. The two countries therefore serve as good examples for economies that face the energy challenge and where solar energy resources have been exploited since the 1970s.

A lot has been written about the solar energy markets of East Africa in the past 20-30 years. Abundant information on various aspects of the solar energy markets in the region is available, with most of the analyses focussing on Kenya. Yet despite of this, a comprehensive, clear and concise picture of how the solar energy markets of Kenya and Tanzania have developed over the past forty years and what their status and structure is today is still lacking. Furthermore, to my knowledge no research has yet been undertaken that explicitly compares the development paths of both markets, which have arguably developed very differently over the past 30 years and which are only now beginning to converge. The comparison of the solar markets of Kenya and Tanzania, an analysis of the major similarities and differences in their development as well as an up-to-date overview of the current status of both markets are therefore the main contributions of this paper.

This working paper combines data and information from a broad range of sources with the aim of producing an overview of the historical development and current status of the solar energy markets in Kenya and Tanzania. The paper is based on an extensive literature survey that takes account of academic as well as 'grey' literature. The literature review has been complemented by 25 personal in-depth interviews with leading experts on the East African solar energy market that were conducted in September 2010. The paper provides a thorough overview that focuses on two of the biggest economies in the region, which are also two of its biggest markets for solar energy applications (GTZ, 2009f; World Bank, 2010b). Due to their current structure, it focuses on the market for off-grid solar photovoltaic (PV) systems, but also makes reference to other solar energy applications.

As mentioned before, East Africa's electricity generation is currently based on large-scale hydro power and fossil fuels, while other energy sources play only a minor role (IEA, 2010a; IEA, 2010b). At the same time, the resource potential for various RES (such as geothermal in Kenya and solar energy in both countries) is deemed fairly substantial. However, despite the advantages that the increased use of such "new" renewable resources (as opposed to well-established hydro power) could potentially bring to the countries in the region, the uptake of renewable energy still lags far behind its technical and potentially economic potential.

For instance, the solar energy endowment of East Africa compares very favourably to Europe, which is currently the world's biggest market for the use of solar energy. Solar irradiation levels in Europe range from approximately 900 to 2,000 kWh/m^2 (JRC, 2006). In contrast, estimates for Kenya range from around 1,460 to 2,190 kWh/m^2 (MoE, 2010a).[1] Likewise, Tanzania's solar energy potential is also reported to be much higher than that of Europe with an estimated range from 1,825 to 2,430 kWh/m^2 (Alfayo and Uiso, 2002). Notwithstanding the remaining uncertainty regarding the exact solar resource potentials in both East African countries, it seems clear that the solar energy endowments of these countries are much bigger than those of the world's current leading solar market, Germany (which on average has a solar irradiation level that is only about half that of the sunnier locations in Kenya and Tanzania).

The remainder of this paper is structured in the following way: Chapter 2 presents the development of the solar PV market in Kenya since the 1970s and its current status and size. Chapter 3 applies the same analysis to the Tanzanian solar energy market. Chapter 4 describes and analyses major similarities and differences between the markets in Kenya and Tanzania. Chapter 5 concludes with a brief summary and some initial policy recommendations that emerge from the analysis.

[1] However, ESDA gives a wider range of estimates from 700 to 2,650 kWh/m^2 with the majority of the country assumed to lie in a range from 1,750 to 1,900 kWh/m^2 according (ESDA, 2006b).

2. Kenya's solar energy market

The Kenyan solar energy market is often described as the leading market in Eastern Africa, if not in all of Africa. It is characterised by persistently strong growth since the 1980s and is a prime example of a market driven largely by the private sector. The "Kenyan experience" therefore often serves as a model for market-driven solar electrification and is well-researched in its impacts on and interaction with the development of Kenya's economy as a whole. Yet after more than three decades of market growth, reliable data on the solar energy market of Kenya is generally still patchy, as pointed out by Karekezi (2002), among others. This chapter therefore draws upon and summarises a wide range of sources to come up with as precise a picture as possible of the development and current status of the Kenyan solar energy market.

The remainder of this chapter is structured as follows: Section 2.1 explains the origins of Kenya's market for solar energy technologies, section 2.2 presents the various solar energy technologies used in Kenya and section 2.3 presents and analyses its SHS market. Section 2.4 analyses the role of solar energy in Kenya's energy mix and the following section 2.5 presents the structure of Kenya's solar industry. This chapter concludes with an outlook for the Kenyan solar market in section 2.6 and a brief summary and some conclusions in section 2.7.

2.1. Origins of the Kenyan solar market

Throughout the world, solar markets started initially as a result of the oil shock of 1973/74, which encouraged governments, scientists and companies to look for alternative energy sources. At the average mid-1970s prices for PV systems of US$ 30-40 per Wp, however, a single 40 Wp solar panel would cost upwards of US$ 1,200, thus rendering it uneconomical for most uses in Kenya (Acker and Kammen, 1996). During the 1970s, the only application of solar systems in Kenya was therefore in government-funded telecoms projects, where these systems provided electricity for signalling and broadcasting (Jacobsen, 2004).

As PV prices declined in the early 1980s, donors and development agencies increasingly started to look towards PV for use in their projects. Early applications of PV technologies were the provision of electric power for water pumps in rural communities, school lighting in remote locations and vaccine refrigeration in off-grid missions and clinics, among others. This "donor market" consisted mostly of the large-scale procurement of PV systems. Funded by donors, it was for some years the only segment that Kenya's PV market was composed of (Acker and Kammen, 1996).

The initial demand for PV systems from donors lead to the development of a PV supply chain as local traders and importers started to stock PV systems (Hankins, 2000). But not only did donors provide much-needed demand to kick-start a Kenyan PV market, donor agencies also supported workshops, training schemes and demonstration projects (Acker and Kammen, 1996). Incidentally, amongst the earliest private adopters of solar energy technologies were headmasters, pastors and other community members who had observed the merits of those initial demonstration systems (Hankins, 2000).

In the 1980s a private market segment thus slowly started to emerge alongside the donor market segment. According to Acker and Kammen (1996), possibly the earliest actor targeting the private sector in Kenya was an American ex-Peace Corps volunteer named Harold Burris, who founded a company called Solar Shamba in 1984. This company focussed on the energy needs of rural Kenyans as opposed to the larger infrastructure projects developed by international aid agencies and the Kenyan government. In addition to the establishment of a new business model through Solar Shamba, Burris and his associate Mark Hankins provided some of the earliest training programmes for PV technicians. In its four years of operation (Solar

Shamba ceased operation in 1988), the company installed at least 150 off-grid PV systems for use by rural households in Kenya (Acker and Kammen, 1996).

These early efforts of developing a private solar market coincided with a global PV production boom, the latter resulting in a significant drop in prices and the appearance of smaller, more affordable solar systems (Jacobsen, 2004). In response to the declining price and increasing local expertise in system installation and management, local demand for SHS continued to grow (Acker and Kammen, 1996) and is today the biggest market segment in Kenya (see section 2.2.).

The PV-driven off-grid household electrification began roughly in line with, and was largely induced by, the spread of television signals and TV sets in the 1980s and 1990s (Jacobsen, 2007). Especially small-scale coffee and tea farmers were able to afford 12-volt TVs, radios and lighting systems during the agricultural "boom years" of the early and mid-1990s (Acker and Kammen, 1996). The combination of a desire for television and the increasing purchasing power of the rural middle class became the key drivers of the Kenyan SHS market (Jacobsen, 2007), as the use of TV sets and radios stimulated demand for electricity amongst rural households.

Since these households were, and to a large extend still are, not connected to the electricity grid, they initially turned to so-called battery-based systems (BBS), which are essentially a large battery that provides the electricity needed to run a TV set, radio or lights. The spread of these BBSs and 12-volt lights was facilitated by the fact that they were widely available due to local production of batteries (Hankins, 2010). In many cases, these BBSs were later complemented with small PV installations as a means to generate the electricity needed for charging the batteries. SHS thus primarily eliminated the need to carry a battery to and from charging stations and therefore increased the convenience of users (Hankins, 2000; ESDA, 2003; GTZ, 2009a).

2.2. Solar energy technologies used in Kenya

In general, energy from the sun can be used in two ways that are both present in Kenya. The first, solar PV, converts the sun's energy into an electrical current that then powers various electrical appliances. The second, solar thermal, directly puts the sun's heat to various uses (Karekezi and Kithyoma, 2003). A third technology that turns solar heat into electricity (often referred to as concentrated solar power or CSP) is becoming more common in various countries around the world, but is not yet being used in Kenya. The following overview will therefore focus on the solar PV and solar thermal applications currently found in Kenya.

It needs to be stressed that, whilst the following overview mentions the largest segments of Kenya's solar market, there are other segments that are usually not reported in the literature. For example, the market for solar lanterns and other very small solar systems is growing in importance in Kenya and beyond, not least due to the World Bank's "Lighting Africa" initiative, yet information on this market segment is even scarcer than on other aspects of Kenya's solar market. Due to the lack of available information, this paper mentions this segment only in passing.

2.2.1. Solar photovoltaic applications

Solar PV applications are the most common form of solar energy use in Kenya. In the early 1990s, the overall installed PV capacity was estimated at around 1.5 MWp. Of these 1.5 MWp, around two-thirds were for social uses and hence government- or donor-funded and the remaining third consisted largely of domestic uses, i.e. SHS (Acker and Kammen, 1996). By 2000, the Kenyan PV market had more than doubled to circa 3.9 MWp and it was estimated that some 75% of the installed capacity was used in households (ESDA, 2003; Moner-Girona et al., 2006).

Mark Hankins, one of the leading experts on the Kenyan solar energy markets, has recently estimated that the overall size of the market is now in the range of approximately 8-10 MWp[2] (GTZ, 2009e). This means that the overall market has increased by more than 100% within the past decade. Growth in the Kenyan PV market has therefore been quite impressive with annual growth rates of around 10-15% since the 1990s. The major driver of this growth was the SHS segment, where the installed capacity reportedly grew by between 10 and 18% annually (Martinot et al., 2000; Jacobsen, 2004; Bailis et al., 2006; GTZ, 2009e).

Annual sales of PV systems for various kinds of uses have reportedly reached around 1-2 MWp. This marks a significant increase when compared to annual sales of a few years ago (that were estimated in the area of 0.4-0.6 MWp). Three reasons seem to lie behind this acceleration in recent market growth: Increased demand from the Kenyan government for institutional systems (see below), increased awareness among consumers, investors and traders and slightly falling system prices that lead to the increased affordability of SHS (e.g. Hankins, 2010).

The Kenyan market can be divided into three broad segments. The first and biggest segment encompasses domestic and small-scale commercial PV applications. Their typical capacity is well below 100 Wp. The second segment comprises systems purchased by institutional buyers such as governments or donors. These systems are predominantly used to provide electricity for off-grid social uses. They can sometimes be bigger than 100 Wp. Traditionally, the third segment consisted of telecoms and signalling systems that tended to be much larger in size, and where a public entity acted as the buyer (ESDA, 2003).

Nowadays, this third segment does not appear to play a major role anymore as it is slowly being overtaken by some new uses of solar that are emerging in Kenya. The new third market segment, which seems to be gaining momentum at the moment, is comprised of larger-scale commercial uses of solar PV in the mobile phone (i.e. telecoms) and the tourism sectors, which are beginning to be develop (GTZ, 2009e). Table 1 shows estimates for the installed capacity of various market segments in 2009.

Market segment	Estimated installed capacity in MWp
SHS and small-scale commercial	> 6-8
Off-grid community systems	> 1.5
Off-grid schools	> 0.5
Off-grid telecom	ca. 0.1-0.15
Off-grid tourism	> 0.05
Overall market size	**> 8-10**

Table 1: Overview of Kenyan solar PV market (based on GTZ, 2009e)

Domestic uses of solar energy, in the form SHS, are one of the most frequent forms of PV applications in rural areas of developing countries such as Kenya. An SHS typically consists of a small roof- or pole-mounted solar module, a charge controller and some rechargeable batteries (Martinot et al., 2000). While according to Moner-Girona et al. (2006), SHS account for approximately one third of the off-grid capacity

[2] While this figure might still understate the true size of the market, Hankins (2010) pointed out that this was only a very rough estimate and that no reliable statistics on the overall installed capacity are available at present. Some observers have remarked that there exists a strong incentive for both importers and dealers to underreport their turnover vis-à-vis authorities and researchers (e.g. Mumbi, 2010). While the Ministry of Energy (MoE) officially puts the current installed capacity at 4 MWp, ministry officials confirmed that the actual market size is probably much bigger (MoE, 2010d).

installed in Africa, in Kenya they account for around three-quarters of the market, as shown in table 1. Due to the importance of this market segment, it is analysed in detail in section 2.3.

When speaking about SHS it is important to bear in mind that a significant percentage of small solar PV systems are probably used for small-scale commercial purposes, such as mobile-phone charging and the lighting and powering of businesses (e.g. barber shops, bars and kiosks) (GTZ, 2009a).[3] Furthermore, some studies have highlighted the fact that in many cases SHS are used for both productive and consumptive uses, i.e. both to provide the necessary electricity for small-scale commercial uses and television, radio etc. in homes. As a consequence, the statistics for the uses of such solar systems may be inexact, as various uses are difficult to disentangle (ESDA, 2003).

2.2.2. Institutional and commercial solar PV applications

In contrast to many other African countries, the institutional and donor segment of the Kenyan market currently accounts for only around 20-25% of the market. However, despite its loss of relative market share this segment continues to play an important role in the Kenyan solar market (Jacobsen, 2004, based on ESDA, 2003, and other sources). In fact, some experts point out that the increase in demand for institutional systems has actually been the main driver behind increasing sales in recent years (e.g. KIPPRA, 2010), hence probably leading to a rising share of institutional systems in the overall market.

Actors in this segment include the Kenyan government, aid agencies, church orders and NGOs that use PV to provide electricity for rural churches, schools, health centres, water pumping and offices, among others (GTZ, 2009a). Typical applications for which PV is used in these institutions are the refrigeration of vaccines and medicine, lighting for classrooms and phone and internet communications (Moner-Girona et al., 2006). For example, there were at least 40 rural boarding schools that used solar PV for various purposes in 2003. Likewise, PV lighting systems were in use at some game parks of the Kenya Wildlife Service (ESDA, 2003).

According to recent information from the Ministry of Energy (MoE), an additional 261 off-grid institutions (i.e. schools, health centres and dispensaries) in rural areas were equipped with alternating current (AC) solar lighting systems between fiscal years 2005/06 and 2009/10. In these institutions an additional 653 kWp were installed at a total cost of KES 764m (US$ 9.47m). The average system size was 2.5 kWp and the average cost per Wp for the entire programme period was KES 1,168 (US$ 14.5). According to the MoE, funding for an additional 380 institutions had already been agreed with the government of Spain (at a volume of EUR 10m or US$ 13.6m) and further expansion to district offices and police stations was under consideration in 2010 (MoE, 2010d).

Solar PV is also used in agriculture, where it powers water pumps and provides electricity for lighting and food preservation (Otiti and Soboyejo, 2006). However, in general, agricultural uses do not appear to play a major role in the Kenya solar energy market. While solar energy systems do not deliver sufficient power for agricultural uses, such as shaft power, large water pumps for irrigation and cold storage (Bailis et al., 2006), some experts argue that a vast potential exists nonetheless in the area of solar water pumps in rural communities (ESDA, 2003). In fact, sales of solar water pumps are reported to rise for both small agricultural uses and community systems (Chloride Exide, 2010a) and annual sales could already be around 100 kWp (Hankins, 2010).

As mentioned above, relatively new uses of solar PV are larger off-grid systems in the telecom and tourism sectors. There, PV powers base stations for mobile phone networks and up-market game lodges,

[3] Cf. ESDA (2006a) for a presentation of productive uses of PV in Kenya. This report identified several thousand solar PV systems used for productive purposes in the country.

among others. Both markets are reportedly gaining momentum as operators of mobile phone networks and tourism establishments realise the potential cost-savings that solar systems could bring in the long run (Winafrique, 2010) and annual sales in the telecom sector alone might already be around 100 kWp (Hankins, 2010).

Additionally, PV is slowly appearing as part of hybrid power sources in isolated mini-grids (GTZ, 2009e). For example, Kenya Power & Lighting Company (KPLC) in 2010 announced its intention to procure a total of 100 kWp of off-grid solar systems for use in mini-grids in northern Kenya through an open tender (Chloride Exide, 2010a). Reportedly this procurement will pave the way for more such systems in the coming years, as KPLC struggles with the high cost of delivering electricity to remote consumers (GTZ, 2010).

Grid-connected PV systems, on the other hand, are not yet a feature of the Kenyan market. However, some predict that this will change in the near to medium future, as enabling regulation is put in place (GTZ, 2009a). However, it remains to be seen which impact the recently adopted feed-in tariff for electricity from solar energy (cf. MoE, 2010b, for details) will have on the on-grid segment or whether the first grid-connected projects will work on a net-metering basis. To this end, a 515 kWp-PV project at the Nairobi headquarters of the United Nations Environment Programme (UNEP), which was connected to the grid in February 2011, and the a smaller on-grid solar system installed at the SOS Children's Village in Mombasa, which was also connected in early 2011, have become the first examples for on-grid solar uses in Kenya (Enkhardt, 2011; BMWi, 2011; Hankins, 2011).

2.2.3. Solar thermal applications

Solar thermal technologies found across Africa include solar water heaters (SWH), solar cookers, solar stills and solar dryers (Karekezi, 2002). Many of these solar thermal applications can be found in agriculture, which remains the mainstay of most rural households in Kenya. Solar dryers used for the drying of crops, vegetables and fruits are frequently mentioned in the literature, as are SWH for dairy processing (Karekezi, 2002; Otiti and Soboyejo, 2006). However, neither of these applications appears to play an important role in the Kenyan solar market. Likewise, only limited applications for solar thermal exist in the heating of greenhouses in Kenya's flower industry (Chloride Exide, 2010a).

Similar to the success of the SHS market, a separate but related market seems to be appearing in the form of SWH. Given low electrification rates and high electricity prices even where the grid exists, these systems typically have a payback period of two to five years (Karekezi et al., 2005; GTZ, 2009g) and are thus catching the interest of consumers and businesses alike. Hence, the bulk of SWH so far in use in Kenya are owned by wealthy households in urban areas and tourism companies, such as game lodges and hotels (Karekezi et al., 2005; Chloride Exide, 2010a).

A 2003 estimate puts the number of installed SWH at 20,000 (Karekezi and Kithyoma, 2003). While it was reported as recently as 2005 that the take-up of SWH was slower than expected (Karekezi et al., 2005), the pace of diffusion seems to have increased since then. Reportedly, the number of installed systems more than tripled to some 70,000 systems within a few years (Karekezi et al., 2005) and had doubled again to 140,000 systems by 2009 (Ikiara, 2009).[4]

While it seems unlikely that there are already 140,000 SWH, as reported by Ikiara (2009), the estimate of 7,000 solar thermal systems in use for drying and water heating put forward by official sources (cf. MoE,

[4] Karekezi et al. (2005) state a figure of 140,000 m^2 based on an estimate of the Ministry of Energy of the previous year. Assuming an average system size of two square meters (as stated by GTZ, 2009a) this gives 70,000 SWH systems.

2010a) appears too modest. Several sources close to the market estimate the number of SWH currently installed at a level much higher than that. For example, it was estimated by GTZ (2009a) that in 2008 alone some 4,000 to 5,000 SWH systems with an average size of two square meters and an average system cost of approximately EUR 1,800 (US$ 2,453) had been newly installed in Kenya. It therefore appears probable that the overall size of the market for SWH currently stands at around 55,000 to 70,000 systems of two square meters each (i.e. 110,000 to 140,000 m²).[5]

This figure is expected to increase substantially in the next few years, as electricity prices rise further and awareness increases. Moreover, the Kenyan government, through the Energy Regulatory Commission (ERC), is currently in the process of implementing a new regulation that will make the installation and use of SWH mandatory for all new and existing urban buildings (ERC, 2010a).[6] If enforced effectively, this regulation is likely to spur dramatic growth, which in the future is expected to occur in equal parts through the increased diffusion among urban households (about half the market), institutions and tourism companies (together about half the market; cf. GTZ, 2009a).

2.3. Kenya's solar home systems market

As explained in section 2.2., the SHS market has been the main driver of growth in the Kenyan solar energy market since its beginnings in the 1980s. Figure 1 shows the annual sales in this segment rising from around 100 kWp in the late 1980s and early 1990s to around 500 kWp or more since 1998. It needs to be stressed, however, that the numbers underlying this graph constitute only rough estimates, as detailed annual data on the Kenyan SHS market is unavailable. In an attempt to present a clear and reliable picture of the development of the SHS market in Kenya, this paper therefore draws upon a wide range of sources and combines the data contained in these sources to arrive at as reliable a picture as possible.[7]

2.3.1. Capacity of installed SHS

The graph in figure 1 shows estimates of both the annual sales of SHS (shown on the left-hand axis) and the cumulative installed capacity of SHS (shown on the right-hand axis) from 1987 to 2009. As the estimate used for the market size in the year 2009 varies from 6-8 MWp (based on GTZ, 2009e), the calculated annual capacity addition between 2002 and 2008 ranges from 181 to 467 kWp. It needs to be pointed out that other sources put the overall installed capacity in 2008 and 2009 at a much more modest 4-5 MWp (Kassenga, 2008; Ngigi, 2008; Ikiara, 2009). The exact market size therefore will remain elusive until reliable data from the Kenyan government or an industry association become available, but both the presented estimate for overall capacity and the estimates for annual sales have been verified and confirmed with a large number of sources and can therefore be deemed the best available estimates.

[5] It is worth noting that estimates for the current cumulative number of SWH derived from the interviews range from a lower figure of around 40,000-70,000 or more. Likewise, annual sales were estimated at 2,000-7,000 systems (e.g. Chloride Exide, 2010a, and Go Solar, 2010).

[6] This regulation only applies to buildings with hot water consumption above 100 litres per day. It will be phased in over a five year period from the entry into force of the regulation. Further details are available on the ERC's website.

[7] Figure 1 uses values from Acker and Kammen (1996) for years until 1990 (own estimates based on graph in source as exact numbers were unavailable), Jacobsen and Kammen (2007) for years 1991 to 2001 (own estimates derived as before) and GTZ (2009e) for 2009. Years 2002 to 2008 have been calculated by interpolation. Numbers underlying this graph were validated with the following sources: Karekezi, 1994; Kammen, 1996; Hankins, 2000; Karekezi, 2002; ESDA, 2003; IEA PVPS, 2003a; Karekezi and Kithyoma, 2003; Karekezi et al., 2005; Moner-Girona et al., 2006; Kassenga, 2008; Ngigi, 2008; Ikiara, 2009; GTZ, 2009e; Chloride Exide, 2010a.

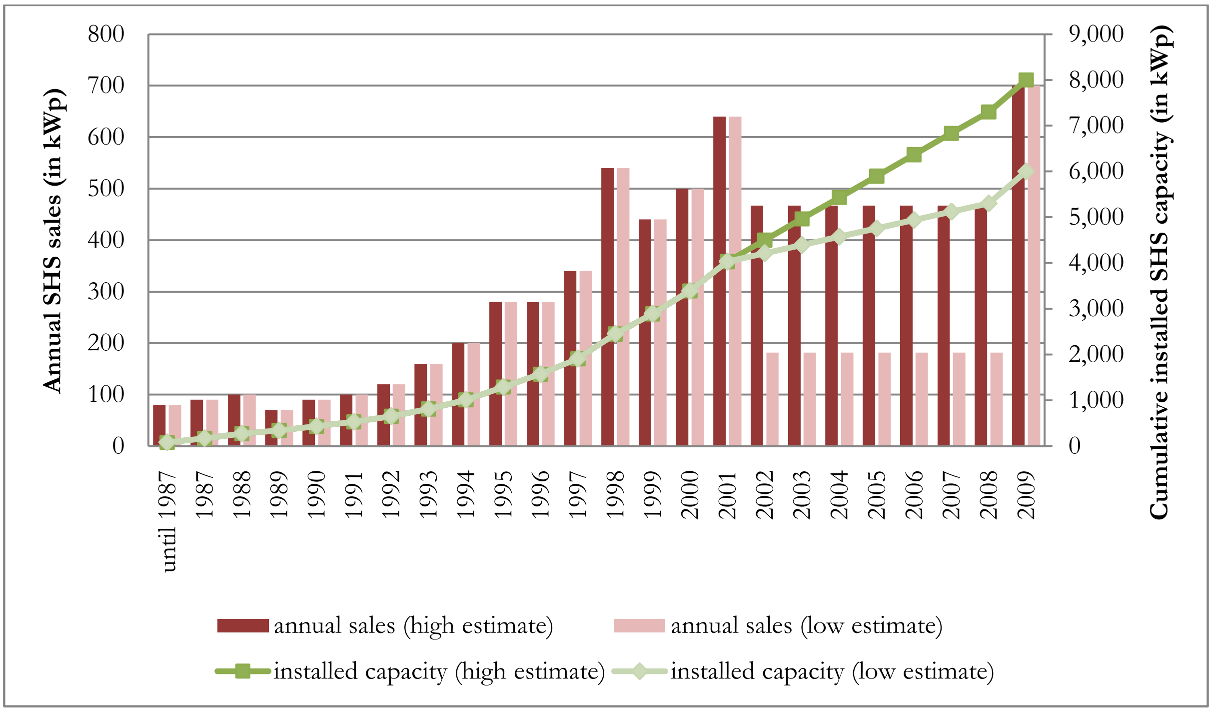


Figure 1: Estimated annual sales of SHS in Kenya and cumulative installed SHS capacity since the late 1980s (in kWp) (*Data sources*: Acker and Kammen, 1996; Jacobsen and Kammen, 2007; GTZ, 2009e)

However, while experts and market participants still remain divided on the question of actual annual installations and the cumulative installed SHS capacity, a calculation of the annual growth rates since the late 1990s suggests that the 2009 market size and annual SHS sales are more likely to be nearer (or even above) the "high" estimate shown in figure 1 than much below it. This assumption is further supported by the fact that an overall capacity of around 4 MWp was already reported for 2001 by Jacobsen and Kammen (2007). Unless the market has slowed dramatically since then, which based on the literature and expert interviews does not appear to have been the case, the overall market size and current annual sales put forward by GTZ (2009e) appear to be realistic.[8]

2.3.2. Number of installed SHS

When attempting to identify the likely development of the number of SHS sold since the late 1980s, similar obstacles in data availability and reliability are encountered. Here the available data is even patchier and somewhat more contradictory. Figure 2 therefore again draws upon a wide range of sources in order to estimate the most likely development of SHS sales in the past two decades. The graph shows estimates and ranges of estimates for individual years from a total of 15 sources.[9]

Based on a review of these sources, it appears very probable that around 320,000 SHS have been sold in Kenya in the past three decades. This figure is towards the upper end of estimates, and exceeds the official

[8] In fact, GTZ's estimate may even be too conservative, as sales for SHS above 100 Wp were already estimated at 5,000 p.a. by one market participant, implying an annual capacity addition in this market segment alone of around 500 kWp (Winafrique, 2010).

[9] The "best estimate" shown denotes the most likely size of the market in a given year based on a critical review of the available sources and after cross-checking reported annual sales figures with reported figures for the cumulative installed capacity.

figure of 220,000 systems from the MoE (MoE, 2010a), but appears to be in line with the estimated annual sales and the reported cumulative SHS capacity shown in figure 1.[10]

Assuming a total number of SHS of above 5,000 in 1990 (Hankins, 2000), 80,000 in 1999 (Martinot et al., 2000) and 300,000 in 2009 (upper value stated by Ikiara, 2009) it is estimated that average SHS sales were in the area of 1,000 p.a. in the late 1980s, around 8,000 p.a. in the 1990s and around 22,000 p.a. in the decade to 2009. The estimates for the past decade are furthermore in line with a number of sources that state annual sales of 20,000-25,000 SHS since 2003 (Karekezi et al., 2005; Bailis et al., 2006; Ngigi, 2008).

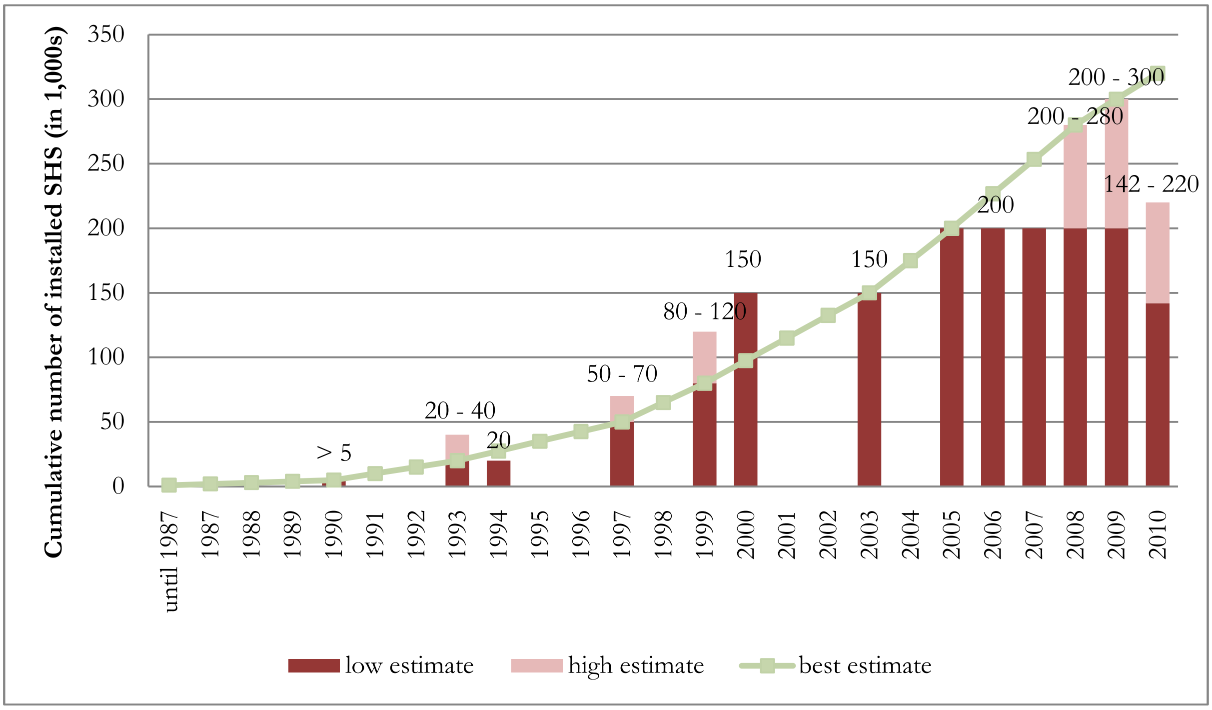


Figure 2: Development of estimated number of SHS in Kenya since the late 1980s in thousands (*Data sources*: Karekezi, 1994; Acker and Kammen, 1996; van der Plas and Hankins, 1998; Hankins, 2000; Martinot et al., 2000; Karekezi, 2002; Karekezi and Kithyoma, 2003; Karekezi et al., 2005; Bailis et al., 2006; Moner-Girona et al., 2006; Ngigi, 2008; REN21, 2008; Ikiara, 2009; KEREA, 2010; MoE, 2010a)

While Kammen (2010) estimated that annual sales increased from about 15,000 in 1996 to about 35,000 today, several market participants and other experts have pointed out that during the past two to three years the market has actually slowed down to sales of about 15,000-20,000 per year. Reportedly, this was largely the result of decreasing rural incomes due to frequent droughts and the post election violence of late 2008 (e.g. KIPPRA, 2010). Furthermore, market growth appears to have slowed recently as a result of the increased diffusion of colour TV, additional rural electrification efforts of the Kenyan government and, potentially, increasing saturation of the SHS market. While colour TV sets require more electricity and thus bigger SHS, it appears to depress SHS demand as households cannot afford such bigger systems. At the same time, very small systems used for mobile phone charging are gaining in importance (e.g. Mumbi, 2010). In result, the assumption of annual SHS sales of 20,000-25,000 still seems to hold and is confirmed by KEREA (2010), which puts annual sales at 18,000-25,000 SHS.

[10] CAT (2010) pointed out that this figure might still underestimate the true size of the market by a factor of two as very small solar systems, such as solar lanterns and solar mobile-phone chargers, alone probably number 300,000. However, these systems are not strictly SHS in the traditional sense.

2.3.3. Share of households owning SHS

Based on the figures presented in the preceding section, the commercial SHS market had reached around 1.5% of rural households in 1999. This estimate is supported by Martinot et al. (2000) who put the market penetration rate at about 1%.[11] In 2003 alone, more rural households were reportedly installing SHS than were being connected to the grid by the national electrical utility (IEA PVPS, 2003a). The percentage rate of households owning SHS rose to 4.4% in 2009 based on the estimated number of SHS and rural households. While some earlier studies suggested that the penetration rate of SHS already exceeded the number of households connected to the national electricity grid (e.g. Jacobsen, 2007, who suggested a share of 4.2% in 2000), the estimates presented above indicate a more modest contribution of SHS to rural electrification in Kenya. This, however, appears to be more the result of increased efforts of the Kenyan authorities to electrify rural Kenya (cf. section 2.6.) than slow growth in the SHS market, as can be seen in figure 3 below.

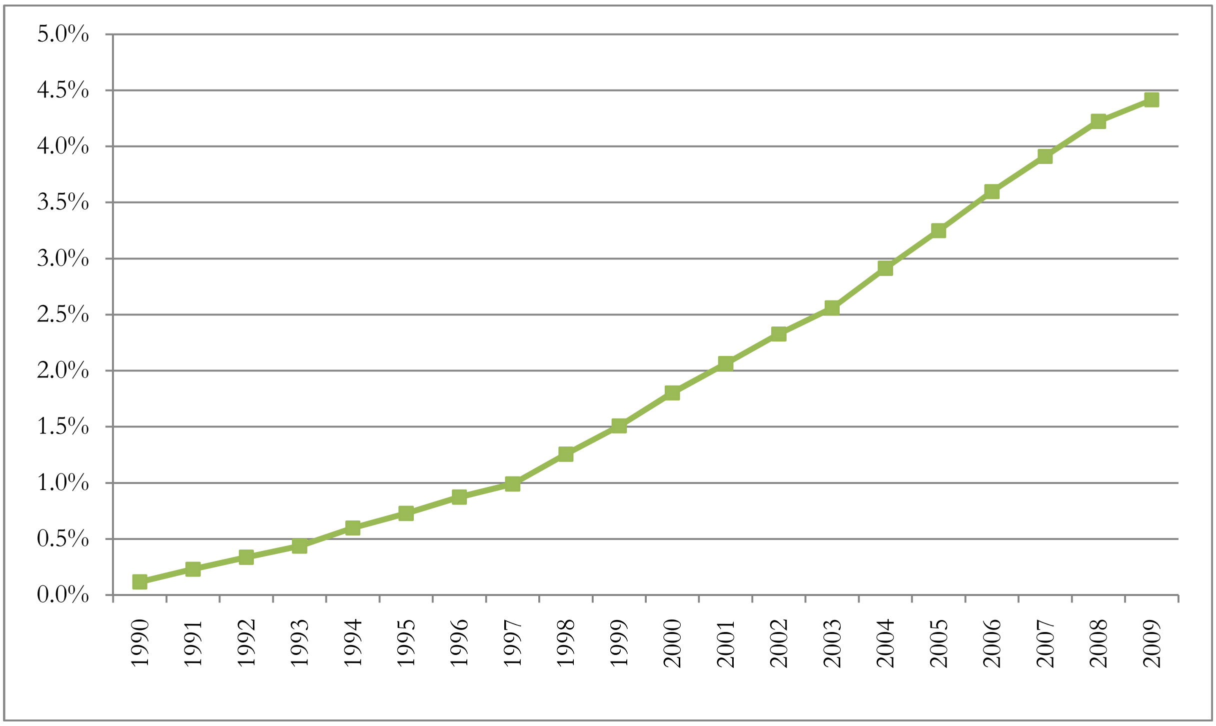


Figure 3: Percentage of rural households in Kenya using SHS (based on own calculations)

2.3.4. Global role of Kenyan SHS market

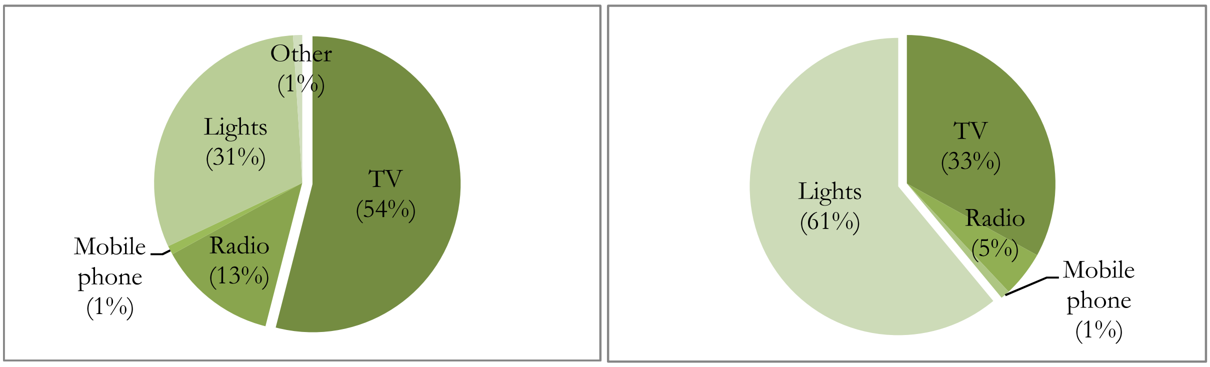
Despite big gaps in the data, a picture of dynamic growth in the Kenyan solar PV market emerges. From its humble beginnings in the 1980s this market has developed into one of the leading PV markets in Africa, supplying some 320,000 households in rural Kenya with SHS alone. This makes the Kenyan PV market, and especially its SHS segment, one of the biggest solar markets in the developing world. Albeit small in terms of the installed capacity when compared to the leading international markets, the Kenyan market is certainly one of the most developed markets when it comes to the overall number of off-grid systems.

[11] The total number of rural households in 1999 was estimated at 5.3 million, in 2008 at 6.6 million and in 2009 at 6.8 million assuming a growth rate in the rural population of 2.3% p.a. and an average household size of 4.6 (own calculations based on Ngigi, 2008; UN, 2010; World Bank, 2010a). Taking preliminary data from the census of 2009 gives a slightly lower number of rural households and would result in an even higher market share (KNBS, 2010).

It was estimated in 2007 that more than 2.5 million households worldwide were receiving electricity from SHS (REN21, 2008). Based on the estimated number of SHS in 2007 (253,000, as shown in figure 2), the Kenyan SHS market therefore made up some 10% of the global SHS market, putting it second only to China, which with some 400,000 SHS in 2007 was the undisputed market leader (REN21, 2008). Furthermore, Kenya has for some time been (and likely continues to be) the leading African market for SHS, with a market share of around 40% (REN21, 2008).

2.3.5. Role of TVs for SHS demand

Several reasons seem to lie behind the success of the Kenyan SHS market. As already outlined in section 2.1., the main motivation for rural households in Kenya to install SHS in the first place appears to be the spread of broadcast signals and subsequent purchases of television sets by rural Kenyans since the 1980s (Jacobsen, 2007). In fact, while several studies found that electricity from SHS is used by households to power televisions and radios and for lighting for several hours per day (Kammen, 1996; Murphy, 2001; ESDA, 2003), it appears that the provision of electricity for television is the key driver for households' desire to acquire a SHS. In a survey conducted in 2003-04 among Kenyan SHS owners, Jacobsen (2007) found that with systems smaller than 25 Wp (the median size of such systems being 20-25 Wp), 54% of the generated electricity was allocated to TV consumption and another 13% to radio consumption. Thus only one third of the electricity was used for lighting purposes. Jacobsen (2007) further found that as systems increase in size, this proportion reverses (see figures 4a and 4b).



Figures 4a and 4b: Energy allocations in solar system smaller than 25 Wp (left-hand picture) and larger than 25 Wp (right-hand picture) (*Source:* Jacobsen, 2007)

In terms of lighting, as one might expect, most energy is allocated to the powering of lights in the living room, which receives around 25% of the energy in both smaller and bigger systems. Only once the energy needs of TV, radio and living room lighting are satisfied do other rooms receive electrical lighting sources, chief among them the kitchen which is allocated some 15% of energy in cases of SHS bigger than 25 Wp (Jacobsen, 2004; Jacobsen, 2007). In some cases, electricity from SHS is also used for refrigeration in households and other appliances (Kammen, 1996). Furthermore, a more recent use for solar PV can be found in the charging of mobile phones (ESDA, 2003; Moner-Girona et al., 2006).

Companies active in the SHS market point out that during the past few years, two developments were changing the shape of the SHS market. Firstly, as consumers in rural areas were increasingly opting for colour TV sets, required sizes of SHS were growing due to the higher electricity demand of such TVs. This change in consumer tastes reportedly has two consequences for the SHS market: Consumers with *existing* SHS are sometimes frustrated by the inadequacy of their existing system, which does not generate enough electricity to power their new colour TV. Consumers contemplating to acquire a *new* SHS on the other hand often find this beyond affordability if a colour TV and other modern amenities are considered in the sizing of their prospective SHS, therefore reducing the appeal and potential market size of SHS.

Secondly, while TV sets apparently lose some of their importance as drivers of the SHS market, the rapid spread of mobile phones during the past years has provided additional demand for solar systems in rural areas. With 63.2% of all households owning at least one mobile phone (KNBS, 2010), and many of them certainly more than one, mobile phone users in rural areas appear to be increasingly looking towards solar as a means to recharge their phones (e.g. Chloride Exide, 2010a).

2.3.6. Role of rural electrification

The spread of television sets and broadcast signals alone cannot explain the rise of the SHS market. Instead, the SHS market would not have developed as it has if other conditions had not been in place too. Of special importance among these are the almost complete lack of rural electrification and the relative wealth of parts of Kenya's rural households. In fact, most homes not connected to the grid or otherwise electrified use few electrical appliances beyond radios powered by batteries. Instead they continue to rely almost exclusively on biomass energy mainly in the form of fuelwood and charcoal for cooking purposes (Murphy, 2001), as further explained in section 2.4.

Until recently rural electricity access in Kenya remained limited to areas close to cities and along major roads (Murphy, 2001). Only a few years ago only around 4% of rural households were connected to the grid (Jacobsen, 2007; Ngigi, 2008). While this was already a vast improvement on the even lower electrification levels of 2% or so reported just a few years earlier (Karekezi and Kithyoma, 2002; ESDA, 2003; Moner-Girona et al., 2006), widespread electrification of rural Kenya for a long time seemed to remain a distant dream. In fact, based on the actual electrification rates in the early 2000s of around 5,000-10,000 new rural connections per year, connecting the remaining 5.5 million households in rural Kenya was expected to take at least another 400 years (Hankins, 2000; ESDA, 2003; IEA PVPS, 2003a; Moner-Girona et al., 2006).

Therefore, rural households wishing to use TVs, radios and lights had to look for alternatives to provide the electricity needed for these devices. As diesel-based generators were usually too expensive for most households and had their own drawbacks consumers typically acquired battery-based storage systems alongside their TV, radio or lighting (as discussed in section 2.1.). In addition to the potential cost-savings that consumers can derive from supplementing their BBS with solar systems, or indeed replacing other non-electric lighting systems (such as kerosene lamps), convenience seems to be a major driver in opting for SHS as the source of electricity: On the one hand, SHS eliminate the need to take batteries to recharging stations that can be far away and on the other hand the quality of electrical lighting is much better than that of kerosene, the typical source of lighting (Kammen, 1996; Hankins, 2000).[12]

2.3.7. Income levels of SHS owners

Where rural households own SHS, they typically come from the wealthiest part of the population (Murphy, 2001). In fact, a household survey conducted in 2000 found that almost all SHS were owned by the top third of households, with almost 50% of all systems owned by the first wealth decile alone (Jacobsen, 2005). Due to the high cost of systems, for the most part solar PV remains unaffordable to the majority of the population in sub-Saharan Africa and solar PV projects and systems have therefore mainly benefited

[12] However, Hankins (2011) argues that many of these solar-charged BBS might use the attached SHS only to a limited extent, suggesting that most of the estimated one million BBS continue to be recharged from the grid. If this claim is backed up by further research into the concrete charge patterns of BBS, it might turn out that the role of solar energy in recharging batteries might currently be overstated.

the middle class and high-income segments of the population (Karekezi, 2002; Karekezi and Kithyoma, 2003), such as rural teachers, professionals, business owners and some cash crop farmers (Moner-Girona et al., 2006). It is this purchasing power of rural middle class households that has proved critical for the success of the Kenyan PV market according to Jacobsen (2007).

This point is illustrated further by an earlier survey of some 40 system owners in three districts of Kenya. In the survey, Acker and Kammen (1996) found the median income of PV owners to be somewhat above that of the average Kenyan household (at US$ 1,380 and 1,030 respectively). Likewise, a typical 40-50 Wp system was priced at around US$ 620 in 1999, and hence much above the average GNP per capita of US$ 350, as pointed out by Karekezi and Kithyoma (2003). And even when comparing the cost of a SHS with the average household income of US$ 2,100 (i.e. GNP per capita times 6), experts such as Karekezi and Kithyoma (2002) pointed out for a long time that the large majority of Kenyans would remain unable to afford such a PV system.

Some scholars therefore argued that despite efforts of donors and NGOs to help the poor with solar energy, there was growing evidence that solar PV in general and SHS in particular do not benefit the poor but rather their richer compatriots (Karekezi, 2002). However, it appears that this pessimistic view may need to be revised a bit as system costs decline and the down-sizing of systems as well as the increased availability of consumer finance have allowed the SHS market to reach at least some of the poorer households as well (Hankins, 2000; Jacobsen, 2005). In recent years, especially the emergence of very small (or "pico") solar systems has probably led to solar technologies reaching ever more consumers. However, strictly speaking, these are not SHS as such (see section 3.3.6. for details).

2.3.8. Development of SHS prices and sizes

In line with developments on the global market for PV modules, prices in the solar markets of sub-Saharan Africa have seen a steady decline in the past three decades. In Kenya, prices for solar modules have decreased from around US$ 9 to below US$ 4 per Wp between 1987 and 2001 (Moner-Girona et al., 2006). However, as PV systems do not only consist of solar modules but typically also comprise batteries, charge controllers, installation and installation materials as well as lights, the overall system cost is much higher than that. Hence, in 2006 a typical 50 Wp system was estimated to cost around US$ 550, or approximately US$ 9.5-11.0 per Wp (Moner-Girona et al., 2006). This represented a significant price decrease from the mid-1970s, when a Wp cost around US$ 30, and also the late 1980s and early 1990s, when the average price was around US$ 20 per Wp (Acker and Kammen, 1996).

In the past two to three years, module prices have reportedly come down further, which is largely a result of developments on the world solar market and increased supply of cheaper Chinese modules. Market participants reported module prices of around US$ 3.3-4.1 per Wp in September 2010 compared to around US$ 4.7-5.0 per Wp one or two years earlier. These lower module prices have translated into some reductions in prices for SHS, albeit apparently only at the lower end of prices: A typical 20 Wp system cost around US$ 6-12 per Wp in 2010 compared to around US$ 7.8-9.5 per Wp in 2008.[13] The wide variation in reported system costs has largely to do with the definition of a "typical" SHS and its components and the biggest price variation probably stems from the inclusion or exclusion of a solar battery in the system price (e.g. CAT, 2010).

The growth in the Kenyan PV market was further helped by the down-sizing of modules to meet the needs of less wealthy costumers. While SHS in the early years of market development had an average size

[13] Cf. Ngigi (2010), which contains more detailed information on prices that results from a market survey among seven major PV companies conducted in September 2010.

of around 40 Wp (Acker and Kammen, 1996), the market subsequently expanded dramatically as 12-14 Wp amorphous silicon (a-Si) modules became widely available (van der Plas and Hankins, 1998; Jacobsen, 2004) and the average system size decreased to between approximately 20-25 Wp (van der Plas and Hankins, 1998; Hankins, 2000; ESDA, 2003; Karekezi et al., 2005; Jacobsen, 2004; Bailis et al., 2006; Jacobsen, 2007; Ngigi, 2008; Ikiara, 2009). As systems became smaller they also became more affordable for a wider range of households (Jacobsen, 2005).

The trend of declining system sizes has apparently not continued in recent years. While 14 Wp a-Si-modules were the most popular at the beginning of the last decade, cheaper and more efficient crystalline silicone (c-Si)-modules from China and elsewhere are now dominating the market. These have a typical capacity of 20 to 30 Wp, but SHS of 65-120 Wp are now also frequently sold (e.g. Davis & Shirtliff, 2010a).

In addition to a decline in the average size of SHS, some studies have also found that these systems are typically sold as individual components (e.g. modules, batteries and lamps), that are then assembled by the user or an installation technician, rather than as a complete system (IEA PVPS, 2003a; GTZ, 2009a). This step-wise approach of purchasing and building systems over time, with individual purchases worth only US$ 50-100, allows households to distribute SHS costs over a longer period of time (Jacobsen, 2007). In the 1990s, at least, it was furthermore found that the overall system cost for SHS was artificially lowered by leaving out the charge controller. This essential component, which protects the battery from over-charging or deep discharge, was found in only 10% of all systems surveyed by van der Plas and Hankins (1998), resulting in overall lower system quality and customer satisfaction (Murphy, 2001). Even today, this trend still seems to persist (e.g. Hankins, 2010), but the Kenyan government and industry are reportedly starting to address quality concerns (see section 2.5.).

2.3.9. Financial innovation in SHS market

In addition to changes in prices and system sizes, business and financial innovation brought the use of solar energy into the reach of even more cash-constrained consumers (Hankins, 2000). In general, the sale of SHS can be organised in two ways. Either an SHS is sold to the user ("sales model") or the user buys the electricity generated from the SHS, but not the SHS itself ("service model"). The sales models can be further divided into "cash sales", where the buyer needs to use his own funds, or "credit sales", where the buyer receives a credit from the vendor or a financing institution in order to pay for the SHS (Martinot et al., 2000).

In Kenya, the most common form of purchase appears to be the over-the-counter cash sale, while credit sale and service models do not appear to play a major role as no end-user finance is available from either vendors or financial institutions (IEA PVPS, 2003a). Also, consumer credit from financial institutions (sometimes assisted by multilateral lenders) for the purchase of SHS has not yet been taken up widely. A Kenyan variation of credit sales that according to some studies accounted for 10-15% of sales in the 1990s was the so-called "hire purchase" model. Under a hire purchase loan, the "collateral" given is the salary of the buyer, and regular payments are deducted directly from the wage (Hankins, 2000; ESDA, 2003; IEA PVPS, 2003a).

However, despite the potential role that financial innovation could play in making solar energy more widely available, financing costs tend to be prohibitive (adding up to 80% to overall costs) and financing is therefore usually not taken up even where it is available (e.g. Mumbi, 2010).

2.4. Role of solar energy in the Kenyan energy mix

2.4.1. Role of solar in primary energy consumption

In 2007, Kenya used around 18,305 ktoe of energy or 490 kgoe per capita. As shown in figure 5, Kenya's energy sector is dominated by the use of combustible renewables and waste, such as fuel-wood and charcoal. According to 2007 figures of the International Energy Agency (IEA), 74% of the total primary energy supply came from this source. Another 19.6% were derived from imported fossil fuels such as petroleum products and crude oil that were ultimately used as fuels for transport, industry and in households. Hydro power contributed another 1.6% and geothermal and other renewables the remaining 4.8% (IEA, 2010a).

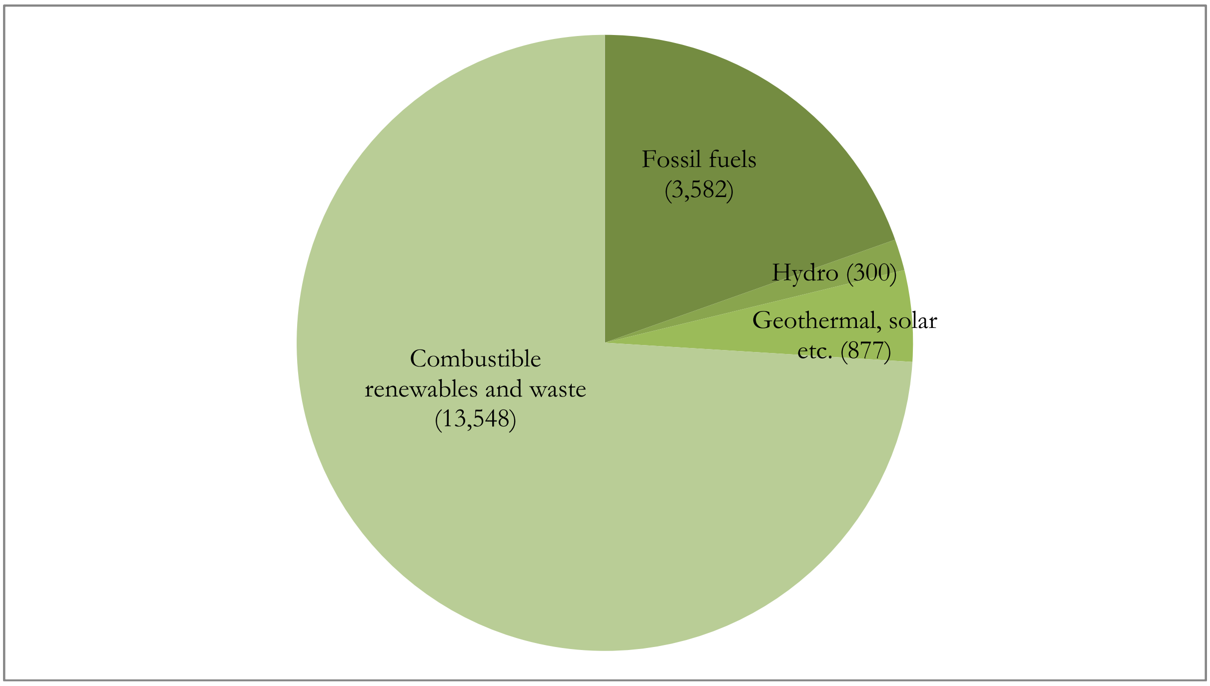


Figure 5: Kenyan total primary energy supply (ktoe) by source in 2007 (*Source:* IEA, 2010a)

While average energy consumption per capita remained fairly constant in the past three decades, with only minor fluctuations between 450 and 490 kgoe per capita per year (World Bank, 2010a), the consumption of commercial energy has actually decreased over the years from 120 kgoe in 1980 to 109 kgoe in 1995 and to around 84 kgoe on average per capita in 2009 (Murphy, 2001; Ikiara, 2009).

The Kenyan primary energy mix is largely a result of the reliance of the majority of rural households on biomass energy for their cooking, lighting and heating needs (Murphy, 2001). Households are estimated to use on average 90-100% of their overall energy consumption for cooking alone, which is dominated by the combustion of biomass (Moner-Girona et al., 2006). As solar energy is only of limited use for cooking and heating, despite widespread attempts to promote solar cookers in various African countries (Karekezi, 2002), as well as agriculture (where capacity requirements often exceed 1 kWp), it appears that solar will not play a major role in the provision of primary energy anytime soon. Some have therefore argued that solar energy is unlikely to contribute much to economic development in the region (Otiti and Soboyejo, 2006).

Furthermore, some studies have suggested that the alleged environmental and health impacts of solar energy use are overstated, as solar PV replaces the burning of biomass only in a very limited way (Murphy, 2001). But other studies pointed at the substitution of kerosene with solar PV for lighting, which constitutes a "dramatic improvement in terms of light quality, air quality and safety" (Moner-Girona et al., 2006, p. 40). Furthermore, solar PV reduces the need for candles, kerosene, liquefied petroleum gas (LPG) or battery charging, leading to direct savings, and it can provide additional benefits such as reduced carbon emissions and facilitating income-generating activities at night (Martinot et al., 2000).

2.4.2. Role of solar in electricity generation

As was explained earlier, solar energy to date only plays a role in the generation of electricity, through SHS and other solar PV systems. In the electricity sector of Kenya, the total installed generation capacity is approximately 1,310 MW. More than half (54.7%) of this capacity is installed in large- and small-scale hydro power plants, which contributed 51.4% of generated electricity in 2007 (see figure 6). Another 33.5% of installed capacity is in thermal (mostly oil-fired) power stations, producing 28.8% of electricity in 2007. The remaining capacity of 11.8% uses mostly geothermal energy and some biomass, with these sources providing 15.1 and 4.7% respectively of generated electricity in 2007 (KPLC, 2009; IEA, 2010a).

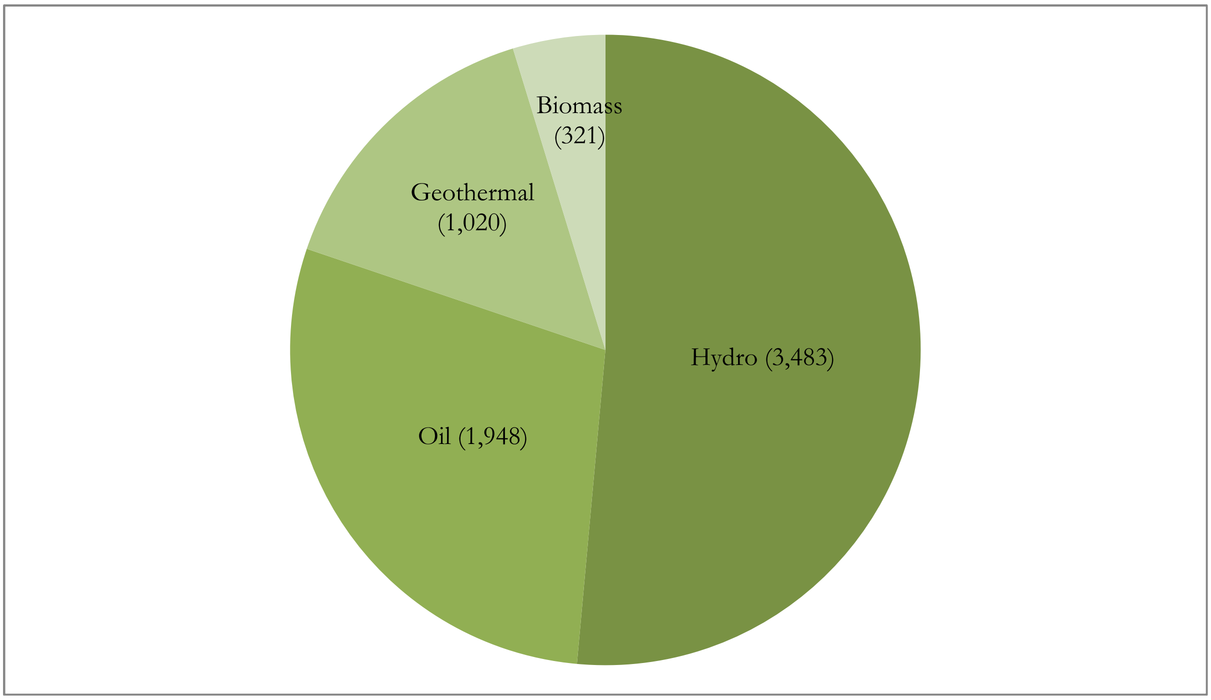


Figure 6: Kenyan electricity generation (GWh) in 2007 (*Source:* IEA, 2010a)

Thus, it appears at first sight that even in the electricity sector solar energy does not yet play a measurable role. However, it needs to be noted that the figures presented above only refer to the electricity grid and therefore only those electricity producers and consumers connected to it. While so far there is no on-grid PV capacity (as explained in section 2.2.), the electricity produced in hundreds of thousands of SHS already accounts for approximately 0.32% of the overall amount of electricity produced in Kenya (KIPPRA, 2010).

2.4.3. Future development in energy and electricity demand

Population and economic growth are expected to lead to strong growth in energy and especially electricity demand. By 2014, electricity demand is forecast to reach 8,561 GWh (Ngigi, 2008), an increase of more than 26% compared to 2007. In the long run, demand is assumed to grow by a rate of 6-10% per year (KenGen, 2010). The average annual electricity consumption in 2006 was 145 kWh per capita, an increase of 32% since the year 2000 (World Bank, 2010a), and increased rural electrification may lead to a further rise in the demand for electricity. The Kenyan government has developed plans to connect 40% of all rural households to the grid by 2020, as stated in the Sessional Paper No. 4 on Energy of 2004. Furthermore, in accordance with "Vision 2030" (a Kenyan policy document outlining Kenya's way to becoming a middle-income county by 2030), the Kenyan state aims to provide electricity to all Kenyans by 2030 (GTZ, 2009b).

Without doubt, rising prosperity, population growth and advances in electrification rates will lead to growth in electricity demand in the coming years. In this respect it remains to be seen whether hydro power as the current backbone of the Kenyan electricity sector can keep up with demand increases. Already in the past years, growing energy demand and low water levels in hydro power plants due to droughts have led to frequent power cuts. In order to counter these, public electricity company KPLC was forced to procure emergency power that was produced by diesel-power generators. This arrangement has had a significant impact on electricity prices and consumers have seen their fuel surcharge increase in line with oil prices (with an especially pronounced spike in 2008) (GTZ, 2009b). While in the meantime the emergency power agreements have been cancelled, this episode still highlighted the need for a more diversified generation base in Kenya.

2.5. Structure of the Kenyan solar industry

Kenya's solar market is generally perceived as well-developed in comparison to other African markets. Its biggest segments are the sale of PV system components for SHS and SWH, which are both sold as over-the-counter goods (GTZ, 2009a). Due to the limited role of donors and the government (when compared to other countries) in the development of its solar market, Kenya is frequently cited as a prime example of a solar market that has emerged largely without much direct donor or government assistance (Martinot et al., 2000).

As explained in section 2.1. donors and other institutional buyers played an important role in the early years of market development. To some extent they have continued their activities in the country's solar market. For example, between 1996 and 1998, bilateral and multilateral donors funded two projects aimed at the promotion of renewable energy technologies (RET) as sources of electricity in Kenya (Murphy, 2001). Furthermore, donors were and probably still are found to be providing funds for various applications, such as water and power systems, game fences, telecommunications, refrigeration and lighting for schools and hospitals (Kammen, 1996).

The development of the Kenyan solar industry therefore seems to have followed the course outlined in ESDA (2003): Different PV delivery models can be found in emerging African PV markets. While these models to some extend depend on the development stage of a market, more than one model can be observed at any given time in many cases. In general, however, in the early stages of market development, international ordering in non-commercial markets is observed most frequently. In this model, a donor or government orders PV equipment from an international supplier, for non-commercial use, such as the lighting of schools or the electrification of health centres. Once a market develops further, these buyers will be able to source their PV systems from in-country suppliers as an in-country industry to supply, install and service solar systems emerges (ESDA, 2003).

This is the case in Kenya, where there were estimated to be 15-40 major suppliers of solar equipment in Kenya in 2009, as well as three manufacturers of lead acid batteries and nine lamp manufacturers (IEA PVPS, 2003a; GTZ, 2009a; Ikiara, 2009). Five of these are "major players", trading PV modules, batteries, charge controllers, lighting kits, solar-powered mobile phone chargers, water pumps and fridges as well as solar cookers (Ikiara, 2009). In addition, 5-8 established importers and a number of "opportunistic" importers bring systems and components into the country (GTZ, 2009a). Several hundred sales agents and high-end niche players serving NGOs, multilateral donors and tourism and telecoms companies are also active in Kenya (ESDA, 2003; GTZ, 2009a). The number of installation technicians is estimated at around 2,000 (KEREA, 2010).

Until today, none of the PV modules installed in Kenya are being manufactured in the country (IEA PVPS, 2003a). However, around 20 companies active in the production of components (balance of system or BOS) and the production of batteries already constitute a sizable industry (Moner-Girona et al., 2006). The output of lead-acid battery makers alone was estimated to be over 50,000 units in 2009 (Ikiara, 2009). While some balance of system production was already located in the country in the early 2000s, Moner-Girona et al. (2006) pointed out that even more local manufacture would greatly strengthen the economies of sub-Saharan Africa. Based on earlier work from IEA PVPS (2003b), they put the opportunities for local manufacture highest for the production of charge controllers, frames and supports.

Despite the generally high level of sophistication in the Kenyan solar market, system quality is still regularly reported to be poor due to low quality components, inadequate system design and untrained installation technicians among other reasons.[14] Companies active in the sale and installation of SHS often do not invest in training of their technicians for fear of "creating" new competitors and/or lack of necessary commercial and management skills and funding (IEA PVPS, 2003a). Furthermore, lack of PV power in the rainy season and generally bad performance associated with batteries and light bulbs sometimes led to reports on complaints from customers in the 1990s (Kammen, 1996).

With the development of consumer demand for PV, distribution networks serving a much wider customer base appear, as is the case in Kenya with markets for SHS and SWH (ESDA, 2003). In the area of SWH, it is estimated that some four to six companies import SWH from Greece, Australia, Turkey, Israel and China. These systems reach clients in two ways: Either wholesalers import SWH and leave the distribution to households to agents such as plumbers and contractors, or wholesalers sell SWH directly to larger clients such as housing estates, hotels and lodges (GTZ, 2009a).

2.6. Outlook for the Kenyan solar energy market

The potential for further growth in the Kenyan solar energy market looks very substantial, as SHS slowly become more affordable for wider parts of the population due to falling prices and increasing incomes. At the same time, awareness of solar energy's uses in all kinds of applications and industries (not just SHS) is growing, with SWH, telecoms and tourism emerging as new market segments. As economic growth and the subsequent rise in energy demand are likely to lead to a widening of the generation base in Kenya more generally, companies and politicians are slowly beginning to look towards solar energy also as a possible source of on-grid electricity (Hankins, 2010). At the same time, it looks likely that the main focus of the solar market will continue to be on off-grid uses for the foreseeable future, as other energy sources are still preferred to solar by politicians, regulators and the main energy utilities.

2.6.1. Future demand for SHS

In 2000, the potential total demand for SHS in rural Kenya alone was estimated to be approximately 14 MWp (Hankins, 2000). Three years later another report produced a somewhat higher estimate of 25 MWp (ESDA, 2003). As the long-term market potential for off-grid PV systems in Kenya more generally was

[14] Cf. KEREA (2009) for a detailed report on the results of a field inspection and testing exercise. This report finds that only 48.68% of systems surveyed were performing "as well as expected", while 40.79% were not performing as well as expected and the remainder were either a "disaster from day one" or completely failed later on. However, a regulation currently under preparation by the ERC will address many of these concerns (ERC, 2011).

estimated to be approximately 26 MWp, SHS are expected to remain the most important solar application for the time being, with much smaller installation numbers in the areas of off-grid schools and health centres (Moner-Girona et al., 2006).

More recently, Ikiara (2009) estimated the long-term market potential for SHS at 22 GWh per annum, or around 9.8 MWp, by 2020. This estimate appears too conservative given that the current SHS market has probably reached 6-8 MWp or more already, as was shown in section 2.3. Yet while it is very likely that the Kenyan market will continue to grow in the next years, it remains to be seen if the much more optimistic forecasts of other studies will be reached. For example, GTZ (2009a) estimates that in the long term SHS alone could reach a size of 30 MWp or more, with the long-term potential for off-grid PV systems in general estimated at over 40 MWp.

2.6.2. Rural electrification programme

A key determinant for further growth in the SHS market will be the success of the Kenyan rural electrification programme. As explained earlier, the slow speed of rural electrification and thus grim prospects of being electrified anytime soon induced many rural households to purchase SHS in order to power their TVs, radios and lights. However, recent reports suggest that electrification has actually picked up speed in the past few years, with KPLC connecting some 120,000 households in 2006/07, some 140,000 households in 2007/08 and over 200,000 in 2008/09 (Ngigi, 2008; Bonyo, 2009; GTZ, 2009b). As KPLC plans to connect an additional one million customers to the grid between 2008 and 2012, this pace seems likely to continue if the government can provide the necessary funds for the rural electrification programme (Ngigi, 2008).

While many of these new connections have been made in urban areas, the pace of rural electrification has also increased and the number of new rural connections was around 30,000-40,000 p.a. in recent years (GTZ, 2009a). In line with Sessional Paper No. 4 on Energy (2004), the Rural Electrification Programme of the government of Kenya aims to connect some 853,000 rural households between 2009 and 2019. If achieved, these connection rates would mark a significant improvement on the electrification rates seen in the early 2000s. Already it is reported that the rural electrification rate has risen from around 4% in 2004 to between 8 and 10% in 2009 (Bonyo, 2009). At this speed some sources suggest that the electrification of Kenya could be achieved much quicker than anticipated in earlier studies (e.g. Adenikinju, 2008).

As some delays to the rural electrification programme have already occurred (Bonyo, 2009), it remains to be seen whether the government can meet its ambitious targets. However, it seems very likely that in many cases the announcement of increased electrification alone will already have a negative impact on the market for SHS. Today, most SHS installed in Kenya are within two to five kilometres of the grid (GTZ, 2009a). With increasing grid electrification these households near the grid appear unlikely to continue being the main buyers of SHS and a gradual shift towards households farther from the grid seems likely. However, it is worth pointing out that the mere availability of the grid does not necessarily lead to an actual connection, as the costs to consumers of grid connection are quite high. The affordability of a grid connection is therefore limited to wealthier households, while other income groups might still opt for solar energy solutions despite being close to the grid (Chloride Exide, 2010a).

2.6.3. Market segments beyond SHS

While the market for SHS is likely to continue much as before, the solar market in general is likely to become more diverse as it grows in overall size. Sizable markets segments are also expected in a number of off-grid PV and solar thermal applications, where solar will meet other consumer needs. As shown in table 2, strong growth (albeit from a very low base) is expected in the coming years in segments such as SWH, telecoms and tourism. Very small solar systems (such as solar lanterns and solar phone chargers) are increasingly going to reach the poorest consumers, providing them with a cheap and reliable source of electricity for their lighting and communications needs. At the same time, bigger systems are likely to emerge not only in the off-grid uses shown in table 2 but also on-grid, as indicated below.

Market segment / solar energy technology	Size of expected market
PV in government procurement for off-grid schools and clinics in Kenya (includes World Bank, European Union and others)	1-2 MWp or more until ca. 2011; ca. 10 MWp in the long run
PV in off-grid telecom installations (off-grid base stations for mobile phone networks in Kenya)	ca. 3-6.5 MWp in the short term
PV in off-grid tourism (game lodges and tented camps throughout Kenya)	ca. 2.5-4.5 MWp
PV in mini-grids and isolated grids (including hybrid systems)	above 3-5 MWp
Small-scale commercial PV systems / uses	500 kWp
Solar water heaters in residential, commercial and tourism uses	10,000 units of 2 m²/annum; long-term potential: 100,000 SWH ("conservative estimate"), thereof in tourism alone: above 15,000 m²

Table 2: Estimated potential for solar PV and solar thermal applications in Kenya
(based on GTZ, 2009a, and GTZ, 2009e)

In the context of small SHS it will be interesting to see what impact the opening of East Africa's first solar module factory[15] will have on the solar markets in the region. Starting in October 2010, Ubbink East Africa Ltd. plans to assemble 20,000-30,000 PV modules per year. The production facility, which is located in the town of Naivasha, will use fractions of polycrystalline cells to assemble modules ranging from 3.6 to 80 Wp. Ubbink East Africa Ltd. is a joint-venture of the German manufacturing company Centrotec Sustainable AG and the local market leader Chloride Exide (Centrotec, 2009).

Due to rising electricity and fuel prices and policy changes, GTZ (2009a) and others expect the SWH market to surpass the SHS market (in terms of units sold) in the near-to-medium term. This seems all the more likely as the Kenyan government, through the ERC, is currently implementing a regulation that will make the use of SWH mandatory for most new and existing buildings in urban areas (ERC, 2010b). While it remains to be seen how strictly this regulation will be implemented, market participants expect that this move will lead to a significant expansion of the solar thermal market in Kenya within the next years.

A market segment that is not yet developed at all in Kenya is the production of grid-electricity by solar energy technologies. So far, on-grid PV is rarely mentioned in the literature, but those who cover this emerging application perceive grid-connected PV as a promising future market segment that could reach 5-10 MWp within five to ten years (e.g. GTZ, 2009e). Given the growing need for new generation sources in the Kenyan grid and the rapid pace with which the global PV and CSP markets develop (with resulting decreases in investment and generation costs) it appears likely that this technology will start to be applied in the not-so-distant future if adequate policies are put in place by the Kenyan government.

2.6.4. Future contribution of solar energy

Despite generally good prospects for on- and off-grid solar PV, the contribution of solar energy to the energy supply of Kenya is likely to remain limited for the foreseeable future. With only a small fraction of

[15] This will reportedly be only the second module factory to open in Africa, with the first one having started operation in South Africa in 2010.

Kenya's geothermal power potential (estimated at around 7 GW) so far being exploited, the government intends to increase the country's geothermal power capacity significantly. According to the country's largest generation company, Kenya Electricity Generating Company (KenGen), an additional 1.26 GW of geothermal capacity is expected to come on-stream by 2018 (KenGen, 2010). Further thermal (mostly oil-fired) power plants are also under development as is an expansion of Kenya's small but growing wind energy capacity. Wind capacity alone could reach around 500 MW by 2020 if several projects currently under development by KenGen and other companies, including the 300 MW Lake Turkana project, progress as expected (e.g. GTZ, 2010). Furthermore, the country plans to expand its existing electricity production from biomass (i.e. bagasse) and biogas (e.g. KenGen, 2010).

These trends are partly reflected in the official Least Cost Power Development Plan (LCPDP) of 2010, which foresees that the majority of additions to electricity generation capacities between 2010 and 2030 will be based on geothermal, nuclear and coal energy (see figure 7). Furthermore, imports from Ethiopia, Uganda and Tanzania are expected to make a major contribution, while all other sources, including hydro power, diesel, gas and wind, are expected to play only a limited role in bringing the country's future power generation base to close to 18 GW (MoE, 2010c).

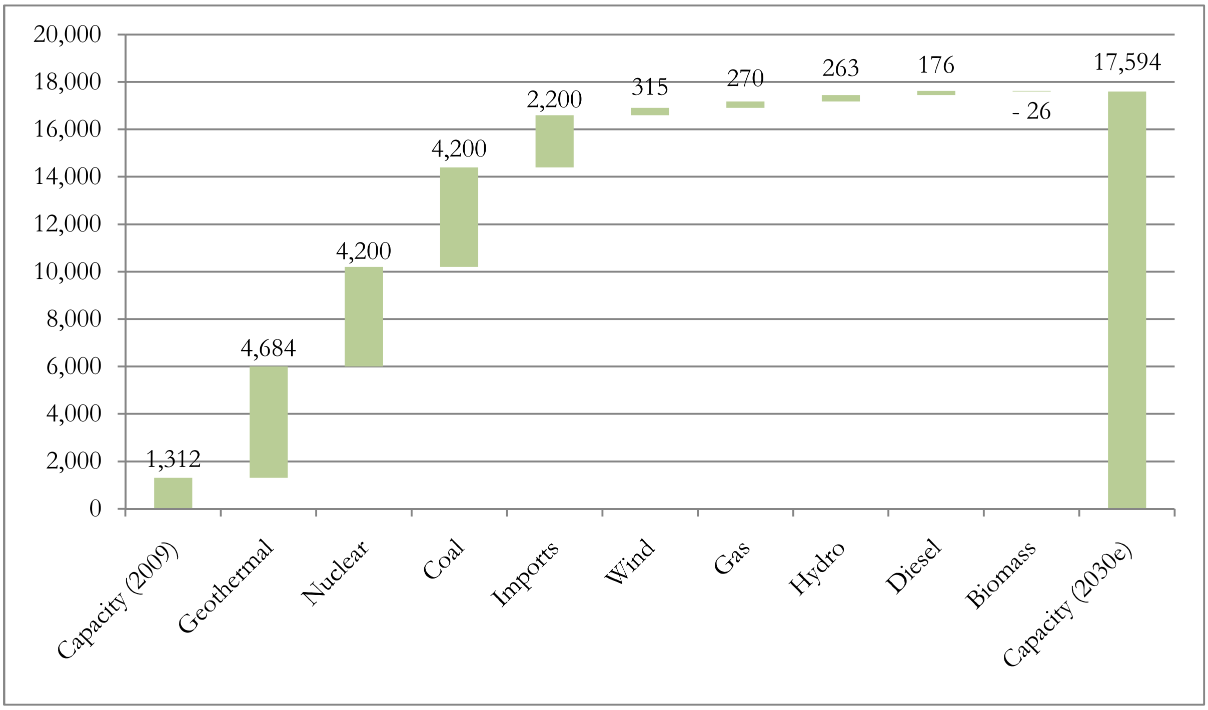


Figure 7: Planned capacity additions in MW between 2010 and 2030 (net of decommissioned plants) according to LCPDP (based on MoE, 2010c)

While the LCPDP appears to limit the scope for the increased use of solar energy in electricity generation by giving preference to other energy sources that are deemed more economical, at least concentrated solar power seems to be a under serious investigation by KenGen for future use. The company reportedly plans to open a CSP pilot plant before the end of 2012 and to complete construction of up to 800 MW by 2018 (KenGen, 2010).

For solar PV, on the other hand, no such plans seem to exist at present from either the government or KenGen. Therefore, it appears likely that, based on present policies and programmes, the use of solar PV will remain largely limited to smaller off-grid and mini-grid uses, and thus to continue past trends, while CSP might play a more pronounced role in Kenya's energy mix after 2018. If, however, rumours about a revision of Kenya's feed-in tariff for solar energy or the introduction of net-metering in the next one or two years are true, then the on-grid solar market could grow to 10-20 MW or more within the next three to ten years (e.g. Winafrique, 2010).

2.7. Summary and conclusions

The origins of the Kenyan solar market date back to the 1970s. During that decade the Kenyan government started to use solar energy as a means to power signalling and broadcasting installations in remote areas. In the early 1980s, the government, international donors and development agencies began including solar energy in their projects for the provision of electricity for various social uses such as school lighting, water pumping and vaccine refrigeration in off-grid environments. The demand for solar systems fostered the emergence of a national PV supply chain. At the same time, donors supported the first trainings, workshops for solar technicians and demonstration projects. While donor and government procurement led to growing demand for solar systems, some early pioneers started solar companies that specifically targeted the energy needs of off-grid consumers in rural Kenya. In the 1980s a private market segment thus slowly started to emerge alongside the donor market segment.

Throughout the 1980s and 1990s the private solar market grew dynamically, as falling system prices and the introduction of smaller, more affordable solar systems combined with rising incomes in rural areas during the agricultural boom years of the early and mid-1990s. It was the spread of radio and TV signals, however, that is widely credited with inducing the rapid expansion of Kenya's solar home systems market. As broadcasting signals reached more parts of the country, consumers were eager to own TVs and radios but lacked grid electricity to power these. Many of these households turned towards batteries for their electricity needs (i.e. BBS), which many subsequently complemented with solar panels and wiring for the recharging of the batteries.

In the early 1990s the overall installed PV capacity was estimated at around 1.5 MWp, with approximately two-thirds installed in institutional systems. By 2000, the Kenyan market had more than doubled to approximately 3.9 MWp and it was estimated that some 75% of the installed capacity was used in households. One decade on, the overall market has reached between 8 and 10 MWp of installed capacity. Annual sales of solar PV systems have recently reached 1-2 MWp and annual growth rates have been around 10-15% since the 1990s, with much of the market dynamic stemming from demand for residential solar home systems.

Today's solar PV market can be divided into three broad segments. The biggest segment comprises the large number of residential SHS and some small-scale commercial PV applications (such as lighting for kiosks and mobile-phone charging). This segment makes up around three-quarters of the total installed capacity, or 6-8 MWp. The second segment consists of systems that provide electricity to off-grid schools, health centres, missions and other social institutions in rural areas. This segment used to dominate the Kenyan market in the early years, but was overtaken in the 1990s by solar home systems. However, increased procurement by the Kenyan government and development agencies have resulted in a limited revival of the role of institutional systems in recent years. Nonetheless, this segment still only makes up around 20-25% of the market, or around 2 MWp of total installed capacity.

While the use of solar energy in telecoms and broadcasting was among the earliest uses of solar energy in Kenya, newer applications such as solar-powered base stations in mobile-phone networks and tourism establishments are slowly emerging as the third market segment, which still remains very small. Likewise, the use of solar energy in isolated mini-grids in rural Kenya so far remains very limited and only tentative steps have been taken with respect to enabling regulation for PV systems feeding into the national electricity grid.

Similar to the success of the SHS market, a separate but related market slowly seems to be appearing in the form of solar water heaters. The bulk of SWH so far installed in Kenya are owned either by wealthy households or hotels in urban areas, who wish to cut their electricity bills, or by tourism operations, such as game lodges, in remote regions of the country where grid-electricity is unavailable. The overall number of SWH is currently estimated at around 55,000-70,000 systems of two square meters each and annual sales are reported to have reached around 4,000 to 5,000 systems in 2008 according to GTZ (2009a).

The biggest market segment for solar PV applications is mostly comprised of SHS. Annual sales of SHS rose from around 100 kWp in the late 1980s and early 1990s to approximately 500 kWp or more since the year 2000, bringing the total installed capacity to the estimated 6-8 MWp mentioned above. This capacity is installed in some 320,000 individual solar home systems that were sold in Kenya in the past three decades, which suggests that around 4.4% of all rural households now own solar home systems. This makes solar the second most important source of electricity in rural areas after grid electricity.

While annual sales of systems are estimated to have grown from 1,000 in the late 1980s to around 20,000-25,000 today, during the past two to three years sales have slowed somewhat. This is reportedly due to stagnating or even falling rural incomes and political instability following the last elections in late 2008, but sales remain high when compared both to historical levels and internationally. On a global scale, the Kenyan SHS market makes up around 10% of the global market, putting it second only to China, which has a market share of around 16%. When only looking at Africa, Kenya's market continues to lead with a share of around 40% of all installed solar home systems.

The key driver for the spread of SHS is the need for electricity of rural households that are not connected to the electricity grid. Since the early days of the Kenyan solar market, many consumers with a desire to own and use a TV set and/or a radio perceived solar home systems as a viable option to generate the electricity needed for powering these appliances. Incidentally, these two appliances reportedly consume the majority of the electricity generated in SHS smaller than 25 Wp and still account for a sizable proportion even in bigger systems. While the use of solar energy for lighting is only secondary in many cases, it remains an important reason to purchase SHS. More recently, a major factor driving the demand for SHS has also been the rapid spread of mobile phones and the need to recharge them.

However, the market for SHS would probably not have developed as dynamically as it has if households had had the option of connecting to the national electricity grid. Therefore, the low rural electrification rates and the dim prospects of electrification in the future have to be considered an important factor in the development of the Kenyan solar market. Further enabling factors that led to the growth of the SHS market can be found in the income levels of Kenya's rural households and in market innovations that made solar systems more affordable to wider parts of the population. Regarding income levels, SHS are typically bought by the wealthiest parts of the rural population and the growing purchasing power of wider parts of the rural households has proven critical for the success of SHS in Kenya. Furthermore, price decreases for solar components led to system prices falling from around US$ 30 per Wp in the mid-1970s to an average price of approximately US$ 20 in the late 1980s and early 1990s. Today, prices have at least halved again to around US$ 6-12 per Wp, rendering SHS more affordable for wider parts of the population. Moreover, the larger variety of system sizes and the over-the-counter nature of the trade (in which systems are usually sold in components) allow customers to scale their purchase of a system according to their needs and financial capacity. Financial instruments on the other hand, such as hire-purchase schemes or credit sales, are not widely taken up due to the high costs of financing, with interest rates sometimes adding up to 80% to overall costs.

Kenya's energy sector is dominated by the use of biomass, such as fuel-wood and charcoal, which accounted for 74% of total primary energy supply in 2007 (IEA, 2010a). This high share of biomass is largely a reflection of the reliance of the majority of rural households on biomass for their cooking, lighting and heating needs, with cooking accounting for most of the energy. On average, households are estimated to use biomass for 90-100% of their cooking energy, which is dominated by what the IEA calls combustible renewables and waste. As solar energy is only of very limited use for cooking and heating, despite numerous efforts to promote solar cookers, solar does currently not contribute to primary energy supply on a large scale. Likewise, the contribution of solar energy to Kenya's electricity supply still remains very limited. With Kenya's electricity generation capacity being based on hydro power, fossil fuels and increasingly geothermal, biomass and wind, the share of solar in the overall electricity supply remains negligible. However, the role that solar plays in the electrification of off-grid households, institutions and businesses in rural areas must not be underestimated.

Alongside the development of Kenya's demand for solar products, a solar industry has emerged that serves the various customer groups. In comparison with other solar markets in emerging countries, Kenya's solar market is perceived to be generally well-developed and quite competitive. The Kenyan market and its solar industry therefore often serve as role models for other African markets that are less mature, especially in East African countries such as Tanzania, Uganda and Ethiopia.

The biggest market segments being served by the Kenyan solar industry are SHS and institutional systems, as well as SWH that are increasingly becoming more widespread. The Kenyan government remains an important player in the solar sector, both as buyer of institutional systems and as a regulator and policy-maker with influence over the development of the industry. Likewise, donors continue to play an important role as financiers of institutional solar systems and as facilitators of market development. However, it is important to note that the role of government and donors is less pronounced today than in the early years of Kenya's solar market, with the bulk of demand for solar systems coming from rural households and other private actors.

Due to the long history, size and variety of the Kenyan solar market, a diverse and broad solar industry has emerged that is unrivalled on the African continent, with the possible exception of South Africa. In 2009, it was estimated that there were between 15 and 40 major suppliers of solar equipment as well as three manufacturers of lead acid batteries and nine lamp manufacturers. In addition, five to eight companies regularly imported solar systems and components and several hundred sales agents and around 2,000 installation technicians served the national market. Along with South Africa, Kenya is therefore the only African country with a sizable production capacity for solar components and lead acid batteries, and serves not only as an import hub, but also as a manufacturing centre for the wider region. The same, albeit yet on a smaller scale, holds for the import and distribution of SWH, where at least four to six companies are currently active in Kenya.

The future of Kenya's solar market seems to depend to a large degree on policies of the Kenyan government. In the area of SHS and other off-grid systems, most researchers expect continued growth in sales and installations, but the potential market for both will ultimately be determined by a number of external factors, including the success of the Kenyan rural electrification programme. If this programme succeeds in connecting increasing numbers of rural consumers and institutions to the grid, this will naturally limit the scope for solar in the long run. Yet it is still expected that the long-term potential for SHS alone could be around 30 MWp (i.e. a four-to-fivefold increase), while the long-term potential for all off-grid PV systems is probably above 40 MWp, which underlines both the likely lasting importance of SHS and the scope for further market growth.

In addition, other and sometimes entirely new market segments will emerge and add to the growth in the off-grid market of Kenya, suggesting that the market will become more diverse and thus potentially less dependent on policy-makers. At the same time, the government can and probably will act as an enabler for some parts of the market that would not develop much without any sort of government involvement. The market for SWH may become one prime example for the potential role of such government intervention. Already the market is heating up in anticipation of new legislation that will make the use of SWH mandatory in many buildings, leading industry observers to expect strong growth in the coming years. Similarly, the potential of on-grid solar PV might be tapped if and when the Kenyan government decides to implement the necessary policies, e.g. in the form of a revamped feed-in tariff or the possibility of net-metering.

Nonetheless, it appears very likely that solar energy will remain a niche technology in Kenya's energy and on-grid electricity mix for the foreseeable future. Current plans by the government as well as KenGen suggest that during the next two decades at least preference will probably be given to more conventional forms of electricity production, such as coal, geothermal and maybe even nuclear. Furthermore, massive imports from neighbouring countries are planned, leaving little scope for a measurable contribution of solar energy (either in the form of PV or CSP) in current plans. Despite the likely continuation of the dominance of other sources of electricity generation, many experts are nevertheless convinced that the field of on-grid solar uses the market looks set to grow to at least 10 to 20 MW within the next decade, once some form of (limited) government support is implemented.

In conclusion, one can argue that the Kenyan solar market is rightly depicted as a good example of a renewable energy market that emerged largely without government intervention. The development of the past thirty years has shown that renewable energy technologies, in this case solar energy technologies, can be successfully deployed without major support from the state if they provide solutions that satisfy needs in a way that is attractive to consumers or donors. However, it is important to recognise that the initial impulse to stimulate the emergence of Kenya's solar market came from the public sector through the work of donors, NGOs and the government. Without the early demand and knowledge transfer from these actors, it seems highly unlikely that the Kenyan solar market would have developed in any meaningful way so early on.

Since its early days the market has seen brisk growth from a very low base, which was largely driven by the demand for solar home systems. The development of an industry that is able to cater to the needs of Kenya's rural households and the successful development of business models to accommodate the specific circumstances under which these households make purchasing decisions is rightly perceived as a good role model that could serve as a template for similar efforts of technology diffusion in other countries and for other technologies.

Yet despite a successful three decades for the Kenyan solar market, the fact remains that solar energy does not yet fulfil much of its technical potential. While the solar irradiation levels in East Africa are generally perceived to be much better than those in other regions of the world, e.g. Europe, where most of the world's solar capacity is concentrated, the contribution of solar energy to the supply of energy and especially to the supply of electricity remains limited to less than one percent. This is not to belittle the role that solar energy plays in the lives of some five percent of Kenya's rural households, where SHS are already having a major impact on the consumption choices of these households. Likewise, the exploitation of solar energy for various social uses is certainly important and should be encouraged further, especially in those parts of the country where modern energy services would otherwise not be available. But the bigger picture suggests that solar, despite all its successes, does not yet fulfil its full potential.

The reason for this are the economics of using solar energy: On the level of private sector investments in on- and off-grid solar energy, most households and companies have so far either been unable or unwilling to use solar energy to a larger extent. While there is probably also a lack of awareness and technical know-how that limits the exploitation of solar energy, the fact that solar energy use for electricity production, water heating etc. still remains expensive has meant that solar remains far below its technical potential.

Furthermore, capital constraints in the solar industry as well as among potential buyers of solar imply that even when there is a general interest to use solar, potential users are effectively shut out from the market if they do not have the necessary funds to acquire and operate solar systems. While this is certainly the case for many of Kenya's rural households, it is probably also the case for those market participants developing on-grid solar projects.

Such investments in on-grid (or even mini-grid) solar systems will most likely only happen if and when the Kenyan government (potentially with the assistance of foreign partners) decides to implement meaningful and adequate financial incentives, e.g. in the form of feed-in tariffs or net-metering. When looking at those solar energy markets around the world that have progressed the most, it is obvious that none of these markets had taken off without certain government incentives. However, it seems clear that the Kenyan government as well as stakeholders in Kenya's energy sector still remain to be convinced that using solar energy in such a way is advantageous from a societal point of view. Unless it can be shown that the economics of solar make its widespread use economically worthwhile and beneficial to the Kenyan economy as a whole, the government should and probably also will not implement any policies that lead to the wider adoption of solar energy technologies, especially when it comes to on-grid electricity generation. Until the government formulates a position on this matter and defines appropriate policies, the outlook for Kenya's solar market will remain unclear. While it seems reasonable to expect that past trends in the large existing PV market segments (especially SHS and institutional PV systems) will continue more or less independent of the government's actions for at least some time, a real boom in the wider market will only happen when meaningful policies are implemented. Whether the recent announcement of regulation regarding the installation of SWHs is a step in that direction remains to be seen, but these first actions from Kenya's government are certainly encouraging.

3. Tanzania's solar energy market

In contrast to the Kenyan solar energy market, which is comparatively well-researched, much less information is publicly available on the Tanzanian market. The reasons can probably be found in the comparatively small size and shorter history of Tanzania's market that has not facilitated widespread interest among academics and other experts. Therefore what little information is available on the Tanzanian solar market often tends to be a side-product of an analysis of its Kenyan counterpart with Tanzania being mentioned only in passing. As is the case with Kenya, this paper therefore draws upon and summarises as wide a range of sources as possible to present the past development and current status of the Tanzanian solar energy market.

The remainder of this chapter is structured in the following way: Section 3.1 explains the origins of Tanzania's market for solar energy technologies, section 3.2 presents the various solar energy technologies used in Tanzania and section 3.3 presents and analyses its SHS market. Section 3.4 analyses the role of solar energy in Tanzania's energy mix and the following section 3.5 presents the structure of Tanzania's solar industry. This chapter concludes with an outlook for the Tanzanian solar market in section 3.6 and a brief summary and some conclusions in section 3.7.

3.1. Origins of the Tanzanian solar market

Like Kenya, Tanzania began to look into solar energy as a means to generate electricity after the first oil crisis in 1973/74 (Sheya and Mushi, 2000). Furthermore, due to a lack of electricity infrastructure in much of Tanzania and the high costs of grid extension, the electrification of rural social institutions such as schools, churches and health centres has for a long time relied on various off-grid solutions, including solar PV. This institutional electrification led to the procurement of solar PV systems by foreign and multilateral donors, missionary groups and the Tanzanian government and created the initial demand for solar systems in the country (GTZ, 2009d).

In the area of communication systems, the country's telecoms company TTCL and its railway company TAZARA were among the earliest adopters of solar energy applications for use in repeater stations and radio communications (Sheya and Mushi, 2000).

Thus, while the development of the PV market in general was largely the result of supported projects and government procurement, the emergence of the Tanzanian SHS market was mostly the effect of a spillover from the Kenyan market. As explained earlier, the SHS market developed in Kenya in the 1980s and 1990s (see section 2.1.) and subsequently expanded into Uganda and Tanzania in the late 1990s (ESDA, 2003). However, it was not until the early 2000s that a number of PV-focussed companies[16] started to develop the market in the same way that the Kenyan market was developed more than one decade earlier (e.g. Zara Solar, 2010). Many of these companies used the help of Kenyan pioneers such as Harold Burris, who had started Kenya's first SHS company (Hankins, 2010).

The result of these early developments is a close integration of the Tanzanian solar market with its bigger neighbour in Kenya. Even today, some ten years later, one can argue that the Tanzanian SHS market is very dependent on the Kenyan market, with much of its supply chain going through Kenya (see section 3.5.).

However, the emergence of a sizable consumer market was not only the result of supply-side actions. On the demand side, the SHS market in Tanzania grew similarly to that in Kenya, with demand for SHS also broadly following the availability of 12-volt television sets and radios as well as battery-based electricity systems (ESDA, 2003). However, as the market emerged later than in Kenya, the main uses and drivers of solar electricity in Tanzania are frequently reported to be different, with lighting and mobile-phone charging coming first and (colour[17]) TVs and radios coming second (e.g. Camco, 2010).

3.2. Solar energy technologies used in Tanzania

Precise figures are currently unavailable for most aspects of the Tanzanian solar market. Magessa (2008), for example, points out that "the number of rural social facilities installed with solar PV systems could not be [...] established precisely" (Magessa, 2008, p.12). Likewise, information on the SHS market is not well-recorded as numerous organisations active in the market do not gather market data centrally (Kassenga, 2008). The market overview presented here therefore draws upon a large number of sources but may still be imprecise regarding the actual size and shape of the overall market as well as its various segments. Furthermore, some segments of the market, such as solar lanterns and solar dryers are not covered beyond anecdotal evidence in the available literature, implying that potentially sizable segments of the market might be underreported.

Nonetheless, the overall solar market in Tanzania appears to consist almost exclusively of solar PV applications. In recent years, solar PV systems have reportedly been used in telecommunication, off-grid lighting, refrigeration, water pumping and to power electronic equipment in homes, schools, health centres and missionary centres. Albeit on a small scale, some productive uses of solar, such as in barber shops, mobile

[16] The earliest companies to start targeting the private solar market were Rex Investments, which started in 2000, Umeme Jua and Zara Solar, which started in 2005.
[17] Several interview partners pointed out that demand for SHS was somewhat depressed in Tanzania as households would typically buy colour TV sets which require more power and hence bigger SHS. Such bigger SHS, however, are beyond the reach of many households (Chloride Exide, 2010a).

phone charging and "bush cinemas", are also reported (Msigwa, 2010). However, these applications remain limited due to the high initial capital cost (Zara Solar, 2010). Thermal uses, such as solar cooking, pasteurising, and technologically advanced crop-drying, on the other hand, are reportedly still in their infancy (WEC, 2007).

Solar systems used in schools, health centres and other institutions, e.g. for vaccine refrigeration and water pumping, remain crucial parts of the market, as governments, donors and NGOs, such as e.g. Solar Now and Solar Aid, increasingly provide off-grid rural projects that they support with PV systems (Msigwa, 2010). Moreover, solar power for telecommunication continues to be an important application, though orders tend to be sporadic (ESDA, 2003).

However, the public or institutional sector is slowly losing its dominant role as the market for private SHS starts to grow in importance. Already in 2001 it was estimated that SHS sales constituted the most important segment (by volume) of the market in Tanzania (ESDA, 2003) and later reports suggest that this remains the case today, as will be discussed in the following sections.

3.2.1. Solar photovoltaic applications

The overall solar PV market had increased from around 300 kWp in the late 1990s to approximately 1.2 MWp in 2003 (AFREPREN, 2003; ESDA, 2003; Karekezi et al., 2005; WEC, 2007). The latter figure broke down into three broad segments: SHS (550 kWp), institutional and government-procured systems (300 kWp) and telecommunication, health and water pumping, which made up the remaining 250 kWp (ESDA, 2003).

While the overall market was reported to have grown at an annual rate of up to 70 kWp in 2002, market growth appears to have accelerated since then, with estimates for annual capacity additions ranging from 200 to 300 kWp until 2007 (WEC, 2007; GTZ, 2009c; GTZ, 2009g). The annual growth rate was hence estimated to be around 15-30% (WEC, 2007; Chloride Exide, 2010b; Hankins, 2010). This market growth was largely seen as being facilitated by a geographic extension of the PV supply chain into more regions (GTZ, 2009d).

Recent sources estimate that the overall solar PV market has reached a size of at least 2.5 MWp or more (GTZ, 2009d). This figure was confirmed by several experts during interviews conducted in September 2010 who put the current market size at around 2-3 MWp (e.g. Chloride Exide, 2010b). Likewise, an upcoming report from the SIDA/MEM project (see section 3.5.1.) is going to estimate the current total installed capacity at 3.1-4.0 MWp. This figure is based on the annual sales of solar PV systems reported for the years 2005 to 2009 (see figure 8). According to other sources, it also appears plausible that the overall PV capacity in Tanzania had reached nearly 4 MWp at the end of 2009 with a further increase likely in 2010 (e.g. Davis & Shirtliff, 2010b).[18]

[18] Camco (2010) actually puts the installed capacity at an even higher 6 MWp, an estimate that was not confirmed by other experts during interviews.

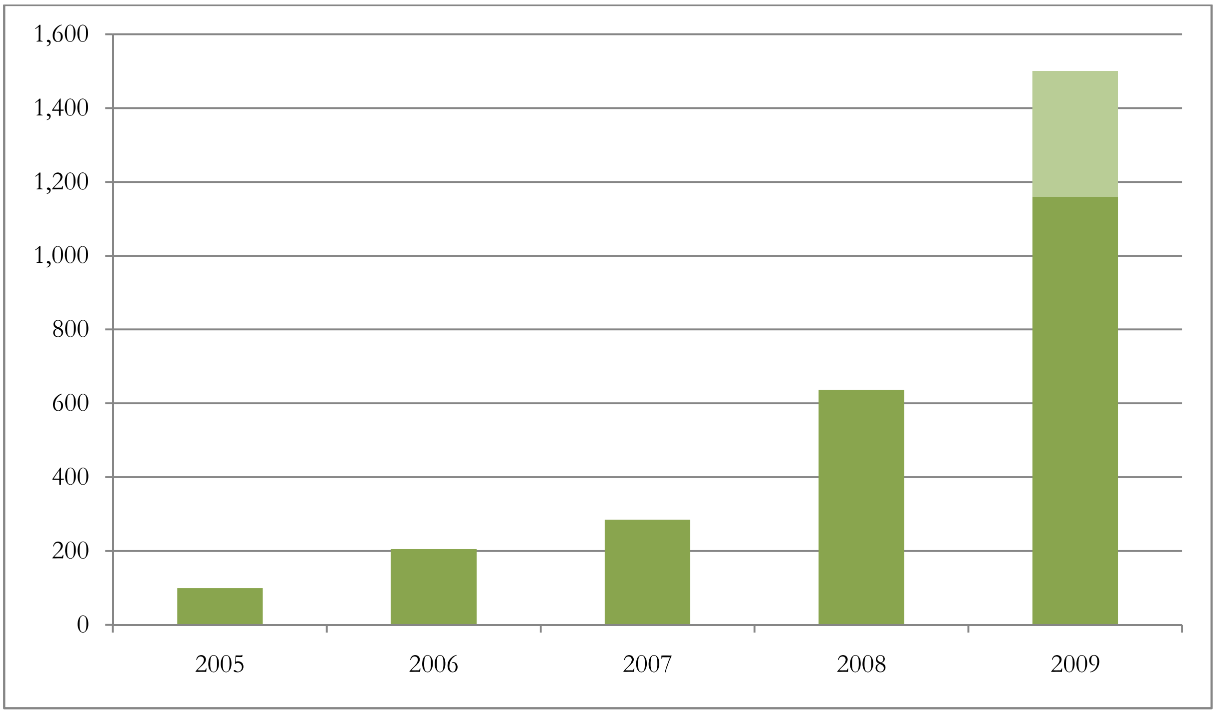


Figure 8: Estimated annual Tanzanian solar PV sales in kWp[19] (based on Camco, 2010, citing SIDA/MEM, 2010)

A GTZ report on the Tanzanian market (GTZ, 2009d) suggests that, whilst institutional procurement has for a long time been the driving force behind Tanzania's market, the SHS and small-scale commercial segments have already surpassed the institutional segment. However, it is worth noting that this report does not analyse some solar applications that have been highlighted in the past as playing a noteworthy role in the market, such as telecommunication and water pumping. Nonetheless, its estimates for the relative sizes of today's main market segments appears to hold true, with SHS and small-scale commercial systems making up around 75% of the market and institutional systems constituting the bulk of the remaining 25% (GTZ, 2009d; Camco, 2010).

More generally, several sources (e.g. Karekezi, 1994; Hankins, 2000; ESDA, 2003; Kassenga, 2008) list three broad areas in which solar PV is currently being used in Tanzania:

- **Electricity generation**: SHS-powered lighting systems are frequently used in institutions such as schools, health centres, mission centres and game parks, as well as private homes. Additionally, PV-based vaccine refrigerators are increasingly being used throughout the country.[20]
- **Information and communication technologies (ICT)**: PV-powered communications systems have been widely used to improve Tanzania's communications networks, e.g. in telephone repeater stations, railway communications systems[21] and offices of the Tanzania Revenue Authority (TRA).
- **Water pumping**: PV power is also being used to drive water pumps for irrigation in agriculture as well as for domestic water supply, but information on this segment is particularly scarce.

[19] The estimate for 2009 ranges from 1.16-1.5 MWp as one major market participant declined to provide the report's authors with 2009 sales figures. These were estimated to be at least 340 kWp by Camco (2010).
[20] E.g. the WHO funded vaccine refrigerators with a total capacity of 200 kWp in 2003 (ESDA, 2003).
[21] There are around 2,000 railway communication systems with a total capacity of 340 MWp (Kassenga, 2008).

The electricity generated by solar PV systems is mostly being used for telecommunications, donor and government-funded health projects (vaccine refrigeration in health stations and hospitals), and office and household electricity. Hence, centrally-procured institutional systems have historically been the most important market segment (GTZ, 2009d). However, PV tends to be unsuitable for energy-intensive uses in agriculture and the commercial sector. Likewise, solar PV is today applied only in a very limited way in water pumping, highway lighting, and the powering of weather stations as well as other productive uses (Kassenga, 2008; Chloride Exide, 2010b).

The Tanzanian government, through the Rural Energy Agency's (REA) "Lighting Rural Tanzania" programme and the Rural Electrification Fund[22] (REF), is one of the chief promoters and users of solar energy in the country. For instance, the government had earmarked US$ 10 million in 2007/08 to install around 1,000 solar systems (costing approximately US$ 10,000 each) in secondary schools and health centres. Given that there were around 2,700 unelectrified secondary schools and over 2,800 unelectrified health centres in the country in 2007, some pointed out that these investments would need to be scaled up in order to make a bigger impact (Magessa, 2008).

In recent years, the SHS market has been growing rapidly (GTZ, 2009d) and now reaches customers in nearly all parts of the country. Until a few years ago, the commercial market for SHS was still very small and most customers were located in and around the economic hubs of Dar es Salaam (largely donors and NGOs), Mwanza (fishing, goldmines and agriculture) and Arusha/Moshi (tourism and agriculture). In all market segments, demand for solar PV is increasing as the success story of solar PV in Kenya is raising awareness among sponsors and consumers alike (Kassenga, 2008; Chloride Exide, 2010b; Msigwa, 2010).

3.2.2. Solar thermal applications

In the area of solar thermal applications, solar water heating, crop and salt drying and solar cookers are being used in Tanzania on such a small scale that no detailed information or data on this segment of the market is available (Kassenga, 2008). However, while small on a national scale, solar drying of coffee and fruits is reportedly getting more common in the Northern and Western parts of the country around Mwanza, Arusha and Moshi (e.g. TaTEDO, 2010).

When it comes to SWH, the exact market size is difficult to gauge. According to GTZ (2009d), annual sales could be anywhere between a few hundred and 1,500 units. While even the low figure would mark a significant increase on the early 2000s, when the total number of installed SWH was probably just 100 (according to Karekezi et al., 2005), other experts put annual sales at a much more modest 100 systems (e.g. Msigwa, 2010). Accordingly, market participants estimate the overall number of systems currently installed at around 1,000-3,000 systems, around two-thirds of which are probably used in tourism establishments (e.g. Nyamo-Hanga, 2010).

Most other SWH are currently being purchased for domestic uses and some are purchased by institutions. Many of these institutional buyers, as well as private consumers and businesses, procure their water heaters directly from manufacturers abroad or import them through Kenya. Because of this, no reliable statistics on the overall market for SWH in Tanzania are available at present and estimates on annual sales and cumulative system numbers will remain guesswork until such statistics are compiled reliably (GTZ, 2009d).

[22] This programme is supported by the World Bank-financed Tanzania Energy Development and Access Project (TEDAP) mentioned in section 3.5.1. below. Funding for the programme is currently ensured until April 2011 (TAREA, 2010). The programme supports ten solar businesses with grants of US$ 100,000 each (ARTI, 2010).

3.3. Tanzania's solar home systems market

Similar to Kenya, the development of the Tanzanian SHS market is closely linked to the BBS market. As in Kenya, the SHS and BBS markets are largely driven by the electricity demand from rural households (e.g. television, radios, lighting and mobile-phone charging) as well as small-scale commercial uses (e.g. mobile-phone charging and music systems in bars and kiosks) (GTZ, 2009d).

3.3.1. Capacity and number of installed SHS

As pointed out earlier, it is difficult to produce very reliable figures on the Tanzanian solar market in general, and the same applies to its SHS segment. However, based on a number of reports, one can at least estimate that the SHS segment reached around 1 MWp in 2008, with a high probability that the true figure was even higher (GTZ, 2009d; GTZ, 2009f). This would mark a significant increase since 2003, when the SHS segment was reportedly only 500 kWp (ESDA, 2003), and even more so since 1993, when only 256 domestic solar PV units were in operation in the country (Sheya and Mushi, 2000).

At least 20,000-40,000 SHS can be assumed to have been installed by 2008.[23] This would imply a doubling or more of the number of SHS currently in use within just three or four years (cf. Moner-Girona et al., 2006), suggesting a significant increase in the uptake of such systems. Based on reported sales of over 200 kWp in 2008 alone (GTZ, 2009d), such an increase in the cumulative number of SHS does not seem implausible, as annual sales would then roughly amount to 4,000-8,000 systems.[24]

In 2009 a further increase in sales and installations of SHS was reported, bringing the total number of systems to 40,000, half of which were installed in 2009 according to Camco (2010). Assuming an average capacity of 50 Wp, the cumulative capacity of SHS had thus reached around 2 MWp, which implies a doubling within just one year (Camco, 2010).

3.3.2. Share of households owning SHS

Despite the rapid growth in the number of SHS, the diffusion of solar PV among households remains very low, as about 90% of households continue to use kerosene for lighting (Kassenga, 2008). Official sources put the number of households using solar electricity at 0.6% in 2007. According to NBS (2009) this was actually a *decrease* of one percentage point since 2001. While it seems unlikely that the overall diffusion rate has actually decreased, these figures underline the limited contribution of solar electricity so far (NBS, 2009). At the same time they also confirm the upper end of the estimate for the overall number of SHS given above, underlining the assumption that at least 40,000 systems had been installed by 2008.[25] A recent report from Lighting Africa (2010a) gives somewhat higher estimates for the number of systems (50,000) and subsequently estimates the diffusion rate at around 1%.[26]

3.3.3. Role of rural electrification

The demand for off-grid energy solutions is largely a result of the low electrification rates of Tanzania, whose overall electrification rate was approximately 14% in 2009 (Camco, 2010). About 80% of all elec-

[23] Assuming an average system size of 25-50 Wp, as reported by ESDA (2003) and Moner-Girona et al. (2006).
[24] Assuming an average system size of 25-50 Wp. Systems for institutions are generally much larger, with an average size of 100-300 Wp (Kassenga, 2008).
[25] The total number of rural households in 2008 was estimated at 6.5 million assuming an average household size of 4.9 (own calculations based on United Republic of Tanzania, 2002; World Bank, 2010a). 40,000 SHS would lead to a diffusion rate of 0.62% which is in line with NBS (2009).
[26] In contrast, a presentation of Lighting Africa (2010b) gives an even higher estimate of 65,000 SHS for Tanzania. However, it is not clear whether this estimate also includes pico-systems, i.e. systems of a few Wp or even less.

tricity users connected to the grid live in urban areas. In other words, while the urban electrification rate had already reached 13% in 2000, only about 2% of rural areas were connected to the grid at that time (Davidson and Sokona, 2002; GTZ, 2009d; GTZ, 2009f; Camco, 2010). And even in villages nominally connected to the grid only about 1-5% of households are typically electrified (Kassenga, 2008), leaving up to 5.1 million households currently without access to electricity (GTZ, 2009d; GTZ, 2009f).

In total, approximately 660,000 commercial and residential customers were grid-connected in 2008. The number of new connections by the national monopolist Tanzania Electric Supply Company (TANESCO) is only around 36,000 per year (Magessa, 2008).[27] Based on data from a recent household budget survey, the electrification rate has marginally increased from 10 to 12% between 2000/01 and 2007 (NBS, 2009). The slow pace of grid-extension and rural electrification is largely a result of Tanzania's geography and the resulting high costs of extending the national grid. In this context, solar-based electrification is increasingly being recognised for its potential contribution to rural electrification in regions far from the grid. However, this recognition does not seem to have been fully translated into government policy as at least one programme aimed at the electrification of district centres favours generators and wind power over solar (Msigwa, 2010).

According to one study, while grid electricity is in principle the cheapest source of electricity for consumers (on a per-kWh level), energy for lighting from SHS could potentially lead to sizable energy savings for consumers if the alternatives are other means of electricity generation or direct lighting. This study, conducted in 2000, estimated that lighting powered by SHS would cost less than half of that from generators, kerosene lamps or battery power (MEM, 2002b). However, other studies have come to other conclusions on the relative costs of various energy options.

3.3.4. Income levels of SHS owners

The majority of SHS are purchased by upper-income households in rural areas (such as cash-crop farmers and rural teachers) as well as urban customers who provide these systems to their relatives in rural areas. Some of these systems are purchased as a complete system, but most consumers can only afford to buy systems gradually by purchasing individual components one at a time (GTZ, 2009d; Hankins, 2010; Msigwa, 2010). Hire purchase schemes or other financial instruments that allow households to spread the acquisition costs over a longer period are not frequently encountered in Tanzania, despite the efforts of projects like the World Bank-financed "Clusters" project and efforts of many NGOs, such as Solar Now (e.g. Hankins, 2010). The reason that any sort of financing is rarely taken up can largely be found in the high interest rates typically encountered in Tanzania, which can reach 16-20% (e.g. TAREA, 2010).

3.3.5. Development of SHS prices and sizes

Prices for SHS in Tanzania have traditionally been higher than in Kenya, which is usually explained by the structure of Tanzania's solar industry. For a 50 Wp system an average price of US$ 1,318 was reported for 2002 (Kassenga, 2008), with other studies citing much lower costs of US$ 520 in Mwanza (MEM, 2002b) and US$ 827 for 2003 (ESDA, 2003). Without further research on past and current market prices it remains unclear how these price differences can be explained, but it seems likely that the big variation in costs results more from different assumptions regarding the contents of a "typical SHS" than actual variations in prices.

However, on average module prices have decreased to around US$ 3-4 per Wp from US$ 5 or more per Wp three years ago, rendering SHS more affordable to larger parts of the population. At the same time,

[27] A recent report puts the current number of grid connections at 940,000 (Lighting Africa, 2010a).

the average SHS size has increased to around 40-50 Wp, from 14-15 Wp a few years ago, leading to the cost of a complete system of US$ 9.5-16.0 per Wp or approximately US$ 380-800 for a complete system (e.g. Chloride Exide, 2010a; Davis & Shirtliff, 2010b; and Zara Solar, 2010). In Mwanza region, prices were reported to be somewhat lower at around US$ 6.0-8.6 (excluding installation) depending on system size and specifications (Zara Solar, 2010). Overall, prices have not decreased as much as could have been expected given price developments in the world market for solar equipment. While several explanations are commonly advanced for this, a reason frequently cited points towards the concurrent rise in battery prices (itself explained by rises in the price of lead) (e.g. TAREA, 2010).

3.3.6. Pico-solar systems

While the average size in the segment of "classic" SHS has increased in the past few years, an entirely new market segment for very small solar systems, such as solar lanterns and solar chargers, has emerged very recently. These "pico-systems" have a capacity starting below 1 Wp and going up to not more than a few Wp, which is typically sufficient to power some LED lights and sometimes a radio or mobile-phone charger. Annual sales of such systems are probably larger than the number of the much bigger SHS mentioned before (TAREA, 2010). Prices for such plug-and-play pico-systems are currently in the area of US$ 12-35 per Wp, which is higher than for bigger systems. However, as pico-systems are generally smaller than classic SHS, these systems are nonetheless more affordable to wider consumer segments. For example, solar products marketed by companies such as D.Light, Barefoot Power and ToughStuff range from around US$ 10 to 45, making costs for the cheaper systems comparable with the average monthly household expenditure on kerosene (e.g. D.light, 2010).

3.4. Role of solar energy in the Tanzanian energy mix

3.4.1. Role of solar in primary energy consumption

The total primary energy supply in Tanzania was approximately 18,278 ktoe in 2007 (IEA, 2010b). As a result of strong population growth, overall energy use has almost tripled between 1971 and 2006 (World Bank, 2010a). Of the overall primary energy supply, some 88.6% was biomass-based and 11.4% is commercial energy in 2007 (IEA, 2010b). Commercial energy consists of fossil fuels, such as coal and petroleum products for transport, electricity generation and lighting (7.9%) and electricity from natural gas (2.4%) and hydro power (1.2%) (Kassenga, 2008; REN21, 2008; IEA, 2010b).

The share of biomass energy has not changed significantly in the past 40-odd years, as the use of biomass has increased by 177% between the early 1970s and the mid 2000s (World Bank, 2010a). Figure 9 shows the 2007 shares of various sources of primary energy supply.

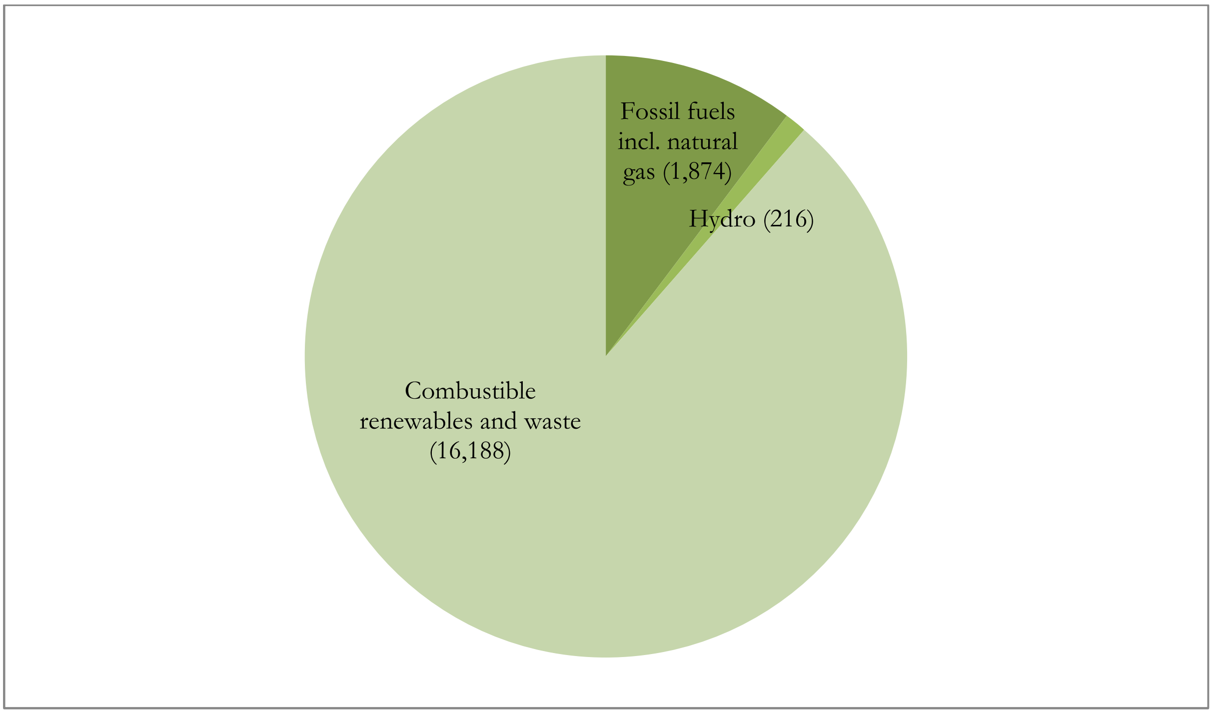


Figure 9: Tanzanian total primary energy supply (ktoe) by source in 2007 (*Source:* IEA, 2010b)

As can be seen in figure 9, the contribution of solar, wind, biogas and other "new" RES to Tanzania's energy supply is not significant (Kassenga, 2008). Traditional biomass accounts for over 90% of all cooking energy (Magessa, 2008), which explains the high share of biomass in the country's primary energy supply. Around 80% of that biomass energy is consumed in rural areas (Kassenga, 2008), as these are far from markets for more modern forms of energy and purchasing power among rural households is too limited to afford commercial energy on any sizable scale.

3.4.2. Role of solar in electricity generation

Electricity generation accounted for only 3.6% of overall energy consumption in 2007 (IEA, 2010b). Until a few years ago, hydro power was the dominant source for the generation of electricity. However, since 2003 Tanzania began to develop its substantial gas reserves and the share of natural gas in electricity production expanded dramatically since 2004, when the first gas-fired power station became operational. Between 2004 and 2006 the electricity production from gas increased almost threefold as new plants were commissioned. At the same time electricity production from hydro power decreased significantly since the beginning of this decade and the share of hydro power fell from around 95% to about 50% between 2001 and 2006 (World Bank, 2010a). This massive reduction in the absolute and relative output of Tanzania's hydro power plants was mostly due to long-standing droughts (GTZ, 2009c). Figure 10 shows the share of the various energy sources for power generation.

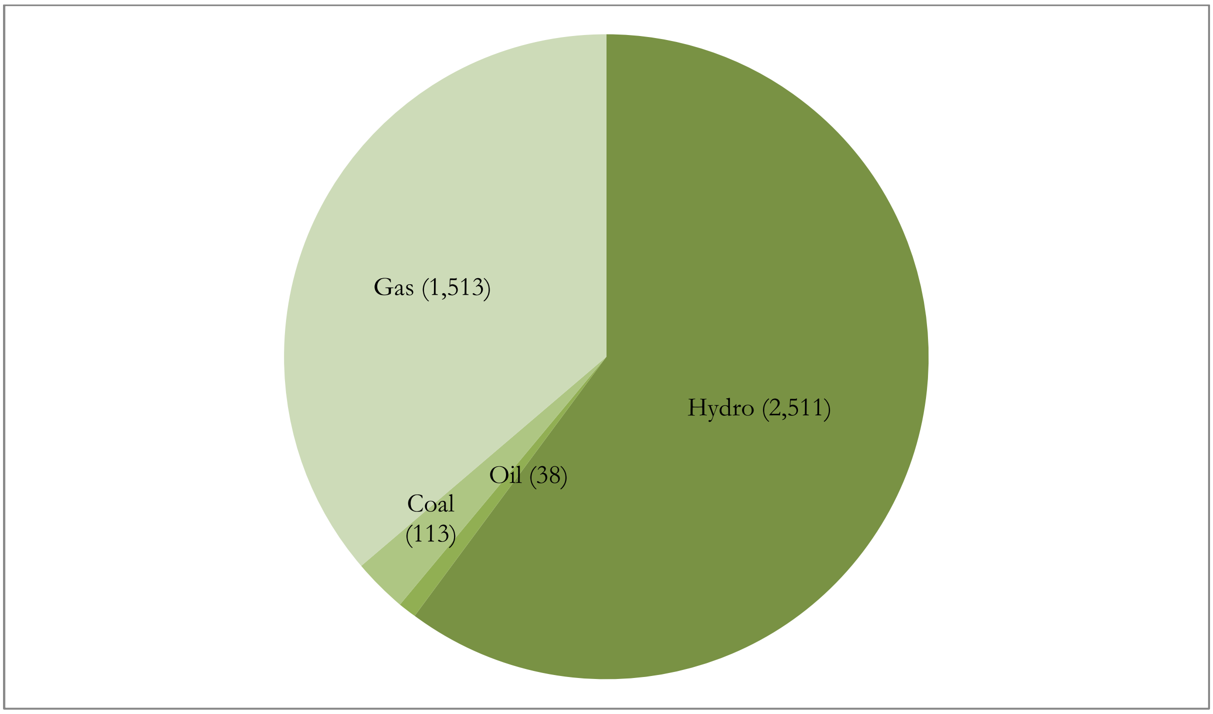


Figure 10: Tanzanian electricity generation (GWh) in 2007 (*Source:* IEA, 2010b)[28]

State-owned TANESCO owns and operates all hydro power plants, one gas-fired and some smaller diesel-fired plants and is currently responsible for 70.6% of all electricity generation capacity in the country (TANESCO, 2010a). After the Electricity Act of 2008 liberalised the generation of electricity, three independent power producers (i.e. SONGAS, Independent Power Tanzania Limited (IPTL) and Artumas), entered the market. These companies use gas and diesel as fuels for their thermal power stations. In addition, two emergency power supply agreements are currently in place with Aggreko (40 MW) and Dowans Tanzania Ltd. (22 MW) in order to mitigate drought-induced blackouts (GTZ, 2009c; TANESCO, 2010a).

Installed generation capacity was 987 MW in 2008 and distributed as follows: 561 MW (56.8%) was hydro power (all of which owned by TANESCO), while gas-fired plants accounted for 290 MW (29.4%). Of those 290 MW TANESCO owned 100 MW, SONGAS 182 MW and Artumas 8 MW. Diesel-powered plants accounted for another 136 MW (13.8%), of which TANESCO owned 36 MW and IPTL 100 MW. 31 MW of TANESCO's diesel capacity served isolated grids (TANESCO, 2010a).

In addition, 62 MW were contracted from Aggreko and Dowans for an initial two-year period, bringing the total installed capacity to 1,049 MW in 2008. For 2010, the Ministry of Energy and Minerals (MEM) reports a total installed capacity of 1,219 MW in 2010, with 658 MW coming from thermal sources (MEM, 2010). This suggests that between 2008 and 2010 an additional thermal capacity of 232 MW has been added to the grid, while the hydro power capacity has stagnated, thus further reducing the share of hydro power in Tanzania's electricity production mix.

3.4.3. Future development in energy and electricity demand

The key drivers behind the quite rapid expansion of Tanzania's electricity generation capacity and its changing generation mix are three-fold. Firstly, recent droughts have led to the realisation that the de-

[28] The IEA (2010b) figures are not completely in line with statements from other sources as they give a higher estimate for the share of hydro power. However, the overall picture of a decreasing share of hydro power is confirmed by information from the IEA.

pendence on hydro power should be reduced. Secondly, sizable capacity additions are required in order to keep up with current and expected rises in electricity demand. Thirdly, recent successes in the exploration of Tanzania's natural gas reserves and the liberalisation of the energy market have allowed new market entries based on gas-fired power plants.

According to the IEA, annual electricity consumption per capita was 83 kWh in 2007 while other sources reported somewhat lower figures for 2006 (58 kWh) and 2008 (78 kWh) (Kassenga, 2008; IEA, 2010b, World Bank, 2010a). Overall, no significant increase in the per-capita consumption of electricity could be observed in the 1990s and early 2000s (World Bank, 2010a). However, the average figure probably masks strong increases in the electricity consumption of those consumers actually connected to the grid. Therefore, the reported growth rates in electricity consumption of 11-13% per year (Kassenga, 2008) appear plausible.

3.5. Structure of the Tanzanian solar industry

As described earlier, public sector involvement in the Tanzanian solar market is very strong. The MEM and its subsidiary body REA both act as buyers of solar systems for rural social facilities, such as schools and health centres (Magessa, 2008).

3.5.1. Role of government, donors and NGOs

Alongside direct procurement, the central government provides subsidies to rural communities in order to allow them to purchase PV systems. These government subsidies are also extended to private consumers on a pilot basis in Rukwa region so that households, institutions and rural communities benefit from such subsidies (REN21, 2008; GTZ, 2009c; TAREA, 2010; Zara Solar, 2010).[29] Furthermore, the Tanzanian government not only implements fiscal measures to stimulate the demand-side, but also pays subsidies to suppliers of solar systems (GTZ, 2009d).[30]

Anecdotal evidence suggests that at least some PV systems brought to users with the help of such subsidies or government/donor procurement were quickly abandoned after their installation due to a lack of technical support from government agencies or donors. Furthermore, the owners/users of these systems in some cases did not appear to take a strong interest in the maintenance of their systems as their financial involvement was minimal once subsidies have been taken into account (cf. Kassenga, 2008).

The efforts of the Tanzanian government to support the solar market are complemented by various development organisations. For example, the Swedish International Development Cooperation Agency (SIDA) has supported a solar market development programme of the Tanzanian government with US$ 2.2 million (commonly referred to as the "SIDA/MEM" project),[31] while the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) until recently supported a market

[29] Subsidies to private households amount to US$ 2.5 per Wp for systems up to a capacity of 14 Wp and of US$ 1.5 per Wp for systems up to a capacity of 100 Wp. Institutions and rural communities receive US$ 1.5 per Wp for systems up to 300 Wp with a maximum subsidy of US$ 450 per recipient (REN21, 2008; GTZ, 2009c; Nyamo-Hanga, 2010).
[30] A premium of US$ 2.0 per Wp is apparently paid to companies selling solar systems up to a capacity of 100 Wp (GTZ, 2009d). However, these subsidies do not appear to be widely available and only very little information is available on the specifics of the programme.
[31] Total project value based on Felten (2011). The SIDA/MEM project consists of four components: quality standards, training, cooperation with TAREA and an expansion of the solar dealer network to all regions of the country (Hankins, 2010).

development scheme for solar PV with US$ 2.5 million from 2004 to 2009.[32] This project induced the installation of 8,400 new SHS in Mwanza region alone (UNDP, 2010). Other development organisations active in the field include the European Union, the UN, and the World Bank, which all support solar through various activities.[33]

The World Bank, through the International Finance Corporation (IFC) and GEF, until recently also operated another project aimed at the provision of 40,000 solar systems with a total capacity of 2.5 MWp and at a cost of US$ 30 million (IFC, 2007). Likewise, non-governmental development organisations are very active buyers and providers of solar systems in Tanzania, such as the Clinton Foundation, which supports the installation of solar systems in rural health centres (Magessa, 2008; Msigwa, 2010).

Many NGOs active in the promotion of solar energy use tend to support only small-scale projects due to limited funds and manpower. However, these small NGOs as well as some of the bigger NGOs and donors, such as UNESCO, churches and the Tanzania Renewable Energy Association (TAREA), are key facilitators of solar-related training courses and awareness-raising campaigns. Other organisations such as the Traditional Energy Development and Environment Organisation (TaTEDO) and Sustainable Development through Renewable Energy in Tanzania (SUDERETA) have promoted solar energy throughout the years (Kassenga, 2008). TaTEDO was supported in its activities by a number of international donors, such as the European Union, Norway, the Netherlands and the United Nations (GTZ, 2009c), and facilitated the establishment of solar companies, such as Umeme Jua, and TAREA's predecessor, the Tanzania Solar Energy Association (TASEA, cf. TaTEDO, 2010).

3.5.2. Private sector involvement

Largely driven by the demand from the government and various development projects, a solar industry has emerged in Tanzania that serves both public buyers and the commercial and residential segments of the Tanzanian solar market. In 2009, around 20 companies with activities in the solar sector were registered (GTZ, 2009c). A number of players active in the stocking, supplying and maintaining of solar systems are subsidiaries of Kenyan solar companies, while others are focusing purely on the Tanzanian market (Magessa, 2008). However, due to high local prices and insufficient supply, many of the solar systems acquired by institutional actors were (and to some extent probably still are) procured from abroad (GTZ, 2009d).

In 2003, almost all components were imported into Tanzania (with the exception of batteries that were partly produced locally by one company) and the industry consisted of only five major importers/distributors, nine PV installers and over 60 retailers (ESDA, 2003; Moner-Girona et al., 2006). In 2008 six major players located in Dar es Salaam and Arusha were reportedly trading solar PV systems and components, as well as providing services such as installation and maintenance. Numerous other players across the country and in cities such as Mwanza are offering PV systems alongside other goods. These actors tend to import most PV equipment from Kenya or South Africa, while some "opportunistic" importers also import directly from Asia on a case-by-case basis (Kassenga, 2008; GTZ, 2009d).

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[32] The project entitled "Transformation of Rural Photovoltaic Market in Tanzania", often simply referred to as "Solar Mwanza" is now being concluded. It aimed at the development of a viable solar market in the Mwanza region and is widely considered a success (Hankins, 2010).

[33] For instance, the World Bank's TEDAP project contains two solar components, the "Sustainable Solar Market Packages" (SSMP) and the "Clusters" project, which aim to aggregate demand from institutions and households respectively and thus lower system and transaction costs (Hankins, 2010). SSMP was piloted in Rukwa region and expansion to five more regions is imminent (TAREA, 2010). SSMP 1 led to the installation of 285 institutional systems and 8,000 SHS in 82 villages. The total subsidy was US$ 1.26 million (Nyamo-Hanga, 2010).

The availability of components such as modules, batteries and inverters is still largely limited to major towns. Despite efforts to address this supply chain issue (e.g. by the SIDA/MEM project), rural areas are only slowly being covered comprehensively. Poor transportation infrastructure, high transaction costs between wholesalers and retailers as well as insufficient competition reportedly lead to high consumer prices. A 2003 study estimated that due to these reasons, margins were around 30% and thus far above Kenya's (ESDA, 2003). Furthermore, quality in components and installation is not always satisfactory. On the other hand, the installation of SHS and institutional systems usually tends to be of sufficient quality, as the market nowadays comprises a pool of experienced solar technicians (GTZ, 2009d).

Lastly, it is noteworthy that supply chains for various market segments operate quite separately from each other, with the supply of PV systems for telecoms and the institutional sector being served by different companies than the SHS market (ESDA, 2003). Likewise, one study in Mwanza found different delivery models for different market segments. While donor-funded procurement was common in the institutional segment, cash sales dominated the consumer or household segment. Other delivery models, such as credit or hire-purchase sales, were not frequently encountered when the study was carried out in 2002 (MEM, 2002a).

3.6. Outlook for the Tanzanian solar energy market

3.6.1. Energy demand growth and electrification

A number of developments suggest that Tanzania's solar energy market will continue to grow in the years to come. Firstly, electricity demand is likely to increase both in rural and peri-urban areas as well as in grid-connected areas due to rising incomes, economic and population growth. TANESCO, the state utility, estimates that electricity demand will grow by around 8% p.a. until 2015 (GTZ, 2009c) while the government's Power System Master Plan (PSMP) expects demand to increase by 11.4% p.a. until 2018 (SNC, 2009). Electricity demand would thus roughly triple by 2020 (MEM, 2010).

Secondly, as rural electrification progresses only slowly, rising electricity demand in unelectrified regions of the country will need to be met by other means and solar energy is one solution that appears to be favoured by consumers, the Tanzanian government and donors alike. In fact, some experts have pointed out that grid extension will not reach the majority of the population for decades to come (Kassenga, 2008) as grid extension, especially in the western part of the country, is at the moment not economically feasible (GTZ, 2009c).

Some even more pessimistic observers are actually forecasting that anything near full electrification might never be obtained in Tanzania (Adenikinju, 2008). At least for the foreseeable future this does not seem implausible as even where villages are close to the grid, TANESCO currently gives priority to the electrification of district headquarters and large towns over the connection of rural households.[34] Moreover, most Tanzanian houses do not meet the building standards needed for a connection to the grid (Kassenga, 2008). Among others, Kassenga (2008) therefore expects the biggest short-term market potential in the area of household lighting, where 90% of households currently use expensive kerosene lamps that could be replaced by solar lanterns or SHS.

[34] Where rural households are connected to the grid, this is usually done under the auspices of, and in many cases financed by, the REA (TANESCO, 2010b).

3.6.2. Obstacles to future market growth

However, many obstacles are currently still holding back the development of the off-grid solar energy market in Tanzania and the market will only really start to grow once these can be overcome. These obstacles include the following (based on Magessa, 2008; Kassenga, 2008; Msigwa, 2010):

- high initial solar system costs largely due to a lack of competition and high distribution costs
- lower initial costs of alternative off-grid power sources, such as generators, compared to PV
- lack of awareness among potential customers and users and lack of experience with PV technology and 12-volt direct current (DC) appliances
- inadequate delivery and service infrastructure in rural areas and limited technical know-how on sizing, installation, operation and maintenance among vendors and installation technicians
- lack of business acumen, weak capital base of solar companies and high costs of doing business
- limited purchasing power among rural institutions and households and lack of finance

It seems probable that these challenges are increasingly being overcome through public and private efforts that range from the training of solar technicians and efforts to prevent counterfeit and sub-standard products from entering the market to awareness-raising. At the same time, the main obstacle that is likely to remain for many years to come is the lack of affordability of larger solar systems for wide parts of the population (e.g. Zara Solar, 2010).

3.6.3. Potential size and segments of solar market

Assuming that the constraints listed above can be overcome, a number of studies forecast the likely size and shape of Tanzania's off-grid solar market. Among the earliest reports, Karekezi (1994) cites study results that estimated Tanzania's potential market for PV systems. This study expected the potential installed off-grid capacity to reach between 25.6 MWp and 72 MWp, respectively with and without rural electrification programmes.

More recently, GTZ (2009e) particularly forecasts demand in the following areas: off-grid schools and clinics, off-grid telecoms, off-grid tourism (both PV and SWH), mini-grids and isolated grids. Undeveloped markets identified by GTZ include tourism and telecoms, with systems typically exceeding 1.5 kWp (see also GTZ, 2009d), while another market study found that in the SHS market the size of systems of most interest to households for lighting purposes would be between 10-30 Wp rather than the 50 Wp commonly marketed until a few years ago (Kassenga, 2008). Table 3 shows expected market sizes for various off-grid applications.

Market segment / solar energy technology	Size of expected market
Solar home systems	29 MWp (200-300 kWp annually until 2012)
PV in government procurement (for off-grid schools and clinics)	above 3 MWp (around 160 kWp annually)
PV in off-grid telecom installations (off-grid base stations for mobile phone networks)	above 1 MWp
PV in off-grid tourism (game lodges and tented camps)	above 3 MWp
Small-scale commercial PV systems / uses	above 2 MWp
PV projects implemented by NGOs	above 50 kWp annually (sales in 2008 exceeded 80 kWp and long-term potential is several MWp)

Table 3: Estimated potential for off-grid solar PV applications in Tanzania (based on GTZ, 2009d; GTZ, 2009g)

It is noteworthy that the expected market sizes shown in table 3 exceed those expected by reports that were written just a few years earlier, such as Moner-Girona et al. (2006),[35] which suggests increased optimism regarding the future size of the Tanzanian solar market. Interestingly, the biggest upward "revision" between 2003 and 2009 has occurred in the area of institutional systems (formerly estimated at only 790 kWp). In addition, new market segments have emerged that were not envisaged a few years ago, such as tourism and telecom.

These segments, as well as the gold-mining sector and cash-crop farmers, were estimated to have the potential for 5.5 MWp of new solar installations within five years by ESDT (2008).[36] The biggest short-term potential for small solar systems was seen in telecoms (2.7 MWp) and among agricultural small-holders (1.9 MWp). Overall, ESDT (2008) forecast the sale of around 180,000 solar systems in all four sectors, including 64,200 SHS bought by cash-crop farmers.

Likewise, the market for SWH in households and in the tourism industry is still largely undeveloped and some market observers expect that it will see some growth in the next five years, notwithstanding a current lack of government incentives (e.g. GTZ, 2009d).

3.6.4. Potential for on-grid solar systems

Another reason why the solar market in Tanzania looks likely to grow in the coming years is the increasing interest of companies and the government in on-grid uses of solar energy. At least according to some studies, grid-connected PV systems are becoming gradually more feasible as high and increasing electricity prices (above US$ 0.18 per kWh) and frequent load shedding make the switch to PV-powered backup systems increasingly attractive (GTZ, 2009d). With appropriate government support, it is expected that the first grid-connected PV systems will appear within the next four to five years (GTZ, 2009e).

One example suggesting that this expectation may indeed turn out to be correct is the Indian renewable energy company Astonfield Renewable Energy Resources, which recently announced that it is planning to invest in on-grid solar PV projects throughout Tanzania. According to press reports, up to 30 projects with a capacity of 3-5 MWp each are set to be connected to the national grid within four to five years, which would result in an on-grid PV capacity of at least 100 MWp (Kanyabwoya, 2009).

The interest in on-grid PV is largely driven by a changing regulatory environment, where the first tentative steps were recently taken with the introduction of Tanzania's first feed-in tariff for small renewable energy projects. While the tariffs paid under this price regime remain insufficient for grid-connected solar PV, the tariff for electricity supplied to rural mini-grids might induce at least some development in this field (GTZ, 2009d; EWURA, 2010).[37]

3.6.5. Interactions with global and Kenyan solar market

It appears very likely that developments on the world solar market will have a positive impact on the Tanzanian solar market. With increasing supply of solar systems (especially in the area of solar PV and SWH) and a levelling-off of demand in Germany, the world's biggest solar market, prices are likely to continue their downward trend. If, as can be expected, these falling prices reach Tanzania, costs will fall and render systems more affordable. In addition, overall system quality and efficiency rates are likely to improve fur-

[35] This report gives an estimate of around 19.2 MWp for potential off-grid solar capacity. This estimate is based on an earlier study by ESDA (2003).
[36] The ESDT (2008) market characterisation study was conducted in preparation of the "Clusters" project, which is now being implemented (see section 3.5.1.).
[37] Tariffs announced for 2010 are TZS 110.30 (US$ 0.07) per kWh for on-grid electricity and TZS 368.87 (US$ 0.24) per kWh for mini-grid electricity (EWURA, 2010).

ther in the years to come, as innovation continues in the global PV industry. Even more of a short-term impact can be expected from the recent opening of Kenya's first module factory, which is set to supply solar markets in Kenya's neighbouring countries as well. While module production in Kenya may lead to lower distribution costs and increased competition, thus lowering prices throughout the region while at the same time improving the availability of quality modules (e.g. TAREA, 2010), not everyone seems convinced that this will indeed be the case (e.g. Zara Solar, 2010).

3.6.6. Future contribution of solar energy

Despite good potential for on- and off-grid solar PV, the contribution of solar energy to the national grid is likely to remain very limited in the next decade or so. With only about 13% of Tanzania's hydro power potential (estimated at around 4,500 MW) so far being exploited, the country intends to increase its hydro power capacity significantly. However, at the same time, severe droughts and subsequent blackouts and power rationing in the past years have led the Tanzanian government to look for other energy sources, such as natural gas, coal and even nuclear power, in the medium to long term (Kassenga, 2008; Kassenga, 2010; Zara Solar, 2010).

In fact, the natural gas resources are already being developed in Tanzania and it looks likely that gas will play an increasing role in the future energy supply of the country (GTZ, 2009c). This would further diminish the potential contribution of solar energy, which may also have to compete with other RES such as wind power (e.g. Zara Solar, 2010) and geothermal energy projects that are currently being planned in Singida and Mbeya regions as well as other parts of the country. These two sources are planned with a reported capacity of around 300 MW and 700 MW respectively. TANESCO for its part does not yet seem to plan including either solar PV or CSP in its own generation portfolio (TANESCO, 2010b). This is also reflected in Tanzania's PSMP, which focuses on the expansion of coal and hydro power as shown in figure 11 below.

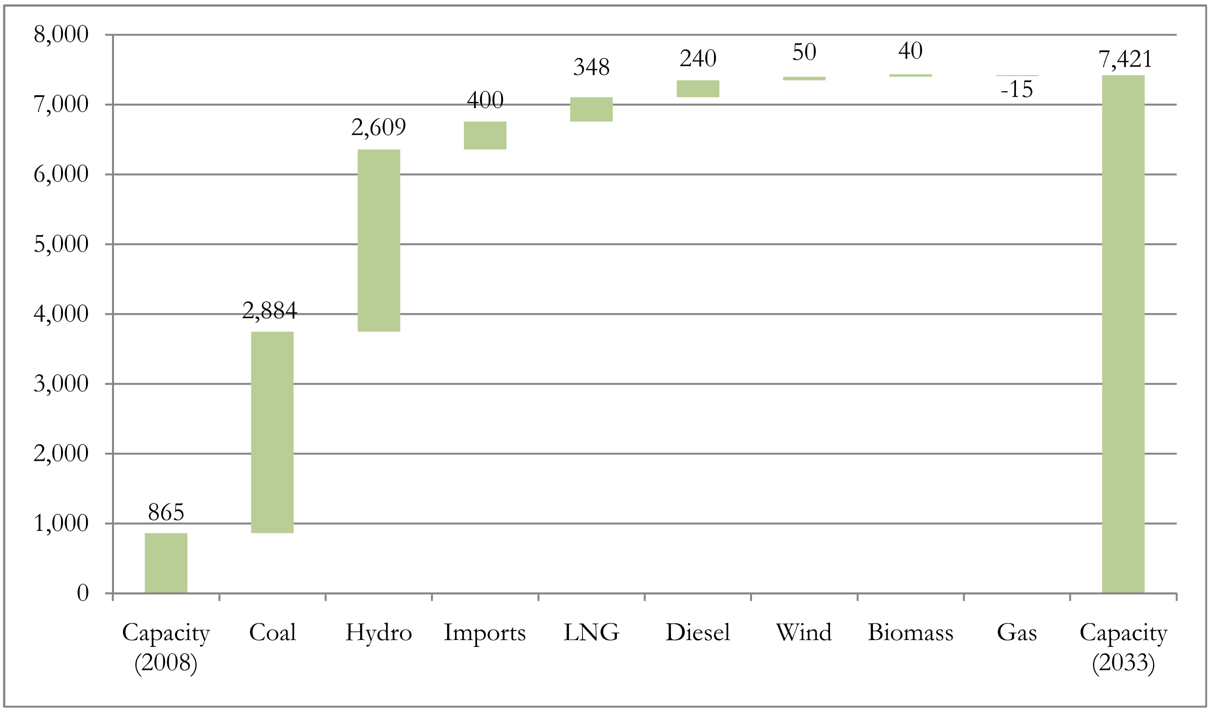

Figure 11: Planned capacity additions between 2009 and 2033 (net of decommissioned plants) according to PSMP (based on SNC, 2009)

Likewise, SWH and other uses of solar thermal energy appear unlikely to grow significantly in the coming years as the government has not yet implemented any policies aimed at a significant expansion of the SWH market. With the possible exception of the market for SWH in tourism establishments, which is already growing in size, the lack of supportive policies of the Tanzanian government will probably mean that solar thermal will remain a niche application in the next years. Nonetheless, some tentative first steps in the direction of a more vibrant SWH market seem imminent, as the government is reportedly considering making SWH mandatory for all new and refurbished buildings in rural areas (TAREA, 2010).

3.7. Summary and conclusions

Tanzania began to look into solar energy as a means to generate electricity for off-grid uses after the first oil crisis in 1973/74. In the early years of market development, the electrification of rural social institutions such as schools, churches and health centres by various off-grid solutions, including solar PV, had been the main driver behind the initial demand for solar systems in the country. Furthermore, the government and the government-owned telecoms and railway companies started to use solar power for repeater stations and radio communication systems as early as the 1970s.

In contrast, the emergence of the Tanzanian SHS market was mostly the effect of a spill-over from the Kenyan solar market. After having emerged in Kenya during the 1980s, that market expanded into Tanzania and Uganda in the late 1990s. At that time, the first companies targeting Tanzanian households started their activities and Tanzania's SHS market emerged. While none of the earliest solar companies had direct links to Kenya, their supply chain was closely linked with the northern neighbour. The close integration of the Tanzanian and Kenyan markets is still present.

Demand for solar home systems, which became the biggest market segment in recent years, was initially driven by the spread of broadcast signals and the availability of TV sets and radios. More recently, consumers have been purchasing solar systems also to charge their mobile phones and to provide lighting in their homes, which according to some sources are the main reasons for the spread of SHS.

While only limited data is available on many aspects of the Tanzanian solar market, the various market segments currently present in the market can still be described and estimated. Like Kenya and other solar markets in Africa, the Tanzanian market can be broken down into two broad segments, solar PV and solar thermal. In the area of solar PV, the market had grown from an estimated 300 kWp in the late 1990s to approximately 1.2 MWp in 2003 and has reached some 3-4 MWp since then, according to most experts. This estimate is underpinned by annual sales that reportedly grew from 70 kWp in 2002 to 200-300 kWp between 2003 and 2007. Since then the PV market has seen even stronger growth of 600 kWp and over 1 MWp in 2008 and 2009 respectively. Hence, while annual growth was traditionally 15-30%, it has considerably accelerated in the past two years.

The solar PV market can be segmented into a number of categories, with SHS and small-scale commercial systems making up around three-quarters. The remainder of the PV market largely consists of institutional systems in schools, health centres, missions and government offices, with other uses of solar PV, such as in telecoms, game parks, tourism etc. playing only a minor role at present. Due to the increasing demand for SHS, which in many cases is promoted by donor-funded programmes of the government, the role of the Tanzanian government as a buyer of solar PV systems has diminished in relative terms during the past few years. However, various government programmes for the electrification of social institutions ensure that this segment remains important.

The use of solar thermal energy with advanced technologies has so far remained small. Although some solar thermal applications can be found in agriculture, e.g. in the drying of coffee and fruits, the available information suggests that these are not yet having a major impact on agriculture. Likewise, the market for SWH remains very small according to most estimates. These currently range from 1,000 to 3,000 installed SWH, around two-thirds of which are probably used in tourism (e.g. game lodges and hotels). The remainder is reportedly installed in households and some social institutions, such as schools and health centres. In the early 2000s, only around 100 SWH were installed in the country, suggesting that sales could be anywhere between 100 and a few hundred systems per year. A large part of this uncertainty is explained by the fact that many SWH are imported from abroad without proper documentation.

In recent years, the market for solar home systems has become the biggest segment in Tanzania's solar market. While between 1993 and 2003 the market had already grown from a few hundred systems to around 500 kWp, the installed capacity had doubled to approximately 1 MWp in 2008. Since then growth has accelerated even further and the overall capacity is estimated to have doubled again during 2009 to around 2 MWp. This capacity was installed in an estimated 40,000 solar home systems by the end of 2008, with annual sales in the area of 4,000-8,000 systems. These figures as well as a 2007 household survey suggest that approximately 0.6-1.0% of rural households currently use solar energy as their main source of electricity.

The low electrification rate and increasing demand for electricity of Tanzania's rural households are the key drivers for the rapid growth in the uptake of SHS. The electrification rate still amounts to only a few percent in rural areas, while the national electrification rate slowly rises mainly due to increases in urban areas. In 2009 the national electrification rate was approximately 14%, with the vast bulk of the circa 700,000 grid connections and the grid itself located in and around the commercial and political hubs of Dar es Salaam, Dodoma, Mwanza and Arusha/Moshi. Many of the households that are far from the grid or unable to afford the high grid connection charges increasingly opt for SHS as a means to provide the electricity they require for mobile-phone charging, lighting and the operation of TVs or radios.

The majority of SHS are purchased by upper-income households in rural areas, such as cash-crop farmers and teachers. Despite somewhat falling prices, SHS remain too expensive for the majority of rural households and financing schemes to spread the initial cost of purchase are not widely available. Even where financing is available, high interest rates of 16-20% deter potential borrowers, thus making the SHS market largely a cash market. However, two recent trends slowly improve the economics and affordability of SHS. Firstly, prices are gradually falling on a national level, with a typical 50 Wp system costing US$ 380-800 in late 2010, depending on system specifications. Secondly, the market has segmented further with the introduction of small pico-systems of only a few Wp alongside bigger conventional SHS with a typical capacity of 40-50 Wp. At prices of usually US$ 10-45, these very small PV systems are vastly expanding the number of potential solar users by generating almost instant cost savings when replacing kerosene or other conventional fuels.

The energy demand of Tanzania is almost exclusively based on biomass, which accounted for around 90% of the overall energy supply in 2007. Solar energy does not play a noticeable role in the provision of the remaining energy supply, nor does it contribute in a significant way to the provision of electricity. The electricity sector has traditionally been dominated by hydro power, but is increasingly shifting to fossil fuels (especially natural gas), as new reserves are found and hydro power is becoming less reliable. Although the share of solar in the overall energy and electricity supply remains negligible, the role that solar plays in the electrification of off-grid households, institutions and businesses in rural areas must not be underestimated.

Large segments of Tanzania's solar market remain dependent on the funding and expertise of the country's government, international donors and development organisations. These actors played a very active role in the establishment of the market and remain important in the segment of institutional systems, where they act as promoters and buyers of solar systems. Furthermore, Tanzania's government provides various subsidies to rural communities, households (on a pilot basis in Rukwa region) and suppliers of solar systems in an effort to stimulate demand and supply for institutional and domestic solar systems. These efforts have been, and in some cases continue to be, complemented by large development programmes funded and run by actors such as SIDA, UNDP, GEF and IFC. On a smaller scale, national and international non-governmental organisations remain active buyers of solar systems and providers of know-how and training.

Through the efforts of these actors and the growing demand for residential and commercial systems, a solar industry has developed in Tanzania in the past ten years. This industry serves both public and private buyers of solar systems and slowly reaches all regions. In 2009 the industry was estimated to consist of around 20 major companies with an explicit focus on solar energy, some of which were subsidiaries of Kenyan solar companies. In addition to these major players, numerous importers, dealers and installation technicians are also actively providing solar systems or solar-related services throughout the country. However, despite the growth in the geographic reach of Tanzania's solar industry and the emergence of new companies during the past years, the industry is generally perceived not to be very competitive. Furthermore, poor transportation infrastructure and high transaction costs lead to high consumer prices, while quality of products and installations is reportedly still poor in many cases.

Economic growth, rising incomes and population growth will lead to growing energy demand in Tanzania, suggesting that the country's solar energy market will grow during the coming years. If current trends in rural electrification persist, much of that electricity demand will not be met by grid electricity and many observers point towards solar energy as a potential solution for the energy needs of Tanzania's rural population. The biggest contribution of solar energy is expected in the area of household lighting, where some 90% of households currently use expensive kerosene lamps that could be replaced by solar systems. This and the growing diffusion of mobile phones suggest that pico-solar systems could play an especially important role in the growth of Tanzania's solar market.

At the same time, solar could advance further in the area of traditional SHS and institutional systems, if a number of obstacles can be overcome that include the high initial cost of solar systems, a lack of awareness and know-how and the limited availability of (quality) systems throughout the country. As these issues are slowly being addressed by a number of initiatives, and with positive impetus from the global solar market, the Tanzanian solar market seems set to grow swiftly for many years to come. Experts therefore estimate that the SHS market could grow by 5.5 MWp within five years, with the overall potential for the off-grid PV capacity expected to lie between 25 and 70 MWp.

While the largest potential for near-term growth is seen in off-grid solar PV installations, the outlook for SWH and grid-connected solar PV systems is also positive. However, these depend on an enabling regulatory framework to a much larger degree than off-grid uses. While some tentative steps have been taken to promote SWH and on-grid solar PV, the government so far does not seem to intend to go much beyond current policies. This is reflected in the government's Power System Master Plan for the electricity sector, which almost exclusively focuses on the expansion of coal and hydro power. Therefore, it appears likely that solar energy will continue to contribute to rural electrification, while not playing a major role in the wider energy and electricity mix of Tanzania.

In conclusion, it is probably appropriate to argue that the Tanzanian solar market is slowly developing into a viable market in its own right and no longer just the spin-off of the Kenyan market that it was during the early stages of its development. While a lot of the initial impetus, ideas, know-how and money for the development of Tanzania's market certainly came from its northern neighbour, the market in Tanzania is now reaching a stage where domestic demand sustains the solar industry and the supply chain becomes less and less dependent on Kenya. Nevertheless, personal and professional links between solar market participants in both countries remain strong and may even become stronger as the East African Community (EAC) deepens the economic integration in the region.

While Tanzania continues to catch up with Kenya, the relative importance of the various market segments shifts in a way that has also occurred in Kenya before. While installations of institutional solar systems in schools, health centres etc. were critical demand drivers in the early years of Tanzania's solar market, the most important segment these days appears to be SHS. Demand for these systems was reportedly behind much of the strong growth seen in 2008 and especially 2009, which led to a doubling of the installed capacity within just one year. This demand is driven mostly by the consumption choices of private households and thus to a large degree independent of government action. The rise in the SHS market and probably even more so the market for pico-solar systems illustrates the potential for transforming energy consumption patterns even under difficult conditions. But it also shows the need for entrepreneurs making the right choices in selecting markets und designing products that meet the needs of consumers at an affordable price.

Despite these apparent successes, the Tanzanian solar market remains far behind its potential. With only 0.6-1.0% of rural households currently using solar electricity, much of the off-grid potential is clearly untapped. Likewise, other market segments, such as SWH, where solar energy could play a potentially bigger role are also still in their infancy and the overall contribution of solar energy to the energy and electricity supply of Tanzania remains minuscule. This observation leads to the conclusion that without more forceful government or donor intervention, the solar market will probably continue to grow strongly, yet still remain far behind its potential for a long time, as numerous obstacles hold back even brisker growth.

Awareness of these obstacles is reflected in the activities of development agencies, NGOs and the government, with examples of programmes and projects aimed at capacity building and market development abounding. At least some of these examples illustrate the potentially beneficial role that these actors can play in kick-starting or sustaining demand, raising awareness and spreading technical and business know-how. The Tanzanian market will probably remain dependent on such programmes for at least some more years as the country's solar industry is still in such an early stage that further efforts to increase its capacities, technical skills and geographic coverage are needed. Without these efforts, market growth would probably be slower or could even stagnate as private-sector actors struggle to reach more customers.

One aspect that future government or donor projects should pay even more attention to is the apparent lack of competition in the market for solar systems and components in Tanzania. There still seem to be too few companies active in all regions of the country on all steps along the value chain so that prices are still higher, availability and quality lower than should be achievable with a more competitive and more efficient industry.

However, the government and its international partners will probably only invest more funds and political capital in the further promotion of solar energy, if they are convinced that using more solar resources is economically reasonable by providing a cost-efficient means of supplying energy. This includes untapped applications such as on-grid PV and SWH, where the government so far has shown no real interest in implementing policies that would make investments in these really attractive. However, even here the government is at least slowly starting to formulate policies, albeit ones that are not yet very ambitious. Therefore, the biggest potential in the next years will most certainly lie in those market segments that are largely independent of government policy, where the outlook is generally good for the reasons outlined before.

4. Comparison of the Kenyan and Tanzanian Solar Energy Markets

A number of similarities between Kenya and Tanzania would suggest that the solar energy markets of these two countries could have developed in more or less the same fashion. However, as the analysis of both markets in chapters 3 and 4 has shown, there are some fundamental differences in their development paths as well as their current shapes. Therefore, a comparison of the Kenyan and the Tanzanian market and an analysis of the observed differences should not only provide useful insights into the drivers behind Kenya's and Tanzania's market but also allow a better understanding of the factors influencing the development of solar energy markets more generally.

The remainder of this chapter is structured in the following way: Section 4.1 presents some arguments that suggest that the Kenyan and Tanzanian solar markets initially faced very similar conditions for their emergence and subsequent development. Following this, section 4.2 compares the most important aspects of the development and current status of these markets and highlights major similarities and differences, and section 4.3 provides a brief summary and draws some conclusions.

4.1. Conditions for market development

Since the early days of solar energy use in East Africa, i.e. since the 1970s, some external conditions for the development and growth of the solar energy markets in Kenya and Tanzania have been quite similar. Given this similarity in conditions it might be assumed that the solar energy markets in these two countries could have developed in much the same way, yet the following comparison of the actual development paths and the current status of solar energy use shows that despite the apparent similarities, other factors must have been at work as Kenya's and Tanzania's markets did neither develop in a similar fashion nor at the same pace.[38]

Before looking at the differences in more detail, a number of observations regarding similar starting conditions for the development and growth of the solar energy markets in Kenya and Tanzania can be made: Firstly, the "solar energy endowments" of Kenya and Tanzania are quite comparable. The solar irradiation levels of both countries range from around 1,460 to 2,430 kWh/m² per annum. Both countries are situated near the equator and feature largely comparable geographic and climatic characteristics (notwithstanding some variations between and within the countries), implying that the physical resource potential in both markets in terms of solar irradiation that could be used for energy services, such as electricity generation and water heating, is quite similar.

Secondly, when becoming independent in the 1960s and continuing through to this decade, the population sizes of Kenya and Tanzania have been relatively comparable. While Kenya's inhabitants numbered some eight million in 1960, Tanzania's population was only slightly larger at around ten million (World Bank, 2010a). By the year 2000, the Kenyan population had almost quadrupled to 31 million whilst that of Tanzania had more than tripled to 34 million. By 2008 (the latest available year), Kenya's inhabitants numbered 38.5 million and Tanzania's population stood at 42.5 million (World Bank, 2010a). One can therefore argue that the population sizes as well as the average population growth rates, of 3.3% and 3.0% respectively, are overall very similar. Likewise, urban migration has occurred at largely identical rates, with 22% of Kenyans and 25% of Tanzanians living in urban areas in 2008 (World Bank, 2010a).[39]

[38] The identification and analysis of possible reasons for the differences described and analysed in this working paper will be undertaken as part of a forthcoming paper. This paper will also attempt to draw more general conclusions for policymakers regarding the promotion of solar energy in developing countries.
[39] However, due to Tanzania's larger land area, its population density of 48 inhabitants per km² is considerably lower than that of Kenya at 68 inhabitants per km² (World Bank, 2010b).

Thirdly, while there was a marked difference between Kenya's GDP of around US$ 30bn and Tanzania's economic output of some US$ 21bn as well as the GDP per capita of US$ 780 and US$ 490 respectively in 2008, both countries rank similarly when compared with other nations both on a GDP per capita basis and on the measure of GNI per capita at purchasing power parity, with both countries located in the bottom 15% of countries worldwide (World Bank, 2010a). Thus, whereas the differences in the level of economic development of both countries are quite marked when comparing them directly, the absolute differences are quite small once one contrasts the economic output of both countries with that of other developing economies and middle and high income countries. This suggests that both countries have for the past fifty years been and largely still are at a similar stage of economic development.

Fourthly, a look at the energy supply and energy consumption patterns of the two countries suggests that the energy sectors of both countries are also quite similar. Both countries depend heavily on biomass for their energy needs, which accounts for around 74% and 89% respectively of Kenya's and Tanzania's primary energy supply. The remainder is largely comprised of fossil transport fuels and the generation of electricity, which traditionally has been dominated by hydro power. As rainfalls are becoming more intermittent, both countries are now shifting away from hydro power towards new energy sources such as geothermal and natural gas, with plans for an expansion of thermal power also underway. In addition to a move away from hydro power, both countries are expanding their power generation capacity in an attempt to meet rising electricity demand, which is largely the result of continued population and economic growth (and not so much per-capita consumption of electricity, which is growing only slowly, according to World Bank, 2010).

Lastly, while per-capita consumption of electricity has grown only slowly in the past decades, this is partly the result of the last major parallel in the external conditions for the growth of the solar market. As pointed out in the second and third chapter, electrification rates in both countries remain very low in rural areas, implying that millions of potential electricity users are effectively excluded from this part of the energy market. Without access to the grid, these rural households are obviously not able to consume any electricity, which may explain the near-stagnation in the per-capita electricity consumption figures recorded over the past decades. As was further explained in the previous chapters, this lack of advances in rural grid-connections effectively serves as one of the key drivers for the demand for solar energy technologies. Despite the fact that Kenya's rural electrification rates have recently improved faster than those of Tanzania, for most of the past four decades their development in this area was quite similar.

While Kenya and Tanzania exhibited a number of conditions that could have suggested similar developments in the use of solar energy, the solar markets of Kenya and Tanzania have in fact developed quite differently over the past 30 to 40 years. This section will highlight some of the major differences that can be observed in the historical development as well as the current state of solar energy markets in both countries by drawing on the preceding chapters.

4.2. Early market development

While both countries started to look into solar energy technologies as a result of the oil crisis of 1973/74, the development of their solar markets diverged quite quickly. With the exception of the use of solar technologies for government-funded telecommunications and broadcasting systems, which was pursued by both countries from the 1970s onwards, Kenya started to adopt solar technologies much earlier than Tanzania. Whereas institutional solar systems were starting to appear in Kenya in the 1980s, it took until the 1990s for Tanzania to also adopt solar technologies for the electrification of schools and other social institutions.

Subsequently, the Kenyan market expanded into the consumer segment with the appearance of the first solar companies that targeted households and introduced solar home systems in the early to mid 1980s. In contrast, it took Tanzanian and Kenyan companies more than one decade until they started serving the residential market of Tanzania with SHS in the early 2000s, and for a number of years that market did not reach much beyond the biggest Tanzanian cities. While the Kenyan market therefore reached a certain maturity already in the 1990s, Tanzania's market was for a long time lagging behind by at least one decade and probably closer to two decades in terms of the geographical reach and maturity of its solar industry.

4.3. Market size and segments

As a result of the earlier emergence and faster growth of the Kenyan solar market, its PV market is now much bigger and more diverse than its Tanzanian counterpart. Whereas the Kenyan market had already reached a cumulative capacity of 1.5 MWp in the early 1990s and about 3.9 MWp by the year 2000, Tanzania's market had only increased from approximately 300 kWp in the late 1990s to around 1.2 MWp in 2003. Today, Kenya's market is estimated at roughly 8 to 10 MWp of cumulative installed capacity, while Tanzania's is still less than half as big with an estimated capacity of around 4 MWp. However, when it comes to annual sales, Tanzania's solar market has been catching up quickly: Sales have reportedly reached between 1.2 and 1.5 MWp in 2009 alone (Camco, 2010), which is about as much as was reported for Kenya, where annual sales are currently estimated at 1-2 MWp.

While the overall size of the Kenyan market still differs from that of Tanzania by a factor of around two, the major market segments found in Kenya are also found in Tanzania. In both countries the SHS segment makes up around 75% of the market and the remainder is dominated by institutional systems in off-grid schools, where the government or donors act as project sponsors. However, Kenya appears to be ahead in the introduction of more novel uses of solar technologies, such as off-grid power for mobile phone base stations, solar PV in the tourism industry and solar-powered mini-grids in rural areas, where only limited applications are currently reported to exist in Tanzania.

The lead of Kenya is probably most pronounced in the area of solar thermal technologies, where over the years an estimated 55,000 to 70,000 solar water heaters have been installed in urban households and the tourism industry. This contrasts very sharply with the much lower estimate of 1,000 to 3,000 SWH in Tanzania. Other uses of solar thermal energy, on the other hand, are equally rare on both sides of the border, with only a few cases of solar energy for crop drying and the like being reported.

The market for SHS has been the key driver behind the growth in solar energy use in both countries for a number of years, overtaking institutional systems as the biggest market segment both in annual sales and in the cumulative installed capacity. The Kenyan SHS capacity grew to an estimated 6-8 MWp in 2009, while Tanzania's capacity in the same year was around 2 MWp. While annual sales in Kenya have been between 200 kWp and 500 kWp during the past decade, sales in Tanzania have seen especially strong growth in 2009, when sales doubled to over 1 MWp.

These marked differences between Kenya and Tanzania are also reflected in the number of SHS that are sold annually and in the total number of installed SHS. Whereas between 20,000 and 40,000 SHS were already installed in Kenya in 1993, only 256 domestic PV systems were counted in Tanzania during that year. Since then, the numbers in Kenya have grown to an estimated 320,000 SHS, while in Tanzania 40,000 SHS are now in operation. This means that the Tanzanian market has now reached as many households as Kenya probably reached already some 17 years ago. Based on the latest available figures, some 15,000-20,000 SHS were sold on average in Kenya during the past two to three years, while in Tanzania sales in 2009 reached around 20,000, suggesting a certain convergence in annual sales between the two countries.

4.4. Domestic uses of solar

Consequently, the time-lag in the development of the Tanzanian solar market is also reflected in the diffusion of solar systems among rural households. Whereas this had reached almost 3.6% in Kenya in 2007 (and almost 4.5% in 2009), the number of rural households using solar electricity was only 0.6% in Tanzania in the same year, i.e. Kenya's diffusion rate for solar energy was about six times as high as that of Tanzania. Given that many of the conditions for the use of solar energy are quite similar in both countries, this figure may illustrate the potential for future growth in Tanzania's SHS market.

The drivers behind households' desire for solar electricity and hence SHS are quite similar in Kenya and Tanzania. However, while the spread of TV and radio signals and the subsequent need to power TVs and radios was largely behind the demand for SHS in Kenya in the 1980s and 1990s, Tanzania's rural households nowadays have somewhat different energy needs as the black-and-white TVs in fashion in the 1980s and 1990s have been replaced by colour TVs. This shift to more energy-hungry TV sets is of course not limited to Tanzania, but probably also necessitates bigger SHS in Kenya. At the same time, the charging of mobile phones has become a new demand driver for SHS in both countries. This, however, probably leads to a new differentiation of the market, in which bigger systems necessary for colour TVs become more common at the same time that very small, or "pico", systems become available that only serve to provide electricity for lighting and phone-charging.

Common to both countries is the prevalence of low electrification rates especially in rural areas as the underlying cause for most of the demand for SHS as well as institutional systems. As the need for electricity of Kenyan households and rural institutions could not be met by buying electricity from the grid, many of them turned to solar systems as an attractive off-grid solution. While the low rates of new grid connections continued throughout much of the past thirty years, the missing prospects of an affordable grid connection led many rural electricity consumers to purchase solar systems despite their technical constraints and initial costs. The same applies to the Tanzanian market, where rural electrification rates are even lower and the probability of the grid reaching all parts of the country within the next decades is even more remote than in Kenya, suggesting that solar energy will remain an attractive source of electricity in the country for a long time.

The income levels of SHS owners have been extensively researched in Kenya and studies found that these systems tended to be bought by the wealthiest part of the rural population. While this trend has generally continued, increasing rural incomes and falling SHS prices have led the SHS market to reach further down the income ladder. Reports and anecdotal evidence from Tanzania suggest that there, like in Kenya, a key ingredient for the successful expansion of the solar market has been the increasing purchasing power of rural middle class households, such as cash-crop farmers and rural teachers. While energy expenditure is also quite high relative to income among poorer rural households, the lack of credit or other financial instruments has meant that many households in both countries have not been able to afford a solar system even if it would have been in their interest for reducing their long-term energy costs.

4.5. System prices and sizes

Prices for SHS have almost always been higher in Tanzania than in Kenya for a number of reasons, such as a smaller domestic market, less competition and high transaction and logistics costs. These reasons were analysed in more detail in ESDA (2003). In September 2010, a typical SHS of 50 Wp reportedly cost US$ 9.5-16 per Wp in Tanzania (i.e. US$ 475-800) while in Kenya a similar system was reported to have cost US$ 6-12 per Wp (i.e. US$ 300-600). Although it is particularly difficult to directly compare such price quotes due to the fact that it is not always clear what parts such a "typical" SHS consists of, it seems that prices in Tanzania exceed those in Kenya by a considerable amount.

At the same time, the average size of such "typical" SHS seems to be more or less identical in both countries. While small a-Si-modules with a capacity of 12-14 Wp helped turn Kenya's market during the 1990s and later also Tanzania's solar market into something of a mass-market by making solar systems more affordable, the average system size has increased again to close to 50 Wp with a wide variation in the module capacities on offer in both countries. Product differentiation has thus enabled the segmentation of the SHS market and increased the product variety from which consumers can choose depending on their energy needs and purchasing power, among other determinants. In this respect, the emergence of pico-solar systems is a common feature in both countries but it appears that the Tanzanian market is more actively pursued by companies offering such systems than the Kenyan market.

4.6. Industry structure and participants

A further difference between Tanzania and Kenya lies in the structure of their solar industries. While the latter comprises hundreds of smaller and dozens of larger companies active in the manufacture of solar batteries, BOS components and since late 2010 also solar modules, as well as the sale, installation and maintenance of solar systems, the former focuses almost exclusively on the sale, installation and maintenance of solar components and systems. In other words, the earlier emergence and bigger size of Kenya's solar market have led to the development of a solar industry that is able to cover many more parts of the value chain than its Tanzanian counterpart. As a result, while Tanzania needs to import nearly all its solar systems from other countries, not least from Kenya, a lot more of the manufacturing required for Kenya's market is occurring locally.

The role of the government, donors and NGOs in establishing a nationwide solar market was arguably more pronounced in Tanzania than in Kenya. While in the latter case, the government supported the development of the solar market in its early stages through purchases of solar systems for institutional uses, the Tanzanian government and its development partners have played a much more active role in the promotion of solar energy, which continues to this day. Despite the fact that the Kenyan MoE also continues to procure solar systems for rural institutions, involvement of the government and donors is clearly more important for the continued development of Tanzania's solar market.[40] There, both the government and various development institutions continue to act as buyers of solar systems and to implement large existing market development programmes. In contrast to Kenya they also initiate entirely new programmes, such as the World Bank's TEDAP project. At the same time the "Lighting Africa" initiative for pico-solar systems that was pioneered in Kenya is now being rolled out to Tanzania and other countries, but this is a rare example of a larger donor-funded PV project taking place in Kenya.

4.7. Role of solar energy

Solar energy does not play any considerable role in the energy or electricity supply of either country. While solar is an important source of electricity (and in the case of SWH also thermal energy) for those households, institutions and business that have installed a solar system, the contribution of solar energy to the overall primary energy supply or the electricity generation mix is negligible. This is not to negate the contribution that solar energy makes to improving the living standards and to enlarging consumption choices of those households in Kenya and Tanzania that use solar energy as their main source of electricity or to the hundreds of thousands of students, patients and other recipients of public services that receive better schooling, treatment or services as a result of solar electrification, but for the overall economy, the role of solar energy is still very small in both countries.

[40] Nevertheless, some experts point out that the absolute spending on solar systems in social institutions was actually higher in Kenya than in Tanzania (e.g. Hankins, 2011).

4.8. Market outlook

The outlook for the solar energy markets in Kenya and Tanzania is equally bright. But it can be expected that the markets of both countries will develop in different ways during the coming years. Whereas Tanzania's market looks set to continue following the trends set by Kenya during the 1990s and 2000s, the Kenyan market appears to be at a turning point when it comes to future uses of solar energy. For Tanzania, most studies and experts expect the market to continue along the lines of the past few years, i.e. with two major market segments moving the market forward. These segments are firstly the SHS market, which is expected to continue its growth path as the market reaches all corners of the country and as solar systems become more affordable for wider parts of the population, both through declining prices and novel approaches to financing (such as those pioneered by the "SSMP" and "Clusters" projects under TEDAP). Secondly, the purchase of institutional systems funded by the government and development partners looks set to continue and might even be expanded during the coming years, as solar and other renewable energy sources are increasingly used for the electrification of rural institutions.

On the other hand, newer applications of solar technologies will probably not appear on the Tanzanian market on a noticeable scale due to the lack of government incentives for applications such as SWH and on-grid PV. With the likely exception of a few solar systems in rural mini-grids that are reportedly already under development, the current feed-in tariffs for solar PV are not yet attractive enough for the wider adoption of this technology. Likewise, in the absence of government incentives for the promotion of SWH, this technology will not grow much during the next years as subsidised electricity prices render SWH unattractive in urban environments. However, SWH might continue to be installed in off-grid tourism establishments, where affordability is not such an issue, assuming that quality concerns can be overcome.

In contrast to the likely continuation of present market trends in Tanzania, the solar market in Kenya looks set to undergo a fair amount of change as it continues to grow. While the government's procurement of institutional systems is expected to continue along the lines of the past few years, the future of the SHS market will depend on the success of Kenya's rural electrification programme. If this programme starts to be perceived as a step in the right direction, rural households may refrain from buying a SHS in anticipation of connection to the grid. However, while this might depress demand for SHS in the long run, it seems unlikely to impact much upon the demand for SHS during the next years. The bigger changes in Kenya's solar market can therefore be expected to come from changes in government policy. In this regard, changes are likely both in the field of SWH, where the recent introduction of regulation will most probably lead to tremendous growth in the number of installed SWH, and in the context of on-grid or mini-grid solar PV systems. While no major policies for the promotion of grid-connected solar PV have yet been finalised, discussions among regulators, policy-makers and the business community are going on at the moment that suggest that such policies are likely to be implemented within the next one to two years. Once adequate policies are in place, Kenya looks set to lead the way in East Africa once again by becoming the first major market in which grid-connected solar PV could take hold alongside the off-grid variety.

Until this happens, solar energy will remain limited to off-grid uses and play no important part in the energy and electricity mixes of both countries. While the role that solar plays in providing energy to rural households and institutions will grow, it will make a positive contribution to the well-being and development of a large number of rural people. At the same time, growth in the use of other energy sources, both for primary energy and electricity supply, will mean that the overall contribution of solar energy will continue to be small until the solar markets of Kenya and Tanzania reach a larger scale. This scale, however, appears unlikely to be ever achieved if solar is only used in (very) small applications far from the grid. This is not to say that a small contribution of solar energy must necessarily be an undesired outcome, as any larger role will only be justified if the benefits of this larger role exceed the costs associated with an increased use of solar energy. To this end, the governments of Kenya and Tanzania so far seem to have concluded that this is not the case, as the long-term plans for their power sectors show.

4.9. Summary and conclusions

While the origins of Kenya's and Tanzania's solar energy markets were largely similar, Kenya's market developed much faster than its Tanzanian counterpart for much of the past 30-40 years. While the adoption of solar energy technologies for the electrification of rural institutions occurred in both countries roughly at the same time, the emergence of Kenya's SHS market led to rapid growth in the installed solar capacity in that country while the Tanzanian market developed much more slowly.

The Kenyan lead continues until today and is especially visible in the SHS market, with many more SHS sold and installed in Kenya than in Tanzania. Furthermore, the lead is also evident in the breadth of the Kenyan solar market and its solar industry, where the market segments are more diverse and the number of companies serving the various market segments is much higher. Moreover, whereas Kenyan companies are already active in the manufacturing of solar products, Tanzania still imports almost all its solar components. While Tanzania is slowly catching up in both respects, Kenya looks set to lead in the further deepening of its solar market by expanding or opening up new market segments, such as SWH and grid-connected PV systems, for which government policies have been implemented or are being formulated at the moment.

Despite these apparent differences, it is probably right to argue that the Kenyan and Tanzanian solar markets have much in common. Not only do they share many of the same conditions for the development of a solar market, but the development paths and characteristics of their markets are also relatively similar. In conclusion, this leads to the following observations. Firstly, Kenya clearly led the way in the development of a solar market. Its lead over Tanzania in the early stages of market development lasted almost two decades for the segment of solar home systems, and to a large degree this lead persists until today. Nevertheless, Tanzania now seems set to catch up with Kenya, which can be seen both by the advances made in the SHS market and the electrification of social institutions.

Secondly, as Kenya's market extends into new segments, Tanzania's appears to be converging with Kenya's in the more "traditional" segments of institutional systems and solar home systems and it could well be that the Tanzanian market will eventually overtake Kenya in these segments. This assumption of Kenya being overtaken by Tanzania is based on the fact that whereas Kenya makes steady progress in extending its electricity grid, Tanzania's grid seems a long way off from reaching many remoter parts of the country within the foreseeable future. This suggests that the rationale for using solar or other off-grid technologies on a much larger scale could be bigger in Tanzania than in Kenya.

Thirdly, within the next decade or so it might no longer be appropriate to speak of *the Kenyan* and *the Tanzanian* market as both markets might converge to such a degree that they become so intertwined that it will be more appropriate to speak of *the East African* solar market (maybe also including Uganda, Rwanda and Burundi, and possibly other countries in the region). Despite the importance of national policies for the growth of solar energy markets, such a scenario could easily happen if current trends towards cross-border solar businesses are reinforced by economic integration under the auspices of the EAC. Furthermore, if and when the use of solar energy becomes less dependent on government incentives (e.g. due to falling capital and generation costs), the economic rationale for a truly integrated solar market will increase even further, possibly leading to a full convergence of Kenya's and Tanzania's solar markets.

5. Summary and conclusions

Developing countries in general and African nations in particular face two concurrent challenges in the field of energy policy that might be called the "energy challenge". This challenge consists firstly of the need for an expansion of modern energy services and secondly the development of energy sectors that do not endanger the long-term sustainable development of these nations or the planet. Modern energy services in this context especially mean the access to clean cooking fuels and electricity, which are necessary for the growth of African economies and for improving the living conditions of their populations. In this respect, Kenya and Tanzania are examples of low income countries that face these challenges and that therefore can serve as case studies on how individual nations attempt to provide their populations with the energy needed for their economic and social development.

Developing countries can choose from a variety of options to increase access to modern energy services and their ultimate choice will depend on a number of factors. Chief among these factors are the physical and technical availability of various energy sources, such as fossil fuels and renewable energies, but also the economics and the politics of using one source of energy or another (or, most probably, a combination of several sources). At the same time, legacies play an important role as they can perpetuate energy policies that are typically focused on large centralised power systems which employ capital intensive energy sources such as hydro power and thermal plants.

However, it looks increasingly doubtful if these conventional energy systems will be able to cope with the demands of the energy challenge, or whether alternative approaches are in fact needed that put a much bigger emphasis on decentralised renewable energy sources. Kenya and Tanzania are naturally endowed with many renewable energy sources, including hydro, geothermal, biomass, wind and solar energy and in order to meet the energy challenge they will probably have to use more of them in the coming decades. Solar energy has been the one resource that has in the past been at the centre of much of the policy debates and research efforts. Solar energy has also featured prominently in the efforts of the governments of Kenya and Tanzania, as well as their partners in the international development community, for its potential role in providing electricity to rural communities far from the electricity grid.

Despite being endowed with very similar solar irradiation levels and in many ways near-identical starting conditions, Kenya's solar market has developed much more vibrantly over the past 30-40 years than its Tanzanian counterpart. Studying the different development paths that solar markets have taken north and south of the border therefore allows a number of interesting observations and lays the foundations for further research into the drivers and obstacles for the increasing use of RES across the developing world. While this working paper focuses on the description and analysis of the development and status of solar energy markets in both countries, analysing the observed differences in more detail is open to future research.

The solar energy market of Kenya, much like its Tanzanian counterpart, started to develop in the wake of the first oil crisis in the 1970s. After both markets initially developed in a similar fashion, Kenya's market began to speed away during the 1980s and continued to expand its lead over Tanzania during the 1990s. Today, the Kenyan solar market is one of the biggest solar markets in the developing world and by far the biggest markets on the African continent. An estimated 8-10 MWp of solar PV capacity are currently installed in the country, which is very small in comparison with the world's leading solar PV markets, but large by regional standards. The installed PV capacity consists largely of SHS, which are currently estimated at some 320,000, as well as institutional systems in rural areas. Furthermore, Kenya already features a sizeable market for SWH (some 55,000 to 70,000 are currently installed in Kenya), while new market segments such as PV systems in tourism and telecoms are slowly appearing.

Tanzania's solar market on the other hand has only really begun to develop during the past one or two decades, i.e. with a lag of almost twenty years compared to Kenya. Since the early 2000s, the Tanzanian market has grown to an installed PV capacity of around 4 MWp, which like Kenya largely consists of SHS, currently estimated at about 40,000, as well as institutional systems that are provided by the government with funding from donors. Other market segments are still much less developed in Tanzania than in Kenya. For instance, only 1,000 to 3,000 SWH have so far been installed in the country and other market segments, such as PV in tourism and telecoms, are still in their infancy. Nevertheless, the Tanzanian market seems to be rapidly catching up with Kenya in some segments, such as the market for SHS and institutional systems, where annual sales recently equalled those of Kenya.

The drivers behind the increasing use of solar energy so far have been quite similar in both countries. The main use of solar PV to date has been in the provision of electricity in areas not connected to the electricity grid. Governments and donors have increasingly used solar energy for the electrification of social institutions in rural areas, where solar PV contributes to the development of rural communities by lighting schools and health centres, cooling vaccines and medicines, and pumping water for drinking and irrigation. Likewise, hundreds of thousands of rural households have opted for solar energy in order to provide them with the electricity needed for the running of TV sets and radios, the lighting of their homes and more recently also the charging of their cell phones. The spread of solar can therefore be seen as a direct result of the lack of electrification, but also rising incomes and living standards in rural areas, that have increased both the demand for and the affordability of solar energy systems. This affordability of solar systems was driven largely by improvements in solar energy technologies that increased the diversity of solar products to suit the needs of different customer groups and reduced costs as the technology matured.

First in Kenya and later also in Tanzania, a whole solar industry emerged that became more and more adept at catering to the needs of the different market segments. The solar industry was pioneered in Kenya, but today both countries feature industries that are increasingly reaching more customers in more regions, and thus raise the awareness for and availability of solar technologies, while also increasing their affordability through tailored products and rising competition. Yet given the lead of the Kenyan solar market, Tanzania's solar industry still lags Kenya's in some important aspects, not least the breadth of the value chain, which includes no major manufacturing activities in Tanzania, whereas Kenya's solar industry even expanded into module manufacturing in 2010. At the same time, Tanzania's solar industry has traditionally been very reliant on the Kenyan market as a source of innovations and for much of its supply chain, and the close relationship between both markets continues to this day.

Governments, donors and NGOs have been of very critical importance for the emergence of the solar energy markets in both countries. They acted both as buyers of the first solar systems and facilitated the development of solar markets, e.g. by training technicians and by funding solar programmes. The role of these actors remains important in both countries, but the approaches to further market development have diverged in some significant ways. While the governments of both countries (usually with the support of donors) remain very important buyers of institutional solar systems, the Tanzanian government, donors and NGOs also continue to play a particularly active role in the further development of Tanzania's solar market. Whereas in Kenya the government has taken a very hands-off approach to the development of its solar market, Tanzania is a showcase for numerous efforts both past and present to promote its solar market.

Despite almost 40 years of market development and their large solar endowments, Kenya and Tanzania at present use only very little solar energy for the provision of modern energy services. The role of solar energy in both countries so far remains mostly limited to rural areas. There, an estimated 4.4% of households in Kenya and a reported 0.7% of households in Tanzania currently use solar energy for their electricity needs. Furthermore, thousands of rural institutions use solar energy when the grid is far away. Yet despite the importance of these systems for rural communities, the overall contribution of solar energy to the supply of primary energy or electricity is still minuscule. Assuming that current government policies do not change, this contribution of solar will remain far behind its potential, which may not be in the long-term interest of both countries.

The past solar market development suggests that future government policies will be crucial for the direction that further development of solar energy markets in Kenya and Tanzania takes. Whereas Kenya's largest market segment has mostly developed without active government involvement, the entire solar market of Tanzania is much more the creation of an active government, its supporters and the NGO community. This suggests that decisions by these actors will shape the future of markets in Kenya and Tanzania. However, these directions could diverge significantly during the coming years, as Kenya's government looks set to promote new uses of solar energy much more vigorously than Tanzania's, especially in the fields of SWH and on-grid solar PV. At the same time, the effectiveness of the rural electrification programme and procurement programmes for institutional systems will determine the future of today's biggest market segments in Kenya, while in Tanzania the market looks likely to follow recent trends by seeing further growth in the markets for SHS and institutional systems, but only half-hearted efforts at enabling new applications.

To a large degree, the future development of markets in both countries will depend on the economics of using solar energy in a variety of contexts. As long as both countries perceive solar energy to be an expensive technology that can only be used beneficially under certain conditions, the solar markets will be constrained by the affordability of solar technologies both on the level of individual households and the economies at large. However, once the costs of solar energy have decreased to a point where the economics rationale for an increased use of solar become clearer, one might assume that the solar markets of Kenya and Tanzania will converge in such a way that the differentiation between them becomes obsolete. Yet even before that point, it might be expected that a far deeper integration and convergence will occur between the market segments that already exist, such SHS and institutional systems, where policies and markets might unite much earlier. Ultimately, this may lead to the creation of an East African solar market that spans the entire region and where the orientation along national borders will become much less important than that along products, companies and customer groups.

The energy challenge, the growing use of renewable energy sources and the expansion of solar energy markets all merit further research that supports policy-makers and market participants alike. Based on the research and analysis undertaken for this working paper, the following aspects appear to merit particular attention:

Generally, the availability of reliable and comprehensive data on almost all aspects of the use and promotion of solar energy in Kenya and Tanzania needs to be improved considerably in order to facilitate further research. The availability of data, or rather the lack thereof, has been one of the predominant problems for many a researcher and better data would clearly allow for better research in the future.

More specifically, the reasons for and the lessons learnt from the different development paths and paces in the emergence of solar energy markets in Kenya and Tanzania should be investigated further. Likewise, the present and future economics of solar energy should be analysed in more detail in the context of these two markets, as such analysis would allow for informed policy making and the design of appropriate policy measures. Lastly, individual aspects of solar energy use should also be examined more closely, as for example insights into fuel choice decisions of households would enable the better understanding of the drivers behind SHS purchase decisions.

References:

Acker, R., Kammen, D.M., 1996. The quiet (energy) revolution: analysing the dissemination of photovoltaic power systems in Kenya. Energy Policy 24, 81-111.

Adenikinju, A., 2008. Promotion of public private partnership to improve energy access for poverty reduction and growth in sub-Saharan Africa. Paper prepared for OFID Workshop on Energy Poverty, June 9-10, 2008, Abuja, Nigeria.

AFREPREN, 2003. Renewable energy technologies in the Eastern and Horn of Africa region: summary for policymakers. Africa Renewable Energy Policy Research Network (AFREPREN), Nairobi, Kenya.

Alfayo, R., Uiso, C., 2002. Global solar radiation distribution and available solar energy potential in Tanzania. Physica Scripta T97, 91-98.

Bailis, R., Kirubi, C., Jacobsen, A., 2006. Searching for sustainability: Kenya's energy past and future. African Centre for Technology Studies (ACTS), Nairobi, Kenya.

Bonyo, J., 2009. Kenya needs Sh73.9 billion to light up more homes by 2019. Daily Nation, October 24, Nairobi, Kenya.

Centrotec, 2009. Solarmodule "Made in Kenia" – da, wo die Sonne fast immer scheint. Centrotext, Centrotec Sustainable AG, December 15, Brilon, Germany.

Davidson, O., Sokona, Y., 2002. A new sustainable energy path for African development: think bigger act faster. Energy and Development Research Centre, University of Cape Town, South Africa, and Environmental Development Action in the Third World, Dakar, Senegal.

Enkhardt, S., 2011. UNEP erhält Photovoltaik-Aufdachanlage. Photovoltaik Magazin (www.photovoltaik.eu), February 24, Berlin, Germany.

ERC, 2010a. Invitation of public comments: proposed regulations in respect of solar water heating. Energy Regulatory Commission (ERC), Gazette Notice No. 8380, Nairobi, Kenya.

ERC, 2011. Energy (Solar Photovoltaic, Wind and Battery System) Regulations, 2011. Draft version dated February 8. Energy Regulatory Commission (ERC), Nairobi, Kenya.

ESDA, 2003. Study on PV market chains in East Africa. Report for the World Bank, final draft, October, by Energy for Sustainable Development Africa (ESDA), Nairobi, Kenya.

ESDA, 2006a. A study of productive uses of PV electricity in rural areas of Kenya. Report for the World Bank, April, Energy for Sustainable Development Africa (ESDA), Nairobi, Kenya.

ESDA, 2006b. Kenya Energy Atlas. Energy for Sustainable Development Africa (ESDA), Nairobi, Kenya.

ESDT, 2008. Market characterization study: preparation of a commercial PV market development component in Tanzania. Report prepared for the Ministry of Energy and Minerals, Tanzania. Energy for Sustainable Development Tanzania Ltd. (ESDT), Dar es Salaam, Tanzania.

EWURA, 2010. In the matter of development of small power projects in Tanzania. Energy and Water Utilities Regulatory Authority (EWURA), Order 10-012, Dar es Salaam, Tanzania.

Felten, J., 2011. Personal communication with Jeff Felten of Camco, Dar es Salaam, Tanzania.

BMWi, 2011. Erste netzgekoppelte Photovoltaikanlage in Kenia. Advertorial of Exportinitiative Erneuerbare Energien, Bundesministerium für Wirtschaft und Technologie (BMWi). Appeared in Neue Energie, January, Berlin, Germany.

Go Solar, 2010. Solar water heating: household and industrial use. Go Solar Systems Ltd., accessed online at http://www.gosolarltd.com/hotwater.html, June 4, 2010.

GTZ, 2009a. Target market analysis: the solar energy market in Kenya. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), October, 30, Berlin, Germany.

GTZ, 2009b. Projektentwicklungsprogramm Ostafrika. Business Guide Erneuerbare Energien: Kenia. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), November, Berlin, Germany.

GTZ, 2009c. Projektentwicklungsprogramm Ostafrika. Business Guide Erneuerbare Energien: Tansania. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), November, Berlin, Germany.

GTZ, 2009d. Target market analysis: Tanzania's solar energy market. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), November, Berlin, Germany.

GTZ, 2009e. Market potentials for German solar energy companies in East Africa. Presentation held by Mark Hankins on behalf of Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Hannover Messe, April 22, 2009, Hannover, Germany.

GTZ, 2009f. Potential for investment in solar energy in East Africa: business opportunities for German companies. Presentation held by Mark Hankins on behalf of Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). November 17, 2009, Berlin, Germany.

GTZ, 2009g. Solar energy market potentials in East Africa. Presentation held by Mark Hankins on behalf of Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). November 17, 2009, Berlin, Germany.

Hankins, M., 2000. A case study on private provision of photovoltaic systems in Kenya. Chapter 11 from Energy Services for the World's Poor. World Bank Energy Sector Management Assistance Program (ESMAP), Washington, DC, USA.

Hankins, M., 2011. Personal communication with Mark Hankins, consultant and leading solar market expert, Nairobi, Kenya.

IEA PVPS, 2003a. 16 Case Studies on the deployment of photovoltaic technologies in developing Countries. International Energy Agency (IEA), Photovoltaic Power Systems Programme (PVPS), Paris, France.

IEA PVPS, 2003b. Stand-alone PV Systems in developing countries. International Energy Agency (IEA), Photovoltaic Power Systems Programme (PVPS), Paris, France.

IEA, 2006. World Energy Outlook 2006. International Energy Agency (IEA), Paris, France.

IEA, 2010a. IEA Energy Statistics: Selected 2007 Indicators for Kenya. International Energy Agency (IEA), accessed online at http://www.iea.org/stats, June 2, 2010.

IEA, 2010b. IEA Energy Statistics: Selected 2007 Indicators for Tanzania. International Energy Agency (IEA), accessed online at http://www.iea.org/stats, June 2, 2010.

IFC, 2007. Selling solar: lessons from more than a decade of IFC's experience. International Finance Corporation (IFC), Washington, DC, USA.

Ikiara, M., 2009. Trade in environmental goods & services: solar energy in Kenya. WTO Workshop, September 23-25, 2009, Geneva, Switzerland.

Jacobsen, A., 2004. Connective power: solar electrification and social change in Kenya. Ph.D. dissertation, University of California, Berkeley, USA.

Jacobsen, A., 2005. The market for micro-power: social uses of solar electricity in rural Kenya. Tegemeo Working Paper No. 09/2005, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Jacobsen, A., 2007. Connective power: solar electrification and social change in Kenya. World Development 35, 144-162.

Jacobsen, A., Kammen, D.M., 2007. Engineering, institutions, and the public interest: evaluating product quality in the Kenyan solar photovoltaics industry. Energy Policy 35, 2960-2968.

JRC, 2006. Photovoltaic Solar Electricity Potential in European Countries. Joint Research Centre (JRC), accessed online at http://re.jrc.ec.europa.eu/pvgis, February 18, 2010.

Kammen, D.M., 1996. Household power in a new light: policy lessons, and questions, for photovoltaic technology in Africa. Tiempo: Global Warming and the Third World 20, 1-8.

Kammen, D.M., 2010. Personal communication with Daniel M. Kammen of the University of California, Berkeley, USA.

Kanyabwoya, D., 2009. Investor plans to build 100 MW solar plants. The Citizen, August 27, Dar es Salaam, Tanzania.

Karekezi, S., 1994. Disseminating renewable energy technologies in sub-Saharan Africa. Annual Review of Energy and the Environment 19, 387-421.

Karekezi, S., 2002. Renewables in Africa: meeting the energy needs of the poor. Energy Policy 30, 1059-1069.

Karekezi, S., Kithyoma, W., 2002. Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa? Energy Policy 30, 1071-1086.

Karekezi, S., Kithyoma, W., 2003. Renewable energy in Africa: prospects and limits. Paper prepared for the Workshop for African Energy Experts on Operationalizing the NEPAD Energy Initiative, June 2-4, 2003, Dakar, Senegal.

Karekezi, S., Kimani, J., Wambille, A., Balla, P., Magessa, F., Kithyoma, W., Ochieng, X., 2005. The potential contribution of non-electrical renewable energy technologies (RETs) to poverty reduction in East Africa. Africa Renewable Energy Policy Research Network (AFREPREN), Nairobi, Kenya.

Kassenga, G., 2008. The status and constraints of solar photovoltaic energy development in Tanzania. Energy Sources, Part B, 3, 420-432.

KEREA, 2009. Photovoltaic systems field inspection and testing: report 2009. Kenya Renewable Energy Association (KEREA), Nairobi, Kenya.

KEREA, 2010. Report on field inspection and testing of PV systems in Kenya: 2009. Kenya Renewable Energy Association (KEREA), Nairobi, Kenya.

KNBS, 2010. Kenya 2009 population and housing census highlights. Kenya National Bureau of Statistics (KNBS), Nairobi, Kenya.

KPLC, 2009. Annual report and financial statements for the year ended 30 June 2009. Kenya Power & Lighting Company Ltd. (KPLC), Nairobi, Kenya.

Lighting Africa, 2010a. Lighting Africa policy support: Tanzania country report. Report prepared by Mark Hankins for Lighting Africa, Nairobi, Kenya.

Lighting Africa, 2010b. Lighting Africa: an overview of the off-grid lighting market. Lighting Africa, Nairobi, Kenya.

Magessa, F., 2008. EAC strategy to scale-up access to modern energy services: Tanzania country report and implementation workplan. East African Community, May, Arusha, Tanzania.

Martinot, E., Ramankutty, R., Rittner, F., 2000. The GEF solar PV portfolio: emerging experience and lessons. Monitoring and Evaluation Working Paper 2, August, Global Environment Facility (GEF), Washington, DC, USA.

MEM, 2002a. Removing barriers to the transformation of the rural PV market in Tanzania: industry survey and evaluation of delivery methods. Ministry of Energy and Minerals (MEM), Dar es Salaam, Tanzania.

MEM, 2002b. Market assessment and evaluation of market aggregation potential. Ministry of Energy and Minerals (MEM), Dar es Salaam, Tanzania.

MEM, 2010. Overview of energy sector. Ministry of Energy and Minerals (MEM), accessed online at http://www.mem.go.tz/energy, July 27, 2010.

MoE, 2010a. Solar energy. Ministry of Energy (MoE), accessed online at http://www.energy.go.ke, June 4, 2010.

MoE, 2010b. Feed-in tariffs policy on wind, biomass, small-hydro, geothermal, biogas and solar resource generated electricity. Ministry of Energy (MoE), January, Nairobi, Kenya.

MoE, 2010c. Least cost power development plan (LCPDP): study period 2010-2030. Ministry of Energy (MoE), Nairobi, Kenya.

Moner-Girona, M., Ghanadan, R., Jacobsen, A., 2006. Decreasing PV costs in Africa: opportunities for rural electrification using solar PV in sub-Saharan Africa. Renewable Energy Focus, January/February 2006, 40-45.

Murphy, J., 2001. Making the energy transition in rural East Africa: is leapfrogging an alternative? Technological Forecasting and Social Change 68, 173-193.

NBS, 2009. Household budget survey 2007: Tanzania mainland. National Bureau of Statistics (NBS), May, Dar es Salaam, Tanzania.

Ngigi, A., 2008. EAC strategy to scale-up access to modern energy services: Kenya country baseline report and workplan. East African Community, April, Arusha, Tanzania.

Ngigi, A., 2010. Financing solar PV in Kenya: the relevance of regulatory issues. Presentation held at the Energy Regulatory Commission's Stakeholder Workshop, September 24, 2010, Nairobi, Kenya.

Otiti, T., Soboyejo, W., 2006. Limited contribution of photovoltaic energy technology to economic development of sub-Saharan Africa. Perspectives on Global Development and Technology 5, issue 1-2, 69-80.

REN21, 2008. Renewables 2007: global status report. Renewable Energy Policy Network for the 21st Century (REN21), Paris, France.

Sheya, M., Mushi, S., 2000. The state of renewable energy harnessing in Tanzania. Applied Energy 65, 257-271.

SIDA/MEM, 2010. Upcoming report for the SIDA/MEM project, currently under preparation by Tanzania Renewable Energy Association (TAREA), Dar es Salaam, Tanzania.

SNC, 2009. Power System Master Plan (PSMP), 2009 Update. Report prepared for the Government of Tanzania. SNC Lavalin International (SNC), Dar es Salaam, Tanzania.

TANESCO, 2010a. Generation. Tanzania Electric Supply Company Ltd. (TANESCO), accessed online at http://www.tanesco.co.tz, July 9, 2010.

UN, 2010. Kenya. World Statistics Pocketbook. United Nations (UN) Statistics Division, accessed online at http://data.un.org, June 8, 2010.

UNDP, 2010. UNDP Results: Tanzania. United Nations Development Programme (UNDP), New York, USA.

Van der Plas, R., Hankins, M., 1998. Solar electricity in Africa: a reality. Energy Policy 26, 295-305.

WEC, 2007. 2007 survey of energy resources: country notes. Solar energy. World Energy Council, London, United Kingdom.

World Bank, 2010a. Various data on Kenya and Tanzania. The World Bank, accessed online at http://data.worldbank.org, June-December, 2010.

World Bank, 2010b. World Development Report 2010: Development and Climate Change. The World Bank, Washington, DC, USA.

Interviews:[41]

ARTI, 2010. Interview with Nachiket W. Potnis of the Appropriate Rural Technology Institute (ARTI), Dar es Salaam, Tanzania.

Camco, 2010. Interview with Jeff Felten of Camco, Dar es Salaam, Tanzania.

CAT, 2010. Interview with Nawir Ibrahim of the Center for Alternative Technologies Ltd. (CAT), Nairobi, Kenya.

Chloride Exide, 2010a. Interview with Guy Jack of Chloride Exide Kenya Ltd., Nairobi, Kenya.

Chloride Exide, 2010b. Interview with Gabriel Odongo of Chloride Exide Tanzania Ltd., Dar es Salaam, Tanzania.

Davis & Shirtliff, 2010a. Interview with Norman Chege of Davis & Shirtliff Ltd., Nairobi, Kenya.

Davis & Shirtliff, 2010b. Interview with Moses Sayula of Davis & Shirtliff Ltd., Dar es Salaam, Tanzania.

D.light, 2010. Interview with Laura Smeets of D.Light Design, Dar es Salaam, Tanzania.

ERC, 2010b. Interview with Bernard Osawa of the Energy Regulatory Commission (ERC), Nairobi, Kenya, conducted by telephone, 13 October 2010.

GTZ, 2010. Interview with Michael Franz and Jasmin Fraatz of Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Nairobi, Kenya.

Hankins, 2010. Interview with Mark Hankins, consultant and leading solar market expert, Nairobi, Kenya.

Kassenga, G., 2010. Interview with Gabriel Kassenga of Ardhi University, Dar es Salaam, Tanzania.

KenGen, 2010. Interview with Simon Ngure of Kenya Electricity Generation Company Ltd. (KenGen), Nairobi, Kenya.

KIPPRA, 2010. Interview with Moses Ikiara and Nahashon Mwongera of the Kenya Institute for Public Policy Research and Analysis (KIPPRA), Nairobi, Kenya.

MoE, 2010d. Interview with Raphael Khazenzi of the Ministry of Energy (MoE), Nairobi, Kenya.

Msigwa, G., 2010. Interview with Godwin Msigwa, solar expert and trainer of Solar Now, Dar es Salaam, Tanzania.

Mumbi, M., 2010. Interview with Maina Mumbi, solar energy researcher and consultant, Nairobi, Kenya.

[41] Conducted in September 2010.

Nyamo-Hanga, G., 2010. Interview with Gissima Nyamo-Hanga of the Rural Energy Agency (REA), Dar es Salaam, Tanzania.

TANESCO, 2010b. Interview with Sabina Daati of Tanzania Electric Supply Company Ltd. (TANESCO), Dar es Salaam, Tanzania.

TAREA, 2010. Interview with Matthew Matimbwi of the Tanzania Renewable Energy Association (TAREA), Dar es Salaam, Tanzania.

TaTEDO, 2010. Interview with Estomih Sawe and Emanuel Yesaya of the Center for Sustainable Modern Energy Expertise (TaTEDO), Dar es Salaam, Tanzania.

Winafrique, 2010. Interview with Anthony Ng'eno of Winafrique Technologies Ltd., Nairobi, Kenya.

Zara Solar, 2010. Interview with Mohamed Parpia of Zara Solar Ltd., Mwanza, Tanzania.