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The compatibility of rural electrification and promotion of low-carbon technologies in developing countries - the case of Solar PV for Sub-Saharan Africa

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Key words: Pv, solar photovoltaic, solar home systems, rural electrification, incentives, renewable energy, development, Africa

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Abstract

Climate change is a major concern, and climate change mitigation measures are currently high on the policy agenda. In 2007 the European Union (EU) made decisions both on binding targets to be reached by 2020 for CO_2 emissions and for a minimum share of energy consumption produced by renewable energy. Increased access to electricity is a major concern for socio-economic development in developing countries, not least in Sub-Saharan Africa (SSA), where only 8 percent of the population has access to electricity. Using solar photovoltaic (PV) in SSA as a case, this paper explores to what extent the objectives of increased access to electricity in rural areas is compatible with low-carbon technologies. Solar PV systems have been disseminated in SSA for almost 30 years, resulting in more than half a million installations concentrated in a few countries. Despite this apparent success, solar PV has been criticized for being expensive, fragile and limited to non-productive uses. If expectations of future oil prices exceeding twice the level experienced from 1985 to 2003 are confirmed, we may see a more positive attitude emerge, and we might expect solar PV to fulfil an important niche for populations living in dispersed settlements outside the reach of grid electrification. Based on a literature review and the author's experience in Burkina Faso, the article provides an assessment of various delivery models for individual solar PV systems, and discusses their strengths and weaknesses.

1. Development and access to electricity

Energy services are generally acknowledged to play a significant role in facilitating both social and economic development, and rural people desire electricity for light, for radio and TV and for income generating activities ([1]). It is therefore considered to be a serious social and economic problem that access to electricity is extremely low in many developing countries and that more than 1.5 billion people, or about 30 % of the world population, have no access to electricity ([2]).

Access to energy in developing countries is driven mainly by three concerns: i) general economic development, ii) poverty alleviation and iii) climate change. Researchers generally agree that electricity is closely linked to economic development, and thus the availability of electricity for productive use is one among several conditions that need to be met to achieve this goal ([3]: 118). Earlier notions of a causal relationship between access to electricity and economic development, which were predominant in the 1960's and 1970's growth models, have today been replaced by an emerging consensus that electric energy may be a necessary but not sufficient condition for economic growth, especially when addressing the issue of rural development ([3]: 118).

This change in perception has to some extent changed the focus in development aid from infrastructure development to social development, but has also resulted in integrating social concerns in energy access schemes. The poverty orientation of international development cooperation, which was manifested by the United Nations (UN) launching the Millennium Development Goals, has been instrumental in redirecting electrification interventions to targeting the poorest ([4]). While it is generally the richest strata of the rural population that benefit from the productive use of grid based electricity, the majority of the poor are more likely to benefit from electricity services through electricity for rural market centres, schools, health centres, water pumping and government administration offices. Consequently, providing electricity services to these institutions has high priority in donor interventions ([5]: 5).

Environmental concerns, which have increasingly been translated into concerns for climate change, are the third important element influencing the debate on access to electricity. Binding targets for CO_2 emissions in the North, emission trading and the Clean Development Mechanism (CDM), have entered the development agenda, but while there is growing concern of the need for mitigation in the rapidly developing countries, such as India and China, it is increasingly acknowledged that climate change mitigation is not the first priority in SSA. While climate concerns were strongly expressed in the development discourse some ten years ago, per capita emissions and poverty in SSA are at a level that it is now argued that the focus should be on economic and social development. This means that there is an emerging consensus among policy makers and in the donor community that least-cost energy options should be pursued, although still with due diligence to benefit from options for cleaner development.

It is in this context that this article addresses the compatibility of rural electrification and promotion of low-carbon technologies, using the promotion of solar PV in SSA as a case.

2. PV as an individual or collective solution

Electricity options for rural dwellers in SSA highly depend on whether they live in nucleated villages, outskirts of nucleated villages or in dispersed settlements.

Solar Home Systems (SHS) are an interesting option for dispersed settlements in most SSA countries, where grid electricity is not likely to be available for the next decades. In this context, SHS compete with charging batteries in a nearby town, with a small gen-set or with a PV charging station. Mini-grids, in turn, are generally the most favourable option for nucleated villages, which are out of reach of the national grid. Most often, mini-grids are established in the most densely populated part of the village, where electricity may be used for income generating purposes in shops, restaurants, workshops and in public service institutions for water, health and administration. The outskirts of nucleated villages may in some cases be serviced by the mini-grid, but in most cases mini-grids will in the foreseeable future only serve a smaller part of the population. SHS may therefore also be an interesting option in the outskirts of nucleated villages ([6]: 123).

The advantages of mini-grids compared to SHS are many. First of all, the mini-grid provides the consumer with high voltage electricity, which has advantages in terms of the productive use of electricity, whether it is for lighting, cooling or motive power, and which allows consumers to use cheaper high voltage appliances. Secondly, investment in a mini-grid can be seen as a transitional investment for a long-term strategy of being connected to the national grid, with the benefits that this may give in terms of cheaper electricity from large-scale hydropower, natural gas or coal. Small diesel engines in the range from 10 kW up to several MW are the baseline production units for mini-grids, and although production costs from diesel units are relatively high, because of low efficiency and high maintenance costs, diesel may be a least cost option the first five to 10 years after establishment, when demand gradually builds up.[1]

Third, the mini-grid itself may be supplied by electricity produced from mini and micro-hydropower schemes and from co-generation from biomass waste, where such resources are available in non-grid connected areas ([7]). Hybrid wind-diesel systems are options in specific areas with good and medium wind potential ([8]). For inland localities with low wind potential, an increasing number of publications claim that PV-diesel hybrids are economically competitive compared to pure diesel solutions ([9]; [10]; [11]; [12]; [13]; [14]). Others point towards small-scale biogas, thermal gasification, and biofuel as a technical and in some cases also economic option compared to dedicated diesel systems ([15]; [16]). However, in spite of the advantages of mini-grids, there is an important market for SHS in dispersed settlements which will be outside the reach for grid-electrification for the next decades.

At present there are more than 500,000 SHS in Africa, concentrated in a few countries that have engaged in specific SHS programmes. Kenya has about 200,000 units, South Africa 150,000, Zimbabwe 85,000, Morocco 37,000 and Uganda 20,000 ([17]; [18]). The poorest countries without specific support structures for SHS, such as Burkina Faso, have less than 3,000 units installed ([19]). Solar PV battery charging stations have been promoted as an option for a cheaper alternative to SHS, but this has only had a limited market penetration ([17]).

[1] The maximum distance for grid extension depends on a number of factors, such as the price of grid electricity, expected load in the village, prices of diesel fuel, options for clustering villages, and the price of transmission lines. Cheaper transmission line technology using only one wire, the so-called SWER (Single Wire Earth Return) technology has been introduced in a number of countries, among those South Africa, in order to reduce the investment costs in transmission lines ([6]).

Specific donor programmes have installed PV for water pumping in West Africa, Niger, Namibia and Zimbabwe ([17]), but compared to the SHS, the numbers are limited, and a large number of installations are no longer in use.[2] Finally, PV is used in stand alone systems providing lighting for village infrastructure such as schools, health centres, police stations, street lighting etc., and for refrigeration at health centres and maternities ([21]). While this use is widespread in all SSA countries, estimations of total numbers have not been available.

Except for electricity supply to radio and telecommunication amplifiers in remote areas, PV has only rarely been used for productive use, such as irrigation. This has mainly been due to the high production price per kWh compared to other alternatives such as small-scale gasoline and diesel engines in the range from one to ten kW ([22]; [23]: 1079).

3. Solar PV in a context of development aid

Despite the apparent success in terms of numbers of units, solar PV has been criticized for being donor driven, expensive, fragile and not fulfilling the needs of productive use ([24]; [25]). This section attempts to provide an understanding of the underlying reasons for the bad reputation that solar PV has acquired in some camps. Thereafter, it will draw attention to increasing oil prices and rapidly growing markets for solar PV in the North as two important factors which may change this reputation and make SHS an important technology for providing electricity for populations living in dispersed settlements outside the reach of grid electrification.

3.1. From Optimism to Scepticism

PV was introduced in the late 1970s as a promising technology for rural electrification ([26]). This was mainly because of an expectation of rapidly decreasing production costs of PV modules in combination with continued high oil prices and expectations of rapid economic development. The dramatic decrease in oil prices in 1985 was perceived of as transitional and

[2] According to Togola ([20]) only 40 % of installed PV pumps for water were functioning in 2000. Newer estimates propose that more than 1000 PV pumps were in use in West Africa in 2007.

the promotion of solar PV in Africa continued. This was mainly done by means of external interventions financed by donations from NGOs, bilateral and multilateral donors, though there were also some loans from international development banks, to be paid back by national governments ([25]).

PV was promoted by converging interests from a number of very different actors. The environmental movement in the North saw a potential for an environmentally friendly energy provision in African countries, which was difficult to achieve in the North because of already established infrastructure providing cheap electricity using oil and coal. The argument was that developing countries should not repeat the mistakes already made in the North. They should 'leapfrog' the energy technology ladder by jumping directly into the PV technology of the future ([27]: 737). It was argued that PV, in spite of its advanced technological level, was well suited to the electrification of dispersed villages and remote locations in Africa because of high solar irradiation, long lifetime, low maintenance requirements, and not least because providing fossil fuels to the alternative, small engines would be difficult and costly. To this may be added other arguments such as CO_2 emission reductions, improved indoor health and poverty concerns ([24]). [3]

These arguments were relatively easy to sell to NGO members and tax payers in the North, and donor support was justified by the need of a market enhancement to reduce production prices ([29]). In the early 1980s, the PV markets in the South were important for the PV industry, mainly located in the North ([30]), and the importance of the developing countries for the PV industry continued well into the 1990s ([22]: 1130). For example, when the EU financed *Programme Regionale Solaire* (PRS I) was launched in 1989, the contracted amount of solar cells for a five year period, constituted 3.5 % percent of the annual world market for PV modules, and 10 % of the annual European production.[4]

A second driver was that PV sales, like other development assistance, have been tied to national industrial interests. Examples of this are two large PV pre-electrification projects that were introduced in Ghana and Burkina Faso

[3] For an example of how these arguments were presented see e.g. GEF ([28]: 1).
[4] The total production of PV modules was 40.2 MWp in 1989, and 69.4 in 1994. The similar European production was 14.5 and 34 MWp. The PRS aimed at a total installation of 1.386 MWp, which constituted 10 % of the annual European production and 3.5 % of world production ([21]: 7, 30).

in 1999. They were implemented by Spanish suppliers, and financed by mixed export credits from the Spanish government ([31]; [19]). And finally, as Jacobson ([32]: 145) points out, a third driver was that solar PV is particularly compatible with market-based distribution. Therefore solar PV fitted perfectly into the neo-liberal privatisation paradigm prevailing during the last two decades.

Villavicencio ([24]: 63) has analysed the viability of solar home systems using indicators such as affordability, efficiency, freedom from risk of obsolescence, flexibility and technological capability. Based on this analysis he contests the rightfulness of PV systems as a universal energy strategy for rural households in developing countries, because, as he argues, solar home systems are expensive, inefficient, have a high risk of obsolescence and are far more difficult to maintain than expected. He even urges "bilateral and multilateral development assistance agencies to rethink their programmes and projects on photovoltaic electrification in developing countries".

The market for PV installations in developing countries has mainly been driven by direct and indirect donor funding. Donor programmes have been criticised for "finding problems to fit the solutions" ([33]), and the case of solar PV is one example of this. PV installations have been applied in a number of cases although far from being a least-cost solution, when compared to small diesel grids ([34]).[5] A number of observers have asked the moral question of why the poorest should pay for the most expensive technology ([34]: 15; [24]: 63),[6] and researchers have increasingly challenged the above mentioned arguments in favour of PV ([25], [23], [32]). They also convincingly contested the claims from various proponents of PV that solar PV would alleviate poverty and facilitate income generation. In a well researched study concerning Kenya, Jacobson ([32]) shows: i) that the benefits of solar electrification are mainly captured by the rural middle class, ii) that solar PV plays a modest role in supporting economically productive and education related activities, and iii) that solar PV is more closely tied to the increased use of TV, and other 'connective' applications such as radio and cellular phones, than to income generation, poverty alleviation and

[5] The price for SHS is often compared to grid extension although the least-cost option would be small-scale diesel grids, or even battery charging by means of small gasoline gen-sets, as shown by Erickson and Clapman ([22]).

[6] This has moral implications as long as it is a non-efficient use of donor financing from the North, and severe economic consequences for the SSA governments, when the financing of large projects has been based on loans.

sustainable development. Finally and not least – donor supported PV projects have in a number of cases only been operational for a few years due to economic, technical and organisational reasons (see e.g. ([20]; [35]; [36]).[7]

In summary, while PV systems have technically matured and markets have gradually developed in a number of SSA countries, PV for rural electrification has increasingly been perceived with scepticism from potential users, donors, government officials and researchers, and PV has in many camps been labelled as a donor driven, expensive fragile technology for the richest part of the rural population, with little value for productive purposes.

3.2. Changing conditions – new opportunities

During the last few years, however, two important changes have occurred, which may to some extent alter this situation. Firstly, world market oil prices, which were relatively stable at a level between 20 and 30 USD/barrel in the period from 1985 to 2003 have recently peeked at a level of almost 150 USD/barrel, which means that oil prices passed the 1979 level of 90 USD taking inflation into account ([38]). Although the economic crisis has brought down the price again to about 55 USD/barrel, oil prices are expected to increase again, and if the world market price in the future remains at a level above 60 USD/barrel ([38]), SSA countries face a world market price of oil products, including kerosene for oil lamps, which is two to three times the level of what has been the reality for almost 20 years.[8] Although existing taxation on oil products in most SSA countries, and targeted subsidies for specific products might reduce the effect of the world market prices, solar PV will be more competitive with alternative products for lighting, such as kerosene, small gasoline engines for individual households and for diesel engines in mini-grids.

Secondly, prices for PV modules have been reduced to about 60 % of the 1996 level and systems to about 70 % of the 1996 level, bringing the average price of modules in the reporting countries down to 4.6 USD/Wp ([39]: 26, 27). Third, the world market for PV products has increased rapidly in the

[7] This is, however, not specific for PV projects. In the high profile multifunctional platform project for rural electrification in Mali, 40 % of the systems were non-operational after five years ([37]; 19)
[8] Source: Energy Information Administration. Official Energy statistics from the American Government. http://www.eia.doe.gov/steo#Global_Petroleum_Markets

last few years, mainly due to national stimulation programmes in Japan, the US and in Germany, such as the German Feed-in Law (EEG). According to this law, PV solar electricity has to be purchased by the utility companies at an enhanced price around 0.5 EUR/kWh, but with a defined decline over time ([: 3298, 3299). The installed capacity for non grid connected PV has increased by about 18 % in the period from 2002 to 2006, while in the same period the grid connected solar PV has increased by an average 60% per year, now reaching a total of 10,500 MWp in 2006 ([17]).

This increase is important, as the 'learning curve theory' suggests that price reductions are related to accumulated sales. According to Hoffmann ([40]), the industrial PV technologies still promise potential for further development and the next generation is well underway. Based on an existing 'learning factor' of between 15 and 18 %, the one EUR/Wp is expected to be reached at an accumulated production of about 100 GW,[9] which according to projected growth will occur around 2020.

In general, however, PV system prices are higher in Africa than in other parts of the world. According to Moner-Girona et al ([18]: 42), an African consumer from Uganda may pay twice as much as an Indian consumer for an equivalent system. High African prices are mainly due to taxes and to transactions costs in the process of delivery. Therefore, as shown in figure 1, there are important differences among African countries, depending on tax levels, sales volume and retail market structure.

However, local production, increased turnover and an increasingly globalized market supplied by relatively cheap Chinese products may gradually adapt the price level in SSA countries to the continuously decreasing world market level. In combination with other incentive models to be discussed in the following section, this may stimulate the market for SHS to dispersed settlements and to the electrification of public infrastructure such as water supply, schools and health centres.

[9] Accumulated capacity was about 10 GWp in 2007 ([17]).

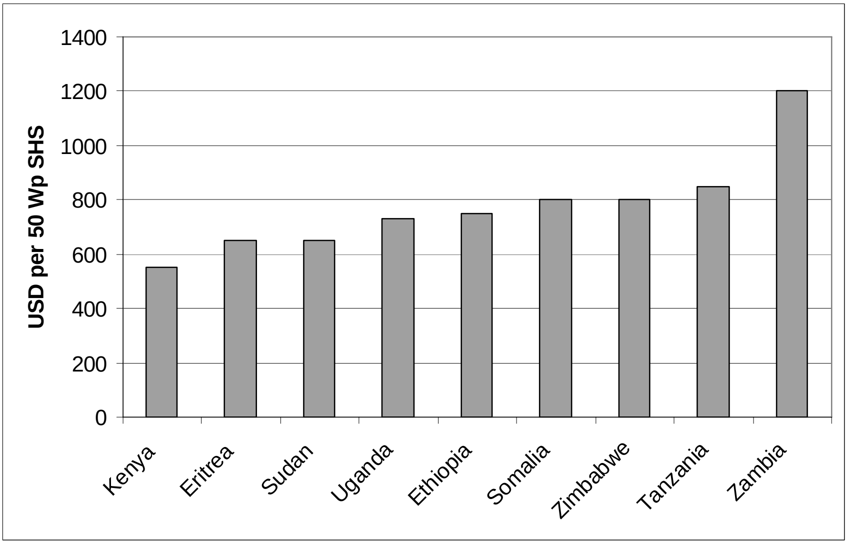

Figure 1: Comparison of costs of a 50 Wp SHS, including panel, four lights, charge controller, installation material and installation. Based on Moner-Girona et al ([18]), who have collected data from different sources dating back to 2001 to 2003.

4. Changing institutional settings for rural electrification in SSA

Rural electrification in SSA was until recently the responsibility of state owned utilities, and the low electrification rates have often been explained by organizational problems related to state ownership, such as politically influenced management, inefficiency and lack of resources. From some camps liberalization and privatization of the power sector was therefore seen as an important option for increasing rural electrification rates ([41]: 1275). There are, however, several constraining non-institutional factors, which may be equally important, e.g. poverty and hence low affordability amongst rural dwellers, low density of consumer demand, small-scale production units and lacking infrastructure for maintenance. The importance of these factors is sustained by recent research, which shows that the most impressive rural electrification rates have been achieved in countries such as South-Africa, Zimbabwe, Morocco and Thailand, where state-owned utilities have been responsible for rural electrification ([42]; [43]: 142; [44]). Also signals from governments and development finance institutions indicate that reforms and privatization do not, by themselves, increase access to electricity in rural areas ([45]).

Rural electrification funds and agencies have therefore been established in most SSA countries in the wake of, or as an integrated part of, the liberalization efforts.[10] These agencies are today small and relatively weak, struggling for authority and funding in a turbulent organizational and political environment. In competition with the unbundled and often privatized utility, the rural electrification agencies face the challenge to develop new expertise in electricity supply within their own organization and in the private sector whose services they depend on. The achievements of the agencies are dependent on an often limited number of private entrepreneurs with the required skills and expertise, and due to the low level of know-how and competition between these entrepreneurs, prices are often high and the service quality is low. In addition to this, as in the case of Burkina Faso, the agencies are funded by a mix of bilateral donors, international development banks, levies on electricity from grid-connected areas and directly from the government budget. This means that they may be constrained or even blocked by divergent plans, incentive structures and administrative requirements from different donors, finance institutions and governments ([19]).

Alongside the utilities and rural electrification agencies, a third group of actors are involved in providing access to energy in rural areas. This group consists of NGOs and other international development actors which are providing development interventions that focus on non-energy sectors, such as water, health, education and agriculture. These interventions often include energy supply in terms of mini-grids, multi-functional platforms and solar PV which are related to sector needs, but which are often installed with limited coordination with other sector needs, other development actors and the electrification authorities responsible for planning. Donor-coordination has been an issue for years, without much effect, and the current initiatives by the World Bank (WB) to unify donors in a sector syndication approach are likely to be constrained by the same institutional barriers as before ([46]). Other initiatives, such as the white paper on energy access from the Economic Community of West African States (ECOWAS), focus on integrated approaches, concentrating on services rather than

[10] An overview of existing electrification agencies can be fund on the webpage for the network for rural electrification agencies, called CLUB ER. http://www.club-er.org/

technologies. This focus has resulted in the creation of national multi-sectoral groups responsible for the coordination of energy initiatives in several West African countries ([47]), but it is still too early to judge to what extent these groups will be able to play the important role they have been assigned.

SHS may be promoted by all three groups of actors mentioned above, the utilities, the rural electrification agencies and the donors, either alone or in a combination. Future delivery models will depend on which of these actors are taking the lead. This will be further elaborated in the next section.

5. Incentives and delivery models for SHS

This section will provide a review of experiences with different incentives and delivery models for SHS. There are five main groups of delivery models emerging from the literature: i) the donation model, ii) the commercially led model, iii) the multi-stakeholder programmatic model, iv) the fee for service dealer model, v) the fee for service concession model ([48]; [49]; [50]; [51]; [52]; [53]; [54]). The characteristics of the five models, which are described above, are summarized in table 1. [11]

[11] There are several possible classifications in the literature. Van Vleuten et al ([48]) operate with five models: Cash sales, donation, credit, fee for service dealer model and fee for service concession model. Banks ([49]) operates with four models: Commercially led delivery model, the multi-stakeholder programmatic model, the utility model and the grant based models. Reinmüller & Adib ([52]) operates with four models: Cash delivery, credit delivery, leasing delivery and service delivery. Martinot et al ([36]) operate with a cash sale model, a consumer credit model and a rental model. GTZ ([53]) operates with five models: two sales models (cash and credit) and three service models (regulated concession, unregulated open market provider, community provider). Nieuwenhout et al. ([55]) operates with four models: Donations, cash sales, consumer credit and fee-for-service.

Model	***End-user***	***Ownership***	***Financing provided by***	***Subsidy level for investment***	***Responsible for installation, maintenance and after sales service***
Donation	Institutions	End-user	Donor	High, 100 %	End-user, committees
Commercially led delivery model (cash sale)	Private	End-user	End user	Zero	End user
Multi stakeholder programmatic model (credit)	Private	End-user	Donor, financing institution, dealer, end-user	Low to medium	Depends on circumstances
Fee for service (dealer model)	Private, Institutions	Utility, Energy Service Company (ESCO)	ESCO	Medium to high	ESCO
Fee for service (concession model)	Private, Institutions	Utility, ESCO	ESCO	Medium to high	ESCO

Table 1: Five groups of delivery models (Mainly inspired by [48], [49])

5.1. Donation model

The donation model has been used in all SSA countries; generally by donors and governments for provision of electricity to rural infrastructure for water, health and education. Social objectives provide the motivation for donation of the hardware to these institutions, on the condition that a user committee should be established to collect fees for maintenance and for reinvestment. Project implementers, however, have often neglected the involvement of the users, and the fact that installations were given for free has resulted in low commitment from beneficiaries ([55]: 460).

In practice, it has proved difficult for these committees to be operational and to collect and save sufficient funding for repairs of batteries and controllers. Failure rates vary and seem to depend on the immediate utility of the service. While solar water pumping for drinking water, in some cases, has proved a relatively low failure rate ([56]), other examples of providing solar PV to public infrastructure show extremely high failure rates. In a project for solar electrification of schools in South Africa in 1996-98, only about 6% of 1400 systems installed were found even partly operational after four years. In a similar project in South Africa financed by the EU, only 40% of 1000 systems were in operation after one year ([35]: 352). These may be extreme examples, but there are several examples of projects where less than half of the installations were in operation after five years (See *e.g.* [36]: 330; 331; [20]; [57]).

Although the built-in difficulties in the donation model are widely acknowledged, donation will probably continue at some level in small multi-purpose socially oriented infrastructure projects, in cases where adequate financing mechanisms are not available. However, today the model must be seen as somehow obsolete and will not be discussed further in this context.

5.2. Commercially led delivery models (cash sale)

The commercially led delivery model can be seen as the baseline for delivering SHS. It is the starting point at all SHS markets and it is also generally considered as the long-term delivery model. The question is how external market interventions can support market growth at lowest cost and most efficiently from market introduction to a full developed market.

SHS is a fully technically developed product and a well known commodity in all African countries. SHS have therefore passed the state of market introduction. A SHS can be handed 'over the shelf' to consumers or technicians and, dependent on general living standards, there are a number of middle class consumers in the country side, who choose to buy SHS at market prices. Market prices differ considerably among countries and prices are generally decreasing with increasing demand. Higher turnover reduces retail prices and stimulates competition among an increasing number of dealers. The consumers will normally buy cash, but in some cases they will obtain credit from the retailer or they will enter into a leasing agreement with the retailer, who may also provide leasing arrangements. The consumer may also buy technical support (installation service, maintenance, repairs, etc.).

The most prominent example of a commercially led delivery model is Kenya, where an estimated 200,000 SHS have been sold on commercial basis. The main drivers for SHS market in Kenya were a relatively large middle class in rural areas and country wide coverage of national TV ([26]). The market was gradually built up by consumers using car batteries in connection with TV, where afterwards relatively small PV panels were bought as add-ons to the battery, in order to avoid transporting the batteries to nearby villages for charging ([58]).

While no other examples have been reported from SSA, Van Vleuten *et al.* ([48]) report on successful examples of similar delivery models in Morocco, Sri Lanka, and on the Tibetan Plateau in Western China.

5.3. Multi-stakeholder programmatic model

The multi-stakeholder programmatic model is a common notion for donor interventions that have moved from the project level to a programme level, and it generally aims at large-scale dissemination of SHS. Such programmes generally establish a multi-stakeholder programme management authority. They involve a consumer credit option managed by specialist finance organizations and they generally set technical standards for the systems. Investment subsidies may be part of the project, but donor support is generally limited to reducing interest rates and indirect market support such as awareness raising, finance establishment, quality assurance and training at various levels. Only pre-qualified dealers participate, which generally include more than one PV supplier or dealer. The United Nations Development Programme & Global Environmental Fund (UNDP-GEF) project in Zimbabwe from 1996 to 1999 is often used as a typical case of this approach ([49]: 46).

The UNDP-GEF programme in Zimbabwe comprised bulk procurement of equipment, which the project delivered to 57 participating installation companies ([59]: 95). This equipment, which was exempted from taxes, conformed to new standards set by the local authorities ([60]: 1070). The programme established a credit support facility which was managed by an existing bank, the Agricultural Finance Corporation (AFC). The loans were available for a three year period, with a down payment of 15 %. The interest rate was set at 15 %, well below a market rate of 40 %. This subsidy element was channelled to the AFC from a revolving fund established for the purpose ([60]: 1075). Unfortunately, the long-term effect of this arrangement failed partly due to the difficult macroeconomic conditions starting already in the late 1990s ([50]: 27). Other examples of this type of approach include programmes in Uganda, Namibia, Tunisia, Morocco and Ghana ([49]: 46; [61]).

5.4. Fee for service model (retailer model and concession model)

In the fee for service model, the service provider owns the installation and the consumers pay a monthly fee (flat rate) for the SHS. The service provider will be responsible for maintenance of the installation, and the model is therefore suited to exploit the synergy of both servicing private consumers and village infrastructure such as water, health centres and schools. The fee for service contract is in some cases similar to a leasing contract, which hands over full responsibility of the equipment after an agreed number of years.

Fee for service providers, who may be utilities or new service companies, can be identified either through a negotiated process, 'the retailer model' or through a tendering process, normally referred to as the 'concession model'. In the retailer model, general conditions on price, quality and business models, etc. are negotiated with one or several service providers. This has been used where existing operators are weak, market penetration is low, and competition among existing operators is limited. Selected service providers generally cover distinct geographical areas, but in principle they work in an open market. Examples of dealer models are pilot energy service companies (ESCOs) established by donor assistance from the Swedish Development Cooperation (SIDA) in Zambia, from UNDP-GEF in Ghana and from the Japanese Development Cooperation (JIKA) in Zimbabwe ([62]: 73, 92-93; [63]; [64]; [65]; [66]).

The concession model grants concessions to a company to supplying SHS to a specific geographical area for a limited number of years, following a competitive bidding procedure. The model has been used in countries with a higher degree of competition, or in countries that can attract interest from more than one external operator. The most well-know concession model was launched in South Africa in 1999. Based on a tendering process, the government awarded concession contracts to 6 private companies to provide SHS to rural dwellers on a fee for service contract, each within a specific area. Each of the 6 concession holders was expected to install

50,000 SHS over a period of five years ([67]: 3) . [12] Two concession holders never started operations, and due to various difficulties, after 5.5 years the four others had only installed a total of 33,000 connections, which is a substantial amount, but far behind the ambitious target of 300,000 ([6]: 117, 118). The government provided a subsidy of 80 % of initial cost equivalent to 3500 ZAR (467 USD) per system connected ([62]:85). The concession model has also been used in Morocco, on a smaller scale in Benin and Togo, and more recently in Senegal ([68]; [69]; [70]: 43, 46; [71]).

The main difference between the fee for service model and the private ownership model is that the service company is responsible for marketing, delivery, financing, customer education, revenue collection and maintenance of battery, charge controller and PV module, while in the private ownership models these tasks are shared between the consumer, the dealer and the finance institution. The fee-for-service model is based on an agreement between the national authority and the service company, according to which the service company has achieved a monopoly-like status. This approach therefore requires a continuous follow up and strong and independent regulation from the national regulator or other government authority.

Reduced consumer fees are the key parameter for the success in marketing SHS, and the four considered delivery models should mainly be tested on their ability to reduce consumer fees. This will be the focus for discussion in the next section.

6. Discussion of delivery models

Most important for price reduction are competition, economy of scale, finance schemes, subsidies and efficient maintenance, and the question is under which conditions the consumer owned models will be more efficient than the service delivery models when taking these parameters into account. The following discussion will elaborate on that.

[12] Solar Vision, Nuon RAPS, Electricite de France, Renewable Energy AFrica, Transenerge and Eskom Shell.

6.1. Competition

Creating competition is the main challenge when developing markets by external interventions, and assuring and enhancing competition follows different logics in several models. The commercially led model is based on free competition, but at the early stages of market creation, when sales are limited, the market will often be dominated by one or two major players who are able to control a market, which at that stage is little price-sensitive due to a high degree of demand from e.g. aid projects. When the market reaches a certain volume, the cash-sale model, on the other hand may reduce prices because of its high level of competition between different retailers.

The justification of programmatic models is generally to increase competition by using subsidies or other market incentives to pull the sales above a ‘critical mass’ and thereby to attract more actors to the market. There is a risk, however, that new dealers will not enter markets they believe are short term and superficial, or that non-serious dealers will enter the market in order to gain an immediate rent and leave after the donors have pulled out as experienced in Zimbabwe ([60]: 1073). None of these situations are ideal, and call for a longer term commitment and a clear strategy for gradually phasing out subsidies.

Bidding for geographical concessions either requires a number of potential national service providers or concessions that are big and profitable enough to attract international service providers. In both cases, the existence of a local market is an advantage, but when opting for national bidding a vibrant local market with experienced entrepreneurs is a precondition in order to ensure competition in the bidding process. In the case of international bidding, competition will be more dependent on potential market conditions than on existing markets. A high investment subsidy was, for example, a major incentive in attracting international service providers to the bidding process in South Africa ([72]).

Negotiated fee for service models may be justified in cases where the level of competition does not lead to a meaningful bidding procedure, such as in the ESCO pilot project in Zambia ([64]: 1257).

6.2. Financing

Consumer finance for SHS is expensive and difficult to obtain in most countries in SSA, and the modality for provision of credit in the different models is therefore important. Micro-credit schemes have often been advanced as an option for financing SHS and it would fit well with a cash-sale delivery model. Unfortunately, as the German Development Organisation GTZ ([53]: 30) notes, most microfinance institutions and programs which deliver financial services to low-income populations do not fit the requirements of SHS. This corresponds to a number of factors, such as credit size, group based lending, focus on women and not least short lending terms ([36]: 328). Outside of SSA there are examples of larger credit institutions, such as Grameen Shakti in Bangladesh ([73]: 1200), which have provided longer terms loans for PV, but examples of such programmes which emerge by themselves are seemingly few.

Due to these circumstances, establishing and enhancing credit schemes for private SHS owners is a main objective in the multi-stakeholder programmatic model. A main instrument in the UNDP-GEF programme in Zimbabwe was to establish a credit support facility which was managed by an existing bank ([60]: 1075). Lately a United Nations Environmental Programme (UNEP) Solar Loan Programme has been instrumental in engaging large Indian banks in providing loans to SHS, in which up front payment has been reduced to 15 % and the repayment period has been five years. The project has ensured loans to 18,000 SHS in two provinces in India. Similar bank partnership loan programmes have been initiated in Tunisia, Morocco and Ghana ([61]).[13]

The main advantage of the fee-for-service model is that financing is the responsibility of the service providers, which are supposed to have better access to finance than the rural customers. Bearing in mind the relatively high subsidy rates, utilities and foreign companies may be able to raise sufficient capital for the investment, as is the case of South Africa and Morocco.

[13] Instead of the traditional capital cost subsidies, the project provides an interest rate subsidy to lower the cost to customers of financing SHS at the retail level, thus reducing the effective interest rate on loans taken by the customers. UNEP has also initiated similar bank partnership loan programmes in Tunisia, Morocco, Ghana and China and new programmes are in development for Algeria, Egypt and Indonesia ([61]).

Small ESCOs, however, have limited finance options, and will need credit backed by donor funding or subsidies, although this may not be sufficient. The ESCOs established in Zimbabwe under the Japanese (JIKA) financed project in 1998 were provided with donated material, but were not able to cover operational costs with the fees paid by clients ([66]), and according to a recent case study under the Development and Energy in Africa project ([63]), the ESCO pilot project in Zambia, which had also received the first shipment of material for free, was not able to cover operational costs ([74,64]).[14]

6.3. Subsidies

Direct and indirect subsidies are included in most rural electrification programs, and there is a general consensus that subsidies are necessary for expansion of rural electrification ([41]). Subsidies are therefore also generally accepted as a condition for SHS and the modality of applying subsidies is an important difference between delivery models.

Investment subsidies can in principle be paid to either the consumer or the retailer. In Denmark, Germany and the US, subsidies have been paid directly to the consumer, but in a developing country context with external financing, weaker states, less control and higher frequency of corruption, subsidies are generally paid to the certified companies and administered by the multi-stakeholder management authority, such as the regulator, a rural electrification fund or other state authorities ([49]: 27).

While the cash sales model almost per definition excludes subsidies, subsidies are what drive the programmatic approach, whether it is direct subsidy to buy down investment or indirect subsidy for buying down interest rates in financing schemes. In both cases, the subsidy is used as an incentive to promote only certified equipment. In the UNDP-GEF supported Zimbabwe project, subsidies were blamed for creating market distortions, partly because only selected companies had access to subsidies, but mainly because the subsidy scheme was short-term and created an

[14] As regards financial returns, i.e. the extent to which the project will generate revenue to fully meet its financial obligations, the companies have been making losses since their inception. Furthermore, the companies have no financial reserves to be used for the purchase of rundown system batteries. This means the project is not sustainable as it has no capacity to reinvest and therefore to continue offering the service ([63]: 26).

overheated market environment ([50]: 27).

The fee-for-service model is also suitable for managing subsidies. The advantage is that the control of subsidies is limited to relatively few fee-for-service companies, compared to a large number of suppliers in the programmatic model. In the pilot stages, all fee-for-service (dealer) models have received an investment subsidy of 100 %, mainly because the established ESCOs were small and did not have the sufficient equity capital. Subsidies have also been used in the concession model to lower costs to a level comparable to grid-connected options. In the South Africa case, an 80 % investment subsidy was paid to the concession holders in order to reduce the SHS fee to a politically acceptable level.

Subsidies to SHS are a necessary instrument for levelling the playing field for SHS in the cases where diesel-based mini-grids receive subsidies or cross-subsidies. Higher investment subsidy rates may even be justified by the need for a push to a 'critical mass' to reduce marketing costs and to enable after-sales activities. However, this latter type of investment subsidies should ideally be reduced as the market grows ([70]: 43).

It is important to acknowledge that subsidies in both the programmatic and the fee-for-service delivery models have side effects, such as increasing overheads, and market distortions. Subsidies should therefore be transparent, targeted, and predictable for a number of years ahead, in terms of a communicated exit strategy ([75]: 59).

6.4. Maintenance and quality assurance

In spite of the fact that long lifetime and simple maintenance have been arguments in favour of SHS, assurance of continued maintenance is one of the most serious challenges for SHS systems. Evaluations of PV systems that have been in operation for more than three years are scarce, but there are sufficient examples to raise concern. Common wisdom would suggest that privately owned systems would be well maintained but private consumers' lack of knowledge of battery charging and difficulties in identifying high quality products (controllers and batteries) may reduce the positive effect of private ownership.

The programmatic model in turn aims at ensuring a higher quality of products through quality standards and certification. This may improve failure rates, but even certified products may have a high failure rate, as in the UNDP-GEF funded Zimbabwe project. According to Banks ([49]: 54) a review of the project indicated that 48% of the supported systems were faulty after a few years.[15] In this case, however, the high failure rate may partly be due to the lack of economic means to replace spare parts, as a result of the poor macroeconomic conditions and the depreciation of the local currency ([60]: 1073).

Another asset of the multi-stakeholder programmatic approach is training of technicians. There is, however, no certainty that trained technicians will remain in the project areas, and according to Banks ([49]: 54), programme experience indicates that maintenance infrastructure will not necessarily establish itself and that the consumers will be able to afford replacement of spare parts to repair.

Better maintenance has therefore been one of the arguments in favour of the fee-for-service models, in which replacement of e.g. charge controllers and batteries is the responsibility of the service provider. In this case, one would assume a high risk of careless use of the equipment and a higher risk of theft, as in the donation model. Consumer participation in the planning process, consumer utility of the energy service and the frequent visits from the service company seem to a certain extent to counterbalance this, but more evidence is needed on this important issue. In this model, the biggest risk for the customer is that the fee-for-service company goes bankrupt, which is unlikely if the service provider is an existing utility as in the case of South Africa and Morocco, but which is more likely in the case where ESCOs are established at the initiative of donor programmes.

7. Issues for consideration in promoting SHS for rural electrification

The literature review shows that each delivery model has its advantages and disadvantages, whose significance depends on the specific context in which the model will be applied. Market based models seem ideal at the early and

[15] Of the faulty systems, 33 percent had battery failure, 23 percent had light failure and 12 percent had charge controller failure.

late stages of market development, while the multi-stakeholder models and the concession models can be used to build up markets that have not yet matured.

In the Kenyan case, however, the market model has also proved efficient at developing the market above the introductory stage. This has been explained by the existence of an important group of middle class farmers and others in rural areas, which can afford a cash payment. The high income level, however, may also partly explain the relative success of concession models in South Africa and Morocco. Therefore income level seems to be a determinant factor for success, independently of delivery model.

The review points at a number of other crosscutting elements, such as long-term political commitment, inclusion of the established financial sector and the subsidy levels, which may be equally important for the choice of delivery model. This will be further elaborated in the following.

7.1. Long-term political commitment

Long-term government commitment is one of the most important factors for achieving rural electrification goals. The effort in South Africa is driven by government social policy and the achievements in the Moroccan case are the result of a long-term commitment from government and the national utility. Unfortunately, long-term commitment is generally not a feature of donor-supported programmes nor SSA governments. While donor-supported programmes have the advantage of bringing needed capital to the sector, their weak points are that they are generally short term, 3-5 years. Donor programmes are often very concerned about reaching the immediate project goals in terms of number of connections or installations. Combined with the short duration, this may have the side effect that the market is over stimulated for a while, until it returns to the pre-project level and maybe lower. This, for example, was the case in the UNDP-GEF project in Zimbabwe ([60])

7.2. Inclusion of a established financial sector

In market based approaches, a key factor for success is the inclusion of the existing financial sector in the programme. Perhaps not surprisingly there is growing evidence that credit programmes should be managed by professionals, but one should acknowledge that when other solutions have been sought, it has generally been out of need, because the financial sector has happened to be very difficult to involve in long-term credit schemes. Most multi-stakeholder approaches therefore attempt to involve the financial sector, but in a number of cases, the programme obligation to achieve measurable project goals within the programme lifetime, has forced the management to opt for other solutions and diverted the focus from this important but difficult issue. There are, however, increasingly promising results, which enforce the notion that the focus should be on long-term sustainable financing concepts rather than on short-term project or programme goals.

7.3. Subsidy levels

Cross subsidizing rural electrification was an integrated part of the former state owned utility models, and there is general consensus that subsidies are a precondition for expanding rural electrification schemes. Fuel for electricity production is often subsidized in SSA. In some cases this is a legacy from the pre-liberalization regime, while in others, it is a reaction against increasing oil prices. Price signals at country levels do not thus reflect world market prices. The first condition is therefore to level the playing field by harmonising import tax levels and subsidy levels for solar PV and for fossil fuel based solutions. In most cases, this will be to the benefit of solar PV. Secondly, subsidies for solar PV may be needed for a period of time, in order to 'boost' the demand, and to ensure a certain quality level. However, when introducing investment subsidies it is important that they are long lasting and that there is a clear, understandable and communicated exit strategy, which may be a gradual reduction of subsidies over a given timeframe.

7.4. Limits of donor interventions

The review supports the notion that aspirations of donor interventions to achieving certain goals are in general over-optimistic. The number of project failures within the energy sector and elsewhere, is a sign that development projects are a kind of social experiment with a number of unpredictable consequences. It should therefore be acknowledged that the establishment of markets for solar PV may depend less on delivery structure and subsidy levels than on a number of existing socio-economic factors as diverse as income level, income diversification, class structure, agricultural opportunities, TV broadcast plans, trade and industry policy – all factors that are considered to be outside the scope of external intervention.

On top of this, a number of specific conditions need to be fulfilled simultaneously before a market can develop. The most important single condition is affordability, which can be achieved by support from a number of means as discussed above, but which is often brought about by non-predictable development paths. The actual flooding of cheap industrial products (often of low quality) from China into SSA, and the exploding market for cell phones, and TV broadcasting in rural areas may be more important than any 'planned interventions' attempting to create a market for SHS. This calls for modest aspirations about the outcome of interventions from donors and development banks, when compared to expected outcomes of good governance, national economic politics and international trade politics.

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