# MEASURES FOR THE DIFFUSION OF SOLAR PV ARE ALIGNED IN TECHNOLOGY ACTION PLANS FOR SIX COUNTRIES IN AFRICA

Ivan Nygaard
Ulrich Elmer Hansen
Mathilde Brix Pedersen¨
Gordon A. Mackenzie
UNEP Risø Centre,
Department of Management Engineering,
Technical University of Denmark
Marmorkajen 51, 2100 Copenhagen Ø,
Denmark

ABSTRACT: Recently, development projects have provided support to governments to facilitate technology transfer for climate change adaptation and mitigation. These include the Technology Needs Assessment (TNA) funded by the Global Environmental Facility (GEF). In the TNA project, which was implemented in ten African countries from 2010 to 2013, dedicated government committees have prioritized climate change mitigation technologies and developed action plans for the diffusion of the selected technologies. The project results show that solar PV is high on the agenda in Africa. Six out of ten countries in the region prioritized solar PV, and action plans for the diffusion of solar home systems were put forward in Cote d'Ivoire, Kenya, Mali and Senegal, while the implementation of grid-connected systems was proposed in Rwanda, Mali and Senegal. The project reports and technology action plans prepared in these six countries are used as the basis for comparing how solar PV is perceived in these countries and how policy measures enabling environmental adjustments and investment programmes are being planned to promote diffusion of the technology in these different contexts.
Keywords: policy, developing countries, PV market, dissemination, rural electrification, solar home systems

## 1 INTRODUCTION

Recently, development projects have provided support to governments to facilitate technology transfer for climate change adaptation and mitigation. These include the Technology Needs Assessment (TNA) funded by the Global Environmental Facility (GEF). In the TNA project, which was implemented in ten countries in Africa in the period from 2010 to 2013, dedicated government committees have prioritized climate change mitigation technologies and developed action plans for the diffusion of the selected technologies.

Reports describing the results of the selection process, the barrier analysis and the resulting technology action plans have been issued by the participating countries and made available on the project website, but so far there has been little analysis of which technologies were prioritized within and across regions (Africa, Latin America and South East Asia) or of the alignment of barriers and measures for the transfer and diffusion of specific technologies (see e.g. [1]). In spite of the great interest in solar PV in Africa, analyses of identified barriers and proposed measures for the further diffusion of solar PV have not yet been carried out.

In order to fill this gap, this paper will investigate how large a share of the selected technologies address solar-related issues and the extent to which there is correspondence between the barriers identified in the African countries and to what extent there is alignment between the measures proposed by governments. The first section provides a short description of the TNA project and approach and is followed by description of the methodology. The next section describes the different markets, products and typical owners of equipment. In order to illustrate distinct trajectories for the transfer and diffusion of PV technologies, this will be followed by three country cases of PV diffusion. Finally an analysis of the similarities and differences in barriers and measures across countries is presented before some brief forward-looking remarks are offered by way of a conclusion.

## 2 THE TNA PROJECT APPROACH

The objective of the TNA project was to identify and facilitate the transfer and diffusion of technologies for climate change mitigation and adaptation through the development of technology actions plans in non-annex 1 countries. The TNA project is being funded by the GEF and implemented by UNEP in cooperation with the UNEP Risø Centre (URC) as part of the strategic programme for technology transfer agreed upon at COP14 in Poznan. The project was carried out in 36 countries in the period 2010-2013 (1). This analysis for Africa covers Cote d'Ivoire, Kenya, Mali, Mauritius, Morocco, Rwanda, Senegal, Sudan and Zambia (2). Funding is currently being negotiated for a new phase of the project, which is expected to be carried out from 2014 to 2017. This next phase will include the following countries from Africa: Burkina Faso, Burundi, Egypt, Gambia, Madagascar, Mauritania, Mozambique, Seychelles, Swaziland, Tanzania, Togo and Tunisia.

The project has followed an overall methodology consisting of the following basic steps: i) selection of priority technologies; ii) analysis of barriers; iii) suggesting measures to overcome barriers; and iv) the preparation of a government plan of action for facilitating technology transfer and diffusion for specific technologies [2].

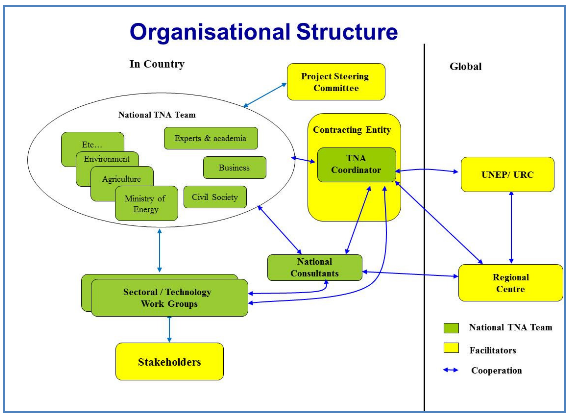


**Figure 1**: Organisational structure of the TNA project [3]

Although funded from external sources and following an overall methodology, the TNA project is a country-driven process led by a TNA committee comprising representatives from the most important line ministries responsible for finance, planning, energy, industry, agriculture and water, as well as non-government representatives from the private sector, civil society and the research community. The actors involved and the organisational structure of the TNA project are illustrated in Figure 1. The work of the TNA committee is coordinated by a TNA coordinator, most often from the ministry that is responsible for leading the climate negotiations. The work of the TNA committee is overseen by a project steering committee with high-level representatives from selected ministries. The TNA committee hires consultants to lead the prioritization of technologies, conduct the barrier analyses in cooperation with stakeholders from each sector and elaborate draft reports and plans to be discussed and endorsed by the TNA committee and later by the relevant line ministers. UNEP, in collaboration with the UNEP Risø Centre, has overall responsibility for project implementation in the countries. This includes overall project management, methodology development, training and capacity-building, quality assurance and dissemination of results [3]

## 3 METHODOLOGY

This paper is based on systematic analysis of the outputs of the TNA project, a thorough literature review and personal insights by the authors gained through participation in the TNA project.

With respect to the prioritization of technologies in the countries, analysis of barriers and proposed measures, the paper mainly draws on data from the TNA reports, the barrier analysis reports and the technology action plan (TAP) reports available on the project webpage. Specific reference will be made to these reports where necessary.

In general, the reports from the TNA project do not include historical data on the diffusion of PV at national level. The historical analysis of PV diffusion in the three case counties and identification of the main drivers behind specific diffusion patterns are therefore based on a thorough literature review of the academic literature, grey literature such as reports commissioned by donors and government institutions, and mainly web-based news articles. Descriptive statistics across countries are mainly based on datasets available from the World Bank [4].

Besides these written sources, the paper is supplemented with information gathered by the authors through country missions, training workshops and conferences in which coordinators and consultants from the countries concerned have participated alongside our colleagues from the regional centre, ENDA, from whom also we have gained much knowledge of the context in the six countries. When necessary, reference is made to specific personal communications.

## 4 MARKET SEGMENTS FOR PV

When discussing barriers and measures for the diffusion of solar PV, it is important to acknowledge that, although PV products all produce electricity, the products are very different in size and are sold in different markets, at different scales, with different potential owners, and not least with different competing alternatives. This is illustrated in Figure 2.

| Market segment | Product and size | Owners |
|---|---|---|
| Grid connected | Large scale 1-50 MWp | IPPs, Utilities |
| | Roof top 1-10 KWp | Firms, private household |
| Mini-grids | Hybrid 5 kW-1 MWp | Utilities, Coops, ESCO |
| Institutions | Large SHS 50-500 Wp | Governm/ municip/ESCO. |
| Waterpumping | PV pumps 50-500 Wp | Municip/CBOs/ESCO |
| Individual houses | SHS 10-100 Wp | Private, ESCOs |
| Lighting and charging mobiles | Lanterns 1-10 Wp | Private |

**Figure 2:** Market segments, products and potential owners of PV

This also means that, although there may be some similarities in the barriers and related measures for PV in general, there will be specific barriers and relevant measures in diffusing PV for each of the market segments. The TNA project countries were therefore advised to relate their choice of technologies to specific markets, that is, large-scale grid-connected PV or Solar Home Systems.

The nine countries in Africa which made action plans for climate change mitigation technologies selected on average about six technologies (a total of 52) for which they carried out barrier analysis and developed action plans. The technologies were related to sectors such as energy, industry, agriculture or waste that had been identified by the country teams. In some cases countries defined certain technologies as being part of the water or waste sectors, while they were in reality producing energy. For the purposes of this analysis we have characterized such technologies according to 'standardized' sectors defined by the project. Figure 3 shows the distribution of technologies between sectors and countries according to these standard sectors. Not surprisingly energy comes out as the predominant sector, with 42 out of 52 technologies.

| Technology group | Cote d'Ivoire | Kenya | Mali | Mauritius | Morocco | Rwanda | Senegal | Sudan | Zambia | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **Grand Total** | 6 | 4 | 7 | 2 | 4 | 5 | 9 | 5 | 10 | 52 |
| **Forest and agriculture** | | | 3 | | | | | | 3 | 6 |
| **Transport** | | | | | | 1 | | 1 | | 2 |
| **Waste** | 2 | 1 | | | | | | | | 3 |
| **Energy** | 4 | 3 | 4 | 2 | 4 | 4 | 9 | 4 | 7 | 41 |

**Figure 3:** Distribution of selected technologies per

'standardised' sector

Figure 4 shows the energy sector technologies according to 'standardized' technology groups, such as wind, geothermal power and solar power. Nine technologies are in the solar power category, with six out of the nine countries represented. Technologies were selected according to criteria defined by the countries using a multi-criteria analysis (MCA) prioritization tool. One of these criteria could be 'added value', as in the case of Mauritius. Here a solar programme was already in the making, and the selection of solar power would therefore not add much value and was hence discarded in the TNA project, making room for other more 'needed' technologies, in this case wind. Nevertheless, selection of solar technologies by these countries remains a good proxy for the high interest in solar power in Africa in 2011 and 2012, when the prioritization of technologies was carried out.

| Technology group | Cote d'Ivoire | Kenya | Mali | Mauritius | Morocco | Rwanda | Senegal | Sudan | Zambia | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **Energy** | **4** | **3** | **4** | **2** | **4** | **4** | **9** | **4** | **7** | **41** |
| 2nd Gen Biofuels | | | 1 | | | | | | | 1 |
| Advanced Coal Technology | | | | | | | | 1 | | 1 |
| Biodiesel | | | | | | | | | 3 | 3 |
| Biogas | | | | | | | | 1 | | 1 |
| Biomass gasification | | | | | | | | | 1 | 1 |
| Biomass power | | | | | | | 1 | | | 1 |
| CFL's | | | | | | | | 1 | | 1 |
| Combined cycle power plant | | | | | | | | | | |
| Combined heat and power | | | | | | 1 | 1 | | | 2 |
| Efficient Lighting Systems | | | | | | | 1 | | | 1 |
| Efficient stoves | | | 1 | | | | | 1 | 2 | 4 |
| Geothermal Power | | | | | | 1 | | | 1 | 2 |
| Hydro power | 1 | | 1 | | | 1 | | | | 3 |
| Less energy intensive products | | | | | | | 2 | | | 2 |
| Methane gas utilisation | | 1 | | | | | | | | 1 |
| Residential energy efficiency | | | | | 1 | | | | | 1 |
| Solar Heating/drying | | 1 | | | | | 1 | | | 2 |
| Solar power | 2 | 1 | 1 | | 2 | 1 | 2 | | | 9 |
| Tidal power | | | | | 1 | | | | | 1 |
| Waste Heat Recovery | | | | 1 | | | | | | 1 |
| Wind power | | | | 1 | | | 1 | | | 2 |
| Briquetting | 1 | | | | | | | | | 1 |

**Figure 4:** Selected mitigation technologies per country according to 'standard' technology categories

| Specific technologies | Cote d'Ivoire | Kenya | Mali | Morocco | Rwanda | Senegal | Grand Total |
|---|---|---|---|---|---|---|---|
| Photovoltaic solar energy | | | 1 | | | 1 | 2 |
| Large Grid Connected PV | | | * | | 1 | * | 1 |
| Solar Home Systems (SHS) | 1 | 1 | * | | | * | 2 |
| PV driven water pumping | 1 | | | | | | 1 |
| PV lanterns | | | | | | 1 | 1 |
| Concentrated PV for power plants | | | | 1 | | | 1 |
| Molten salt for thermal solar plants | | | | 1 | | | 1 |
| Solar Power | 2 | 1 | 1 | 2 | 1 | 2 | 9 |

(*) means that it is included in the general PV category in first line

**Figure 5:** Selected solar power technologies per country

Figure 5 shows the solar power technologies selected per country. In spite of the recommendation to focus on technologies tied to specific market segments, Mali and Senegal choose PV as a broad category and thus also including market segments such as large grid-connected, mini-grids and solar home systems. Rwanda chose large-scale solar power and thus worked with issues related to this technology while negotiating to erect an 8.5 $MW_p$ grid-connected plant. SHS were specifically chosen by Cote d'Ivoire and Kenya, and PV-driven water-pumping was selected by Cote d'Ivoire, although at the end this was merged with SHS, as the barriers and measures were seen to be very similar. Morocco, which is already well advanced in terms of its exploitation of solar power, chose to focus on research and development projects: concentrated PV for large power plant, and the production and use of molten salt for concentrated thermal solar power (CSP).

## 5 PV MARKET DEVELOPMENT IN THE COUNTRIES CONCERNED

The six countries included in the analysis have experienced very different policies and development trajectories with respect to the diffusion of solar PV.

This section will first provide overviews of the status of PV diffusion in the six countries and of the policies already adopted. The diffusion of PV in these countries will be related to the main socio-economic parameters and the diffusion of mobile phones in the countries. Following this overview, the background and drivers for diffusion in Kenya, Morocco and Rwanda will be analyzed in more detail in order to illustrate three very different diffusion trajectories.

### 5.1 Socioeconomic context, incentives and diffusion of solar PV

An overview of selected development indicators, PV capacity installed and applied measures for the promotion of solar PV in these six countries is provided in Figure 6 below.

| | Cote d'Ivoire | Kenya | Mali | Morocco | Rwanda | Senegal |
|---|---|---|---|---|---|---|
| Population, Millions (2011) | 20.2 | 41.6 | 15.8 | 32.3 | 10.9 | 12.8 |
| GDP per Capita, Current USD (2011) | 1,195 | 808 | 684 | 3,105 | 583 | 1,119 |
| National electrification rate (2011) | 59.0% | 19.0% | 27.1% | 99.0% | 16.0% | 57.0% |
| Rural electrification rate (2011) | 32.0% | 7.0% | 14.9% | 97.0% | 5.0% | 33.0% |
| Mobile phone subsribtion (2011) | 86% | 68% | 68% | 113% | 41% | 73% |
| Installed PV capacity MWp (2009) | NA | 6-8 MWp | 2.3-10 MWp | > 9 MWp | < 1 MWp | 2.3 MWp |
| Installed PV Wp/capita | NA | 0.168 | 0.388 | 0.279 | 0.091 | 0.180 |
| Installed PV capacity MWp (2012) | NA | 16 MWp | NA | NA | > 2 MWp | NA |
| Installed SHS total (2009) | NA | 300,000 | NA | > 50,000 | NA | 22,000 |
| Installed SHS total (2012) | NA | 400,000 | 130,000 | > 50,000 | NA | NA |
| Local assembly of panels (size) | None | 2.5 MWp/y | None | None | None | 25 MWp/y |
| Feed in Tariff (FiT) | None | 2008/2012 | None | None | None | TBI |
| Excemptions from import duty | (Panels) | 1990 | 1999 | NA | None | TBI |
| Excemptions from VAT | NA | 1990 | 2009 | NA | (LED only) | TBI |

(TBI) = To be implemented; (NA) = Data not available

**Figure 6**: Key development indicators, installed solar PV capacity and incentives applied by 2013 in the six countries. Authors' compilation based on [4]–[20]

Selected data from Figure 6 above are illustrated graphically in Figures 7 and 9 below. Figure 7 shows a relatively high correlation between rural electrification rates and GDP. Mobile phone subscriptions

(subscriptions per capita as a percentage) shows a similar correlation, although mobile phone penetration is relatively high (above 40%) in all countries. This indicates, not surprisingly, that rural electrification rates and mobile phone diffusion rates are to a large extent correlated with economic development.

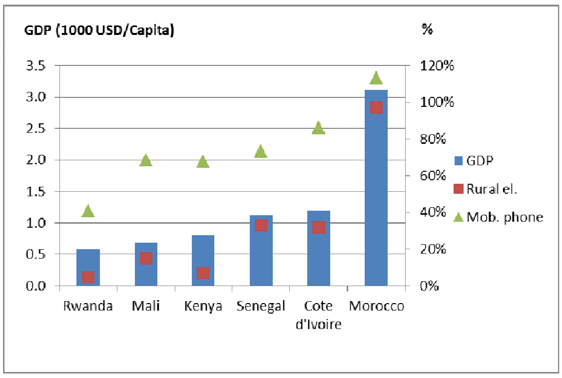


**Figure 7**: Rural electrification rate (2011) and mobile phone subscriptions as percentages (2011) related to GDP per capita (2011) [4], [10], [19]

As Figure 8 shows, diffusion of mobile phones has taken place within a short period of twelve years from 1999 to 2011, and although there are important differences between people's wishes and their willingness to pay for communications and electric lighting, the rapid diffusion of mobile phones shows that technology diffusion in the African region is possible when price compared to perceived need reaches a certain threshold value.

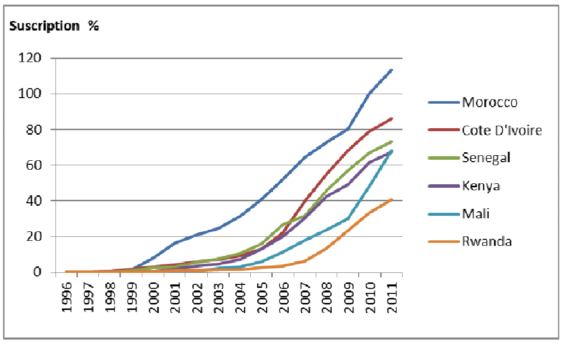


**Figure 8**: Number of mobile phone subscriptions per 100 people (%) [4]

The installed capacity of PV per capita ($W_p$/capita) is presented in Figure 9. These data should be interpreted cautiously. First, no data are available for Cote d'Ivoire. Secondly the data from Mali are based on an estimate by one of the experts in the field [15], which is three times higher than another estimate from GTZ, though the latter is considered too low [16]. Figure 9 shows a weak but generally positive correlation between installed capacity and GDP, thus indicating that economic development is a significant parameter for PV diffusion. If the value for Mali is correct, the installed capacity in Mali is outstanding compared to the other countries, and this would still be the case even if the value for Mali is overestimated as indicated above.

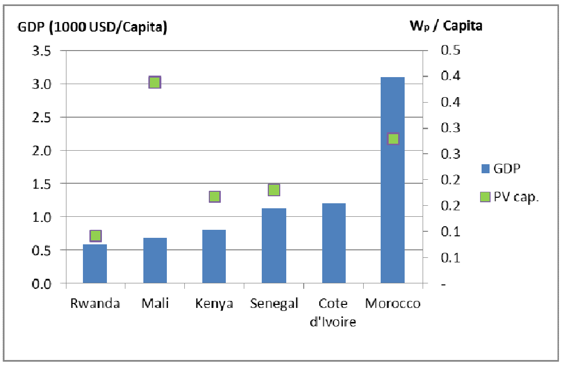


**Figure 9**: GDP per capita (2011) and installed PV capacity (2009) in $W_p$ per capita. Based on Figure 6. Mean values of intervals are used for Kenya and Mali [4], [16], [19], [20]

Mali and Kenya are the only countries which introduced exemptions from import duties and VAT on solar panels at an early stage (Figure 6). It is remarkable that both countries have a high penetration of PV compared to the others, suggesting that exemptions from duties and taxes have a significant effect. This would, however, need more analysis to be substantiated. As we shall see in the following three country cases, there are a number of other drivers that may have determined the diffusion trajectories.

## 5.2 Kenya

Kenya today boasts a solar market that is one of the most mature and best established in Africa. Its origins date back to the 1970s, when the Kenyan government started to use solar energy as a means to power signaling and broadcasting installations in remote areas. Subsequently, from the 1980s onwards, international donors (and NGOs) began to play a larger role by including solar in their development programmes by means of workshops, training programmes and demonstration projects that contributed to generating a demand for PV in Kenya [21], [22]. While government and donor programmes have continued to play an important role in promoting PV in Kenya, this support has gradually been phased out in parallel with the establishment of a private market that slowly started to emerge during the 1980s with the first established suppliers of solar equipment to customers in rural areas [23].

During the 1980s and 1990s, this private market grew rapidly along with a continued reduction in PV system prices, which led to a genuine boom period during the late 1990s [6] (see Figures 10 and 11). Thus, while overall installed PV capacity was estimated at around 1.5 MW peak ($MW_p$) in the early 1990s, with approximately two thirds installed in institutional systems [21], the Kenyan market had more than doubled by 2000 (to approximately 3.9 $MW_p$), with around 75% of the installed capacity in households [24]. A decade later, the overall market had reached between 8 and 10 $MW_p$ of installed capacity, as shown in Figures 10 and 11 [6]. After the comprehensive market review in 2009, information about development in installed capacity has been sporadic. Ondraczek [12] estimates that 320,000 SHS were in operation in 2010 and refers to Ramboll (2012) claiming 16 $MW_p$ in operation in 2012. Tobias Cossen from GIZ estimates 20 $MW_p$ in operation in November 2013 [14].

| Solar PV Technology | Estimated installed capacity | Estimated capacity installed/year (2008) | Estimated financial volume[2] (€/Year/2008) | Degree of competition |
|---|---|---|---|---|
| Off-grid HH Electrification and Small Scale Commercial | > 6-8 MWp | > 700 kW | > 5 million Euros | Extremely competitive – many players |
| Off-Grid Community Systems (including institutional and pumping systems) | > 1.5 MWp | > 250 kW | > 2.5 million Euros | Dominated by wholesaler/agent partnerships |
| Telecom | > 100 kWp | 100 kWp | N/A | Emergent – few players |
| Tourism | > 50 kWp | N/A | N/A | Emergent |

**Figure 10:** Installed capacity for different market segments in 2009 [6]

Since 2009 the increase in capacity has mainly been in the market segment for SHS. Ondraczek [26] estimates that 320,000 SHS have been installed as of 2012, and da Silva claimed that about 400,000 units were installed in 2014 [17]. However, the use of PV for grid connection and in mini-grids has so far been limited. According to Ondraczek [26] and *PV Magazine* [14] only three systems with sizes respectively of 60, 72 and 515 kW were connected to the grid.

These developments have spurred the emergence of a substantial supplier network of PV systems and associated components, such as batteries and inverters, making Kenya a regional PV-manufacturing hub [6], [22], [24]. In 2010, Ubbink, a joint venture of the German group Centrotec and Cloride Exide, set up the first solar module manufacturing company in East Africa, located in Naivasha, Kenya, with the objective of producing 20-30,000 PV modules per year [11]. While actual production output is unknown, according to the company website production of off-grid modules from 13-60 $W_p$ and larger modules up to 250 $W_p$ started in 2011 (3).

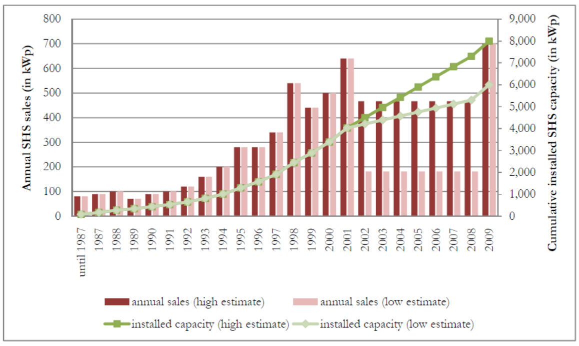


**Figure 11:** Estimated annual sales of SHS in Kenya and cumulative installed capacity [11]

The Government of Kenya has high expectations regarding the future of PV in Kenya. According to the National Energy Policy [27] Kenya expects installed capacity to grow as follows: 100 $MW_p$ by 2016, 200 $MW_p$ by 2022 and 500 $MW_p$ by 2030.

Feed-in tariffs (FiTs) for power from renewable forms of energy were first introduced in March 2008. The last review took place in December 2012. The scheme is technology-specific, and the tariff for solar is fixed at US$0.12 per kilowatt hour. The main principle underlying the calculation of the FiT is that the tariffs reflect generating costs plus a reasonable return for investors. Furthermore, the tariffs should not exceed the long-term marginal generating costs (LRMC), which are US$0.12 per kilowatt hour according to the Least Cost Power Development Plan for Kenya [14].

5.3 Morocco

In Morocco the installation of solar home systems has mainly been driven by the rural electrification scheme led by the Moroccan utility, Office National de l'Electricité (ONE), which, as illustrated in Figure 12, brought the rural electrification rate from a level of less than 20% in 1995 to about 96% in 2010.

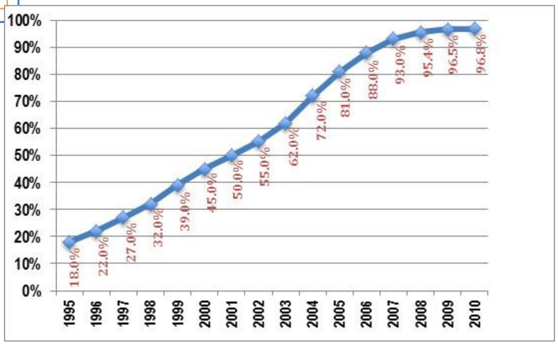


**Figure 12:** Rural electrification rate in Morocco. [9]

The high rural electrification rate was mainly achieved through grid-connection, but as Figure 13 shows, more than 50,000 houses were supplied by individual solar home systems.

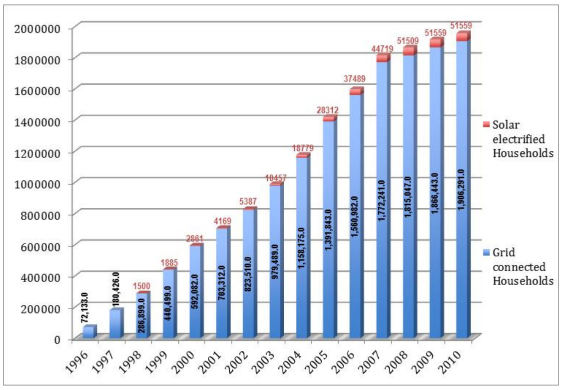


**Figure 13:** Connected households in rural areas [9]

The Moroccan delivery model for SHS is a fee-for-service model. This means that installations are owned and maintained by the national utility, ONE, and, as in the case of grid-connected electricity provision, consumers pay a monthly fee for electricity. In the Moroccan case, through a competitive bidding process, ONE has engaged with international Energy Service Companies (ESCOs), such as TEMASOL, a joint venture between the French companies Total and EDF which has been responsible for installation, maintenance and the collection of user fees [28]. The SHS program has been subsidized with up to 90% of investment. This subsidy is part of a general subsidy needed for the rural electrification program (PERC), which, according to ONE, has received about 47% of its funding from international donors.

Other initiatives, such as the Photovoltaic Market Transformation Initiative (PVMTI) funded by the GEF, was also implemented in Morocco, but in contrast to Kenya, where this initiative supported the market-led approach, in Morocco this project supported one of the smaller ESCOs working under the ONE rural electrification programme [29].

Until 2012 Morocco had only two smaller grid-connected PV systems of 200 kW in the Promasol programme, but unlike most other African countries, Morocco has shown great interest in concentrated solar power (CSP). The Mathar thermo-solar combined-cycle power plant, with a total capacity of 470 MW, was inaugurated in 2010. The plant was supplied by natural gas, but 20 MW of its power could be attributed to CSP. Morocco has recently launched the Moroccan integrated solar project, which aims at a capacity of 2000 $MW_p$ by 2020 at five sites. The programme, which will comprise both PV and CSP technologies, has started construction of the first 160 MW CSP plant at Quarzazate, which is expected to be in operation in 2015 [30].

5.4 Rwanda

According to Hankins et al. (2009), Rwanda is presently an 'early stage market of small players that is poorly integrated into the global and regional solar energy industry'. In 2009 there were only about six to eight companies competing in the market, which was estimated to be worth no more than 60 $kW_p$ per year. Most of the business was financed by donors and mainly served government clinics and schools, as shown in Figure 14. At the same time Hankins et al. [6] note that there is an important future market of up to 4.2 $MW_p$ for private households, as illustrated in Figure 15. Due to the low rate of competition, consumer prices are reported to be high compared to other countries in the region, and there was limited spillover from neighboring Tanzania and Kenya. In spite of the above, Rwanda hosted the largest grid-connected installation in the region, a 250 $kW_p$ pilot plant installed in 2008 [7].

| Solar PV technology | Size of opportunity | Estimated kWp installed/year (2008) | Notes |
|---|---|---|---|
| Government administrative centres | >0.4 MWp | ±15 kW | Good government contacts required |
| Government clinics and schools | >1 MWp | ±40 kW | World Bank, EU, Belgium |
| NGO & NGO health sector | >0.3 MWp | <±5 kWp | PEPFAR |
| Solar Home System | >4 MWp | N/A | Low rural spending power |
| **TOTAL** | **>6 MWp** | **>50kWp** | |

**Figure 14:** Estimated PV market in Rwanda in 2009 [7].

| Type of solar home systems | Size of system (Wp) | Estimated % of households buying | Total number | Size of market (kWp) |
|---|---|---|---|---|
| **No System** | 0 | 55.0% | 944,690 | - |
| **Micro Systems** | 2 | 35.0% | 601,166 | 1,202 |
| **One Light & Radio** | 10 | 7.3% | 124,527 | 1,245 |
| **Two light and radio system** | 20 | 2.0% | 34,352 | 687 |
| **Four light system or higher** | 50 | 0.5% | 8,588 | 429 |
| **Larger systems (inverter or hybrid)** | 150 | 0.3% | 4,294 | 644 |
| **TOTAL** | | **100.0%** | **1,717,618** | **4,208 kWp** |

**Figure 15:** Estimated future market for PV in private households [7].

According to Jacobsen [13], there has been an important increase in activities since 2009. In his 2012 research, he counts 21 companies as compared with six to eight in 2009. Many of them are operating in both the SHS market and the newly established pico market for lanterns and mobile chargers, and he finds that annual sales grew from about 50-100 $kW_p$ in 2009 to about 1400 $kW_p$ in 2011 and 2012, as illustrated in Figure 16 (4).

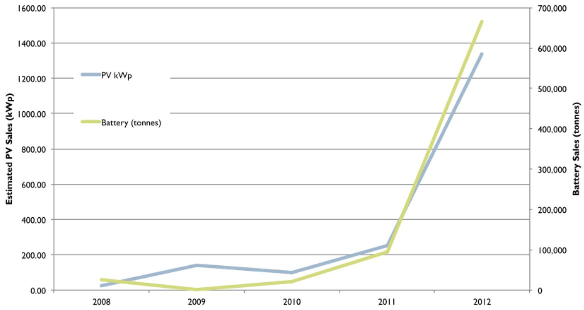


**Figure 16**: Estimated annual sales based on import data [13].

The government only reluctantly supported PV until 2012. The influential *Rwanda Vision 2020* report had a strong focus on renewable energy, but without including targets for PV [31]. Likewise the feed-in tariff, discussed since 2006, did not include PV. The only government support, except for the donor programmes for institutions, schools and health centres, was a VAT exemption for LED lamps, which mainly helped the market for solar lanterns. Jacobsen [13] therefore talks about a paradigm shift in government around 2012. This is visible in the Economic Development and Poverty Reduction Strategy, which states 'that the government in partnership with the private sector will support the rapid dissemination and sales of solar home systems (up to 1.2 million units) through a large-scale awareness programme of the benefits of solar power for rural households', and further that 'the regulatory environment and standard on solar products will be reviewed were appropriate' [19].

The effect of these promises is still to be seen on the market for SHS to rural households, but interestingly, in parallel with the TNA process focusing on large-scale grid-connected PV (2011-2013), a group of international investors has closed a PPA with the national utility in 2013 [32] and in early 2014 reached financial closure for a 8.5 $MW_p$ grid-connected project [33] (5).

5.5 Discussion

These three cases illustrate three different transfer and diffusion strategies. Kenya presents one of the most mature markets for solar home systems in Africa and is an example of a mainly private, market-led approach. Morocco is another leading country in the region when it comes to the diffusion of PV. In Morocco, solar PV diffusion has mainly been driven by a utility-led rural electrification programme, which has provided PV-produced electricity using a fee-for-service model. However, in spite of the relatively high number of SHS in Kenya, this corresponds to about 5% of the rural population using PV electricity [11]. As the rural electrification rate is only 7%, there is still a large market for SHS (Figure 6). This is in contrast to Morocco, where the rural electrification rate of almost 100% has left little room for a private market for SHS. Morocco has subsequently initiated a plan for large-scale grid connection, focusing mainly but not exclusively on concentrated solar thermal power (CSP), and it is currently working on developing a plan for grid-connected roof-top PV systems [34].

The impressive development in Kenya in terms of the highest number of SHS diffused on the continent is less impressive when these installations are converted to installed capacity per capita and seen in relation to GDP, as illustrated in Figure 9 above. In this context, Kenya is only slightly above the trend for installed capacity in the other countries. Likewise Figure 9 shows that per capita PV capacity in Morocco is low compared to GDP, in spite of being remarkable in absolute terms.

Both Kenya and Morocco are examples of countries where PV has increasingly been diffused over a number of years (6). Rwanda, on the other hand, has experienced slow progress in solar PV, which has mainly been supported by donor programs to rural institutions such as schools and health centres, though a political paradigm shift can be observed in the last couple of years. This paradigm shift follows a more general trend in African countries, due to the fact that PV has now finally reached a cost level that makes it economically feasible or 'almost' feasible on most markets under certain conditions. Under these circumstances, properly created measures and incentives in terms of a comprehensive enabling framework are important to ensure a smooth market development.

## 6 COMMONLY IDENTIFIED BARRIERS

This section provides the results of an analysis of the barriers for diffusion of solar PV identified in six country studies [20], [35]–[40]. Because of Morocco's strategy favoring large grid-connected solar power systems, this country has selected technologies that are at the research level. Barriers to bringing technologies from this research to the market are very different from barriers to the diffusion of already market-mature technologies. For the other five countries, namely Cote d'Ivoire, Kenya, Mali, Rwanda and Senegal, in spite of their different development paths and socio-economic contexts, there is a high level of alignment of the barriers that have been identified. The most common barriers are described below, both in general and for each of the main market segments.

### 6.1 General barriers for PV diffusion

- *High upfront costs*. This was partly explained by low volume, few suppliers and low competition, partly by the fact that equipment is imported with high transport costs, and especially because equipment in most countries was subject to VAT and import duties (all countries).
- *High interest rates and difficult access to capital* (all countries).
- *Low quality products*. This was mainly seen to be due to a lack of standards or to poorly enforced standards (Rwanda, Kenya and Senegal).
- *Low level of technical skills* for installation and maintenance, and *low level of engineering expertise* in relation to large-scale grid-connected systems and hybrid systems for mini-grids (Rwanda, Mali, Kenya and Senegal).
- *Low level of R&D* in solar PV at the national level (Rwanda, Mali, Kenya and Senegal).

### 6.2 Large-scale grid connection (relevant for Rwanda, Mali and Senegal)

- *High production costs for PV electricity* compared to the alternatives (Rwanda and Senegal).
- *Little experience at national level*, i.e. none or few pilot and demo-projects (all).
- *No fixed selling prices* for electricity (Rwanda and Senegal).

### 6.3 Solar home systems (relevant for Mali, Kenya, Senegal and Cote d'Ivoire)

- *Low purchasing power* by rural population (all).
- *Little knowledge about PV* among consumers (Kenya and Cote d'Ivoire).
- *Poor delivery and service network* in rural areas (Kenya).

## 7 PROPOSED MEASURES

This section provides the result of an analysis of proposed measures for the diffusion of solar PV identified in technology action plans (TAP) for the six countries [18], [35], [36], [39]–[42]. Except for Morocco, there is a high level of alignment of these proposed measures. These most common measures are described below, both in general and for each of the main markets.

### 7.1 General measures

- *Support to local production.* All countries – except for Kenya and Senegal, where local production is already established – suggest measures to support local production. This comprises initiatives from support to information, field visits and network formation in Rwanda, via support to public-private partnerships in Mali to support to and training of small and medium enterprises (SMEs) in Cote d'Ivoire. Support is apparently based on a belief that local production will reduce prices and generate income and jobs locally.
- *Financing schemes.* All countries propose support to financing schemes, with a combination of guarantees and low interest rates, addressing both costs and access to finance.
- *Tax exemptions.* Mali and Kenya already have exemptions from VAT and import duties. Cote d'Ivoire has exemption from import duties, and Senegal is awaiting the implementation of a law from 2010 stipulating exemptions. The other countries have proposed exemptions. To support the newly established local assembly of panels, Senegal is also proposing removing import taxes from 'elements' of solar panels, such as wafers, glass and aluminum frames, which are inputs to the assembly plant.
- *Establishment and reinforcement of standards.* While most countries see low-quality products as a barrier, only Kenya and Senegal have proposed taking action. Kenya is calling for a strengthening of general measures against corruption, while Senegal proposes support to the bureau of standards.
- *Support to technical training.* This measure is proposed in all countries except for Mali, which, on the other hand – and like Cote d'Ivoire – proposes training for employees in the finance sector.
- *Support to R&D.* Strengthening of research and development is proposed by all countries except Cote d'Ivoire. A new research centre is proposed in Rwanda, revival of an old research centre in Mali, while Kenya and Senegal suggest more support to existing research and development centres.

### 7.2 Large-scale grid-connected (relevant to Rwanda, Mali, Senegal)

- *Feasibility study, pilots and demo projects* are proposed in Rwanda and Senegal.
- *Standard PPAs and feed-in tariffs* are proposed in Rwanda and Senegal.

7.3 Solar Home Systems (relevant for Mali, Kenya, Senegal and Cote d'Ivoire)

- *Subsidies* for PV in rural electrification are proposed in Kenya, while elaboration of wider 'incentives' is suggested in Mali, Senegal and Cote d'Ivoire.
- *Awareness raising* in terms of information activities for rural population is proposed in Kenya and Senegal, while in Cote d'Ivoire awareness raising is proposed to address the supply side, such as importers, the financing sector and technical personnel.

## 8 CONCLUDING REMARKS

The African countries which participated in the TNA project have shown high levels of interest in solar PV technologies. 25% of the action plans for energy-related mitigation technologies were focusing on solar power, and six out of nine countries had selected solar power as one of their mitigation technologies. An even more tangible sign of the high level of interest is that local production has been established in Kenya and Senegal, and that this is also high on the agenda for the other three countries in the analysis.

In spite of their very different points of departure, these countries were proposing measures which were aligned to a high degree. The most common measures were support to i) local production, ii) financing schemes, iii) tax exemptions, iv) establishment and reinforcement of standards, v) technical training, and vi) research and development.

The analysis above, coupled with the experiences drawn from capacity-building and training courses in the TNA project in which the authors were involved, suggest some concluding remarks regarding future donor support to PV diffusion in Africa.

First, we see that direct donor support to projects providing and installing equipment is and will be vanishing. From being a niche relying on donor-supported equipment, PV is currently a viable or 'almost' viable alternative for consumers and private investors in most market segments. This calls for the development of enabling frameworks to sustain large-scale market-based diffusion, and implies that that donor agents and government officials go through a transition from 'project holders' to enabling framework specialists. In the training and capacity-building provided in the TNA project, we have learned that this transition is difficult at the institutional level as well as on the personal level, which has encouraged the project to retain its focus on market analysis, measures and enabling frameworks in building capacity.

Secondly, upgrading in the global value chain in terms of the local assembly of panels and local production of other system elements is an opportunity acknowledged by the TNA project participants. Ensuring adequate and efficient support to this upgrading is a challenge, which will not only be solved by the energy sector, as success will also be contingent on applying a multi-sectorial approach as seen in the TNA project, involving expertise in financing, niche development, learning in firms and technological innovation systems. Researchers, policy-makers and industry both in and outside Africa are currently showing a great interest in following how and to what extent African firms, in collaboration with external partners, will be able to seize this chance for local 'green' business development and local employment.

## 9 REFERENCE LIST


[1] UNFCCC, "Third synthesis report on technology needs identified by parties not included in Annex 1 to the convention," United Nations Framework Convention on Climate Change, http://unfccc.int/resource/docs/2013/sbsta/eng/inf07.pdf, (2013).

[2] J. Boldt, I. Nygaard, U. E. Hansen, and S. Trærup, "Overcoming barriers to the transfer and diffusion of climate technologies," UNEP Risoe Centre, DTU, Roskilde, Denmark (2012).

[3] S. Dhar, J. P. Painuly, and I. Nygaard, "Organizing the National TNA Process: An Explanatory Note," UNEP Risø Centre, Technical University of Denmark (2010).

[4] WB, *Africa Development Indicators*. The World Bank (2012).

[5] M. Taoumi, "Les energies renouvelables au maroc," Powerpoint presentation by Mustapha Taoumi, Directeur Conseiller au CDER (2008).

[6] M. Hankins, A. Saini, and P. Kirai, "Target Market Analysis: Kenya's Solar Energy Market," Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Berlin (2009).

[7] M. Hankins, A. Saini, and P. Kirai, "Tartet Market Analysis: Rwanda's Solar Energy Market," Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Berlin (2009).

[8] D. A. Bamba, N. Ibrahim, S. Mamadou, K. Mamadou, W. S. Dramé, T. Ibrahima, N. Ibrahima, and N. Gora, "Système d'Information Energetique du Sénégal - un outil d'aide à la prise de décision," SIE - Sénégal, Ministère de la coopération internationale des transports aériens des infrastructures et de l'énergie, Dakar, Senegal (2010).

[9] ONE, "Rapport d'Activités," Office Natinale de l'Electricité, Morocco (2010).

[10] DNE, "SREP Mali- Investment Plan: Scaling Up Renewable Energy in Mali: Volume 1, Investment Plan," Direction National de l'Energie de Mali (2011).

[11] J. Ondraczek, "The Sun Rises in the East (of Africa): A Comparison of the Development and Status of the Solar Energy Markets in Kenya and Tanzania," Hamborg, Working Paper FNU-195, (2011).

[12] J. Ondraczek, "Are we there yet? Improving solar PV economics and power planning in developing countries: the case of Kenya," *Renew. Sustain. Energy Rev.*, vol. 30, (Feb. 2014), pp. 604–615.

[13] R. Jacobsen, "The diffusion of solar PV technology using TIS perspective," VU University Amsterdam, (2013).

[14] E. Meza, "Special Report Africa: Kenya," *PV magazine* (2013).

[15] A. I. Maïga, "Personal communication with Maiga Alhousseini Issa, CNESOLER, Mali in 2012." (2012).

[16] S. Sarr, A. Ndour, O. Gning, and A. Diop, "Accès aux services énergétiques dans les pays de la CEDEAO: Etudes de Cas," ENDA, Energy,

Environment, Development, Dakar, Senegal, (2012).

[17] I. P. da Silva, “Personal communication, 28 March 2014 with Izael Pereira da Silva, Strathmore University, Kenya.” (2014).

[18] I. Nygaard, P. Norgaard, L. Dewilde, O. Ouattara, F. Kamissoko, A. I. Maiga, S. Diarra, and N. Coulibaly, “Screening of feasible applications of wind and solar in Mali: Assessment using the wind and solar maps for Mali,” UNEP Risø Centre, Technical University of Denmark (www.frsemali.org), (2012).

[19] GoR, “Shaping our Development: Economic Development and Poverty Reduction Strategy 2013-2018,” Republic of Rwanda, Kampala: Rwanda, (2013).

[20] IEA, “World Energy Outlook 2013: Electricity Access Database,” OECD/IEA, (2013).

[21] R. H. Acker and D. M. Kammen, “The quiet (energy) revolution: analysing the dissemination of photovoltaic power systems in Kenya,” *Energy Policy*, vol. 24, no. 1, (1996), pp. 81–111.

[22] M. Hankins, “A case study on private provision of photovoltaic systems in Kenya,” in *Energy Services for the World’s Poor. Energy and Development Report 2000*, P. J. Brook and S. Smith, Eds. Washington: ESMAP, World Bank, (2000), pp. 92–99.

[23] A. Jacobson, “Connective Power: Solar Electrification and Social Change in Kenya,” *World Dev.*, vol. 35, no. 1, (Jan. 2007), pp. 144–162.

[24] M. Moner-Girona, R. Ghanadan, A. Jacobson, and D. M. Kammen, “Decreasing PV Costs in Africa: Opportunities for Rural Electrification using Solar PV in Sub-Saharan Africa,” *Refocus*, vol. 7, no. 1, (2006), pp. 40–45.

[25] Ramboll, “Technical and Economic Study for Development of Small Scale Grid Connected Renewable Energy in Kenya,” London, (2012).

[26] J. Ondraczek, “The sun rises in the east (of Africa): a comparison of the development and status of solar energy markets in Kenya and Tanzania,” *Energy Policy*, vol. 56, (May 2013), pp. 407–417.

[27] GoK, “National Energy Policy,” Republic of Kenya, Nairobi: Kenya, (2012).

[28] B. Allali, “TEMASOL : Providing Energy Access to Remote Rural Households in Morocco,” (2011).

[29] N. Magradze, A. Miller, and H. Simpson, “Selling solar: lessons from more than a decade of IFC’s experience,” International Finance Cooperation (IFC) & Global Environmental Facility (GEF), Washington D.C., (2007).

[30] C.-C. Cîrlic, “Solar energy development in Morocco,” *Libr. Briefing, Libr. Eur. Parliam.*, (2013), pp. 1–7.

[31] GoR, “Rwanda vision 2020,” Republic of Rwanda, Kigali, Rwanda, (2000).

[32] M. Hall, “PPA for Rwanda’s first grid scale solar park,” *PV magazine*, (2013). [Online]. Available: http://www.pv-magazine.com/news/details/beitrag/ppa-for-rwandas-first-grid-scale-solar-park_100012128/#axzz2xwaw8W9e. [Accessed: 04-Apr-2014].

[33] B. Willies, “Scatec Solar to build East Africa’s first utility-scale PV plant in Rwanda,” *PV Tech*, (2014). [Online]. Available: http://www.pv-tech.org/news/scatec_solar_to_build_east_africas_first_utility_scale_pv_plant_in_rwanda.

[34] A. Lahbabi, "Personal communication 11 April 2014 with Abdelmourhit Lahbabi, Consultant, Président ADS Maroc" (2014)

[35] MESD, “Evaluation des besoins en technologies et plans d’action technologiques aux fins d’atténuation de changement climatiques, Côte d'Ivoire,” Ministère de l’Environnement, des Eaux et Forêts, Abidjan, Côte d'Ivoire, (2013).

[36] MEAT, “Evaluation des besoins en technologies et plans d’actions technologiques pour l’atténuation des changements climatiques, Mali,” Agence Nationale de la Météorologie, Ministère de l’Equipement et de l’Aménagement du Territoire, Bamako, Mali (2012).

[37] NEMA, “Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation, Kenya,” National Environmental Management Authority (NEMA), Nairobi, Kenya, (2013).

[38] RoR, “Barrier Analysis and Enabling Framework for Technology Transfer and Diffusion,” Republic of Rwanda, Kigali, Rwanda, (2012).

[39] MEDD, “Evaluation des besoins en technologies (EBT) et plans d’action technologiques (pat) aux fins d’atténuation aux effets du changement climatique,” Ministère de l’Environnement et du Développement Durable (MEDD), Dakar, Senegal, (2012).

[40] MEMEE, “Evaluation des besoins technologiques et plan d’actions technologiques aux fins d’atténuation du changement climatique,” Ministére de l’Energie, des Mines, de l'Eau et de l'Environnement (MEMEE), Rabat, Morocco, (2012).

[41] NEMA, “Technology Action Plan Report, Mitigation,” National Environmental Management Authority (NEMA), Nairobi, Kenya, (2013).

[42] RoR, “Technology Action Plans for Climate Change Mitigation and Adaptation,” Republic of Rwanda, Kigali, Rwanda, (2012).

[43] I. Nygaard, “Compatibility of rural electrification and promotion of low-carbon technologies in development countries: the case of solar PV for Sub-Saharan Africa,” *Eur. Rev. Energy Mark.*, vol. 3, no. 2, (2009), pp. 125–158.

## 10 NOTES

(1) More information about the project and its results is available at www.tech-action.org

(2) In the proposal, twelve countries are listed for the African region and the Middle East. The list only comprises nine countries for mitigation, as Ghana was only selected for adaptation technologies. Ethiopia was postponed to a later phase, and Lebanon is not included here, as it is situated in the Middle East.

(3) http://www.ubbink.co.ke/

(4) With reference to a study based on import data (Marge 2013).

(5) ‘The capital investment for the project will be financed through FMO, the Dutch Development Bank, the Emerging Africa Infrastructure Fund and

Norfund. Scatec Solar and Norfund will be majority owners in the solar park with project developer Gigawatt Global maintaining a 20% share in the project' [33].

(6) For an overview of delivery models for solar PV, see e.g. [43].