Learning a lesson

Assessing PV programmes in rural South Africa

Several programmes have been set up over recent years, to provide rural communities in South Africa with electric power by means of photovoltaics. PV systems have been installed successfully at numerous schools and clinics, yet experiences following installation have been mixed. Many systems have fallen into a poor state of repair, and are vulnerable to criminal activity, as WIM KLUNNE and his co-authors explain.

The first democratic government in South Africa initiated large-scale programmes to improve the quality of life in the rural and less-developed areas. One of the political targets set was the electrification of all schools and clinics in the country by the year 2000. Three programmes were established to achieve this goal in rural areas, namely:

- *The RDP schools programme*. As part of the Reconstruction and Development Programme (RDP), the national utility Eskom managed the programme to electrify 1340 rural schools using PV between 1996 and 1998.The Dutch government funded 300 schools under this programme, the remainder being funded by the South African government.

MAIN PHOTOGRAPH School staff and pupils in the Eastern Cape province, in front of one of the thousand EU-funded, 800 Wp solar power supplies installed in rural South Africa

TABLE 1. Electrification status of schools and clinics. Sources: Department of Education (information on schools, as of 16 February 1998 – these figures are from before the start of the EU programme on schools); IDT, 1995, (information on clinics)

Province	Schools					Clinics				
	Number	With grid electricity[a]	Without grid electricity[b]		With PV system[c]	Total	Urban	Rural	Unelectrified	
									Major clinics	Day clinics
Eastern Cape	5916	1082	4799	81.6%	1170	450	249	201	317	40
Northern Province	4174	873	3270	78.9%	170	400	48	352	282	10
Kwazulu-Natal	5234	1944	3267	62.7%	–	348	271	77	77	31
Gauteng	2229	1929	286	12.9%	–	430	428	2	0	0
Free State	2898	1200	1663	58.1%	–	240	177	63	5	7
Mpumalanga	1900	957	931	49.3%	–	220	95	125	100	7
North West	2413	1004	1382	57.9%	50	290	127	163	125	8
Northern Cape	530	412	111	21.2%	50	120	94	26	5	20
Western Cape	1772	1553	202	11.5%	–	450	428	22	0	25
TOTAL	**27,066**	**10,954**	**15,911**	**59.2%**		**2948**	**1917**	**1031**	**901**	**161**

[a] Includes only schools that are wired and supplied with grid electricity

[b] Includes schools that are wired but not supplied with grid electricity, that are not wired and/or have no electricity, that have petrol/diesel generators, and the classification 'other energy supply', including solar energy

[c] Numbers were only available for Eastern Cape and Northern Province but in the other provinces, relatively very few systems are installed

- *The EU 1000 schools programme*. In 1998, an EU-funded programme to electrify another 1000 schools was initiated as a follow-on from the RDP schools programme, also implemented and managed by Eskom. Most of these solar systems were installed by the end of 2001.

- *The IDT clinics programme*. The Independent Development Trust (IDT) managed the electrification programme for clinics in 1996–7 (phase 1) and 2000 (phase 2), under which 200 rural clinics were provided with solar electricity.

Although the target to electrify all rural schools and clinics by the year 2000 was not met, substantial numbers of systems were installed. For schools and clinics, the systems comprised a stand-alone photovoltaic power supply system with lighting fixtures, and this was complemented by a vaccine refrigerator at the clinics, and by audio-visual teaching aids in schools such as TVs, VCRs or overhead projectors.

Research and evaluation

Various different anecdotal sources gave the impression that the performance of the installed systems was not as good as one might expect, but few formal technical evaluations of these three programmes were available. Substantial analysis has, however, been made of the implementation processes for the programmes, and clear conclusions drawn on their developmental benefits.[1–3] It is only now, following the most recent research, that causal links can be established between process issues and technical outputs.

The research described in this article was carried out by Raf Cox and Luc Gys between September 2000 and May 2001, to evaluate the installed solar PV systems at these rural schools and clinics in South Africa. They gathered information through the study of available reports on the projects, interviews with experts involved, and a field survey in which they visited a representative sample of 160 schools and clinics in the Northern Province and the Eastern Cape province. Information gathered at 149 of the 160 visited sites is analysed. The technical assistance team from the EU-funded programme (IT Power Ltd and Energy & Development Group) assisted the researchers in preparation of the survey questionnaires, as well as in conducting the field survey, mainly for the EU-funded schools.

Rural schools and clinics

In 1995, approximately 25,900 rural schools and a number of rural clinics in South Africa were identified as being in need of electrification. Of these, 16,400 rural schools and 2000 clinics were identified for off-grid electrification. In 1995, the national utility, Eskom, estimated that approximately 75% of the schools and 47% of the clinics in South Africa would still not be grid-electrified by the end of 1999.[1]

Information on schools is limited in South Africa. Until 1996, no accurate national database was available on the number, locations or the individual situations of the schools in the country. In 1996, the 'School register of needs' survey was conducted by the Department of Education, to make a good start on monitoring the situation.

IDT had established – via extensive needs assessment surveys in 1995 – that there were about 900 unelectrified major residential clinics in South Africa and 161 day clinics, while about 250 new rural clinics under construction would require electrification.[4] Table 1 provides more detailed information on electrification of schools and clinics.

Survey design

The focus of the research described is on the two provinces of South Africa where the majority of the rural schools and clinics are located, the Northern Province and the Eastern Cape Province. The population of schools and clinics is stratified according to the programme that provided the PV system, whether RDP, EU or IDT. A representative sample was taken from each project by simple random sampling. All the schools and clinics in the sample were visited and physically inspected, rather than the more remote method of sending questionnaires. Headmasters and nurses present at the location were interviewed, using the standard survey document, to learn more about the systems' usage and functioning.

Survey results: technical performance

Availability of the systems was chosen as the method for evaluating the electrification programmes' technical results. In this research, 'availability' is defined as the extent to which the PV systems were functioning or performing properly. The analysis was complicated by the fact that some systems had been installed and operational for four years, while others were only a few months old. However, the research methodology attempted to take this into account.

Schools

Out of the 48 RDP systems visited, installed in the period 1996–98, not one was entirely functional. In 81% of the cases, the reason for this was theft or vandalism of one or more of the critical parts (panels, batteries, inverter, regulator). Two systems had technical problems with the inverter, which meant that no AC current could be provided.

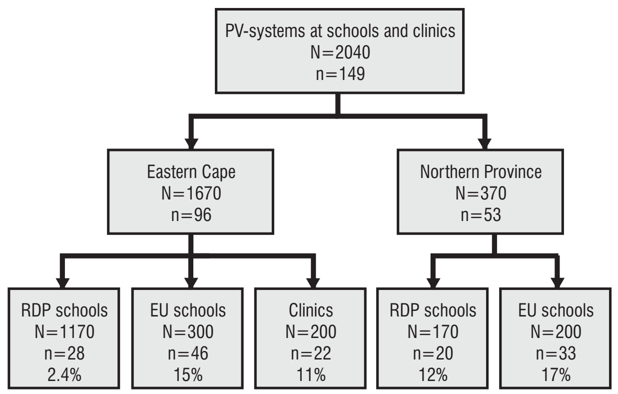

FIGURE 1. Field survey sample design
N – total number of schools/clinics
n – number of schools/clinics visited

Of the 48 RDP systems visited, not one was entirely functional

Performance of the EU systems visited was better, but these were of course much newer. Of the visited systems, 44 (57%) were working, 16 (21%) were partly working, and 19 (22%) were not working at all. Of the systems that were not working at all, 31% were not functioning because of theft or vandalism.

The survey clearly showed that theft and vandalism play a major role in the failure of rural electrification for schools. Fear of the wide-scale theft of systems has in some areas even led to the removal of the solar system by headmasters as a precautionary measure. The removed systems are put into secure storage but not utilized, which rather reduces the potential benefits.

As the EU systems were installed only recently (1999–2001), the long-term success of the EU programme could not be evaluated, but might have been similar to that of the RDP schools programme. At least, that would arguably have been the case, had the EU programme not undertaken an internal mid-term review (IMTR) between June 2000 and April 2001, to assess the state of the technical implementation process.

Quite unusually, the installation phase of the EU programme started in 1999 without a technical assistance team (TAU), and was managed by the same organization as the RDP programme. On arrival in 2000, the TAU quickly identified problems, and advised suspension of the programme in order to solve recurrent technical and quality assurance problems.[5] This

intervention, while costly, appears absolutely justifiable, as it will address various recurrent shortcomings which would have severely limited the sustainability of the EU project.

Clinics

The performance of the systems at clinics, where the first systems were installed in 1996, was better, as in all cases but one, no theft or vandalism was reported. The only widespread technical problem that occurred was that batteries had worn out after four years. This resulted in a reduction of electricity availability for general lighting use during cloudy periods. However, due to the unique dual-redundant battery system configuration installed, which gives priority to the vaccine refrigerator and communication radio, there was never a shortage of electricity to the most important appliances, though further deterioration in the performance of the batteries might ultimately change this situation. A programme for planned replacement of the batteries needs to be initiated, in order to extend the lifetimes of the systems. After an operation period of four years, the inspected systems at the clinics had no other technical failures.

Theft and vandalism: a key issue

Schools

Systems under both the EU and RDP programmes were installed in schoolyards, with the panels on an unfenced ground-mounted array that was easily accessible. This made the panels easy targets for criminal activities. Photograph 1 demonstrates just how accessible, and thus how vulnerable, the panels are to opportunistic criminals.

However, in the post-IMTR EU programme, all systems are provided with substantial anti-theft mounting frames, which make panel theft impossible without cutting torches. Furthermore, the schools are required to ensure that classrooms are burglar-barred, fenced, and provided with night guards prior to installing audio-visual equipment.

While only 27% of the RDP schools had night guards, 60% of the EU schools were guarded. A limiting factor is the fact that schools themselves are responsible for employing night-guards, even though they are within severe budget constraints. In many cases, night-guards were on leave during the summer vacation period, leaving the schools vulnerable.

1 Vandalized system with few panels remaining
2 Array of panels at a school with burglar bar framing. The local community made and fitted the burglar bars themselves

All building maintenance, including fencing, is the responsibility of the schools as well. In general, this results in well intentioned but poor-quality fencing. For fences to be effective, they should ideally be two metres in height, with multiple layers of razor wire and gates with proper locks, as well as being concentrated around the PV array structure itself.

The nature of the panel thefts, and input from several school headmasters, suggests that local people might be involved in the removal of the panels; indeed, in some villages people have been arrested for such theft. Panels are sometimes removed in such a way that they can no longer be used, and in some cases have been found vandalized in the bushes near the system installations. However, there are also criminal organizations, which have been identified in the re-sale of panels in neighbouring countries. The police force has been invited to take part in stakeholder workshops within the EU programme to raise awareness and address security issues, and several arrests have followed.

Clinics

Clinics are treated as assets by the Department of Health, and are thus mostly provided with a night guard and proper fencing, to protect the physical structure of the clinic and its contents as well as the nurses living on the premises. Another factor that might lower incidence of theft at clinics is that staff are present at clinics 24 hours a day, every day, whereas at schools the teaching staff are obviously not present during the evening and overnight, nor during school holidays. There is also external security lighting around all clinic buildings, as specifically requested by nursing staff. Furthermore, as

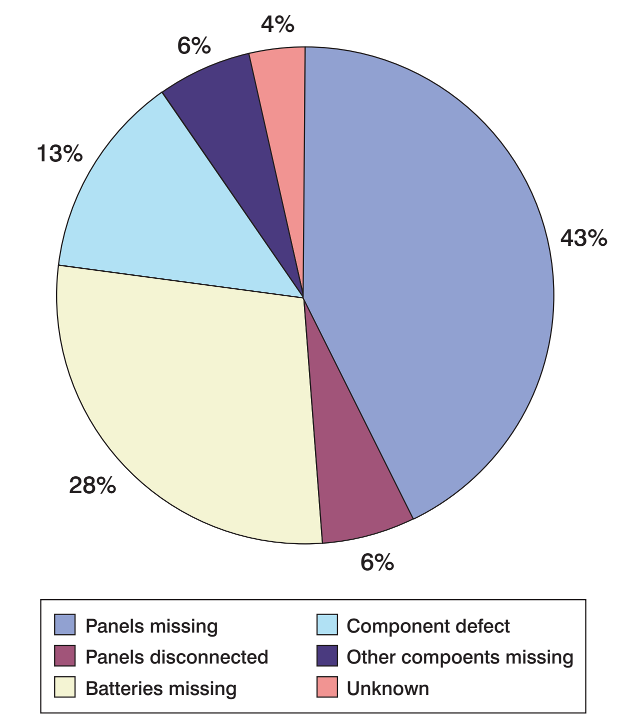

FIGURE 2. Problem breakdown, RDP school systems

PV panels are installed on the roof, theft is considerably more difficult.

Need and use of the system

Lighting apparatus was always supplied in conjunction with the solar power systems. In schools or clinics, it is clear that the extended use of the systems depends on the presence of other electrical appliances.

Schools

Although it was intended that televisions, VCRs and overhead projectors would be supplied concurrently with the solar power supply system, they had not generally been delivered at the time of installation. Such appliances were still not installed when the field research was carried out, and this clearly limited the benefits of the system. In practice, the systems were mainly used for lighting during exam periods, so students could study at night, and to charge the mobile phones of the teachers, students and other community members. At several schools, the charging of cellular phones was a source of income. Adult education and community meetings were also held in some schools.

A key assumption in the design of the school electrification programmes was that access to audio-visual equipment and lighting would improve education, but clearly, such equipment alone is insufficient. Institutional support, in the form of educational resources, suitable training programmes and assistance in sustaining the systems, is needed at the schools if the electrification programmes are to meet with success. (Considerable resources have been spent within the EU programme, compared with the RDP, to raise awareness at all levels of the Department of Education about the potential of the AV equipment. On a practical and operational level, the EU programme is supplying full-colour user manuals and a 20-minute video to increase system usage and maximize the benefits of the solar power system and AV equipment. Furthermore, programme extension workers attached to groups of schools provide ongoing support and guidance specifically for schools with solar systems and AV equipment. It is clear that this is an ongoing process rather than an individual task.)

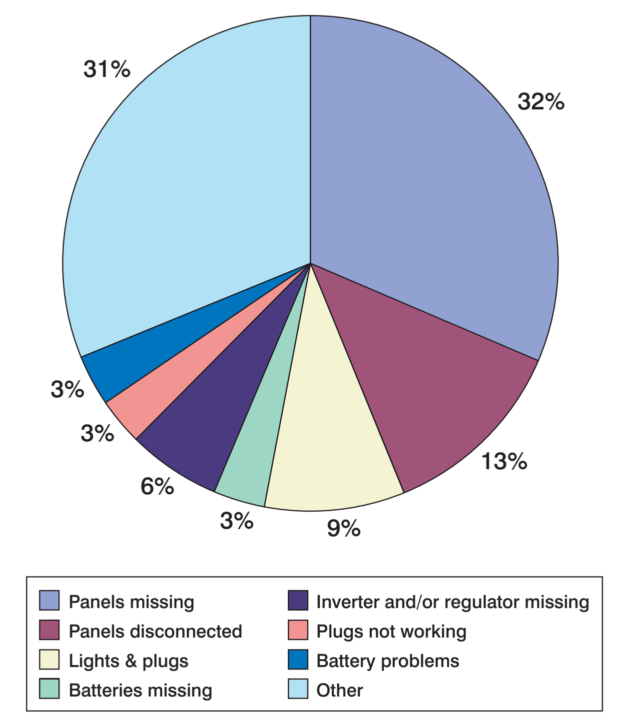

FIGURE 3. Problem breakdown, EU school systems

Clinics

At clinics, the demand for electricity is both higher and more immediate than it is at schools, because it serves several purposes, including cold storage of vaccinations and medicines, as well as emergency lighting. Besides the electricity demand of the clinic itself, the clinic compound has a streetlight and floodlights as a safety measure for the nurses. As nurses' houses are also electrified, they have the chance to listen to the radio or

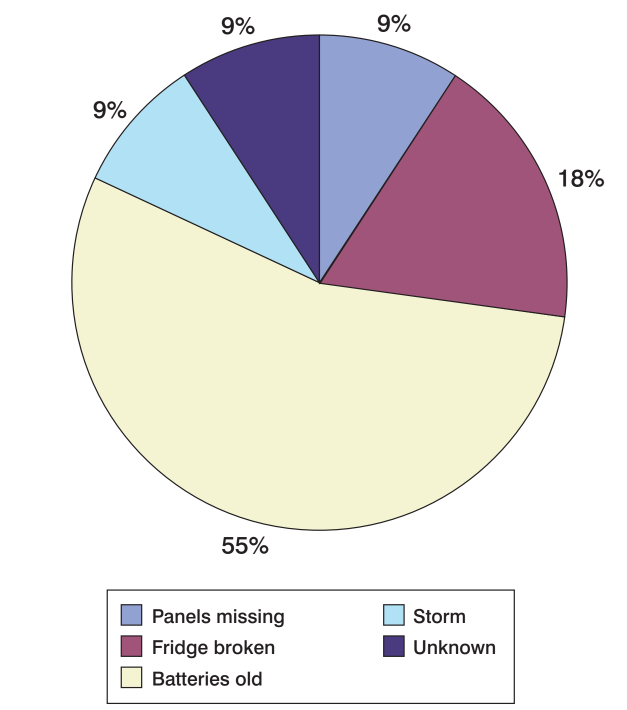

FIGURE 4. Problem breakdown, IDT clinic systems

watch television, or simply use lights to read by.

User satisfaction and involvement

Schools

It was not easy to ascertain real 'user satisfaction' with the systems. In the RDP programme, some headmasters at schools that previously had a system said that they are better off without it than with. In the EU programme, some headmasters said that they are enthusiastic about the systems, and maintain and protect them to ensure they will be in working order when the AV equipment is delivered. Some indicated that they need a system that can produce more power, without giving examples of how such additional power would be used. At schools where the promised AV equipment was not yet installed, use of and satisfaction with the PV systems is limited; this sometimes seems to influence involvement and motivation in maintaining the system. Failing systems are often neglected, which can then provoke theft and vandalism.

Comparing the attitude of the users towards grid electricity and the PV systems, most users prefer a grid connection. The main reason given is that the grid provides more power, but it was also pointed out that PV systems are vulnerable to breakdown, theft and vandalism. The response of schools that have grid connections, on the other hand, highlights the more positive aspect of the PV systems – not only is equipment provided for free (under the programmes described), but the electricity provided by such systems is also free. Furthermore, during windy periods, solar systems are more reliable than the grid.

The approaches adopted by headmasters, in particular their level of involvement, do have quite an influence on the success of the system, but such approaches are very difficult to quantify. In some cases, the headmaster was able to motivate the community to look after the system and to prevent theft and vandalism. The systems were used for the benefit and development of the whole community, but in some cases even an involved headmaster could not prevent damage to the system.

Clinics

Although the condition of the PV systems at clinics was generally better than at schools, nurses are far more critical of the systems' performance than teachers, and far more aware of the limitations of PV energy. This can be explained by the clinics' reliance on electricity to function properly, and the higher security and use of appliances it allows at the nurses' accommodation.

Training, system support and maintenance

It must be remembered that the average user of the PV systems has a limited technical background, and therefore a lack of knowledge about the system prior to training.

RDP schools

For the RDP programme, the training and the reference manual that were provided give the user basic information on how to maintain the panels and the batteries, and what to expect from the system; use of the system is also briefly described. No other educational methods, such as videos, were used.

At most schools, the physics or mathematics teacher is made responsible for the maintenance of the system. System capabilities are generally understood, since 87% of the people interviewed knew that the system was not powerful enough to run heaters or an electric kettle.

The maintenance of the systems has to be very well organized. Systems that are broken down for some time are more likely to be vandalized or stolen than systems in good working condition. At this point in time, no maintenance system is in place for the RDP systems. Although at the commissioning of the system a service phone number was given to headmasters, many of them could not recall this number. However, even in cases were faults were reported to the correct phone number, the follow-up is not clearly defined – no organization has

TECHNICAL SPECIFICATIONS OF PV SYSTEMS RESEARCHED

The research described in this article has investigated three different types of PV systems: RDP and EU systems at schools, and IDT systems at clinics.

RDP schools

The solar system used at RDP schools has 12–18 solar panels placed on a frame next to the building. The installed lights work on 24 V DC, and an inverter (24 V DC – 220 V AC) is installed for the plugs. Lights were installed in three classrooms and either the headmaster's room or another classroom. The battery box is installed in one of the classrooms, with a tube to remove the battery gases.

Technical configuration RDP systems

Component	Number	Make and type	Power	Lifetime
Solar panels	12–18	Siemens, Solarex, Kyocera, Helios, BP Solar, Total, Franklin H800, Suncorp, Photowatt, ASE	50–51 Wp	20 years
Batteries	16	Raylite, Willard SLI (automotive type)	12 V, 96 amp-hour in series-parallel	3 years
Regulator	1	Photo Voltage Regulator, various local South African types	–	–
Inverter	1	MLT Drives, Franklin	Approx. 1 kW	10–15 years
Lights	12–16	Philips	24 V DC	–

EU schools

One standard system was designed and used for this programme. Eight solar panels are installed on a galvanized steel frame, next to the school building. The galvanized steel battery box is placed under the solar panels, and a box containing the regulator and inverter is attached to the frame. A distribution board is installed inside the classroom.

Three or four classrooms are provided with lights, and a plug (220 V AC). A TV, VCR, digital satellite decoder and satellite dish are also installed in each school and housed in a metallic security enclosure.

Technical configuration of EU system.

Component	Number	Make and type	Power	Lifetime
Solar panels	8	Isofoton	110 Wp in series-parallel	20 years
Batteries	12	First National Batteries, or Fulmen Solar batteries 2 V heavy duty cells	2 V, 510 amp-hour in series	7–8 years
Regulator	1	Isofoton Isotel	–	10 years
Inverter	1	Steca Solarix with load-sensing	800 W	10 years
		Isofoton Isoverter with load-sensing	1200 W	–
Plugs	3–4	RSA standard	220 V	–
Lights	12–16	Fluorescent tube	36 W, 220 V	–

NB As a result of the IMTR, several improvements are being put in place, including user interface and security frame of PV modules

IDT clinics

A dual PV system was installed in the clinics, joined by a common DC bus, so that critical loads could be supplied by a highly reliable, generously sized system, and the remaining lighting and nurses' accommodation loads could be met by a more economically sized system. The common bus was designed to allow surplus energy from either system to be utilized by the other system. The configuration normally installed in a large clinic (with nurses' home) is two battery banks. The solar panels are installed on two arrays on the roof of the clinic, or on a frame next to it.

Technical configuration of IDT systems

Component	Number	Make and type	Power	Lifetime
Solar panels	8–16	Kyocera, Siemens, Photowatt	51 W, 75 W	20 years
Batteries	12–18–24	Willard M-Solar 11/13, or First National Batteries RSO332 heavy duty cells	2 battery bank (1 x 300 Ah, 1 x 900 Ah)	7–8 years
Regulator	1	PDI Prioritized Solar bus, 3 priority load-shedding	2 x 30 A., 12 V DC	10 years
Inverter	1	ASP TC 400/12	400 W (small clinics)	10 years
		ASP TC 800-100/12	1000 W (large clinics)	–
		Fronius Steca	800 W	–
Refrigerator	1	Minus 40, 90 litre, model B90-10-12 V with separate freezer	700 Wh/24 h at 43˚C, 300 Wh/24 h at 30˚C normal use	15–20 years
Examination light	1	Dichroic halogen 18 W	220 V	10 years
2-way radio	1	Motorola GM 950	–	–
Lights		Compact fluorescent EL.	15 W, 220 V	8 years-

3 Training of field workers in an EU school programme

direct responsibility for maintenance, and none had any funds available for this purpose.

EU schools

User training for operation and maintenance of the EU systems is better organized. As mentioned earlier, field or extension workers have been appointed, one for every 125 schools. Their main tasks are to train users, help users detect problems and establish reporting mechanisms, and keep communities informed, to build community ownership of systems. The technical knowledge of these field workers is limited and they are not qualified to make system repairs, only to report problems to the responsible technical staff. The first-year maintenance is the responsibility of the installation contractor, and consists of technical visits twice a year. Maintenance after the first year is the responsibility of the provincial Department of Education. Strategies and funding possibilities are currently being investigated, and should be put in place by 2002.

Clinics

Initially clinics were provided with a one-year maintenance as per the EU schools, but maintenance of the IDT systems is now organized through the district hospitals. Clinics have to report problems to the hospital, where action will be taken. Distilled water (to refill the batteries) and light bulbs are supplied through the same infrastructure that is in place to supply vaccines and other medical equipment to the clinics. Nurses on site have a greater understanding of the limitations of the systems through their daily experiences with PV.

Lessons to be learned

The field survey showed a disappointingly low number of properly functioning systems at the schools. However, some very successful schools were visited as well, and this, coupled with the very good overall performance of the clinics, means the authors are confident that there is a future for PV at schools and clinics in South Africa.

The study revealed that the performance of the EU systems at schools is better than the performance of the RDP systems. The main problems were theft and vandalism. The IDT clinics' systems, in general, performed better, though the main problem with these systems is the need for battery replacement. Theft and vandalism seem to be a much less problematic at the clinics.

One general conclusion is that the two school programmes – though to a lesser extent the IDT clinic programme – prioritized the quantity of the installed systems. The clinic programme has focused a great deal on process as well as technical quality, however, and this has resulted in a high success rate for working systems.

Instead of focusing on the number of installed systems, the emphasis must be on how many schools or clinics have been provided with trouble-free electricity for the lifetime of the PV system. This requires a focus on implementation processes, as well as ensuring that fundamental technical problems are identified and avoided. The establishment of a maintenance programme needs to be an integral component of such an improved approach, and must be undertaken before further programmes are embarked on as a matter of high priority

Another lesson that can be learned from the report is that more attention can be paid to the user need assessment, and involvement of users with the systems and projects. Furthermore, several technical improvements seem to enhance the availability of the systems, such as installation of panels on the roofs of buildings (as in the IDT programme – see photo 4) instead of mounted on a pole next to the buildings (as at the schools – see photo 5).

Overall, the study confirmed the general feeling that the availability of the installed systems, especially at schools, would be very low, and this study has managed to quantify the performance of systems. Looking on the bright side, many clinics are working despite a lack of organized maintenance. However, the authors wish to see the research as a way of learning lessons for improvement, as many schools and clinics in rural South Africa still awaiting electrification can benefit from these lessons.

4 Panels are installed on the roof of clinics, instead of on the ground next to the building, as at schools

5 PV systems provide clinics with electricity and telecommunications

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