# HOME POWER IN AFRICA
## PV Field Training in Karagwe District Tanzania

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## Introduction

PV technology is taking root in East Africa, and one of the fastest growing applications is home lighting. In the space of 5 years, more than 30,000 homes in Kenya, Uganda and Tanzania have lit up with PV, almost entirely on a commercial basis. Other applications are commonplace. Game parks routinely use PV fences and 2 way radios, clinics use vaccine refrigerators and lights, while schools and businesses use PV for lighting, television and radio. Cattle ranches, missions and refugee camps use solar water pumps. Kenya, the regions' leader, has an installed capacity of over 1 MWp. The commercial market is expanding into Tanzania and Uganda, and, despite low incomes, prospects are excellent. Three quarters of the region's population has little chance of being hooked up to grid power any time soon.

With this rapid expansion of the solar market into Africa, infrastructure must be built to support PV technologies in the field. Human resources urgently need to be developed: technicians are needed to install systems and trouble shoot, educators are needed to raise awareness in communities and to teach PV, business people are needed to supply spare parts, manufacture components, and import decent equipment. In Western Tanzania, the KARADEA Solar Training Facility has addressed itself to this human resource development challenge. Last November it opened the first institution in the region exclusively devoted to training solar technicians.

## KARADEA

Karagwe District is three hours by road to the east of Lake Victoria and just south of Uganda. The Karagwe Development Association (KARADEA) is a grass-roots community development organization located midst fertile banana and coffee plantations and atop a series of high ridges adjacent to the Rwanda/Tanzania border. KARADEA helps the district's inhabitants to improve their lives through better use of local resources. Working chiefly with women's groups, it implements projects in rain catchment, afforestation, carpentry, appropriate technology, education, agriculture and credit. It also administers 5000 AIDS orphans. Its record over eight years under the dynamic leadership of Oswald Kasaizi serves as an excellent example of what can be done by a committed group of rural people with limited resources.

In response to a high local demand for electric lights, KARADEA got into PV-powered rural electrification in 1988. They began selling and installing solar electric systems among their community when, as part of a fund-raising exercise, a Swedish group provided PV systems which KARADEA sold to raise operating capital. Over several years, KARADEA sold and installed dozens of donated single module lighting to community members in need of electric lights. When I met Oswald at a 1992 Nairobi Solar Workshop, KARADEA had already installed over 50 lighting systems in homes, businesses, and at their district library. He asked me and Harry Burris (long-time solar hand in Africa) to help KARADEA plan a solar PV strategy. On this and subsequent trips, we developed a PV programme with several objectives: (1) to develop and identify low-cost systems that could meet the needs of small businesses and homes (with a focus on lighting) and (2) to train and support a network of local people to install, maintain and market systems (Note that there are already many scores of PV installations that need to be maintained in Karagwe District, mostly installed by donor and missionary groups). In July 93, CSC provided KARADEA with support to equip a training facility and to conduct an initial trainings course. The Solar Electric Light Fund contributed funding to enable participation of two trainees from Maasailand, Tanzania.

**People Demand Lights and Radio**

But why "expensive" solar lighting? Why not PV water pumps, which could reduce the work load on the water bearers (women), why not solar cookers, which could reduce the work load on the wood fuel bearers (again women)? This is a hotly debated and complex issue worthy of another article. My own field experience tells me that, at this early stage in the development of a solar industry here, it is difficult to mobilize communities to finance and maintain "large" PV projects such as community pumps. So small systems make sense from a sustainability standpoint. Solar cooking faces serious extension obstacles: a major issue is changing behavior. African women are as accustomed to managing wood-fired kitchens as we Americans are to our own particular kitchen management schemes. Even if it makes sense practically or environmentally, change comes slowly (how many Arizonians cook using solar?).

At any rate people need electricity for lights and radios *now*. A lack of good lighting has been a deterrent to progress in literacy, health, and small enterprise. People need lights at night so that they can read and study, so that their productive days don't end at sunset, and so that they can see in the dark. They need radios to keep up with events in the outside world, to enjoy music and to listen to the World Cup.

In most of Karagwe district, grid power is not a viable option. The only power line in the district reaches two towns (without juice as of December 93) and there are no plans yet to run lines to the scores of out-lying villages. TANESCO's (Tanzania's power monopoly) rural connection rate is not even keeping up with the population growth rate. In fact, rural electrificaton programs in sub-Sahara Africa have been spectacularly unsuccessful over the last 20 or 30 years. Today less than 5% of rural families are hooked up to power lines. It's one thing to build a 180 MW dam and march the power into the city with high tension cables, its another to distribute power to the 75% of the population that grow the cash crops and food. Distribution is an expensive nightmare.

Today, rural people light their houses with kerosene purchased at $0.35 per liter. They buy dry cell batteries to power radios, flashlights and boom boxes at $0.70 per pair. These expenditures add up, and families end up spending a significant portion of their incomes on such "amenities." The attraction of replacing kerosene and dry cells with one's own harvested solar power is great; so great that in Kenya PV systems have sold by the thousands. Kenya's experience, and the interest generated by systems that KARADEA and others have already installed in Karagwe, convinced us that PV lighting has the best chance of being taken up sustainably – and creating jobs – in Karagwe.

**Short Lecture on the Need for Technicians and Spare Parts Networks**
PV power supply problems are more on the extension and finance side than on the technical side in Africa. Properly selected solar stuff – be it PV modules, box cookers, driers or water heaters – works well in the equatorial sun. However, setting up infrastructures to manufacture, market, and maintain these gadgets is quite challenging in cash-starved economies.

Setting up a solar base is more difficult than simply airlifting consultants or "parachuting" in imported equipment and leaving it. We in the west have been shamelessly airlifting engineers and parachuting equipment into Africa for decades and there have been too many unsupported technology gifts. In the past month, I've seen two multi-kilowatt PV projects that are baking derelicts in the African sun because donors – and the western consulting firms that installed them – did not plan sustainability into the program. Unfortunately, local Governments are often not much of a help, either, for various reasons (which, for lack of space, I will not go into now).

Home Power readers have long known what solar development workers in Africa are just learning. As good as a technology is, there must be someone on the ground – preferably the end user – who can fix it. As well, there must be a nearby source of spares. No matter how efficient, PL-type fluorescent fixtures are useless in an isolated place like Karagwe unless there are spare tubes available, and unless there is someone who can explain to customers why fluorescents are worth the extra cost. Otherwise they might as well come from the moon.

Unlike Kenya, Tanzania's PV "industry" is now, for the most part, donor-driven. Aid workers increasingly recognize the role of PV in off-grid areas. So Scandinavian development workers buy equipment from Scandinavian companies, Italian missionaries buy from Italian companies, American Peace Corps buy from American companies and British buy from the British. Today, international PV companies are fighting for project contracts and market shares in a battle which Tanzanians cannot afford. Companies fly in, make an installation, and fly out. From the perspective of the international company, getting a contract is seen to be more important than developing the local industry. The result is that there are so many different types of controls, lamps, modules, wiring systems, pumps and inverters that the local technician has little chance of making sense of the situation. During field visits to systems installed by Karagwe, I saw dozens of different types of light fixtures – baton lamps from China and Kenya, PL-lamps from Amsterdam, quartz halogens from the the US, incandescents, etc. Customers have no idea where to get replacement bulbs, so they often replace burnt ones with less functional incandescent automotive fixtures. Hamstrung by a diverse and expensive range of imported solar equipment, local repair people can do little.

A sustainable supply network needs to be developed. Proper equipment needs to be chosen and imported, and links have to be developed to connect rural markets such as Karagwe with the business centers (i.e. Dar es Salaam). Local codes and practices have to be developed. There must be some standardization of equipment, and international companies and projects must submit to these standards. There have to be long-term maintenance contracts. Somewhere along the line, marketing, installation and maintenance has to be handed over to local people – they need the jobs. So KARADEA's work is cut out for it.

**Launching the Project**

Karagwe is far from my base in Nairobi. With no fax, a mail service that often takes months, and skittish telephone lines, KARADEA has serious communication problems. So it took quite a few cross-border visits for Oswald Kasaizi and I to lay the project groundwork; we did much of the planning on-site using my solar-powered PowerBook. We had to prepare a syllabus and bilingual resource materials. We had to select students, to design and find customers for systems. We had to tender for and price equipment (locally and internationally), order it and get it delivered. As well, we had to overcome a wide and interesting variety of logistical crises – but this is standard practice for a project funded from London, coordinated in Nairobi and based in a district without electric power.

By air freight, our PV equipment arrived on-time in Arusha from Neste Advanced Power Systems (NAPS), Norway. However, three days before the trainings were scheduled to begin, Tanzanian customs were still sitting on the supposedly duty-free equipment. I nervously drove down from Nairobi with Frank Jackson (an Irish volunteer PV electrician) to see about the held up PV modules, lamps and controls. The project was lucky. Martin Saning'o (leader of a Maasai group) had, by hook and crook, negotiated the release of the equipment from Arusha International Airport Customs. Now we had to carry all 250 kgs across the hundreds of miles of parched savanna and Lake Victoria between us and Karagwe. The next morning Peter de Groot (project funder just arrived from London), Frank, Martin, two Maasai student technicians and myself pulled out of Arusha in my junkheap Toyota Land Cruiser pick-up loaded up with PV equipment. We traversed the rim of the spectacular Ngorogoro Crater that afternoon, then got lost in the rainless Serengeti on a hellish night-time "game-drive" during which we dropped a muffler, unhinged the air filter and were chilled by the staring beady red eyes of various nocturnal beasts. Early in the morning the pick-up limped into Mwanza where we booked a motel room and slept most of the day. That night, we ferried westward across Lake Victoria to Bukoba, where we spent another day – Peter recovering from dysentery and the car undergoing minor surgery in the carburettor and exhaust system. We made it to Karagwe a day late on a rainy Monday in November; eighteen students from Tanzania and Uganda were waiting for the course to begin.

The goal of the course was to build each student technician's skills so that he or she (four of the eighteen were women) could complete all the tasks required in a single module system installation. As well, each technician would be able to gather design information and to perform simple trouble shooting jobs. The training was loosely based on one Harry Burris and I gave in Meru District, Kenya in 1985. Morning sessions covered theory; afternoons were hands-on, either conducting practicals or visiting, installing and repairing systems.

The training staff included myself, Daniel Kithokoi (a graduate of the Meru '85 training), Frank Jackson, Dickson Kawiru, Gaspar Makale and Oswald. Kithokoi and I were the chief trainers – he had arrived in Karagwe a week earlier from his home in Kenya to inventory equipment and to prepare sites. During the course, I covered theory while Daniel, who has hundreds of PV installations under his belt, led the practical work. Dickson, a teacher from the local polytechnic (he installed many of the KARADEA systems), volunteered as instructor and later as a team leader when we were laying wires and fixing lamps. Gaspar Makale, the Solar Training Facility technician, didn't sleep from beginning to the end – he caught the bus to Bukoba to chase forgotten wire clips and screwdrivers, he supervised last-minute carpenters building battery boxes and sub-boards, he cleaned up classroom clutter, and he rigged the stereo system for the final party. Frank, now serving as a PV volunteer at KARADEA thanks to the networking efforts of the Solar Electric Light Fund, taught a few classes and played a critical role in the field practicals. Dickson and several of the students handled swahili-english translations in the classroom, as about a third of the students spoke no English.

Students each received a tool kit containing digital voltmeters, assorted screw drivers and tools, a solar installation manual, training material in Swahili and English, and data collection forms [see Table]. They had been selected to attend the course from KARADEA's solar program, from the Olkenerei Integrated Pastoralist Survival Program in Arusha, from the Uganda Rural Training and Development Program, from a small solar company based in Musoma called Jua , Ltd and from the Ministry of Livestock's solar refrigeration team. Over 17 days, the students ate, drank and slept solar. The course included an orientation to solar based rural electrification, and classes on the solar resource, PV, batteries, controllers, wiring, lamps and appliances, system maintenance and basic system sizing. We also discussed small business/PV network development in East Africa. The class was broken into small groups during practical sessions, which we tried to integrate with theory.

The students got plenty of installation practice and exposure to PV. Each morning, they helped set out several small modules that charged solar lanterns, hand tools, AA-size ni-cads and my PowerBook's gel cell. They visited and critically examined systems in the town's post office, veterinary clinic and library. Under the watchful eyes of the trainers, they rewired and installed switches in the hostel's solar electric system. With the instructors, they installed a 212 Wp system at the training centre and a 53 Wp lighting/radio system at KARADEA's headquarters. Laying cables, placing switches, and fixing lamps was time consuming, and we would not have completed without after-hour efforts by Dickson, Daniel (who demanded perfection from the students) and a few dedicated students.

There were a few diversions in the schedule. For example, Oswald took the students on a much-appreciated day trip to Biharamulo Game Reserve. Surprisingly, many of the students – especially those from Uganda – had never seen wild animals before. When they repaired his PV radio system, the park warden rewarded the students by shooting a topi (a large antelope) and loading it into the Land Cruiser. We ate well over the next two days under the solar light of the hostel's dining room. .

In the last week students were split into 4 teams and given a field practical exam, which would make up a third of their final mark. They were sent into villages to install 22 Wp lighting systems for kiosk businesses. Daniel, Frank, Dickson and I watched and marked (without offering assistance, correcting as necessary) as the four teams fixed systems. By the evening, all of the systems were commissioned, and there was electric light in 4 villages which had not known electricity before. On the second to last day of the course, the students were given a final exam with theory questions and practical exercises.

All 18 students passed the course and marks were high. Even if the exams were a bit too easy this time, the good marks were testament to the seriousness of the students and their committed interest. I was especially pleased with the work of the women in the group. Nkurunziza Immaculate of URDT was at the top of the class, and Farida Katunza of KARADEA was up in the dusty crawlspaces laying wire long after most of her male counterparts were too beat to continue.

**Village Home Power Systems**

When designing the 9 systems to be installed by the class, the project had three over-riding design objectives: (1) Systems had to be reliable, (2) they had to be low cost and (3) they had to use local equipment whenever possible. The 212 Wp system at the Training Facility would be used for lighting and powering small tools in its workshops. The two 53 Wp systems were for lighting and powering laptops and office equipment in KARADEA and

URDT offices. Six 22 Wp would light two rooms and power radio/cassettes in village kiosk businesses. All of the systems included button operated security lights and sirens.

Use of local spares was a departure from earlier KARADEA practice. The one-panel systems they had been installing had been bought off-the-shelf in Sweden and crated – wires, bulbs, switches and batteries all – to Tanzania. Because systems arrived complete, the KARADEA technicians had not previously investigated the prices and availability of local parts. There was a spare parts problem. So, when tendering for equipment, Daniel and Gaspar scoured electrical and automotive shops in Bukoba and Mwanza for parts we could use. In the project's 9 installations, we used locally–purchased tools, switches, outlets, low-voltage supplies, wires, security systems and automotive batteries. We also built what we could on-site from local raw materials, including the tracking mounts, battery boxes and sub-boards in KARADEA's shops.

A number of design compromises were made. To increase functionality, we ran all the systems at 12 volts and stayed away from inverters – the Training Facility's electric tools are all 12 volt. Without a local supplier of inverters, an unsupported unit would be hard to replace or repair. We used locally-made heavy duty truck batteries instead of deep discharge batteries. Such local automotive batteries have short lifetimes, but they're much less expensive than imported ones – if the PV revolution is to continue in Africa, somebody's got to manufacture a decent deep discharge battery.

We imported fluorescent lamps, controls and modules. Although there are several companies manufacturing lamps in Kenya, experience with their units has been mixed. We didn't want to let lamps be the weak link; better to demonstrate quality lamps that don't blacken bulbs or interfere with radio reception. We chose batten-type lamps because spare bulbs are available in Bukoba and Mwanza. We used the same NAPS charge controllers that had been installed earlier in other KARADEA systems – NCC-1's are quite adequate and we saw no need to change. They give the user a rough idea of the battery's state of charge, they're fused, they have master switches, and they tell the user whether the module is producing charge. We should have asked the factory to set the low voltage disconnect a bit higher because they're protecting automotive – not deep discharge – batteries.

We used Seimans M-55 and M-25 modules. A serious problem with crystalline modules is that they get scandalously expensive at smaller sizes. For the kiosks, we needed 20 Wp modules. Small shops simply can't afford 50 Wp systems. Faced with the choice of crystalline at $11 per peak watt or amorphous (Chronar-type) at $6.50 per peak watt, we chose the crystalline because of its proven quality. But still, $220 for a 22 Wp module is steep, and unless a reasonably priced crystalline type becomes available, amorphous dealers will swamp the market.

**Low-Tech Tracking [BOX]**
At the equator, modules should be mounted flat – or almost flat – to receive the most radiation . Right? Well, this is generally true if the modules are mounted fixed. But give it some thought. Many northerners wrongly assume that the sun passes directly overhead in Equatorial Africa. Not true. From season to season the sun's incident angle actually shifts from 23°N to 23°S (it only passes directly overhead on March 22 and Sept 22), and each day it moves in a 180° arc from east to west. There is, therefore, a low-tech way to get up to 30% more power from modules – or to reduce the number of modules required for a system – without having to invest in an imported tracker.

Harold Burris invented a rotatable pole tracking mount with the solar module(s) fixed on a frame 25° from horizontal. The pole is turned so that the module faces the position of the ten o'clock sun in the morning and again so that it faces the two o'clock sun in the afternoon. Our experience is that pole trackers work well in school and home situations where the task of rotating the module at noon and in the morning can be incorporated into the daily routine. An additional benefit of this type of tracker is that it keeps the modules cool and off the hot tin roof. We used rotatable pole tracking mounts on all of the KARADEA systems.

**Supporting the Network & Making PV More Accessible to Rural Tanzanians**
Now that they've been trained, we're trying to keep this small group of solar pioneers supported. Immediately after the training Frank Jackson safaried with the Uganda Rural Development & Training to help them complete their installations (a 53 Wp system at URDT's offices and two 22 Wp lighting systems in kiosks) in Kagadi, Uganda. Meanwhile, Peter de Groot, the Solar Electric Light Fund and I are trying to keep funding in the pipeline for more training, business support and seed credit funding – especially for the women. We hope to run another training at KARADEA in June 94. Daniel and my company, Energy Alternatives AFRICA, will be taking on at least one of the trainees as an intern so that he can learn about the Nairobi solar industry.

Still, times are tough and things will move slowly. Few people can afford to pay the up-front costs of PV systems. Even if financing were available, many people would still not be able to purchase the "standard" 50 Wp systems. $1000 is more money than most will see in a year. Cash is hard to come by and the terms of trade are stacked against small farmers in Africa. Although only "wealthy" individuals can afford 50 Wp systems at present prices, PV lighting is viable among high-income groups, businesses and institutions who have no other comparable power alternatives. The introduction of an infrastructure to support PV for the above groups – and for the hundreds of vaccine refrigeration, pumping, lighting and 2-way radio systems already in place in the district – will inevitably make smaller 5 - 20 Wp systems more available and less costly.

Smaller systems and credit are needed to keep the commercial market in East Africa on its feet. With us at the training, we had several types of solar lanterns. At about the price of a bicycle, these were items that many villagers wanted and could think of buying. The problem is that solar lanterns are not widely available (if you know of a decent unit, please let me and KARADEA know!!).

There is no question. PV is already playing a role in rural development in Africa, and the role will grow. Village homes, businesses and institutions need the small amounts of power that PV can provide. Unlike kerosene, diesel or mega-dam power, each PV system installed in Africa increases the resources of the village and makes it more self-sufficient. Sun-electricity beats inflation and currency devaluation. PV energy means jobs for installers and spare parts suppliers, and for the people who can work and study longer under electric light. In Karagwe, it is a cornerstone for rural empowerment.

Mark Hankins has participated in the development of solar markets in East Africa over the past ten years, starting as a Peace Corps science teacher and now as co-director of a Nairobi-based company called Energy Alternatives AFRICA.

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## Table 1: Training Materials Provided

| | |
|---|---|
| 1 | Small Solar Electric Systems for Africa (book) |
| 2 | Prepared notes |
| 3 | Notebook & pen |
| 4 | Screwdriver set |
| 5 | Digital voltmeter & battery |
| 6 | Pliers |
| 7 | Small hammer |
| 8 | Mathematical Set |
| 9 | Insulating tape |
| 10 | Carrying Bag |

**KARADEA Solar Enterprise Project**
**PV Solar Electric Systems Materials List**

**1 Solar Training Facility Workshop (1 SYSTEM ONLY)**

| QTY | ITEM | MANF | MODEL | SOURCE |
|---|---|---|---|---|
| 4 | Solar Module | Seimans | M-55 | Import |
| 1 | Tracking mount for 6-8 modules | KARADEA | Burris design | Karagwe |
| 4 | Lead-acid Battery | Yuasa Tanzania | 100 Ah @ 12 VDC | Mwanza |
| 1 | Charge Controller | NAPS | NCC-2 (24A charging, 30 A load, LVD) | Import |
| 5 | Tube Light | Thin-Lite | 8W @ 12 VDC | Import |
| 6 | Tube Light | Thin-Lite | 8W @ 12 VDC | Import |

| | | | | |
|---|---|---|---|---|
| 2 | Security Light | Thin-Lite | 9 W @ 12 VDC | Import |
| 11 | Switches (w/ Box) | Chinese | Rated for 240Vac | Bukoba |
| 2 | Low Voltage Supply | Chinese | 12VDC-9/7.5/6/4.5/3 | Bukoba |
| | Cable | | 2.5 mm2 Twin w/o Earth | Bukoba |
| | Cable | | 6.0 mm2 Twin w/o Earth | Bukoba |
| 12 | Socket Outlet | Chinese | 240 Vac-rated 13 A w/ Plug | Bukoba |
| 1 | Main Switch | Chinese | 2 Way | Nairobi |
| 1 | Security system | | Panic button/siren | Nairobi |
| 1 | Battery box | KARADEA | Burris design | Karagwe |
| 1 | Sub-board | KARADEA | Kithokoi design | Karagwe |

**2 Kiosk Lighting Radio and Security (6 SYSTEMS TOTAL: 4 KARADEA, 2 URDT)**

| QTY | ITEM | MANF | MODEL | SOURCE |
|---|---|---|---|---|
| 1 | 22 Wp Solar Module | Siemans | M-25 | Import |
| 1 | Tracking Mount | KARADEA | Kithokoi design | Karagwe |
| 1 | Lead-acid Battery | Yuasa | 70 Ah @ 12 VDC | Mwanza |
| 1 | Charge Controller | NAPS | NCC-1 (5 amp w/LVD & indicators) | Import |
| 2 | Tube Light | Thin-Lite | 8W @ 12 VDC | Import |
| 3 | Switch (w/ Box) | Chinese | Rated for 240Vac | Bukoba |
| 1 | Low Voltage Supply | Chinese | 12VDC-9/7.5/6/4.5/3 | Bukoba |
| 1 | Security System | | Panic button/siren | Nairobi |
| 1 | Socket Outlet | Chinese | 240 Vac-rated 13 A w/ Plug | Bukoba |
| | Cable | | 2.5mm2 Twin w/o Earth | Bukoba |
| | Cable | | 6.0 mm2 Twin w/o Earth | Bukoba |
| 1 | Battery box | KARADEA | Burris design | Karagwe |
| 1 | Sub-board | KARADEA | Kithokoi design | Karagwe |

**3 KARADEA & URDT HQ Lighting & Power Supply (2 SYSTEMS)**

| QTY | ITEM | MANF | MODEL | SOURCE |
|---|---|---|---|---|
| 1 | Solar Module | Seimans | M-55 | Import |
| 1 | Tracking Mount | KARADEA | Kithokoi design | Karagwe |
| 1 | Lead-acid Battery | Yuasa Tanzania | 100 Ah @ 12 VDC | Mwanza |
| 1 | Charge Controller | NAPS | NCC-1 (5 amp w/LVD & indicators) | Import |
| 4 | Tube Light | Thin-Lite | 8W @ 12 VDC | Import |
| 8 | Switches (w/ Box) | Chinese | Rated for 240Vac | Bukoba |
| 1 | Main Switch | Chinese | 2 Way | Nairobi |
| 1 | Low Voltage Supply | Chinese | 12VDC-9/7.5/6/4.5/3 | Bukoba |
| 1 | Security System | | Panic button/siren | Nairobi |
| 1 | Socket Outlet | Chinese | 240 Vac-rated 13 A w/ Plug | Bukoba |
| | Cable | | 2.5mm2 Twin w/o Earth | Bukoba |
| | Cable | | 6.0 mm2 Twin w/o Earth | Bukoba |
| 1 | Battery box | KARADEA | Burris design | Karagwe |
| 1 | Sub-board | KARADEA | Kithokoi design | Karagwe |
| 1 | Security light | Thin-Lite | 11W tube, weather-proof | Import |