Solar Lanterns Test:

Shades of Light

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In their outward appearance the solar lanterns tested mostly resemble the kerosene lamps they are intended to replace.
Photo: Gocke

SOLAR LANTERNS TEST: SHADES OF LIGHT

Torches and lanterns that obtain their energy from sunlight could replace environmentally damaging kerosene lamps in many developing countries and supply high quality light to a large proportion of poor households. For this, however, the products must be well-made and priced within the reach of the poorest people. A laboratory test shows that there are still too few solar-powered lanterns that meet both criteria.

Today, more than 1.5 billion people in Africa, Asia and Latin America live without the benefits of electricity. When the sun goes down, however, their day is far from over: when the daily work in the fields is done, family and social life take over, goods are sold at night markets, and kiosks and community centres become meeting points for village locals. Not until late at night do housewives find the opportunity to sew or do housework, and many students only get down to work after nightfall.

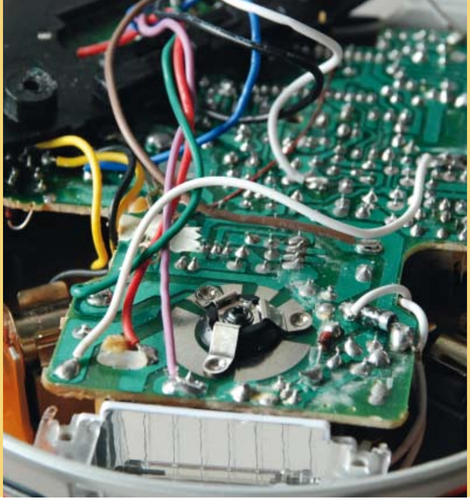
Lighting for these colourful scenes comes in many forms. The wealthy are able to afford diesel generators, while the poorest must make do with candlelight and the glow from the fire. But the most common source of artificial light in countries such as Kenya, Peru and Afghanistan is the kerosene lamp – ranging from simple low-cost wick lamps to the high-quality pressure lamps with gas mantles that are popular among campers in Europe. The luminous efficacy of many traditional methods of lighting is very low and also poor value-for-money: lamp oil and candles cost a typical household in developing countries some 40 to 80 US dollars per year (actual expenses vary greatly depending on international fuel prices, national taxes and household behaviour).

Kerosene: A Local and Global Environmental Hazard

According to a report published in the American scientific journal Science in 2005, 77 billion litres of fuel are burned in kerosene lamps every year. That amounts to 1.3 million barrels of oil per day. The oil consumption of these traditional lamps represents about one third of worldwide primary energy demand for domestic lighting and is responsible for emissions of 190 million tonnes of CO_2 greenhouse gas per year. Moreover, cheap kerosene lamps give off other emissions that are harmful to health, and pose a significant fire risk.

An Alternative: Solar-powered Lanterns

In an effort to curb this wasteful use of resources, development organisations have been propagating alternative lighting technologies for two decades, among them solar-powered solutions. In these devices, solar cells convert sunlight into electricity during the day that charges a battery, which then produces light for use after dark. The most common lighting source used in such solar systems is the compact fluorescent lamp (CFL), though recently more efficient light emitting diodes (LEDs) have become more widespread.



Shoddy workmanship, which compromises the durability of a system, can usually be recognised at sight.
Photo: ISE

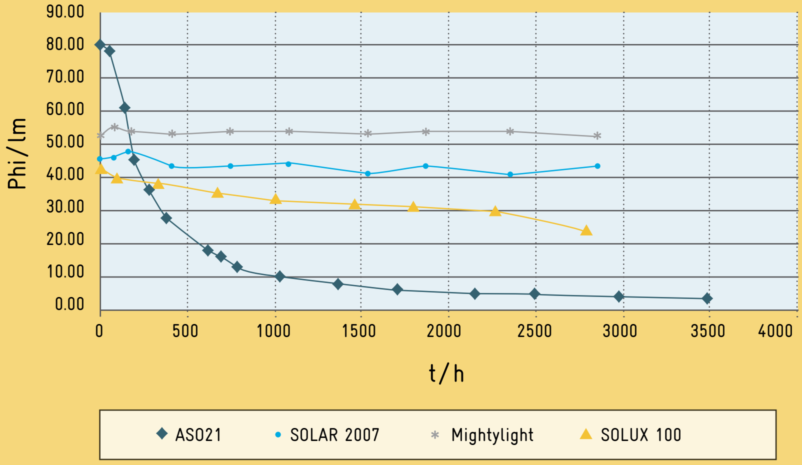
Progress in solar technology has recently led to a growing use of solar-powered lighting solutions in developing countries. Particularly in rural areas with a dispersed population, where connection to the electricity grid would be uneconomic, solar lighting systems are a promising alternative.
Solar lighting systems may broadly be divided into three classifications: simple models, similar to ordinary *torches*, are already available in many countries for a retail price of about ten US dollars. These are sometimes sold with a crank dynamo in place of the solar cells. Luminous efficacy and durability are usually poor. Such low-cost lanterns often last for only a month, or give light for only a few minutes.
At the other end of the price scale are '*solar home systems*' with a solar module of 20 to 100 watts and an optimised car battery, capable of powering several lights, a radio and a TV set simultaneously. Although some three million such solar home systems have already been installed worldwide, for most users they remain unaffordable: in Africa and Latin America they cost between 500 and 1000 US dollars. Only in Asia are they somewhat less expensive.
For its testing of PV lighting technology, therefore, GTZ (German technical cooperation) has concentrated on a third product category, which is rapidly gaining importance: *solar lanterns* or 'pico-PV systems' whose retail prices currently fall between the two extremes above. In their outward appearance they resemble kerosene lamps – but they promise greater lighting convenience and minimal running costs. In most models available so far, a small solar module – typically with a capacity of 3 to 10 watts – is separate from the lantern, so that it can be placed outdoors without the lantern being exposed to the weather. The best of these lanterns can be hung indoors or placed on a table, but are also portable enough to light the way when walking at night.
Another way in which these 'pico-PV systems' stand out from simple solar torches is the auxiliary uses available on many newer models. These offer outputs for a radio, a mobile phone charger or other functions, thus making a minimal basic provision of electrically powered micro-devices conceivable for all poor rural populations in the near future.

Following exhaustive research on solar lanterns currently on the market, twelve promising models were selected for technical examination and tested by the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany. This examination is the preliminary stage of a field test that GTZ plans for 2009. Experience in development cooperation shows that one thing must be avoided at the outset: that users of cheap and inadequate devices should become so disillusioned that the entire technology is discredited.

Table 1: Cost comparison

Lighting system	Typical cost (USD/klmh)
Candle	2.00
Kerosene lamp	0.10 – 1.00
Solar lanterns	0.10 – 4.00
Solar home system	0.04
Mains electricity	0.01

Estimated unit costs of lighting from different sources, measured in kilolumen-hours. Kerosene prices fluctuate widely. Lighting costs of better solar lanterns are currently roughly at par with kerosene lamps. Several solar lantern manufacturers have announced significant price reductions for 2009.



The luminous flux of the Astral AS021 (dark blue curve) falls sharply relative to other tested solar LED lanterns after only 100 operating hours.
Source: ISE

Graph 1: Degradation of the light output of poor low-power LEDs

The Preliminary Test

In an initial testing phase ISE examined all twelve systems for quality of workmanship. Five of the worst examples were eliminated and not passed to the next stage of testing. Simple methods – that can be performed with ease in developing countries – were used to test the functioning of the devices. Mechanical and electrical parts, such as soldered joints and plug connectors, were examined for durability; and the layout of the electronic components, the weather protection and the exterior quality of the solar module were evaluated.

One of the few models in which the solar module is built into the lantern, the Chinese *Global Marketing Technologies SL9000SW*, failed because the fold-out mechanism for the module is not robust, the module itself is poorly made and not resistant to rain. In addition, the main switch did not function correctly. The *Macro-Solar MS-L01*, from China, was also rejected because of its very low light output. The unit's 14 LEDs give very inconstant light, after only 30 minutes luminous efficacy fell to around 20 %.

The most poorly constructed solar lantern in the test was the *Wuara 2212 SL* from a South African company, whose price, however, at about ten dollars, is also extremely low. But its performance does not even live up to this low price. With its poor LED output, the system most closely resembles a cheap garden lantern: after two hours, light output falls to practically zero. Here again the solar module is built into the lantern and not weather-protected. A loose contact in the switch and a foot that comes off only add to the poor impression.

Nor did the two lanterns from the Chinese manufacturer Astral Solar pass the preliminary test. The CFL-based *Astral AS018* failed on the basis of sloppy physical construction with wiring that broke off, defective switches, faulty electronics and a lack of weather protection. The *Astral AS021* displayed similar shortcomings in workmanship such as poorly soldered joints. The cable between lantern and solar module is so short that the lantern must be placed outdoors along with the module. Moreover the LEDs used are unfavourably wired, resulting in a very low efficiency. The decisive factor in failing this system, however, was the lack of deepdischarge protection. As a result, the battery will be damaged in a very short time.

Solar Lanterns Test (pico-PV systems)

Product photo												
Product name	Sun x-set mobile	Aishwarya NEST-6543	Solar 2007-1	Solux LED 100	Mightylight 3040	Solux 50	Glowstar GS7	AS018	AS021	MS01	SL9000SW	Wuara 2212SL
Manufacturer	Würth Solergy (Germany)	Noble Energy Solar Technologies Ltd. (India)	Solarprojekt Freilassing e.V. (Germany)	Solux e.V. (Germany)	Cosmos Ignite Innovations (India)	Solux e.V. (Germany)	Sollatek Ltd (UK)	Astral Solar Technology Co. (China)	Astral Solar Technology Co. (China)	Macro-Solar Technology Co. Ltd (China)	Global Marketing Technologies Inc. (China)	SolEnergy Africa PTY Ltd (South Africa)
Internet address	www.we-online.de	www.solarnest.net	www.solarprojekt-freilassing.de	www.solux.org	www.cosmosignite.com	www.solux.org	www.sollatek.com	www.astsolar.com	www.astsolar.com	www.macro-solar.com	www.gmtems.com	www.solenergycc.com
Weight in kg (lamp)	0.7	1.2	0.6	0.5	0.5	0.5	3.2	n.s.	0.9	0.8	2.1	0.5
Light source	CFL	CFL	LED	LED	LED	LED	CFL	CFL	LED	LED	CFL	LED
Battery	NiMH/Lead	Lead	NiMH	NiMH	NiMH	NiMH	Lead	Lead	Lead	NiMH	Lead	n.s.
Module	external	external	external	external	external	external	external	external	external	external	integral	integral
Additional utility	12 V socket, battery charger unit	no [2]	Radio can be connected	2 brightness levels	3 brightness levels [3]	no	12 V socket	6 V socket, mobile phone charger	steplessly dimmable	no	Radio, flashing light	no
Preliminary test												
Function	2	3	1	1	1	1	3	2	2	5	3	5
Visual examination: lantern	4	3	1	1	1	3	1	4	4	2	4	5
Lantern mechanics	2	3	1	1	1	4	3	5	5	2	4	5
Electrical components	2	2	1	1	1	2	2	4	4	4	4	5
Electronic components	4	2	3	4	3	4	2	4	4	4	4	2
Weather protection	4	4	2	1	2	4	4	n.s.	2	4	5	5
Visual examination: module	n.s.	2	2	2	2	3	3	2	3	3	6	5
Module mechanics	n.s.	2	2	3	2	4	4	2	4	2	5	5
User manual	2	2	2	2	3	2	1	5	5	5	4	3
Preliminary evaluation	satisfactory	satisfactory	good	good	good	satisfactory	satisfactory	poor	poor	poor	poor	very poor
Main test												
Deviation of solar module from specifications	1	1.5	3.5	4	1.5	2	4					
Battery capacity deviation (5%)	1	1	1	1	2	2	1					
Battery capacity loss in continuous test (5%)	1	–	2	1	5	1	–					
Efficiency of charge controller (15%)	1	1	2	1	4.5	1	3					
Efficiency of ballast unit (5%)	2	4	1	1	3	1	3					
Cycle test/degradation	ok	ok	ok	ok	ok	ok	-1					
Breakage test	ok	-0.5	ok	ok	ok	ok	ok					
Luminous flux (10%)	1	1	4	2.5	2.5	2	1					
Luminous efficacy (5%)	2	2	4	2	2	1.5	3					
Solar fraction (20%)	1	3	1	1	1	1	4					
Burn time/light duration (20%)	1	2	1.5	1	4	3	3					
Main test evaluation	very good	good	good	good	satisfactory	satisfactory [1]	poor					
Costs												
Purchase price CIF, USD (2008)	500 [4]	52 [5]	122	117	55 [6]	36	210 [7]					
Running cost per month, USD	30	1	4	2	3	2	12					
Running cost per kilolumen-hour, USD	2.6	0.1	1.0	0.4	0.6	0.2	0.7					
Price-to-performance winner:		●										

Products that achieve the same score are arranged alphabetically by product name.

Overview of marks: 1.0–1.4: very good; 1.5–2.4: good; 2.5–3.4: satisfactory; 3.5–4.4: poor; 4.5–5.0 very poor;

n.s. = not specified

Notes:

[1] Mark reduced by one point because of lack of weather resistance.

[2] Alongside the model tested, this manufacturer also produces a similar model that includes a radio that costs approx. USD 8 more.

[3] Alongside the model tested, the manufacturer produces a similar model that includes a mobile phone charger that costs approx. USD 10 more.

[4] In early 2009, the manufacturer offered a one-lantern version of this system for about USD 350 CIF price to GTZ.

[5] The manufacturer announced price reductions in 2009.

[6] In early 2009, the manufacturer announced improved battery charging and price reductions of about one third.

[7] According to the manufacturer, the Glowstar price has fallen in 2009.

The difference in light quality is obvious: here is the brightest lantern and the weakest.
Photo: Gocke

The Shortlist

Thus seven solar lanterns reached the second testing stage, of which four are German-made: the *Solux LED 100* and *Solux LED 50* of the Solux e.V. development assistance project, the *Solar 2007-1* by the Freilassing solar promotion project, and the *sun x-set mobile produced by* Würth. Of these, the products of the two non-profit projects make an impression with their individual and functional design, while the system design from the manufacturer Würth drops out of the picture since it offers two lanterns and a separate charging station allowing for a variety of additional functions such as operation of a radio. This product therefore comes closer to a solar home system – a fact that is reflected in the price. Alongside these, the shortlisted systems included the *Glowstar GS7* of the British company Sollatek, the *Aishwarya NEST-6543* of the Indian manufacturer Noble Energy and the *Mightylight 3040*, also Indian made. The latter model was one of the first mass-produced products in this market sector and may have the widest distribution of all the products tested. The ISE test engineers still noted a number of shortcomings even in the preferred models. They criticised the *Glowstar* for wrongly designed circuitry; the *Aishwarya* was not considered sufficiently robust, the *Solux LED 100* and *Solar 2007-1* lacked current control for the LEDs, as did the *Mightylight*, which also did not have any form of charge control. The examiners found shoddy workmanship in the *Solux LED 50* and criticised the significant divergence in quality in the *sun x-set mobile* between the Chinese-made lighting systems and the well-constructed base charging station.

Major Differences in the Main Test

The seven selected systems were subjected to an indepth laboratory examination. The actual output of the solar module was compared with that specified by the manufacturer. The capacity of the batteries was examined, with NiMH rechargeable batteries further subjected to a durability test. The charge controller was checked for efficiency and discharge protection, and the ballast for efficiency. An additional cycle test was carried out on the CFLs for switching endurance. The central issue of the laboratory examination was, however, the testing of the light performance criteria – measuring the luminous flux and luminous efficacy, and calculating the solar fraction of the lanterns. Finally, the maximum light duration on a full battery was measured.
Operating costs of the products were established in addition to the technical testing, in terms of both the lifetime of the batteries contained in the system and the actual light output. While the calculation of monthly running costs based on lifetime should be structured in terms of a typical customer's use (to allow a direct comparison with the costs of kerosene or candles), the calculation of measured light output is more complex – yet is the one on which the value-for-money of the systems can most fairly be based. To get a yardstick for the price-to-performance ratio, the running costs obtained in the test must be placed in relation to other forms of lighting (see Table 1). However, the running costs can only be considered an approximate basis for calculation. This is primarily because the durability of the battery can only be estimated very crudely.

Test Results

The winner of the technical test was, without doubt, the *sun x-set mobile*. Even if the two lanterns do not show the best workmanship, the system functions with the largest and most powerful module by far and with an outstandingly good and versatile charging station. The extremely high purchase price and consequently huge operating costs, however, force this system unequivocally out of the range discussed here. These are almost ten times the comparison costs of kerosene lamps, thus making any argument that the target group should adopt this new lighting system untenable. Certainly, the high-quality charging unit offers a whole range of additional functions. But in this price bracket the potential customer will probably opt for a solar home system or a diesel generator. Of the systems rated 'good' in technical terms, the Indian *Aishwarya* stands out because of its especially favourable price. It failed to attract a better technical evaluation only because of its faulty ballast and minor issues in workmanship. The *Aishwarya* is therefore the clear winner in the price-to-performance comparison.

In the 'good' technical category, two other products are ranked behind this model, both from German development initiatives. The systems did not achieve a better ranking because of their unsatisfactory solar modules. While the *Solux LED 100* otherwise deserved a 'very good' rating in technical terms, the weak light output of the *Solar 2007-1* counted against it. Taking into account their substantially higher price, both systems fall by one grade. Their purchase price is higher than the annual lighting costs of the typical target household, and the running costs are also substantially higher than those of most other systems examined. Thus in terms of value-for-money the two German solar lanterns fall behind the systems technically assessed as 'satisfactory'. In this category the second Indian system, the original *Mightylight*, shows up well. Here a better technical assessment is prevented mainly by the poor battery durability and the lack of a ballast. The manufacturer has, however, prompted by this test result, already brought an improved version to market. The German *Solux LED 50* just succeeded in gaining a positive rating for its price performance. The chief fault on this especially bright and handy lantern is its lack of weather resistance.

The *Glowstar* failed both the technical test and in terms of value-for-money. This unusually heavy and cumbersome lantern was a pioneer of the market sector, but exhibits defects in workmanship and offers only a poor solar fraction and modest light duration.

Outlook

The quality of solar lanterns on the market is mixed, and prices are still too high for them to sell in great numbers in view of the low saving rates of poor households. However, we expect prices to drop below 50 % of 2008 values over the next few years, which will make solar lanterns clearly more economic than kerosene lamps. As they offer higher quality lighting, better handling, environmental advantages and sometimes radio or mobile phone charging, massive market growth can be expected in the near future – despite the limiting influence of higher upfront payments for solar lanterns (which can only partly be addressed through credits). In light of the mixed test results, informing potential consumers about lantern quality will be of great importance for a healthy market development.

Price-to-performance winner:
Aishwarya NEST-6543
Photo: Gocke

Table criteria:

Testing Criteria: Preliminary Test

The distribution of marks in the preliminary test is based on the following examiner's checklist:

Function: Does the lantern function? How is the distribution of light? Does the lantern cause glare? Is the switch mechanically robust? Can an illumination be created on a level surface that is sufficient to allow reading / writing?
Visual examination of lanterns: Operating elements, displays and reflector usefully arranged? Robust housing? Wiring and components firmly fixed? Components correctly placed and soldered to PCB (Printed Circuit Board)? Cables correctly soldered or crimped?
Lantern mechanics: Switch function given? Socket mechanically stable? Splash guard provided? Handle robust? Reflector and cover glass unbreakable or protected? Does lantern holder ensure reliable contact?
Electrical components: For CFL illuminants, can the electrodes be pre-heated? With LED illuminants, is a high-quality brand-name LED used? In the case of power LEDs is an appropriate heat sink fitted?
Electronic components: Does the ballast allow constant luminous flux irrespective of the battery charge state? Is a charge controller provided to prevent overcharging or deep discharge? Weather protection: Is weather protection / a splash guard evident? Is the cable weatherproof and long enough – or must the lantern be charged outdoors?
Visual examination of module: Is the module mechanically robust and resistant to ageing (aluminium frame, glass cover)?
Module mechanics: Are the connection points protected from moisture? Is strain relief provided for the cable connector?
User manual: Is there one, and is it easy to understand?

The overall mark for the preliminary test is obtained from the average of the individual marks. Serious defects may lead to a failure result and exclusion from the main test.

Testing Criteria: Main Test

The system for marking in the main test begins with a base value of 1 for each category, from which points are deducted for individual faults or shortcomings. These are assessed as follows:

Deviation of solar module from nominal rating: Does the system deliver the nominal rated values of power output, open-circuit voltage and shortcircuit current? If these are less than 90 % of rated value, deduct 2 marks. For absence of impact protection, fixing options or strain relief or for a cable length ‹ 5 m, deduct ½ mark each.

Deviation from battery capacity: Do the test results for battery capacity agree with the rated capacity? 1 mark deducted for a deviation of more than 10 %, 2 marks for a deviation of more than 20 %.

Loss of battery capacity during continuous testing: This test applies only to NiMH batteries. Is the battery resistant to overcharging? How does capacity hold up under a continuous load? Loss of over 5 % – deduct 1 mark, over 10 % 2 marks, over 15 % 3 marks, over 20 % 4 marks (i.e. a mark of 5).

Charge controller: Of concern here, besides the efficiency of the controller, is particularly the protection of the battery against discharge and overcharging (load rejection), the power consumption of the controller, and signalling. For efficiency, deduct 1 mark per step as follows: less than 90 %, less than 80 % and less than 65 %. If there is no charge controller at all, deduct 2 marks if there is a likelihood of damage to the battery. Lack of load rejection – also deduct 2 marks. If it is not possible to recharge fully discharged batteries, deduct 4 marks.

Efficiency of ballast device: How good is the efficiency of the ballast? If less than 90 %, deduct 1 mark; less than 80 %, deduct a further mark.

Testing Criteria: Costs

Cycle test / degradation: How long do CFL lamps last when subjected to a switching cycle of 'on' for 60 seconds, 'off' for 150 seconds? For failure before 10,000 cycles – deduct 1 mark. For LED systems, is there a significant fall in light output from the LEDs? If the luminous flux falls by 25 % after 1000 hours, deduct 1 mark; by 30 %, deduct 2 marks, by 35 %, deduct 3 marks.

Breakage test: Are the lanterns seriously damaged by the impact of falling onto a hard floor from the edge of a 60 cm high table? For total failure, deduct 1 mark; otherwise pro rata.

Luminous flux: Luminous flux in phi / lm is measured over a period of 210 minutes and the average value determined. If this value is less than 100 lm, the mark is 1.5; less than 80 lm, 2.0; less than 60 lm, 2.5 and less than 40 lm, 3.0.

Luminous efficacy: Here again the average is obtained from a period of 210 minutes, beginning from a fully-charged battery. Above 40 lm / W luminous efficacy: 1.5 marks; less than 40 lm / W, 2.0; less than 30 lm / W, 3.0 and less than 20 lm / W, 4.0.

Solar fraction: The proportion that the solar system can meet of daily need (here assumed at 3.5 hours' lighting per day) was determined for five simulated locations – Bolivia, Senegal, Indonesia, Mozambique and Uganda. Less than 95 % cover – deduct 1 mark; less than 90 %, deduct 2 marks.

Light duration: The duration is measured until luminous flux falls to 70 % of the initial value. If the maximum light duration is less than 7 h, mark as 1.5; if it is below 6 h, 2.0; if lower than 5 h, 3.0 and if lower than 4 h, 4.0.

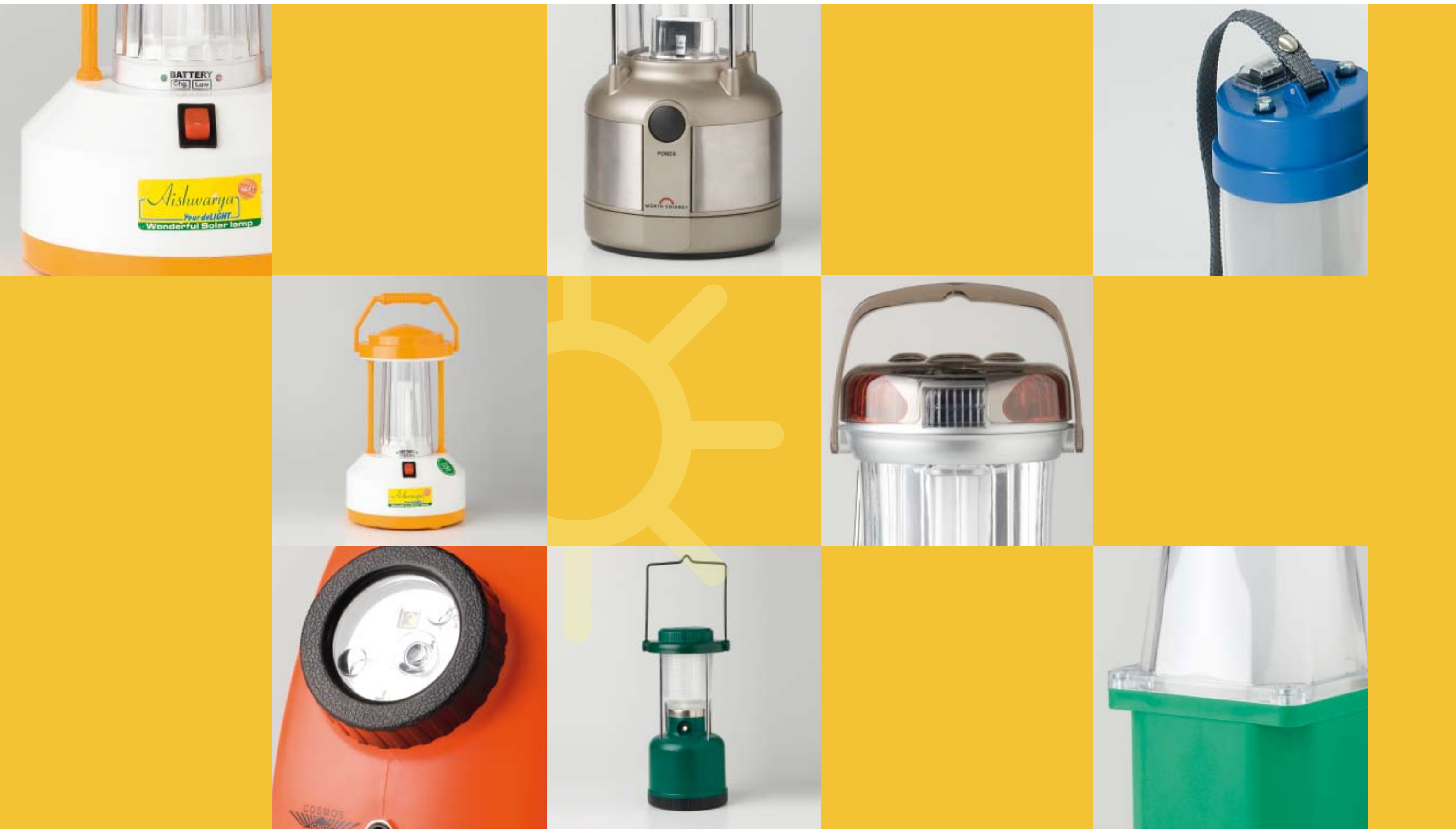
In the main test the overall mark is derived by averaging the individual marks and applying the percentage weighting specified.

Purchase price: Because of strong fluctuations of local customs duties and taxes, and in order to assure the comparability of delivery costs, the purchase price is given as the CIF-price in the port of discharge. At current annual lighting costs for a target household of some USD 60 for kerosene and candles (the actual annual figure varies sharply with income and use patterns), the maximum purchase price for high-quality solar lanterns at an early stage of the market should be of the order of half this amount.

Monthly running costs (battery durability): The purchase price is divided over the service life, which is mainly determined by the life of the battery. It is assumed that the user does not change the batteries. The life of the better solar systems tested exceeds 2 years without change of battery.

Operating costs per kilolumen-hour: Here the price is established in relation to the light output of the lantern over its lifetime. Since the light output of traditional light sources is often very weak, the merits of solar lighting in terms of the quality of the lighting are important. This value should therefore be considered in addition to the purchase cost and monthly operating cost in order to correctly assess the value-for-money of the products.

Note on cost calculation: Acceptance of this environmentally friendly system of lighting is heavily restricted by the low level of liquidity of the target-group households in all developing countries. Although the operating costs of the solar lanterns, in a full cost calculation, are lower than those of most traditional alternatives, because no more maintenance costs are incurred, the purchaser still incurs roughly a year's lighting costs in advance. For the annual lighting costs, therefore, a price limit for solar lanterns may be expected. Credit from dealers or through microcredit institutions is still rare in this market sector.



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