Safe and Desirable Female Toilets in Refugee Camps

I am an electronic designer & consultant.
I have extensive experience in the design and hands-on oversight of in-China manufacturing of **solar powered lighting intended for developing country applications.**

I have substantial experience in embedded systems development and communications.

I won a prior Wazoku (then Innocentive) challenge[1] for solar lighting systems for developing country use, which resulted in large scale production of my designs[2].

I am an international level expert in developing-country lighting, experienced and highly proficient in radio communications, and proficient at the practical level in the area of mechanical door locks and security.

I am personally interested in the development of life improving systems for developing country use and have several related self-funded projects in process.
Financial profit is not my primary aim. I would be delighted if my proposal was considered to be able to add value in this current application.

Proposed solution:

The proposal consists of the following subsystems which will be assembled into a solution which completely addresses all nn facets of the Challenge.

This system when fully implemented will connect a 'community' of latrines

which use Doppler RADAR and PIR sensors

to control lighting and

to analyse usage system status and to

send reports and alarm signals and

receive control signals

via a network of low cost radios,

with a bridge to a cellphone network and which

can charge cellphones using surplus energy to encourage community support.

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[1] Wazoku can confirm this challenge result. I have also provided Wazoku with links to web pages which demonstrate my technical competence and which show examples of the products that I developed in real-world use. Wazoku can choose whether to provide these to the seeker.

[2] See Appendix A19 - Prior developing country lighting solutions.
Focused on engineering design and manufacturing of cost effective, robust, reliable & effective lighting systems for deployment in developing economies.

The lighting and alerting systems utilise complex technology, but once engineered will be easily assembled and set to work in the field by unskilled operatives after less than an hour's training. The engineering, can be tailored to suit decisions in the field as to which aspects should be implemented, and how, given constraints of cost and practicality.

My proposal is entirely practical and in its fully implemented form will achieve all the requirements of the Challenge and of the seeker's request, including cost.

Less capable and lower cost solution subsets are also proposed.
For example a solution covering only lighting aspects, with the ability to be provide occupancy information to a complete system if desired.

As a demonstration of practicality, and as a step on the path to a useful implementation, this proposal includes an offer to produce a demonstration system that will perform essentially all the tasks described below.

This includes lighting control, renewable energy & battery management, an alerting system & remote control with low cost inter-latrine radio links and overall cellphone network connectivity.

This is not intended to be a final commercial solution but, rather, a demonstration 'template' that can be used for investigation, understanding, scoping and establishing what a commercial solution should look like.

CONTENTS

1 This proposal covers:

An integrated lighting and alerting system:
The lighting and alerting systems complement each other significantly.
I propose

- An integrated solution covering all aspects of the seeker's request

- Plus a lighting only subset with the ability to be provide occupancy information to a complete system if desired.

> Lighting:

Design and implementation of lighting systems meeting the functional, practical and cost requirements of this challenge. Includes automatically and manually controllable lighting. Reliability & practicality of various options are discussed.
A flexible system able to be tailored to real-world requirements as desired.

> Renewable energy power sources & battery system

- Renewable energy sources:
The only viable renewable power source applicable in all locations is solar power.
Other systems with more restricted applicability are also discussed in "Appendix A22 Choice of renewable energy system".

Economies of scale for groups of latrines are discussed.

- Battery system: Type of battery, capacity and implications, environmental conditions, sizing, costs, operation in all situations & environments, security.

Optionally: Use of surplus energy to provide cellphone charging facilities (remote from the latrines) to increase community ownership is proposed

> Alerting - Usage & maintenance:

Design and implementation of a maintenance and usage monitoring system.
Utilise visit-frequency and occupancy-times plus sensor systems to determine latrine status. Provision of both "local alert" and real time low cost "mesh connected" radio linked alerting system (to improve operation and security and reduce cost),
Plus cellphone network connection to the mesh network.
Optional: Intruder discouragement alarm.

> Wireless information transfer and system control.

Maintenance information and system status is communicated by radio.
Inter-latrine medium range mesh network with cellphone linkage via some nodes.

Optionally:

- Radio linked emergency alarm system (& potentially voice communications.
- The system could be configured and controlled remotely by radio.
  (eg varying lighting profiles to suit weather conditions).

This system when fully implemented will connect a ‘community’ of latrines

which use Doppler RADAR and PIR sensors

to monitor occupancy and

to control lighting and

to analyse usage system status and to

send reports and alarm signals and

receive control signals

via a network of low cost radios,

with a bridge to a cellphone network and which

can charge cellphones using excess energy to encourage community support.

Central to the proposal is the delivery of a realistically achievable end product, and not just an on-paper pipe dream.

In this solution, what may appear to the users as little short of “magic” is based on a solid but unseen technological foundation.

> “Any technology, sufficiently advanced, is indistinguishable from magic.”
>
> Arthur C Clarke.

None of this is, in itself, ‘technically hard’, but it is potentially complex, and needs to be carefully designed.

The use of low cost microcontroller(s) enables immense capability to be incorporated at little or no extra capital cost. Once the core hardware is available most features depend on software. The challenge largely lies in defining and implementing sensibly useful capability.

The offered prototype system will greatly facilitate this aim.

Proposal

The solver values any award received for this proposal not only for the monetary return but for the acknowledgement that the material will be of value to others.

In addition to offering this document under the terms of the challenge I propose the supply of a prototype system intended to demonstrate and investigate the concepts in this document. This would demonstrate all functionality described in the document. While it would NOT be anything like a final product, it would very greatly aid the investigation and development of a real world solution.

The cost of providing this system and an agreement on what is deliverable would be by mutual agreement. The intention is to provide exceptional value for money.

Any award received from this challenge would be considered to contribute towards payment for the prototype development.

Outline details are provided in section 2.15

> **"Offer to produce a working functional model of a multiple latrine system demonstration and investigation purposes."**

Supplied "nodes" by arrangement, but suggested configuration is

- one full latrine model (lighting, solar & battery system, alerting etc)
- two latrine partial models to demonstrate wireless-mesh connectivity
- one latrine partial model with cellphone network connectivity.

This would allow demonstration & investigation of all features.
Model provides all latrine related features.
Mesh network provides access via other latrine-nodes cellphone portal to demonstrate interconnectivity and control.

Hardware would include (as per 2.15) items functionally equivalent to

Solar panel	PET or ETFE PV panel. Initially 6 Watt Wmp, 5V
Battery	LiFePO4 battery. 1 or 2 x 18650. About 1800 mAh.
Light	LED Cree JB2835BWT 210 lumens/Watt 5000 K.
Inter latrine data	NRF24L01 + LNA + PA mesh wireless
Cellphone gateway	SIM800L GSM GPRS/SMS with audio
Person sensor	Doppler RADAR RCW-0516
Person sensor	PIR HC-SR501
Time of flight sensor	VL53L0X
Controller core	Arduino – various.

Notes:

1. **References to appendices** may be shown in more or less detail depending on context.

> Refer to "Appendix A10 - Solar panel design and implementation and costing."
> Or just [Ref A10] or even just [A10]

2. Resource files relating to this challenge are available at

> **https://bit.ly/irclatrine** ← **Dropbox repository.**

This is an unordered list of material that has potential value but which is in totally raw form.

A list of these files is provided in uploaded document

> "Files Refs.doc"

3. A PV panel + Battery + LED lighting spreadsheet is in uploaded file

> **PVBATLEDFF.XLS**

See section: Spreadsheet "PV Panel to Battery & LED calculator

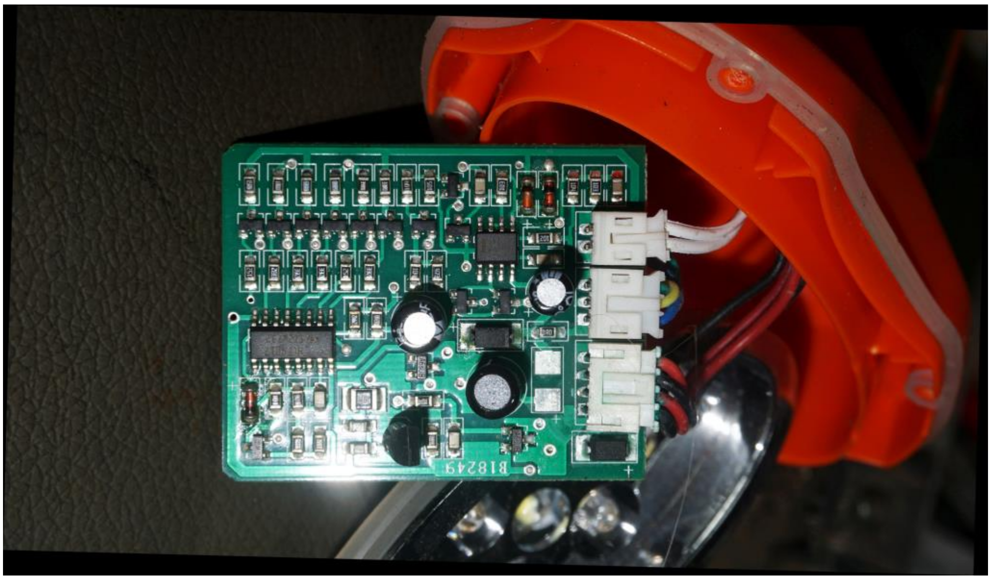
4. PET PV panel abrasion tests.

Full sequence of photos and panel output here https://bit.ly/PETpanelabrasiontests

See A20 for details.

Prior products. I designed the electronics and played a major role in overall product design and development and production oversight for these solar charged portable lights, targeted at developing country use. 350,000+ produced.

See "Appendix A19 - Prior developing country lighting solutions."



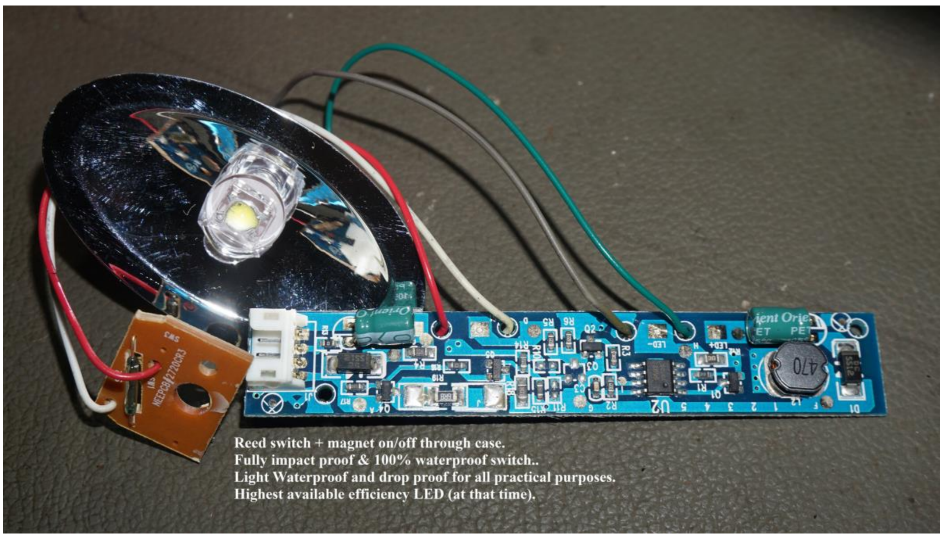
Roomlighting- 3 levels.   Tasklight – 3 levels.
Turn off in sun. Streetlight mode.
Waterproof. Drop proof. Rugged and reliable.

The white ring is NOT the main water-seal. A formal O-ring seals the lens interface.

Simple on/off solar charged portable light.

Ultra high efficiency LED.
Boost converter from 1 x NimH
NimH Charge control.

Waterproof, drop-proof, … .



2 How does it work, what does it do? – A whole system overview.

Brief overall system 'picture'

The following system description is provided to give the reader an easily followed overview of the solution. This is necessarily very simplified, and may not cover some potential alternative proposals. But, overall it should provide a good feel for what is an entirely practical solution based on sound engineering principles.

ALL the hardware components to implement this solution are readily available. Versions of almost all them are currently in the solver's possession. (A23 - components)

Volume pricing of all major components has been obtained. (A24 Pricing)

Where the use of specialist hardware is proposed links are provided to websites providing example of them in practical applications - usually code of working systems provided. (Appendix A25 - Example applications of sensors and subsystems.)

Overview:

A microcontroller (a small computer) provides overall system management. In a simple lighting only system control can optionally be provided by simple dedicated hardware.

One or more LEDs can be controlled across the full range of desired brightnesses. Additional LEDs can optionally be provided for latrine status display (empty / occupied / clean-me!) and external lighting. Light control can be fully automatic – or can also have user controlled short term "extra bright" lighting.

A roof or mast mounted solar panel charges a battery with enough capacity to operate for multiple low sun days.

A physically secure housing contains a physically protected LED for latrine lighting plus battery and the controller.

A hidden "person detector" (PIR or Doppler RADAR) controls lighting, monitors occupancy and provides usage rate and occupancy information to the alerting system. Additional sensors may be used to monitor latrine condition.

A radio network provides inter latrine information transfer and connectivity to a cellphone network if available. Operational information is passed to an external monitoring point and control information is passed down the network.

Optional features include emergency alarm alerting, intruder discouragement system (light/sound), cellphone charging using surplus energy (at a distance from the latrine).

An easily used, secure, low cost door locking system easily adapted to any latrine door is provided. Mechanical available / occupied status is shown and optional electronic status reporting and display can be provided.

2.1 Energy: A solar paneSee A20 for detailsl is mounted on the latrine roof in a manner aimed at minimising damage or theft. The panel wattage is chosen to be large enough to provide for multiple days operation under normal worst case winter conditions and even after prolonged weather degradation of the panel. In really extreme conditions the system can manage lighting levels to prolong battery life. Far more energy than needed will be available in most cases.

The solar panel may be mounted either on a robust sloping sun-oriented panel or on a short "mast". Optionally security systems can be[3] provided to discourage attempts at 'attack' and to notify them locally and remotely.
(Appendix 10 Solar panel design and implementation and costing.)

The battery system is housed in the internal enclosure – (see "Controller below.)
(See Appendix 11 Battery design and implementation and costing.)
While they are not preferred, lead acid batteries can be accommodated if required.

Optionally, if desired, any excess energy can be used to supply a cellphone charging station located some distance from the latrine. The aim is to provide "extra value" to the community and to thus engender an increased community sense of ownership and an increased incentive to defend the facility against vandalism and theft.

Where latrines are in groups solar panels and possibly batteries can be shared.
Panel to battery distances are relatively non crucial. Battery to controller and LED distances should be shorter.

Power can be transferred efficiently over significant distances using "technical magic" in some selected cases. (Appendix 21 - Power distribution.)

2.3 Controller: Controls all system activities.
The prototype controller is Arduino system based for ease of development. The system can be equally well supported on other platforms.
Very low cost processors are available for production versions if desired.

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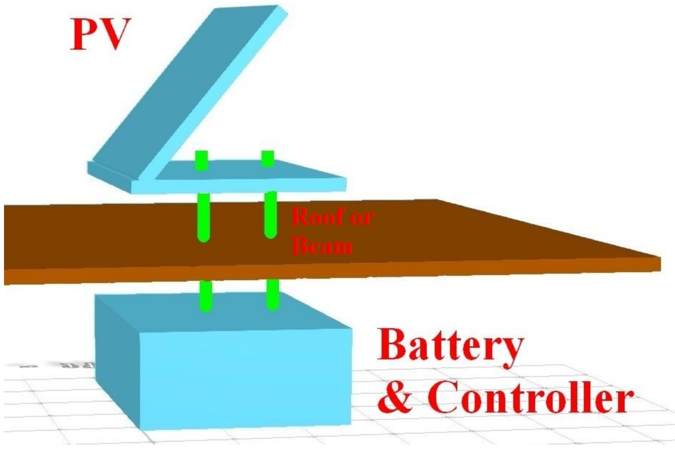
[3] "can be" versus "is" or "is able to be" :
Throughout this proposal
- Use of "can be" indicates a feature or action or choice is optionally possible at the seeker's discretion.
- Use of "is able to be " or of "is" indicates that the indicated feature or action is intended to be implemented in the proposal (but anything can be changed at the seeker's discretion).

2.4 Housing and mounting: The above roof structure attaches by bolts of adequate length to a metal housing inside the latrine. Any roof thickness is able to be easily accommodated. A fastening system is used to make it very very very hard indeed to remove either the internal enclosure or roof mount.
eg special bolt heads inside a raised rim with no line of sight to head).
Easy enough with the cheap and simple special tool. Otherwise almost impossible.

A13 Door locking



2.5 Lighting An internal LED for latrine lighting mounts in the ceiling mounted controller & battery housing, and is protected by a polycarbonate “near bulletproof” LED cover.
Additional LEDs are possible if needed.

Light level is fully variable by the controller.
Level is “very adequate” by design and is able to be increased at user request for selected periods. Average long term LED brightness is constrained by sizing of solar panel and battery which in turn are cost constrained.
Choices are able to be altered dynamically to suit site specific requirements.

2.6 Latrine occupancy / User detection:

Occupancy is detected by a non contact person sensor which is not user perceptible. PIR and Doppler RADAR types are available and will be trialled for comparison. Both have pros and cons.

Latrine usability / condition is expected to be able to be inferred by recording and analysing usage patterns. If visit rates are typical within defined limits for the time of day, and visit lengths fit a usual distribution, then the latrine is extremely likely to be functional. If usage rate drops markedly, and if most occupancies are very short (user opens door, reacts with dismay, go somewhere else), then a “needs service” state very probably exists. However, sensor based systems can be trialled if felt necessary.
eg a contamination protected “time of flight” sensor allows non contact measurement of the height from the top of the ‘heap’ to some higher point. And a hydrostatic level detector allows pit liquid level to be measured. (Dealing with contamination may prove intractable in this case.) If necessary other sensor systems will be possible.

2.7 Door locking.

The door lock could, easily enough, be electrically operated.
An electrically based locking system could use any of an electromagnetic “strike”, a magnet latched drawn bolt, or other motorised or electromagnetically powered systems. These could draw no power except while changing state, and could be mechanically over-ridden internally.

However, any form of powered system is unnecessary – adding complexity, cost and unreliability. It is strongly suggested that a purely mechanical system targeting effectiveness, reliability and low cost is liable to be more satisfactory overall. The door lock needs to be robust enough to survive both years of normal use and occasional intentional assault. An electrical lock needs to be powered by its own battery, or to have power fed from the control unit. Any wiring is prone to both accidental and malicious damage.

A very good “universal door lock” allowing good locking, ease of use, occupancy notification and low cost is able to be readily implemented. Proposals, based on the solver’s long engineering lifetime of experience of practical real world implementations include “drawn bolt” and “swinging latch” which are easy to use, easy to mount in almost any latrine, provide good security and user assurance, are relatively fail-safe in operation and are low cost.

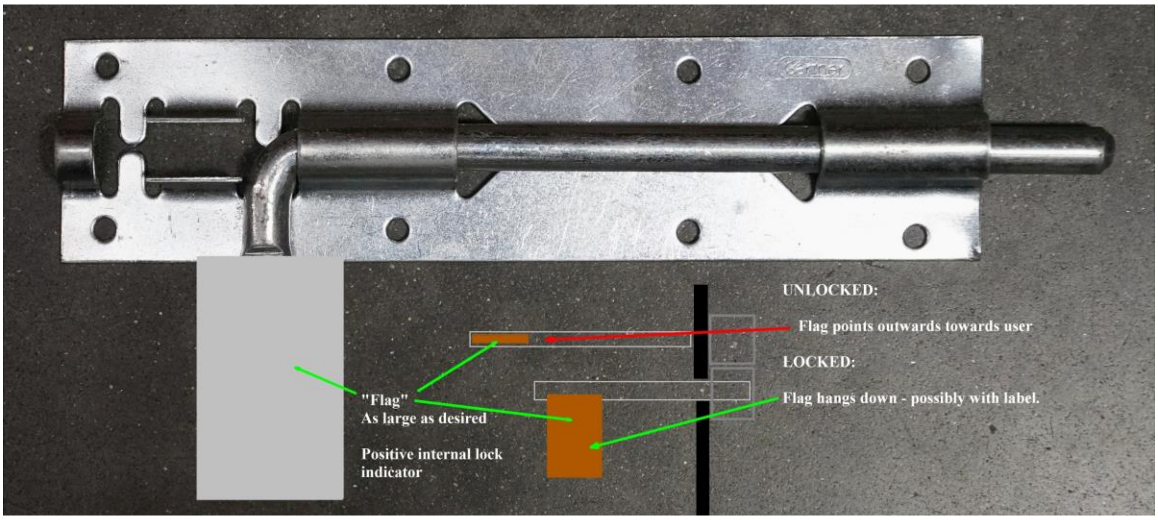
Of importance is the ability to provide not only good protection against intrusion but also high certainty that users will not be trapped inside the latrine.

Example only. One of very many possibilities.

See “A13 Door Locking” for larger image.

“Flag” on handle signals locking status to user.
Flag horizontal = open.
Flag folds down only when locked.

Can be as solid as desired. Stamped construction. Strong but cheap.



2.8 Door locking status:

Locking status may be monitored electronically – locally & remotely if desired.
If desired a sensor to allow electronic monitoring of the lock status can easily be added. This would allow both local LED reporting and remote reporting. Challenges in providing secure connection to the door locking monitor are discussed.
Wiring from lock to controller is vulnerable to damage. If used, steps can be taken to make its existence unobvious. Wireless lock-status monitoring is possible, adding some complexity and cost.

2.9 Alerting and remote communications:

A radio “mesh network” is provided consisting of a low cost radio transceiver in each latrine “node” with a range of about 1 kilometre (more if necessary).
Information can be passed from node to node (latrine to latrine) across the network to achieve increased range if required. Multiple paths will usually be possible so that a “dead” node does not impact overall operation.

An occasional master node will provide a latrine-network to cellphone network “bridge” allowing the status of all latrines to be reported and monitored remotely. Control information can also be passed from a remote centre to selected or all latrines.

If desired, emergency alarm information can be passed across the network from any latrine. The system also has a limited ability to pass two way voice communications. This would take extra effort but not necessarily very much extra cost.

The solver’s cellphone gateway modules operate on the GSM cellphone system. This system is in very common use internationally, but all other systems can be supported.

Optional:

Security features can make the combination of light + controller + solar panel work ONLY when used together – less than all 3 results in an inactive product.

A single external LED can indicate that the latrine is empty or in use, or that the latrine is out of service.

External LED lighting can be provided. (One to many LEDs)

2.10 System Security – theft, malicious & accidental damage.

The solar panel, battery and the LED lighting are attractive targets for theft – either for resale and own use. Radio system components are liable to be less attractive but may be stolen in ignorance of their purpose.

There are many possible way of attempting to render the system theft and damage proof. The reality is that any system can be compromised by a determined enough attacker. Accordingly, it can be useful if the system can also include means to provide local and remote alerting to discourage malicious action.

The suggested solution uses a folded metal structure (or two mechanically connected structures) to accommodate solar panel, battery, controller and the main internal light. The external structure mounts on the latrine roof – with the solar panel either on a sloping face, or on a mast. A plate or secondary enclosure mounts inside the latrine, with the two bolting together through the roof.

If desired the system components could be designed to not operate if removed from the latrine. This takes extra design time & effort and a little extra cost, but could be done if considered worthwhile.

Alternatively:

Solar panels

- Could be mounted on a "mast" to both make access harder and also attempted theft more obvious to observers.

- Could be mounted on a plate securely fastened to and through the latrine roof. Les secure than a tower but cheaper and easier.

The battery system

- Could also be mast mounted, but this is not attractive technically (due to wiring voltage drop reasons).

- Could be mounted under the solar panel on the roof in a relatively hard to remove fixture.

An emergency-alarm system could be implemented, using any mix of

- local LED light (modest cost),

- local audible alarm (somewhat costlier) and

- Radio system alerting (almost free but requires extra design).

2.11 Cellphone charging - Community "buy in": As an incentive to community ownership and protection of the system, a "cellphone charging station" can be provided external to the latrine when excess energy is available. This can be located a reasonable distance from the latrine itself. Excess energy may not always be available in the very worst conditions but usually will be.

2.12   Blank

2.13 Reliability and quality

2.14 Real-world viability.

- What practical real-world aspects & pitfalls should be looked for and what should be avoided in evaluating both this and other designs.

- What can and cannot be realistically achieved within the applicable constraints

2.15 Offer to provide a working demonstration system:

Offer to produce a working functional model of a multiple latrine system demonstration and investigation purposes.

Provide a “working model” which at a minimum includes but is not limited to:

- User aware lighting with profile able to be tailored as desired.
  Internal and external illumination control

- Solar powered battery charging and management

- Occupancy & out-of service visual alerting.

- Serviceability alerting based on occupancy statistics and optionally on sensors.

- Mesh radio communications with other latrines and a master station.

- Cellphone network connectivity for remote reporting and control.

- Supplied “nodes” by arrangement, but suggested configuration is

    - one full latrine model (lighting, solar & battery system, alerting etc)
    - two latrine partial models to demonstrate wireless-mesh connectivity
    - one latrine partial model with cellphone network connectivity.

  This would allow demonstration & investigation of all features.
  Model provides all latrine related features.
  Mesh network provides access via other latrine-nodes cellphone portal to demonstrate interconnectivity and control.

This implements the following offer made in the introduction.

> As a demonstration of practicality, and as a step on the path to a useful implementation, this proposal includes an offer to produce a demonstration system that will perform essentially all the tasks described below.
>
> This includes lighting control, renewable energy & battery management, an alerting system & remote control with low cost inter-latrine radio links and overall cellphone network connectivity.

This is not intended to be a final commercial solution but, rather, a demonstration ‘template’ that can be used for investigation, understanding, scoping and establishing what a commercial solution could look like.

In particular, software would be intended to provide agreed on functionality but would be unlikely to be anything like a final implementation.

The system would include the following hardware of functional equivalent.
Various parameters are operator variable to allow investigation.
Components are able to be enabled/disabled and “mix and matched” to suit.

Prototype hardware – major items only

Solar panel	PET or ETFE PV panel. Initially 6 Watt Wmp, 5V
Battery	LiFePO4 battery. 1 or 2 x 18650. About 1800 mAh.
Light	LED Cree JB2835BWT 210 lumens/Watt 5000 K.
Inter latrine data	NRF24L01 + LNA + PA mesh wireless
Cellphone gateway	SIM800L GSM GPRS/SMS with audio
Person sensor	Doppler RADAR RCW-0516
Person sensor	PIR HC-SR501
Time of flight sensor	VL53L0X
Controller core	Arduino – various.

2.16 Components used – and rough costings.

The core system for a lighting only application can involve only low cost “discrete hardware” without a microcontroller. See the examples of my prior solar powered lights in “Appendix A19 - Prior developing-country lighting solutions.”

These lights were purposefully designed without a processor due to the desire to minimise problems in the production environment. I would prefer to use a uC. in even a simple light if possible.

In this application hardware alone *could* ramp up light brightness when a user arrives, detect user presence by using a PIR or Doppler RADAR module, and provide an occupancy status LED. Using a uC. Would add the ability to analyse usage patterns and predict latrine usability and need for servicing.

Driving an LED or several requires only a cheap MOSFET transistor and a resistor and capacitor per LED. Maybe 20 to 30 cents per channel or less includig LED.

PIR sensors will cost around $US0.40 or less.

Doppler RADAR sensors would cost about $US1.00 – but the PIR sensor will probably suffice.

TOF excrement level sensor, if used would cost maybe $1.50 or less for electronics, but it is liable not to be required.

Door latch monitoring may add up to a dollar due to need for wiring and sensor.

An Integrated lighting and monitoring system can be “tailored” to meet its share of the budget. Biggest single capital cost is the combined PV panel and battery. If multi day low-sun operation at full brightness in all reas in all seasons is desired then a PV panel cost ex factory of $4-$5 is in order. Battery cost is maybe $2-$3.
However if operation at lower lighting levels (under system control) in extreme weather conditions is acceptable, substantially lower PV panel and battery costs are acceptable. In many area in eg Africa a PV cost of maybe $3 and battery cost of $1-$2 is possible.

It is important to note that these costs apply to ANY proposal using solar energy.Any proposal suggesting substantially lower costs is ‘missing something’.

3 System components & subsystems

The following "subsystems" are commented on in more detail, with reference to Appendices as required.

The lighting and alerting systems interact significantly.
While separate solutions for either one of these are possible, the integration of the two is liable to be worthwhile.
See the "Lighting and alerting interaction and integration example" on the next page.

The following "subsystem summaries" outline the roles played by each as part of the overall system.

Microcontroller – System "brain". Integrates and manages all other functions

LEDs – Light production. In cubicle and exterior as required.

Battery System – energy storage for lighting, alerting & radio systems

Solar energy system – Means of providing renewable energy:

Alerting system – occupancy, utilisation, alarms, remote communications

Radio communications – inter-latrine "nodes" medium range 'mesh' network with shared connection to cellphone network at selected nodes.

Security – eg built in measures to make the system components non-functional if stolen.

Locking.

EXAMPLE ONLY: Lighting and alerting interaction and integration.

As an example only – occupancy and usage of the latrine is detected by a "person sensor" – most probably a Doppler RADAR unit or a passive infrared sensor, although others means can be accommodated.
(Either of these would be implemented so as to be undetectable by the user.)
This occupancy information 'informs' both lighting control and state of use.

Information of frequency and duration of use and current status form *part* of the data used to formulate usage and maintenance output. Latrine 'hydrostatic level' can be sensed, and absolute level can be sensed with eg "time of flight" sensors (to measure pit fullness) but both of these have a cost and both have potential issues and are best not used if possible.

It is expected that experimentation will show that frequency of use and duration patterns plus some intelligent analysis will be adequate as a measure of system status.

The alerting system can utilise very low cost medium-range radio units in a "mesh" to achieve connectivity at low cost, with the ability for any latrine to interface with cellphone network "gateways" installed in only some latrine based nodes.

Once a radio network exists

- Lighting and battery status are able to be reported.
  Remote lighting control is able to be implemented

- The system could, if desired, forward user alarm information to other locations in the event of an emergency.

- The system is potentially capable of providing voice communications – eg in emergencies, with some practical limitations.

The whole system needs to be powered by a PV (photovoltaic) / solar power system, which in turn charges a battery and which employs a microcontroller to control lighting, occupant detection, status monitoring, messaging and more.

A single microcontroller can perform all of the above functions.

Separation of these components is possible but probably not desirable.

3 System components & subsystems

The following "subsystems" are commented on in more detail, with reference to Appendices as required. Sub-system summaries

3.1 Microcontroller – System "brain"

The 'heart' of the solution is a low cost microcontroller.
A fully microcontroller free "hardware" solution is possible for the lighting, but the flexibility of a software configurable solution is highly attractive.
The radio communications aspect of the alerting system requires a microcontroller.
A single microcontroller can control all aspects of system operation or the two can be independent but intercommunicate.

The solver's offered demonstration unit is based, for reasons of convenience and development simplicity, on an "Arduino" processor module selling for under $US2. The final system microcontroller could cost under $US0.20 in modest production quantities.[4] Other costs will dominate the overall capital cost.

The microcontroller can

Control lighting,

Monitor occupancy (using Doppler RADAR or PIR sensor or other means),

Read any other sensors used to monitor latrine condition

Analyse occupancy information

Store results for forwarding and/or later recovery

Transfer data by radio links to and from other latrines

Via selected nodes, communicate whole system status and receive control information via cellphone network.

If desired – forward user alarm requests.

Control battery charging and battery usage.

Optional:

Control door locking IF this is electrically controllable – which is not considered necessary or desirable – see end of this section.

Possibly provide voice communications in emergencies.
alarm

And more …

[4] See Links-100

3.2 LEDs – Light production

LED light level is able to be continually varied as desired from off, to a mere guiding glimmer, to as bright as desired. (Energy usage aspects set upper continuous operation brightness levels).

If a light management profile can be described it can be implemented.

> **<u>Example</u> only**:
>
> - LED on exterior above door operates at a glimmer when unoccupied.
> - Can be eg set to flash when occupied.
> - Low internal light level on entry, rising to medium level over say 10 seconds. - User can select a high level for a set period.
> - Light then fades back to medium.
> - On user exit light fades to low level and then to a glimmer after a set period. - Exterior light can also signal maintenance status

The selected LEDs are about as efficient as any available (over 200 lumens/Watt) while costing about $US0.12 cents each. These are twice as efficient as the best home LED light bulbs. Final LEDs used may differ but will have similar efficiency.

Electrically the lighting controller could operate multiple LEDs, each at independently selected brightnesses, including ones outside the latrines.

External lighting not on the latrine structure would probably be best managed separately, mainly for security reasons. The main obstacle to the latrine based system also powering approach and external lighting is the vulnerability of these components to external "attack".

Security: If desired the system could discourage theft by designing the system so LEDs + Battery + PV panel would only work together. Attempts to eg operate the lights from a battery from another source would not work. It could even be arranged that the PV panel would only charge its own battery pack. This requires some thought and a little 'hardware' but is entirely doable.

Example LEDs only.

These are strong candidates for a final design but alternatives exist.

JB2835BWT-G-H40GA0000-N0000001 JB2835B 3V G CLASS *CreeLED, Inc.*	77,658 In Stock	100 : **$0.11990** Cut Tape (CT)	Active	White, Neutral	4000K 3-Step MacAdam Ellipse	30lm (Typ)	32lm (Typ)	55mA	2.67V	218 lm/W	80	480mA	120°
JB2835BWT-G-B50GA0000-N0000001 JB2835B 3V G CLASS *CreeLED, Inc.*	46,513 In Stock	100 : **$0.11990** Cut Tape (CT)	Active	White, Cool	5000K 3-Step MacAdam Ellipse	32lm (Typ)	34lm (Typ)	55mA	2.67V	231 lm/W	70	480mA	120°
JB2835BWT-G-H30GA0000-N0000001 JB2835B 3V G CLASS *CreeLED, Inc.*	1,715 In Stock	100 : **$0.11990** Cut Tape (CT)	Active	White, Warm	3000K 3-Step MacAdam Ellipse	28lm (Typ)	30lm (Typ)	55mA	2.67V	204 lm/W	80	480mA	120°

<u>3.3</u> Latrine capacity sensing

Possibly the biggest challenge is establishing when a latrine is near capacity.
Any sensor or sensing system that achieves this can be accommodated.

Changes in the number of occupants over time and the residence time would provide a good indication of latrine usability. This can be confirmed by field tests – either automated or manual.

Active measures of actual physical status are harder to achieve.

A number of possible ways of achieving this are suggested.
These include

TOF sensor to deteermine latrine fill level.

Hydrostatic head measurement.

I is likely that discussions with the seeker will greatly assist in optimising this capability.

3.4 **Energy storage – Battery System**: – (Details – see Appendix A11 Battery)

A battery is chosen for energy storage. Alternatives to battery energy storage are discussed in appendices, but none are universally practical.

The preferred choice of battery both for in-latrine and other use is either
LiIon (Lithium Ion) or LFP (Lithium Ferro Phosphate).
Lead Acid and NiMH batteries are less suitable – (See A11 - Battery).

Battery life depends on seeker-specified illumination levels, and how many days of sun-free operation (rain, clouds etc) are required from the battery.
At say 200 mW LED power and 8 hours full strength operation per night
the number of low or no sun days that they would operate an LED for are:

- LiIon (Lithium Ion) "18650" cell will provide about 4+

- An LFP (Lithium Ferrophosphate) 18650 cell about 3 days.

If longer sunless day periods are required two batteries can be used, or a larger capacity battery can be provided.

With the very efficient LEDs used, 200 mW will provide about 40 lumens of light – which should be very acceptable.

The system can progressively reduce light levels if battery capacity drops below a preset level.

LiIon has greater energy content per cell but needs to be managed more carefully to achieve long lifetimes. LFP is more certain to achieve many years of operation.

If required the system can progressively reduce light levels if battery capacity drops below a preset level.

Allowable operating temperature ranges are similar.

LiFePO4 allows perhaps a slightly higher maximum charging temperature.
Both should be charged out of direct sun in a ventilated location.

Charging temperature range	0C to 55C charge
Discharge temperature range	-20C to 55C discharge

If charging energy is available when the battery temperature is below 0 degrees C the charge energy should be used to warm the battery to above 0 C

Lead acid batteries have issues with longevity without use of deep discharge cells. Overall lifetime cost is dearer than Lithium based batteries. Use below 0C is potentially fatal due to battery freezing at lower states of charge.

NiMH batteries are extremely hard to manage properly in a solar charging environment and are not a good choice overall.

3.5 Energy source – Means of providing Renewable Energy:

Both lighting and maintenance systems (and possibly door locking) require provision of energy - from a renewable source for lighting, and ideally so for maintenance.
There are a number of potential renewable energy sources, but only one which meets the requirements of cost, availability, reliability and real-world achievability.

Use of Photovoltaic / solar panels for power provision is discussed in great detail and guidelines for implementation and proposals are provided. Other possible means of power are also discussed, but in lesser detail, for the reasons summarised below.

PV (photovoltaic / solar) energy, for the reasons summarised below, is the sole source of power that can be designed to operate at acceptable power levels, reliability and longevity. While "using s solar panel" sounds easy and simple (and is), designing and implementing a system that meets real requirements is achievable but non trivial. Aspects include but are not limited to panel power, sunshine hours throughout the year, temperature extremes (not and cold), panel degradation (dirt, UV, temperature, ...), battery types and suitability for conditions, and more. Also theft, inaccessibility, and cost.

Mechanical generation of electricity is practical at the scales envisaged here but les likely to be widely accepted. I have substantial experience in designing such systems (used in exercise equipment). Children using play equipment, users operating a hand crank and similar mechanical means are possible and feasible.[5] About a minute of acceptable lighting can be obtained from 2 seconds of hand crank at an acceptable activity level. (Far less than needed for cheap hand operated lights).
However, cost and likelihood of user acceptance are liable to be limiting factors.

One possible solution is a weight lifted on a 'rope' by a metre or two and used to operate an alternator as it falls. 5kg lifted 1 metre will give maybe 5 minutes of acceptable light.

Overall, such systems are workable in practice, but "have problems" in this context.

If the seeker wished a costing of a practical user powered system could be provided.

Very small wind turbines, in *some* locations, would easily provide adequate energy for small groups of latrines. Aspects such as durability, cost, wind availability and more make them unacceptable as a general solution. (The writer is actively involved with people developing and producing wind turbines and is investigating the provision of small low cost wind turbines for selected developing country use in appropriate areas. Initial target uses are lighting and cellphone charging.)

M**ethane gas -** produced by the latrines an abundant source of energy, it's utilisation at such small scales is not currently practical. (Internet sources describe many means of producing energy from Methane but none of realistic direct applicability).
(A22 Choice of renewable energy system.)

[5] The writer has designed power generation equipment and controllers used in exercise equipment. Estimates of achievable power levels are based on professional experience. Small hand cranked torches are invariably poorly implemented and far less efficient than is possible.

3.7 **Spreadsheet "PV Panel to Battery & LED calculator**

Uploaded as **PVBATLEDFF.XLS**

Allows substantial "what if" experimentation to see how Panel wattage, Battery capacity, LED operating power along with various related factors and choices affect light output, ability to accommodate sunless days and more.

The spreadsheet is not overly sophisticated by allows a vastly better feel for how choices affect results.

The user selects PV panel, battery & LED parameters and is provided with various brightness, operating hours, battery sunless days capacity and more.

While only one calculating column is seen here, the spreadsheet provides an unlimited number of parallel calculating columns (20+ initially) allowing multiple side-by-side comparisons as parameters are varied.

To Use:			
	Choose		
1	Panel Wattage		
2	Panel degradation factor - sun, age, wear, dirt		
3	PV to battery efficiency 0-1		
4			
5	Battery to LED efficiency 0-1		
6	LED efficiency in lumen per watt		
7	LED equivalent full brightness operating hours per day		
8	Equivalent hours full sun per day average		See http://www.gaisma.com
9	LED mW operating power		
10	Days of desired no-sun operation from battery		
11	Nominal battery voltage		LiFePO4 = 3.2, LiIon = 3.6, Lead Acid = 4 6 12
12	LED operating voltage at selected power level		3V default.
13	Battery mAh rating		
14			
15			
16	**READ**		
17			
18	Battery Wh capacity		
19	% that battery will charge by per day		
20			
21	PV panel watts after degradation		
22	Wh/day charge into battery		
23	Wh/day available for LED		
24			
25	LED average mW	if all PV energy used daily	
26	LED avg lumen	if all PV energy used daily	
27	LED avg mA	if all PV energy used daily	
28			
29			
30	LED average mW	if LED operated at user selected level of 200 mW	
31	LED avg lumen	if LED operated at user selected level of 200 mW	
32	LED avg mA	if LED operated at user selected level of 200 mW	
33	Days of LED operation at user set power evel to use daily PV energy		

		Inputs		
	Wmp	6	W	Panel rated Watts at full power
	Kaging	0.75		Panel degradation with time.
	Kpvb	0.70		Efficiency of charge transfer to battery
	Kbled	0.70		Efficiency of power transfer to LED(s)
	Klpw	200	l/w	LED efficiency in lumen per watt.
	Hledpd	8	hours	LED hours per day
	SSH	2	Hours equiv	Equivalent full sunshine hours per day.
	Pled	200	mW	LED operating power
	Dbu	3	Days	Days of battery only backup operation
	Vbatnom	3.2	V	Nominal battery voltage
	V_LED	3	V	LED operating voltage
	Battery capacity	1800	mah	Battery mAh
	Battery Wh capacity	5760	mWh	
	Battery % chg per day	109.375	%	
	Panel Power	4.50	W	Panel power after degradation
	Wh/day into battery	6.30	Wh/day	Battery charging energy
	Wh/day avialble for LED	4.41	Wh/day	Available LED energy
LED uses all energy	LED avg W	551.25	mW	LED mW using all panel power daily
	LED lumen	110.25	l	LED lumen using all panel power daily
	LED mA	183.75	mA	LED mA using all panel power daily
LED operates at set rate	LED avg W	200	mW	LED mW using set mW
	LED lumen	40		LED lumen using set mW
	LED mA	66.67		LED mA using set mW
	Days operation actual LED setting	2.76		Days operation actual LED setting

Multiple parallel calculations for comparison.

Panel rated Watts at full power	W	**12**	**9**	**6**	**3**
Panel degradation with time.		**0.75**	**0.75**	**0.75**	**0.75**
Efficiency of charge transfer to battery		**0.70**	**0.70**	**0.70**	**0.70**
Efficiency of power transfer to LED(s)		**0.70**	**0.70**	**0.70**	**0.70**
LED efficiency in lumen per watt.	l/w	**200**	**200**	**200**	**200**
LED hours per day	hours	**8**	**8**	**8**	**8**
Equivalent full sunshine hours per day.	hours equiv	**2**	**2**	**2**	**2**
LED operating power	mW	**200**	**200**	**200**	**200**
Days of battery only backup operation	Days	**3**	**3**	**3**	**3**
Nominal battery voltage	V	**3.2**	**3.2**	**3.2**	**3.2**
LED operating voltage	V	**3**	**3**	**3**	**3**
Battery capacity	mAh	**1800**	**1800**	**1800**	**1800**
Battery Wh capacity	mWh	**5760**	**5760**	**5760**	**5760**
Battery % chg per day	%	**218.75**	**164.0625**	**109.375**	**54.6875**
Panel power after degradation	W	9.00	6.75	4.50	2.25
Battery charging energy	Wh/day	12.60	9.45	6.30	3.15
Available LED energy	Wh/day	8.82	6.62	4.41	2.21
LED mW using all panel power daily	mW	1102.50	826.88	551.25	275.63
LED lumen using all panel power daily	l	220.50	165.38	110.25	55.13
LED mA using all panel power daily	mA	367.50	275.63	183.75	91.88
LED mW using set mW	mW	**200**	**200**	**200**	**200**
LED lumen using set mW		40	40	40	40
LED mA using set mW		66.67	66.67	66.67	66.67
Days operation actual LED setting		5.51	4.13	2.76	1.38

LINKS

100 LCSC sourced microcontrollers.

eg https://www.lcsc.com/products/Microcontroller-Units-MCUs-MPUs-SOCs_11329.html?brand=1246)

102 Excellent LiFePO4 information

https://www.bravabatteries.com/lifepo4-battery-discharge-and-charge-curve/

For long and happy LFP battery life, in order of importance, you should be mindful of the following:

Keep the battery temperature under 45 Centigrade (under 30C if possible) – **This is by far the most important!!**

Keep charge and discharge currents under 0.5C (0.2C preferred)

Keep battery temperature above 0 Centigrade when discharging if possible – This, and everything below, is nowhere near as important as the first two

Do not cycle below 10% – 15% SOC unless you really need to

Do not float the battery at 100% SOC if possible

Do not charge to 100% SOC if you do not need it

See document

A10 Solar panel design and implementation and costing.

PV panel sizing depends on desired power output

Factors include.

Wmp	Panel rated Watts at full power
Kaging	Panel degradation with time.
Kpvb	Efficiency of charge transfer to battery
Kbled	Efficiency of power transfer to LED(s)
Klpw	LED efficiency in lumen per watt.
Hledpd	LED hours per day
SSH	Equivalent full sunshine hours per day.
Pled	LED operating power
Dbu	Days of battery only backup operation

& more

As a start we can conservatively set

Kaging	= 0.5	very conservative.
Kpvb	= 0.7	
Kbled	= 0.7	
Klpw	= 200	

Challenge docuiment says Hledpd = 12 hours, but this will not be full power operation. Probably significantly less in most cases. Set
Hledpd = 10 to start (conservative).

SSH = 2 is very conservative for Africa and most other sites in worst Winter month.

Set Pled = 0.1 watt as a starting point.

For one days operation of LED only

LED power = (Wmp x SSH) x Kaging x Kpvb x Kbled /Hledpd
= Wmp x 2 x .5 x .7 x .7 /10 ~= Wmp x 0.025

Or Wmp = 40 x LED average power.
For Wmp = 100 mW, Wmp = 4 Watt

At 100 mW Pled klpw x 0.1 = 20 lumen.
For a 6 Watt panel Pled = 30 lumen.
That is a “very adequiate” level but

Appendix A11 **Battery systems -** Battery design and implementation and costing

Lighting, security and maintenance & alerting (and possibly) door locking all require storage of electrical energy.

A rechargeable battery based system is the only practical solution.
Alternative systems such as flywheels exist, but a mix of practical aspects, cost, maintenance, safety and more make them unacceptable.

Batteries of practical interest come in five types

NiCd –	Nickel Cadmium
NiMH –	Nickel metal hydride
LA	Lead Acid
LiIon	Lithium Ion
LiFePO4	Lithium Ferro Phosphate (also = LFP)

NiCd is an old but superb technology, but not practical for consideration. ROHS regulations (Restriction of Hazardous Substances) make NiCd illegal in essentially all applications. Some vendors may still offer them.

NiMH are capable of adequate notional performance but have issues including temperature range (especially in hot climates), charging well without damaging the battery in this type of application, general long term reliability.[6]

Lead acid Limited cycle life unless "deep discharge" type and then still limited in discharge capacity. Good high temperature performance. Storage under 0C acceptable if fully charged but a discharged battery will be destroyed by freezing.
Whole of life cost per cycle worse than Lithiums. Heavy and bulky.
Availability in Africa MAY justify their use occasionally. PV energy and charging and energy use need to be adapted to suit. An interface module could be made, but it would be preferable not to use them.

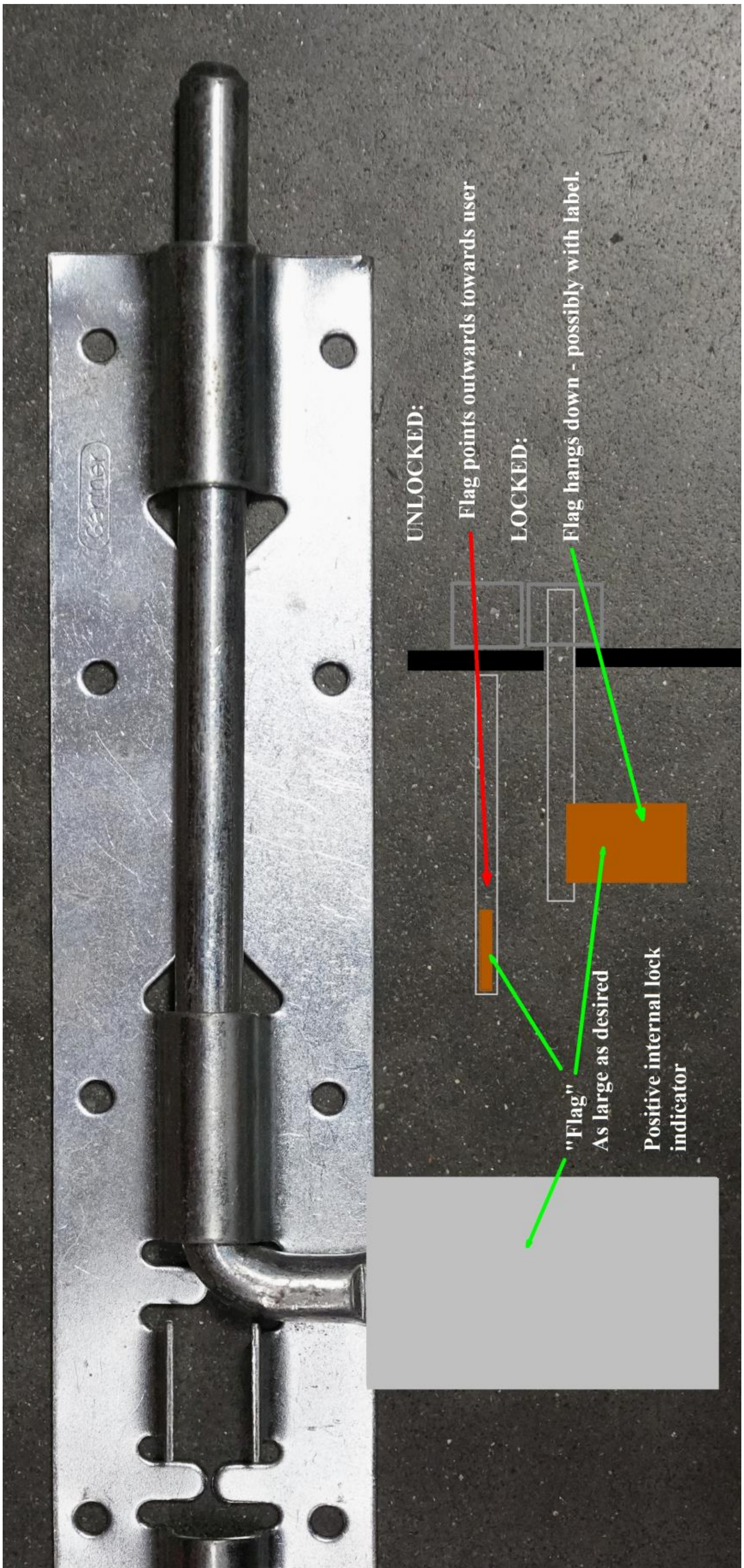
LiIon Many good features. Acceptable lifetimes only achievable with very careful and understanding design of battery management systems.
Usable in this project with due care and proper design.

LiFePO4 Many good features. Substantially longer lifetime than LiIon. Lower energy density than LiIon, but entirely acceptable in this context. Low average discharge voltage (about 3.2V across most of discharge) requires appropriate care in design. Two series cells a possibility – requires somewhat more electronics.
2 series cells makes remote powering of eg LEDs slightly easier.

Energy storage – Battery System: – Details – see Appendix A11Battery
The preferred choice for in-latrine use is either LiIon (Lithium Ion) or LFP (Lithium Ferro Phosphate). Lead Acid and NiMH batteries are less suitable –
see Appendix. A11 - Battery systems

[6] I have been involved with equipment using over 1 million NiMH cells, for use in environments such as this one. I would not happily ever use them again in this sort of application. My client would not allow the use of any Lithium based cells, for reasons not relevant to this project, and the old but workable NiCd chemistry was no longer legal.

A13 DOOR LOCKING


UNLOCKED:
Flag points outwards towards user
LOCKED:
Flag hangs down - possibly with label.
"Flag"
As large as desired
Positive internal lock
indicator

Another example of many possible.

Actual orientation in use:

Big.
Simple.
Solid

Could be made from “rebar”
(concrete construction reinforcing bar).

Mounting plates can be as large as required to accommodate through-door and through-frame bolts.

External plates provide strength on weak structures.

Shear off bolts can be used for best protection against removal.

Provide large clearances to tolerate misalignment and to allow ease of use.

Of importance is the ability to provide not only good protection against intrusion but also high certainty that users will not be trapped inside the latrine.

1st photo:

“Flag” on handle signals locking status to user.
Flag horizontal = open.
Flag folds down only when locked.

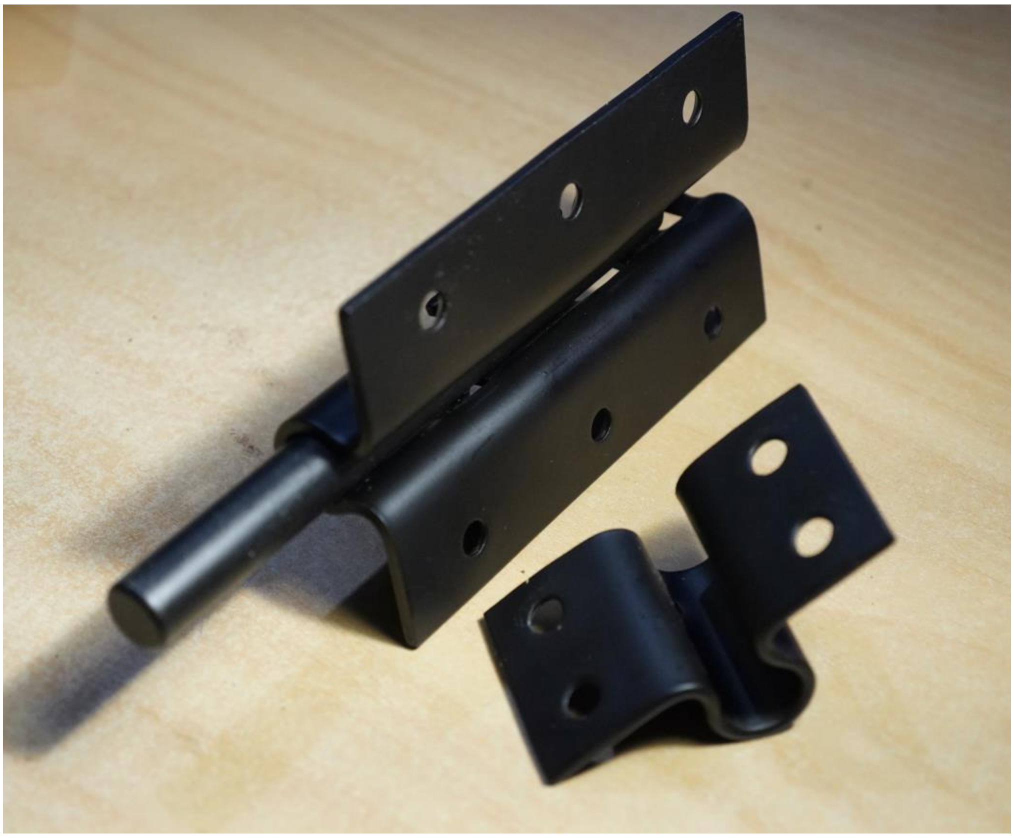
Can be as solid as desired. Stamped construction. Strong but cheap.

Another example.
Stamped construction
Can be as robust as required.

Locking status is NOT shown here.
Various means are possible.
eg a "flag" on the bolt that slides sideways with the bolt and then rotates when the bolt is fully closed so that the flat protrudes through the door/jamb slot.

Or, with the "hollow" rear construction seen here a coloured section could be visible through a slot.
None of these is ideal.

An LED indication driven by the controller can be provided, but locking sensor is then required.



A19 Prior developing country lighting solutions.

Total distribution from these two lights was 350,000+

Circuit boards from two portable solar charged light with “Room” and “Task” lights that I designed.

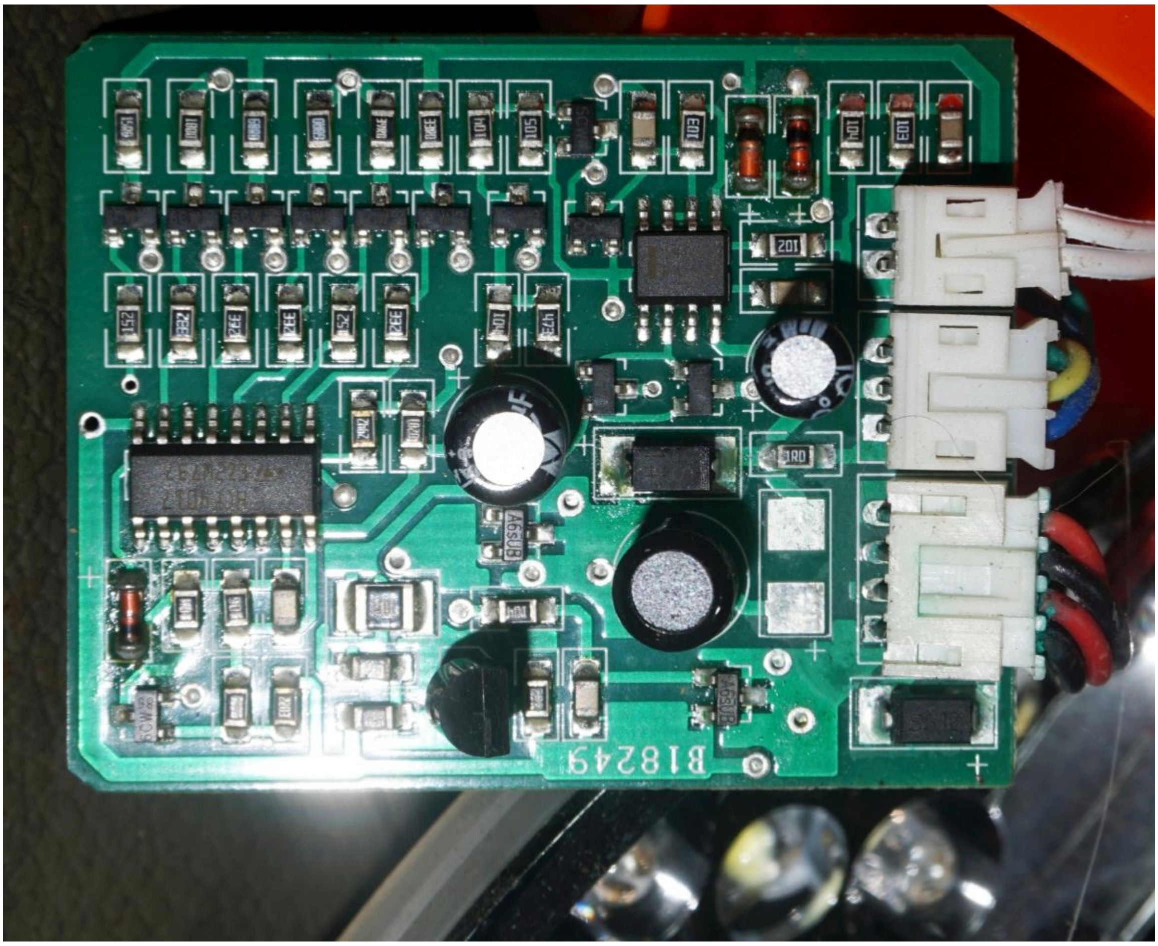
Purposefully designed without a microcontroller.
Two low cost ICs
Boost converter to drive serial LED strings
3 x tasklight brightness levels
3 x roomlight brightness levels

Turn off in daylight
Streetlight mode – automatically turn on at prior setting at dusk.

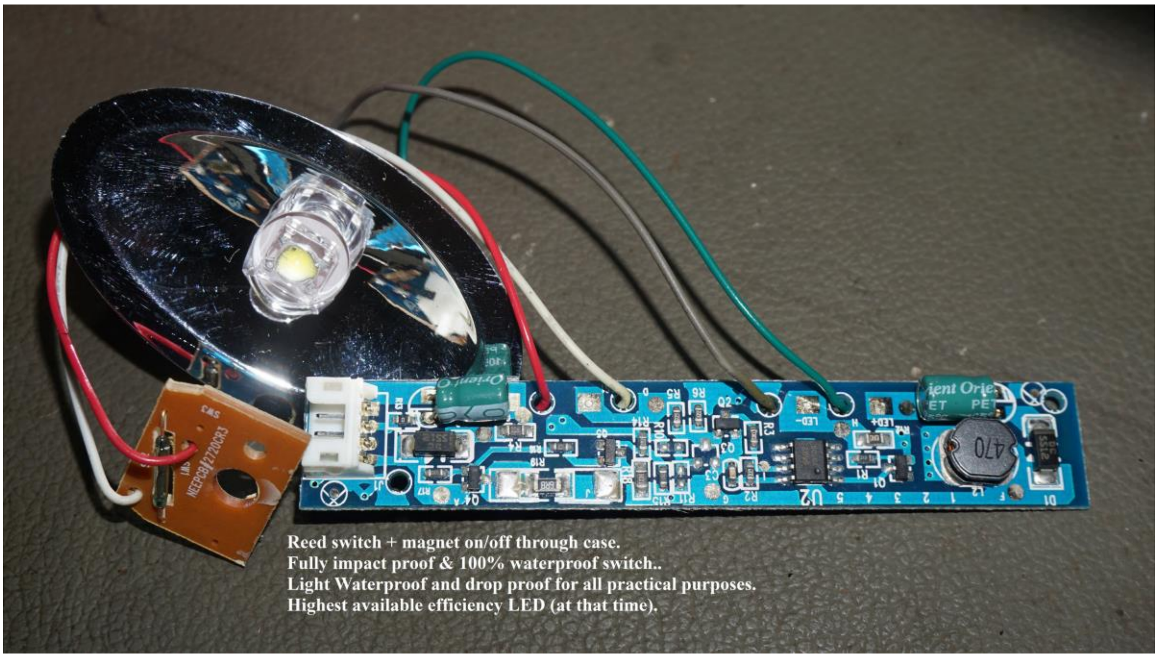
Roomlight LEDs 160 lumens/Watt – then best in world,
(Now 210+ l/W available.

NimH charge control.
Reverse battery protection

Waterproof to 2m x ? hours
Drop-proof on concrete from 2 metres.



Simple on/off solar charged portable light.
Ultra high efficiency LED.
Boost converter from 1 x NimH
NimH Charge control.



A20 PV panels

Panels proposed are PET or ETFE.
Glass laminated panels are superior IF cost is acceptable – possible a factor of two.
PET Panels have lifetimes in the 5-10 year range, which is liable to be able to be improved on by working with the manufacturer.

My experience is that PET plastic will survive 1 years outdoor exposure in UV-intensive environments with acceptable levels of degradation. Panel failures in under 10 years are liable to be due to delamination. Improved modest cost increase manufacturing methods are liable to greatly reduce delamination.

ETFE is well regarded in the industry. Surface self cleaning is superior.
Claims are made re it's better high temperature performance, but this may be directed towards larger panel sizes.

If glass panels are not used then trials of comparable ETFE and PET panels are recommended.

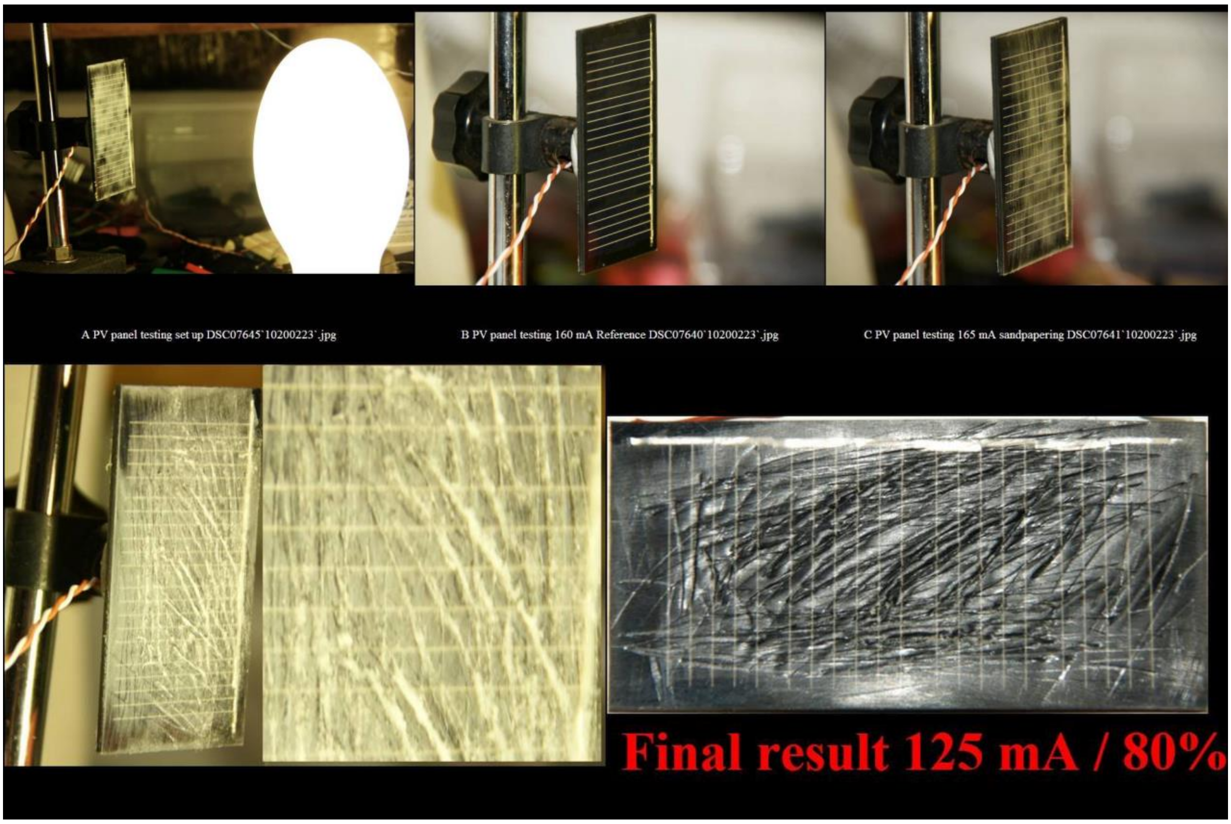
PET PV panel abrasion tests.

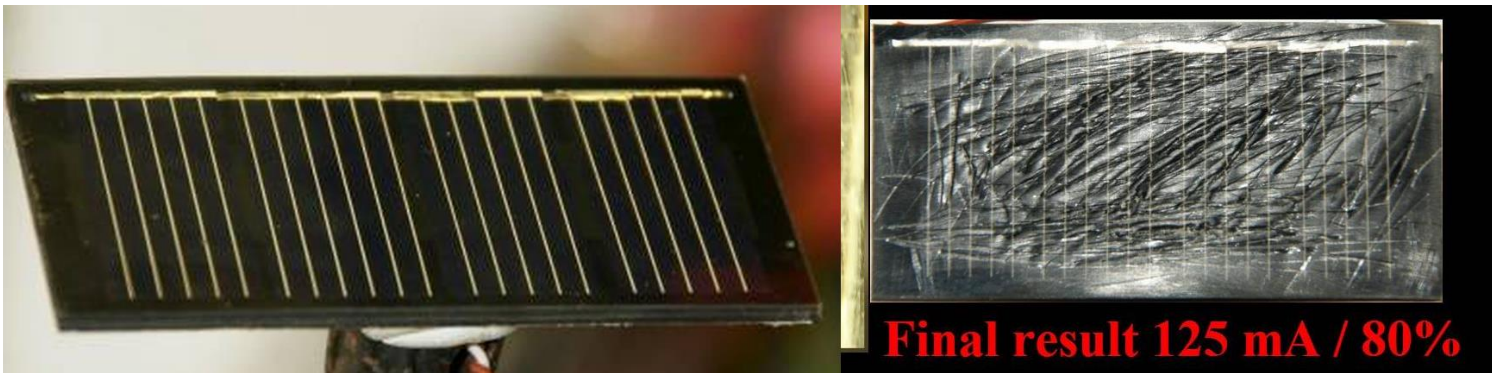
PET surfaced laminted PV panels are resistant to UV and abrasion and when competently manufactured have a useful service life in the 5 to 10 years range. Extra attention to sealing with eg a larger than usual border would extend that lifetime at minimal extra cost.

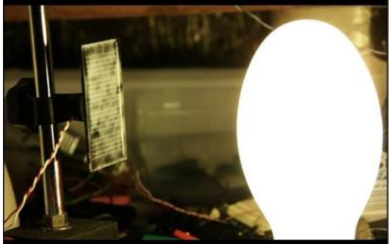
Some users queried the effect of abrasion on PV panel output on my "Mini" light.

I used a metal halide phosphor lamp to illuminate a panel to equivalent 1000 W/m^2 insolation and carried out a progressive series of surface scarring, sanding, gouging … tests. After surface marring far in excess of anything that would be experienced in real use the output was still 80% of original.

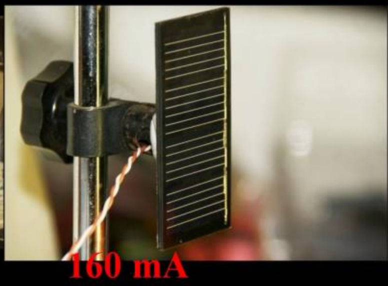
Full sequence of photos and panel output here https://bit.ly/PETpanelabrasiontests


A PV panel testing set up DSC07645`10200223`.jpg
B PV panel testing 160 mA Reference DSC07640`10200223`.jpg
C PV panel testing 165 mA sandpapering DSC07641`10200223`.jpg
Final result 125 mA / 80%

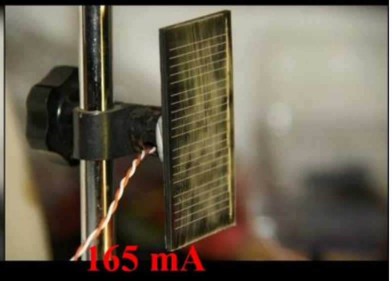

Final result 125 mA / 80%



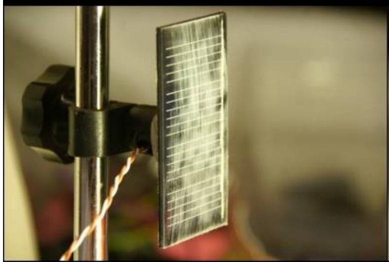
A PV panel testing set up DSC07645`10200223`.jpg



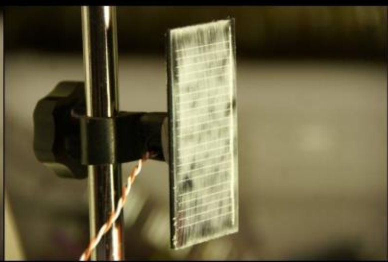
B PV panel testing 160 mA Reference DSC07640`10200223`.jpg



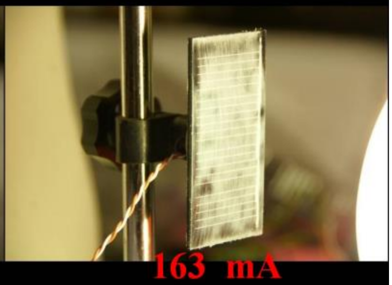
C PV panel testing 165 mA sandpapering DSC07641`10200223`.jpg



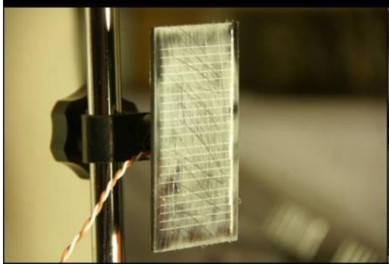
D PV panel testing 165 mA more sandpapering DSC07642`10200223`.jpg



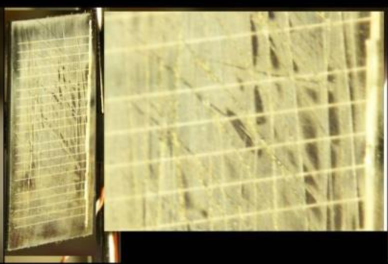
E PV panel testing 150 mA sandpapering and sctratching DSC07643`10200223`.jpg



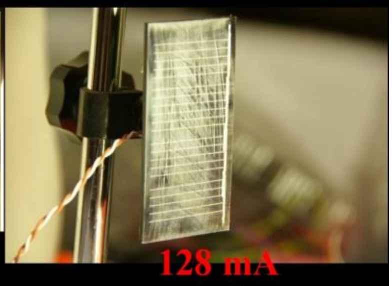
F PV panel testing 143 mA sandpapering DSC07646`10200223`.jpg



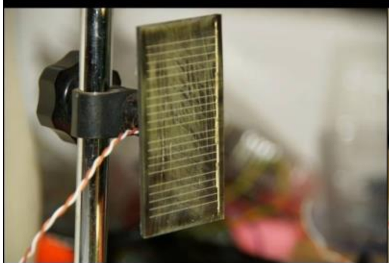
G PV panel testing 138 165 mA scratching DSC07647`10200223`.jpg



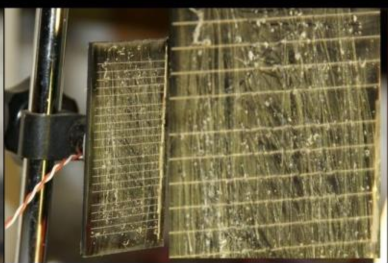
H PV panel testing 125 mA filing DSC07648.jpg



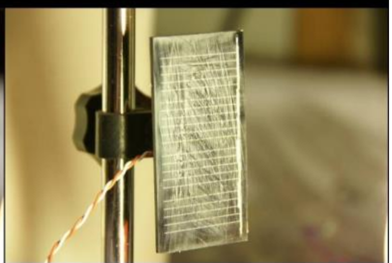
J PV Panel testing 128 mA Hacksaw DFSC07650.jpg



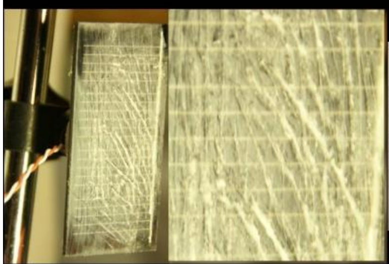
K PV Panel testing 139 mA Clean up surface DSC07651`10200223`.jpg

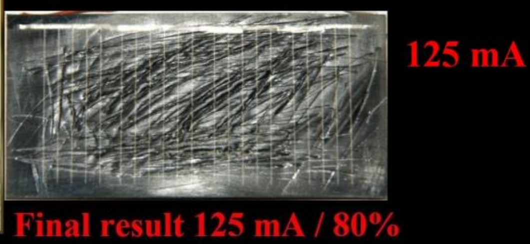


L PV Panel testing 120 mA major gouging DSC07652`10200223`.jpg



M PV panel testing 122 mA Clean up DSC07654`10200223.jpg





A21 Power distribution.

PV panels operate at high enough voltage above battery voltage that modest wiring voltage drop is tolerable. This needs to be minimised for best efficiency but a few tenths of a volt are not significant.

If a LiFePO4 battery is used (with consequent very good lifetimes) the battery voltage (of about 3.2V across most of the battery discharge period) is about 0.2 to 0.3 V higher than the LED operating voltage. Direct LED drive is easily achieved if wiring losses are small. With the main latrine LED mounted in the controller adjacent to the battery this is easily accomplished.

A front-of-latrine external LED for occupancy and use status display can also be driven acceptably due to lower power levels.

LEDs at any distance from the controller that are used for substantial illumination may ned to be driven by a "boost converter" This is easily achieved but adds slightly yo the system cost (a few tens of cents).

As an option, if excess solar energy is available this could be utilised for cellphone charging. A major aim is to increase the perceived value of the installation to the community. The charging point **must not** be adjacent to the latrine.
Cellphone charging energy can be supplied directly from the PV panel to the remote charger – with either a battery at the charging point, of just direct PV panel to charger with no battery. Voltage drop of a volt or slightly more is acceptable.

Depending on acceptable latrine-charging point separation the wire size may be uneconomic and so may require a boost converter at the PV panel to reduce wire loses (lower current, lower loses) and a buck converter at the charger This adds to cost (probably a few dollars) but may be acceptable if the social gains prove substantial.

Centralised large PV panel provision:

Power losses over more than a few metres preclude achieving economise of scale by using large shared panels to directly power distant latrines.

A possible solution is to use inverters to produce higher voltages for distribution.
This involves "power lines" which may be the target of interference. Buried cables may be practical.

At even 50 volt DC wire losses drop to under 2% of those at 6V for the same size wire – or much thinner and less costly wire can be used. 50 VDC is generally considered as safe "extra low voltage" by regulatory authorities. Large PV panels operating at say 40VDC can provide energy for distribution with no electronics required. Conversion to required voltages at the latrines is technically easy. Such a system has the ability to also supply cellphone chargers and eg "streetlights" at any point on its route, with latrine lighting having priority.

The "power lines" are an obvious target, but their protection would be highly valued by the community. Such lines can be very simple and low cost compared to eg mains distribution systems.

A22 Choice of renewable energy system.

A number of potential candidates for an energy source exist.
These include but are not limited to

Solar

Wind power

Methane from latrine

Mechanical energy from user actions or children playing

Biogas or agricultural waste to electrical separate from latrine.

Hydrocarbon fuels - unacceptable

Of these only solar energy is available at all locations and able to be utilised in a consistent and cost effective manner. Actual utilisation is somewhat more complex than may at first appear.

Panels need to be sun-oriented (best winter sun position if fixed),

Degrade with time due to dirt, UV attack and internal factors.

Are at risk of theft and vandalism.

Output varies substantially with site and season and somewhat with temperature.

Available output MUST be calculated using worst case factors – output degradation across lifetime, worst average insolation month annually, number of low or no sun days that can be accommodated, losses in battery charging and in battery to LED driving.

A say 10 watt panel at a selected location in winter may provide 10 Wh of available LED energy. In summer the output may be 3 or more times higher.

The spreadsheet **Spreadsheet “PV Panel to Battery & LED calculator**
Uploaded as **PVBATLEDFF.XLS**
Allows a wide range of scenarios to be investigated.

Briefly – other ‘alternatives to solar’

- Wind power

Widely but not universally available.
Conficts between low cost and long life due to cube law energy in wind.
Prone to vandalism.
Costly in many cases.
(I am working on an ultra low power, rugged, long life low cost wind turbine system, but even if it meets all ecpectations it wold not be universally suitable for this application).

- Methane from latrine

Available energy in latrine methane is adequate for the projects needs IF it were able to be harvested and used reliably and cost effectively. No current technology allows this in a manner appropriate for latrine use in the envisaged application area.

- Mechanical energy from user actions or children playing

This is a potentially viable energy source, but user acceptance and cost are liable to be insurmountable barriers. An efficient hand cranked system is viable – I have tested such a system for use in a related project and could readily produce adequate LED energy with modest mechanical hand input of a few seconds per minite of LD illumination. More details on request if of interest.

Energy from children’s play equipment would provide enough energy but is not a good fit to this application.

- Biogas or agricultural waste to electrical separate from latrine.

Use of methane from bio-waste is a viable energy source, but does not match the current application profile.

- Hydrocarbon fuels

Unnacceptable

End A22

A23 Component - Major components “in stock”

I currently stock all the complex function modules (of functional equivalents) except for the V53L0X “Time of flight sensor” This is available locally.

All other items here are stocked or I stock functionally equivalent items.
eg LEDS – many – none as efficient as the CREE JB2835BWT .
These will be acquired.

Solar panel	PET or ETFE PV panel. Initially 6 Watt Wmp, 5V
Battery	LiFePO4 battery. 1 or 2 x 18650. About 1800 mAh.
Light	LED Cree JB2835BWT 210 lumens/Watt 5000 K.
Inter latrine data	NRF24L01 + LNA + PA mesh wireless
Cellphone gateway	SIM800L GSM GPRS/SMS with audio
Person sensor	Doppler RADAR RCW-0516
Person sensor	PIR HC-SR501
Time of flight sensor	VL53L0X
Controller core	Arduino – various.

End A23

Appendix A24 Pricing

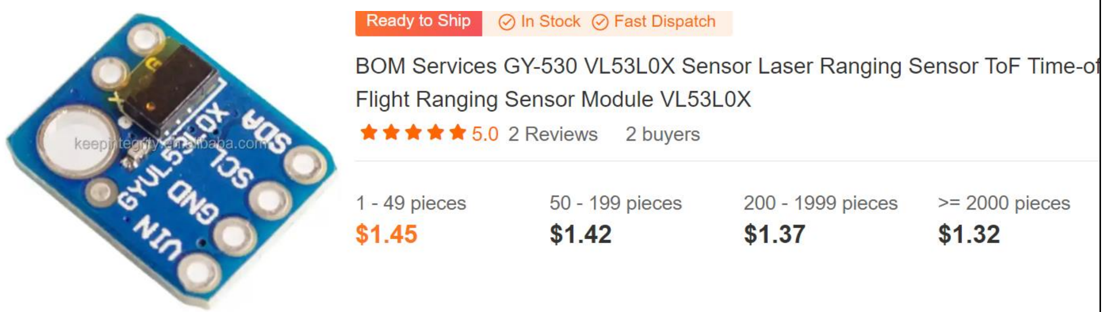
Prices are based on both review of many Alibaba sites and also requests for prices to multiple sellers. Even these directly received quotes can not be relied on – some are so low as to be obviously wrong. Prices shown are based on general trends and should be “right enough” for budgeting.

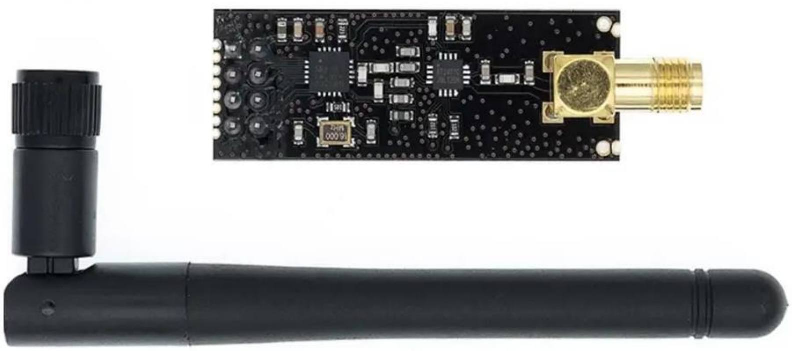
VL53L0X TOF sensor probably under $1.25
Used for excrement level sensing.

Example only quotation;

- 49 pieces $1.45 50 - 199 pieces $1.42 200 - 1999 pieces $1.37 >= 2000 pieces $1.32

https://www.alibaba.com/product-detail/BOM-Services-GY-530-VL53L0X-Sensor_1600403619835.html?spm=a2700.7724857.0.0.4ccd3ba01II1PO





2a 1100 meter

NRF24L01+PA+LNA Wireless Module with antenna Wireless Transceiver Communication Module DC 3.3V NRF24L01P NRF24L01

Used for inter-latrine mesh network.

2b SIMCOM 2G Module Quad-band GSM GPRS Module – about $5 (or less)

Used to provide cellphone network gateway.

3. PIR Under $US0.50

Provides user presence sensing

4. LED - $US0.10 - $US0.15 – probably less in volume

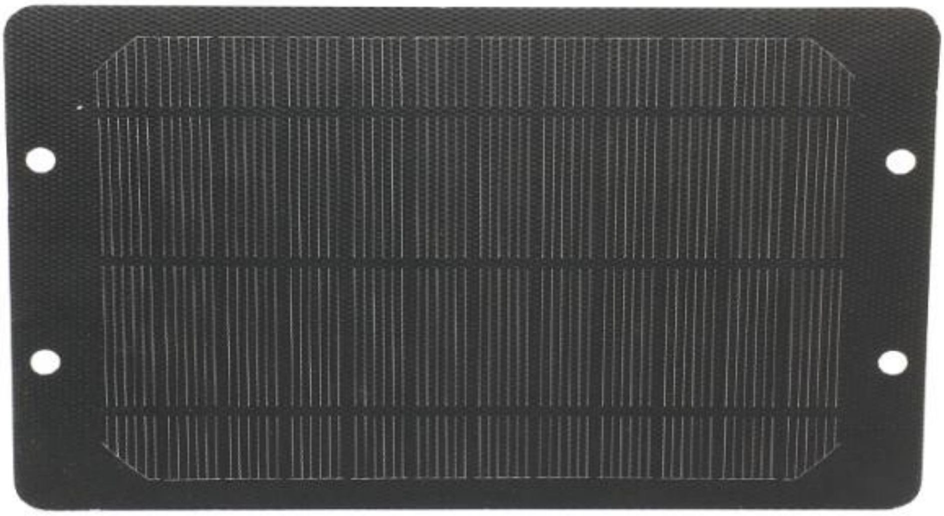
5. “Glue’ components for main PCB – under $US1.00

6. Battery LiFePO4 – 18650 x 1800 mAh - $1.00 range
26500 x 6000 mAh - $3 range

About 2000 mAh/ $ very roughly.

7. PV panel 6W, 5V. ETFE or PET – About $3.50

The supplier that I ultimately dealt with in China for PV panels, after several bad experiences elsewhere, makes over 1 million panels of this general type per year. I found then the best company to deal with of any that I encountered in China.



Specifications

Nominal Peak Power (Pm)	6W
Maximum Power Voltage(Vmp)	6V
Maximum Power Current(Imp)	1000mA
Short Circuit Current (Isc)	1060mA
Open Circuit Voltage (Voc)	7.2V
Optimized Cell Efficiency (η)	20%
Power Tolerance	±5%
Dimensions	270x175x2.8MM
Net Weight	208 Grams
Standard Test Condition	AM1.5 1000W/㎡ 25℃

Processing

ETFE laminated

Solar cell

High efficiency Mono Crystalline 156x156mm solar cell

Limits

Working temperature : -40℃ to +80℃

8. Inner metal box housing for:

Battery, Controller, LED.

Outer PV panel mount and clamp bolts to inner box.

9. Assembly

As a rough guide, if components are priced at around 1000 volume, but manufactured in significantly higher volume, then assembly cost is essentially “free”.
Obviously does not apply to complex and specialist boards – which are not involved here. PCB requirements are relatively modest.

Initial designs could usefully utilise available functional modules (eg PIR, Doppler RADAR, NRF2401 transceiver, GSM cellphone gateway) as these modules (especially the RF ones) include some proven construction methods to achieve performance

Once significant volume was achieved the subsystems could be migrated onto a single PCB, but the gains would be modest. Mounting the radio communication modules on the PV panel structure is liable to improve range.

End A24

PIR HC-SR501 application note / product description – 3 pages

Specification: ◦
Voltage: 5V – 20V ◦
Power Consumption: ◦
TTL output: 3.3V, 0V ◦ ◦
Lock time: 0.2 sec ◦
Trigger methods: L – disable repeat trigger, H enable repeat trigger ◦
Sensing range: less than 120 degree, within 7 meters ◦
Temperature: – 15 ~ +70 ◦
Dimension: 32*24 mm, distance between screw 28mm, M2,
Lens dimension in diameter: 23mm

https://www.mpja.com/download/31227sc.pdf?ref=iot-experiments.com

End A22

A24 **SOLAR INSOLATION DATA FROM AROUND THE GLOBE**

Two example locations only

Web search gaisma place_name for many more

Monthly average:

Temperature ranges
Sunshine hours
Night-time hours

Beirut, Lebanon

hccttps://www.gaisma.com/en/location/bayrut.html

7C to 26C monthly averages
2 to 7.5 Sunshine hours
12h 40m longest night

c

Bayrūt, Lebanon - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	2.30	3.03	4.16	5.56	6.76	7.50	7.34	6.74	5.62	4.07	2.75	2.09
Clearness, 0 - 1	0.45	0.46	0.50	0.56	0.61	0.66	0.65	0.65	0.63	0.57	0.49	0.44
Temperature, °C	7.14	7.98	10.92	15.91	19.94	22.99	25.56	25.75	23.53	19.59	13.72	8.80
Wind speed, m/s	5.23	5.64	5.38	4.96	4.80	5.00	5.22	5.09	4.67	4.40	4.65	5.04
Precipitation, mm	161	120	98	44	12	2	0	0	3	42	95	149
Wet days, d	15.1	14.2	10.6	6.4	2.8	0.8	0.4	0.5	0.8	5.5	8.4	13.4

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	*05:46*	*19:42*	13:56		*05:19*	*20:10*	14:51	
+1 day	*05:47*	*19:41*	13:54	00:02 shorter	*05:20*	*20:09*	14:49	00:02 shorter
+1 week	*05:51*	*19:36*	13:45	00:11 shorter	*05:24*	*20:03*	14:39	00:12 shorter
+2 weeks	*05:57*	*19:30*	13:33	00:23 shorter	*05:30*	*19:56*	14:26	00:25 shorter
+1 month	*06:08*	*19:11*	13:03	00:53 shorter	*05:42*	*19:37*	13:55	00:56 shorter
+2 months	*06:29*	*18:30*	12:01	01:55 shorter	*06:04*	*18:55*	12:51	02:00 shorter
+3 months	*06:52*	*17:52*	11:00	02:56 shorter	*06:26*	*18:17*	11:51	03:00 shorter
+6 months	06:39	17:02	10:23	03:33 shorter	06:12	17:29	11:17	03:34 shorter

Kabul, Afghanistan

Temperatures -6C to 18 degrees C month averages.
Sunshine hours per day 2.2 to 7.4
12h 45m longest night

LiIon batteries would need heating before charging on some days.

https://www.gaisma.com/en/location/kabul.html

Kabul, Afghanistan - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	2.29	2.83	3.86	5.06	6.38	7.40	7.30	6.67	5.66	4.23	2.95	2.17
Clearness, 0 - 1	0.46	0.44	0.47	0.51	0.58	0.65	0.65	0.65	0.64	0.60	0.55	0.47
Temperature, °C	-6.30	-4.90	-0.16	5.66	11.12	16.23	18.61	17.43	12.73	6.60	1.95	-3.24
Wind speed, m/s	6.22	6.12	6.22	6.37	5.82	5.89	5.69	5.67	6.04	6.95	6.61	6.09
Precipitation, mm	38	60	79	69	24	2	9	5	3	6	12	27
Wet days, d	2.0	3.2	9.8	10.7	7.7	1.4	2.5	1.7	1.4	2.3	3.8	3.0

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	05:00	18:59	13:59		04:32	19:27	14:55	
+1 day	05:01	18:58	13:57	00:02 shorter	04:33	19:26	14:53	00:02 shorter
+1 week	05:05	18:53	13:48	00:11 shorter	04:38	19:20	14:42	00:13 shorter
+2 weeks	05:11	18:46	13:35	00:24 shorter	04:44	19:13	14:29	00:26 shorter
+1 month	05:22	18:27	13:05	00:54 shorter	04:56	18:53	13:57	00:58 shorter
+2 months	05:44	17:45	12:01	01:58 shorter	05:19	18:10	12:51	02:04 shorter
+3 months	06:08	17:06	10:58	03:01 shorter	05:42	17:32	11:50	03:05 shorter
+6 months	06:56	17:16	10:20	03:39 shorter	06:29	17:43	11:14	03:41 shorter

A29 Abbreviations & Glossary

PV	Photovoltaic = solar
SSH	Sunshine hours
	Equivalent full sin hours insolation per day
PIR	Passive infrared detector
TOF	Time of Flight (distance sensor)

Alerting system

Radio communications.

BONUS ☺

A30 Pink coloured lights for women !

Identify them as "women's lights"
A man carrying a pink light is seen to be using a woman's light.

That was the purpose of this colour scheme.

CONTENTS