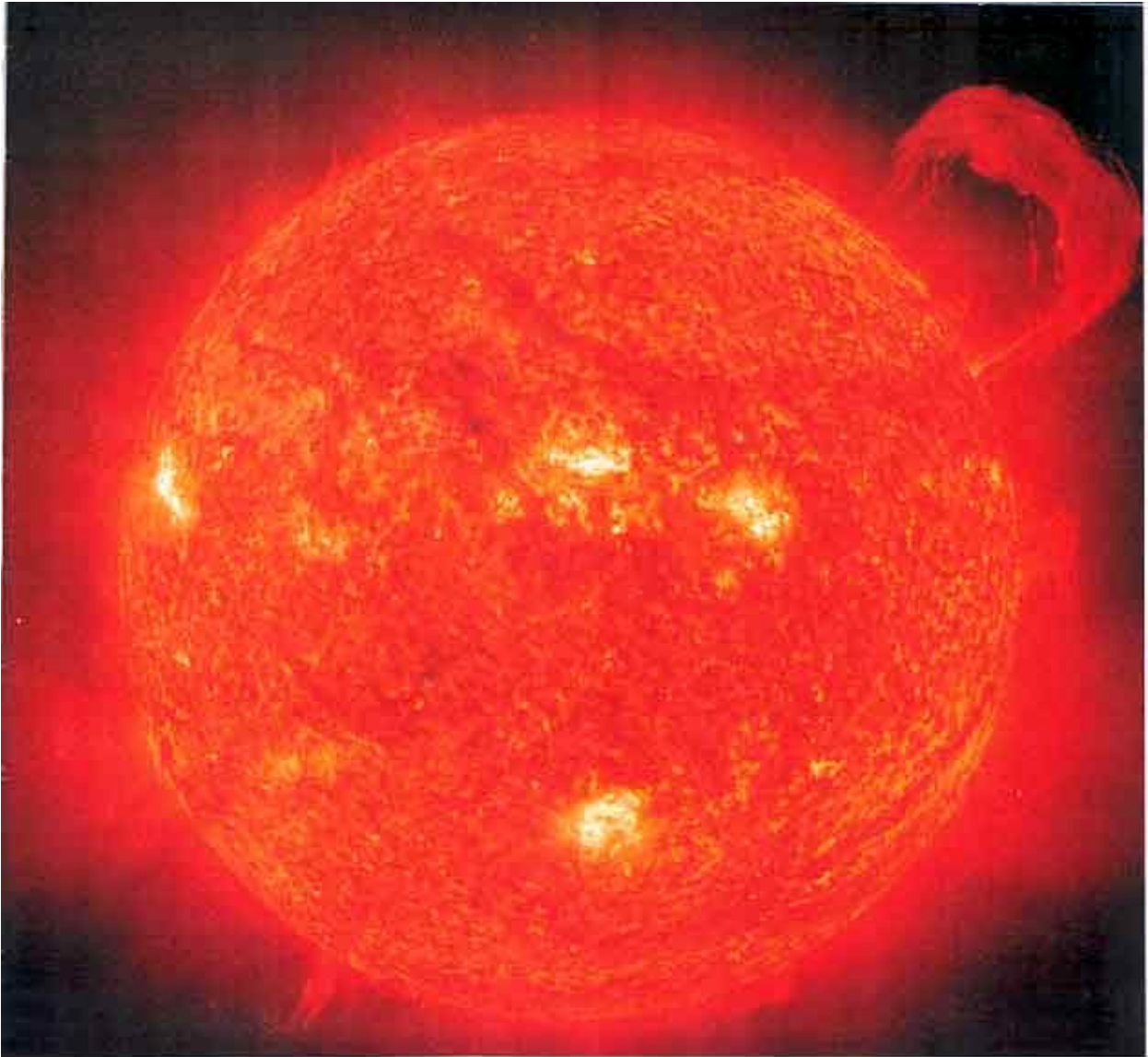


# A Manual of Home Solar Power Management, & WHY

14.5.26

Please feed back, any small error or ambiguity is important, and, new knowledge is always welcome!

*The New Solartariat Must Live Long, And Prosper..!*



NASA

**As of 2008**, improved Solar PV technology has reduced manufacturing energy payback time from >20 years in 1975, to >3 years, as per 'PV Energy Payback', [Homepower Magazine](#) #127 and HP Home Page, citing this significant EPBT/Estimated Pay Back Time reappraisal.

Home <http://nofrillstech.net/>

*Note that the Solar Manual PDF version is set for printing, as is, and, this Word version is available for editing/cutting and pasting purposes, as a general aid to personal note-making.*

# A Manual of Home Solar Power Management, & Why

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Thanks are due, for their interest, support, and consent to initiate mutual links, to [Homepower Magazine](#), and to [Bill Darden](#).

Flooded lead acid (FLA) batteries are the principle power storage units utilised for the purposes of this Manual. Please note, other battery types may have differing operating ranges, voltages, chemistry, and/or charge regimes, see also [Excerpts](#)

Australasian main grid power ratings are 240 volts AC at 50 Hz, this will vary in other parts of the world. (See also [Eaton Powerware](#))

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*2020 Li-Ion batteries are now in production, with differing charging regimes; PV management generally remains the same.*  
<https://solarcompare.com/solar-panels/battery/lithium/>

## Foreword:

This Home Solar Power Management project all began in 2001, when a second-hand solar system, with all its faults and problems, was inherited, and there were no accompanying records or instructions, no trustworthy professional advice or support, no information in the then local public library or local high school, only the Net, and basic electricity and science texts and dictionaries to turn to.

There was plenty to choose from Net-wise, however, (but sadly, nothing easily found at the time from the then home country of Australia), so a healthy exercise in Web research ensued. After garnering and winnowing, the information had to be condensed, systematised, collated, tested, corrected, and properly written up, and so the Manual gradually emerged. Do it for one, might as well do it for anyone in similar need, and, what follows actually grew from early felt pen jottings on a handy wall.

The data utilised is standard, in the sense that electricity, batteries, charging, and PV technology, are standard, so a thank-you for all that was freely available, and this small Manual, by no means The Last Word on these subjects, is likewise free to all who may benefit from the information herein. This sort of information exchange really is the best facet of the Internet, linking shared interest and information for the common good, and more simply and easily than ever before.

The Manual is not, therefore, supposed to be an academic treatise, apart from common standard solar and electrical data being utilised, and, any specific or special references have been listed as required, or as deserving. So much scattered information was discovered, some was very generalized with important detail glossed over, some was out-of-date, some was very well-prepared, and some was garnered from textbooks and reference books, and the rest from home trial and error management. The impression was that the information-gathering process should not have been so complicated, having stemmed merely from a consumer Q&A exercise at the time, and this in an age when alternative energy, and the information needed to understand and manage it, should be much more accessible. Hopefully, the Manual will help to make this accessibility somewhat easier, for domestic solar power at least.

More knowledgeable people are most welcome to contribute corrections or enhancements, the Unanswered Questions do need expert attention, and there will be errors in the text to be attended to. Please help if you do have the expertise, the Manual is for the benefit of all who seek basic domestic solar knowledge. For those seeking a glimpse of the cutting edge, go to any website that carries technical manuals pertaining to monitor-regulators, (monitregs), and there, you will really see the scope of state-of-the-art solar power technology, eg, [Plasmatronics](#).

Certainly, as part of this solar beginner's experience, there was respect gained for relatively old, simple, and very useful technology, viz., the 50 year old solar cell, and the 150 year old 2 vpc flooded lead acid battery, still being the cheapest, most basic, electrochemical storage technology, yet still mostly forgiving of, at least, moderate mismanagement. There was also the realisation gained of how complacent main-grid fossil fuel dependence has made us all. Even with outages, only time intervenes before the switch is flicked on once again. The new habits of imminent urgent energy conservation will be hard learnt by us all, but learned they must be, and the sooner the better. Only 20 years ago, best climate science was predicting a mini ice-age, and in that time world population has increased 40%. There are now far too many of Us!

The simplest way to decentralise and yet still enhance energy generation is to initiate de-centralised alternative energy, from single houses to energy farms, to take the burden from the grid, to eke out what fossil fuels there are still remaining, and to attempt to right some of the wrongs done that are altering the world's climate so dramatically. Sun, wind, water, waves, biofuels, and biomass, will come into their own in the service of all our increasingly energy-dependent societies, and individuals and groups must act; governments seem to have no real sense of urgency or responsibility as yet.

Note also that 'biofuels' require energy to grow, harvest, and process, and do produce greenhouse gases when burned, albeit less damaging than fossil fuels, and there is pressure now to commandeer agricultural land and resources for these biofuel crops. Once again, solar, water, and wind power need greater development support, and the use of biofuels should only be within the perspective of limiting their respective greenhouse gas emissions. Biomass, from which gas fuels, such as methane, are produced, can be collected from organic waste, albeit with CO<sub>2</sub> being an end-product of gas combustion.

Meanwhile, in Australia, for example, salaried leadership with healthy expense accounts and Superannuation continues to ignore the impending fossil energy crisis, and climate change, largely in the short term interests of re-election. In August 2003, a senior Federal Government politician was seen, and heard, smugly saying that Australia would only co-operate with reducing global emissions if the rest of the world did so as well. So, nothing learnt, a cute pollie Catch 22 avoiding electorally unpopular decision-making, and all during the worst Australia-wide drought ever, with constant TV bulletins of climatic extremes and shaky energy grids from the rest of the world. In 2005, the Kyoto Protocol languishes, and the USA also refuses to sign, positing that high-tech solutions are the answer, when that leadership really means to continue 'business as usual..'?

The winter of 2003, in the NSW Southern Highlands, some trees were blooming a week after the shortest day, (and where were the bees..?), but at least, on 2 September, 2003, Global Warming was finally declared Official, albeit proceeding at many times the rates of previous Interglacial periods. In March 2004, the Coalition was chided by its own Auditor for not spending the budget set aside for research into Global Warming, just after the hottest February on

record in Australia. Australia did not ratify Kyoto because Australia has no contingency plans for limiting greenhouse gas emissions, or for dealing with the consequences of global warming, at least at Federal level, simple as that. NZ also does not pay proper attention to alternative energy priorities either, especially in regard to solar power potential, despite good natural resources and potential. See also [Countering Alternative Energy Misinformation Extant in NZ, Epitaph for a Planetary Biosphere](#).

**Tendency for exponential energy growth is a proportionately linked property of both unchecked human population growth, (and attendant increasing energy consumption), and of increased global warming.**

The latent heat capacity of the oceans and Antarctica are our present under-acknowledged buffers, but even these are being overcome, so changes that could reverse global warming will only now do so over an increasingly extended period, and world temperatures may never return to pre-industrial levels. The oceans also act as a carbon sink, but there are limits to this facility also, for both organic and chemical reasons, which interact to further exacerbate the effects of global warming. Part of the WHY of alternative energy use is bound up with climate change and over-use of fossil fuels, so this Manual attempts to incorporate this reasoning to help convince responsible people, with some perseverance, to convert to alternative energy, and to educate and convert others as well. (See **Appendix 2, Fuel Efficiency Is Not the Same As Energy Efficiency**)

**See also**, for a detailed description of our **anthropogenic greenhouse**, the still-relevant and most useful book, **Hothouse Earth**, John Gribbin, Bantam, 1990, not least because the predictions noted therein have very real manifestations today. **The Breakdown of Climate**, P. Bunyard, Floris 1999; **The Ice Chronicles**, P. Mayewski & F. White, UNH 2002; **Coal**, B. Freese, Perseus 2003, ISBN **0738204005**, (**chronicles the beginning of human fossil fuel dependency**); and, **Hothouse Earth**, all should be compulsory reading for any putative national or world leader! Plus [Epitaph for a Planetary Biosphere](#)

A Nobel Peace Prize has been awarded to Al Gore and the IPCC, October 2007, for publicizing the need to counter climate change, so there are now no excuses for ignorance of the issues these days, and hopefully, world leaders, especially leaders of major greenhouse gas emitting countries, will take note, and co-operate on reducing the world-wide effects of Anthropogenic Greenhouse Warming. Mind you, there have been many Nobel Peace Prizes awarded in the past, but there are still new and ongoing wars..?

**Global dimming, due to particulate atmospheric pollution, is the newest terrestrial greenhouse twist, masking global warming by inhibiting insolation, >20%-30% in some areas. However, given that greenhouse gases are to be reduced as the effects of this pollution are countered, solar power thus has an even 'brighter' future, especially in the higher latitudes, as the sun literally shines more brightly than before!**

Meanwhile, to garner data for the Manual, formal and informal approaches by one ordinary individual, when in Australia, to two battery companies, several solar professionals, one state government, one university of technology, one town council, two technical colleges, and one national daily newspaper, all in the name of information gathering and basic public education in solar technology, have been ignored. With no responsible leadership example, and no sense of urgency, what else could be expected? Lop that poppy!

Some sections of private enterprise dealing in alternative energy, sadly, may think short term that they benefit from consumer ignorance, not understanding that public education will lead to public confidence, confidence to demand, and demand to a market that will grow indefinitely. Consumer education is not a form of industrial espionage! The customer base only needs education and example to foster infinite market growth, and this growth will in turn foster more research and development when this is most urgently needed. Solar technology, although not new, is nowhere near its potential, in materials or performance, or in optimum educational standards for the general public.

For this Manual, information has been collected from many sources, and any lessons hard-learned are included. The Internet, and some trusty reference books, also came to the rescue. **Tables**, data, and calculation examples discussed have been tested in real situations, and new data is always added when available. Other information sources are listed, and/or suggested, and the Web is always there to help. Heuristic hands-on, with much learned from dealing with one failing secondhand system, also played a major role. Research, plan, prepare, and, seek optimal advice, in your own turn!

Also, every solar energy system is unique, both in the power needs, and in the final site characteristics, geographical and latitudinal, both of which need to be taken into consideration. As well, there will always be those ubiquitous budgetary considerations. The solar sizing guidelines listed are necessarily conservative, and there is plenty of other conservative, and hopefully, commonsense advice, that will help with planning and decision-making. Power needs, present and future, must be known, PV specifications are then based on these needs, and battery decisions and any ancillary charge planning will follow. Grid interface, even just for solar farming and power reselling, is a further consideration if circumstances permit.

**Decisions are always easier, and easier to live with, if optimum information is available at the time, and decisions needed to proceed with a home solar energy project are a good example of this principle.**

**However, the final arbiters of your PV system's overall effectiveness will be the verdict of your voltmeter, and especially, that of your ammeter. Therefore, it is strongly recommended that you do some surveying of existing systems, if possible, to gain information about overall performance in relation to size, especially useful when proposing solar power system operation in a similar local or regional setting. In a**

**unique location, you may need to experiment with a portable or mini-system over an entire year before committing to major solar system deployment, including, of course, the consequent capital investment required.**

Finally, the intention of the Manual has not been to re-invent the solar power “wheel”, or rewrite the textbooks, but simply to give the increasingly important reasons why of basic solar power management, illustrated by a modicum of technical description involving standard solar energy data, plus the emerging environmental implications, thus enabling more reasonable levels of consumer confidence and decision-making.

Whenever a grid goes down, you will at least have lights, radio, TV, computer, internet, and telephone, which are now regarded as basic essentials for modern living. This ready energy access will enable keeping in touch with the rest of the world, (as well as keeping at bay literal and figurative ‘darkness’), and maintaining that unique facility for extensive communications which define, so aptly, the best accomplishments of our modern society.

***Do not ignore safe assembly and informed management practices, and source optimum quality components. Plus:***

***For optimum performance, safety, and value for money, be sure to use matched components, in age and condition, plus, respective capacities, for both solar arrays and battery banks. All-new is usually the best way to go, for setting up main solar power system assemblies.***

[Real-World Solar Panel Safety.... Must-Read](#)

[2025/10/31/surge-rooftop-blazes-sparks-concern-using-solar-panels/](https://www.solarpanelsnetwork.com/blog/2025/10/31/surge-rooftop-blazes-sparks-concern-using-solar-panels/)

[Mixing Solar Panels With Different Wattages](#)

[Mixing-battery-brands-risks-warranty-safety/](#)

<https://www.howtogeek.com/ive-used-rooftop-solar-for-a-decadeheres-x-things-id-do-differently-if-i-were-installing-it-today/>

***FLA still best for large battery banks, for hard work, longevity, and for safety. Be aware that Gel-LA battery overheating can form voids due to steam pockets. In the future, greater energy density requirements means Li-Ion, (or other storage battery types), will supersede the use of FLA batteries...BUT, always advisable to have a solid concrete/brick wall between any structures and Li-Ion battery banks...? Plus, as always, natural disasters must be planned for, regardless of what power generation is in use..***

**2020** *Li-Ion solar batteries are now in production, with differing charging regimes; PV planning and management generally remains the same.*

**2026** *Plug-in solar is already a common sight in Europe, and particularly in Germany.*

<https://solarcompare.com/solar-panels/battery/lithium/>

<https://industrywired.com/technology/advanced-24v-lithium-ion-battery-technology-for-solar-installers-9673030>

<https://www.solarpanelsnetwork.com/blog/plug-in-solar-panels/>

<https://www.sunsave.energy/solar-panels-advice/solar-technology/plug-in> .

<https://www.myminisolar.co.nz/>

<https://www.solarreviews.com/blog/dont-invest-in-plug-in-solar-panels> ....Just negative marketing misinformation..?

**So, for all those anywhere in the world interested in alternative energy and climate issues, in particular solar energy generation and storage, and, with the foresight and common sense to change their energy technology, this humble Beginner’s Manual is for you, too, and welcome!**

[\*\*Contents Return\*\*](#)

## An Introduction to the Use of Solar Energy:

Climate change, greenhouse gases and finite conventional energy resources now means a new emphasis on the mainstream use of alternate energy. For those contemplating the switch to solar energy, the most immediate advantage is independence from the grid, especially from power fluctuations, surges and blackouts, which apart from inconvenience, are bad for modern electronic equipment. Even if used, grid-dependent **uninterruptible** power supplies cannot fully replace actual **uninterrupted** power supplies. Also, most convenient of all, when there is no access to the grid because of distance, terrain, or cost, solar power will dramatically reduce generator use to back-up status and minimising associated noise and fuel cost.

With major climate change now apparent, we can anticipate rising conventional energy prices, especially of fossil fuels which the world now relies on predominantly. Hydroelectric power in Australia, and even New Zealand of late, now only has future potential in small regional or privately owned plants, and, most obviously, in areas of projected adequate rainfall. Those hydro water levels must be optimally fostered and buffered in all seasons, as well.

Wind power depends, of course, on wind, and has at best an auxiliary role, as does tidal power. Ocean thermal energy conversion is still being developed. Atomic power has a very uncertain future in any country, resources are limited, and anyway, reticulation will still be via the main grid with all its costs and constraints. Increasing use of biofuels will bring a new set of energy and pollution problems, even if cleaner than fossil-fuels. Solar power can have a main grid auxiliary role, but for the smaller and domestic applications, with batteries, solar can be the **staple** power provider. In this sun-drenched world, in some parts projected to become even sunnier, solar power is an obvious first option for individual, community, industrial and national grid power supplementation needs.

**Solar systems also soon pay for their manufacture, sale, and installation, and then continue on in their working life providing vital energy as electricity, and definitely make significant year-round terrestrial power generation contributions anywhere outside the Polar Latitudes. Higher altitudes make for even better efficiency, due to less dense air and less pollution. This also good news for sheltered montane locations within higher latitudes, such as found in the alpine regions of the world, and, where applicable, low-tech mechanical snow-dumping from panels can be implemented.**

More solar power generation will thus reduce strain on the main system, and those solar producers with access to the grid can export profitably when they have a net surplus. Of course, this surplus will occur in daylight hours, but this is the time of major consumption by business, industry, hospitals, and schools, and air conditioning, and such energy supplementation means less water released from dams, less fossil fuels used, and several time- zones can spread the benefits of such savings even further. **Most importantly, solar power is low-maintenance, there are no moving parts except electrons, and furthermore, solar installations are more easily made secure against the increasing turbulence of increasing climate change than other energy generation plants that must, of necessity, be positioned, and thus remain, more exposed to those very elements that are used to effect power generation.**

The main grid will deal with supply outside of daylight hours, when, as well as solar, tides, winds and water, from major and minor plants, will supplement fossil/bio fuels, also given sensible conservation and optimal usage of energy by dependent consumers. The same factors may apply anywhere else in the rest of the world. Given that population, infrastructure, and industry continue to increase, as well as increasing climate change, planning for energy conservation and energy independence becomes even more important, **serious matters ignored in the latest Australian and New Zealand censuses, and doubtless in other countries as well.**

**Solar technology is not new**, the modern solar cell dates back to the 1950s, and the flooded lead-acid battery, still the best option for domestic solar power, and automotive electrical energy storage, dates back to the 1850s. What is now needed is to develop and extend such alternative energy usage to complement power generation, and thus aid in conserving conventional energy as long as possible, and limiting any future greenhouse gas emissions.

**Every solar power generator and user here will contribute to world's benefit, whether on the grid or not, by being optimally independent or supplementary power producers, and that, of course, includes solar hot water.** Current solar users, therefore, see the future, plan for the future, and, in reality, already live in the future. Indeed, in the future, households, businesses, and industry, with mixed solar and grid electricity usage, will become more and more common, regardless of their geographic domicile. Satellites, themselves so much symbols of the future, have been powered by solar panels for decades, replacing heavier and more costly power plants in those areas of the solar system with adequate sunlight. This is especially true of geostationary satellites which contribute so much to earthly communications.

The future of solar is already well defined, research continues, and solar technology will continue to improve, (as will other alternative power technology complementary to solar), reducing costs, and increasing efficiency of operations. Currently, there exist flooded lead acid Telecom batteries, properly maintained and managed, which have done good service for 30 years or more, including stints in domestic situations after their Telecom use-by-date had expired. They have a shallower deep cycle than conventional deep cycle batteries, as well as having heavy plates set up with an initial forming charge, which is more robust than pasted plates. (See also **Appendix 1**) Conventional FLA solar batteries should last at least 5-6 years with conservative use and careful management, gel batteries perhaps less. Alleviating any battery materials stress is the key.

Panels will last even longer, (declining in performance only after about 25-30 years, but are still usable, more panels just being added to the array), as will the other ancillary system parts, all with careful management. Solar power systems, once installed, are relatively low-maintenance, after all, the only 'moving' parts are electrons, so, these systems are especially useful for solar-farming with grid-interface, as well as for stand-alone installations utilizing battery backup. Further research, supported by demand, can improve performance and useful life of these solar power systems, and solar batteries, even more. **But only mass demand, driven by public education and climate change awareness, will really drive the technology further.**

Solar electricity itself is derived from the effect of the sun's rays on masses of manufactured solar cells, otherwise known as **photovoltaic devices. The technology involved is that of Semi-conduction and the Photoelectric Effect.** These solar cells are composed of layers, being of semiconductor materials doped with trace elements incorporated into sandwiches of silicon, plus having different (+ve/-minus) electrical potentials in order to utilise photoemission power-generation potential. The silicon component itself is non-conductive, but the metallic ions in the dopants are, as are the system current-carriers.

When exposed to sunlight, electrons are dislodged by **photoabsorption and concomitant thermal agitation**, which then generates excess electron-hole pairs, plus increased conductivity, and, an increased reverse current proportional to light intensity. **Electron current** thus flows from within the layers, by crossing a 'junction', and then returns, via the external circuit, usually to a battery bank, or, to a main grid. **A solar cell is thus a junction photodiode, with zero applied voltage**, that, when intercepting light, is thus capable of generating the reverse electron current that is then applied to 'work' in electrical circuits. However, **the wavelength/frequency, and thus the energy, of the striking photos** is critical in determining whether electrons are initially dislodged; this also depends on the nature of the surface being struck, ie, the nature and type of metallic atoms or molecules incorporated as dopants when the solar cell was originally manufactured. (See also [Solar Spectrum Utilisation](#))

**A single conventional silicon photovoltaic cell**, on average, presently generates 1.5 watts, 3 amps, and .5 volts. **Thermal agitation** promotes conductivity within the solar cell, and also increases electron bond disengagement by collision, but, **excess heat can have a resisting effect on other parts of the system**, as well as contributing to overall material stress, so, a **heat balance** needs to be struck whereby the panels, and especially concomitant circuitry, are kept relatively cool by airflow or other means, and this also includes **batteries** when they are utilised. **Series and/or parallel connection of cell modules make up the panels**, and, multiple panels in larger modules, similarly connected, will thus increase these values accordingly. The panels themselves are protected by high impact glass, and supported by aluminium framing. (See also [Appendix 2](#))

**Basic components of a solar system** consist of panel array, battery bank, control board, which includes fuses, monitor /regulator (aka **monitreg**, and preferably with a display), inverter for DC to 240 volts AC/50 Hz, (in Australia and New Zealand, for other national voltages, see [Eaton Powerware](#)), auxiliary generator, and ancillary 240 volt AC/DC charger. Electricity is stored in purpose-built deep-cycle batteries. Normal domestic wiring is installed for power reticulation, and a grid interface may be included. Some applications may utilize only DC power, for others, AC and DC circuitry will interface via an inverter, or perhaps two, for high and low demands. ([Solatron Technologies](#) has an excellent description of series/parallel connections)

The solar switchboard may incorporate access to mains power where this is available, to facilitate sale of excess power generation to the main grid. Also, mains power may be utilised for more heavy duty power appliances, while solar derived power may assist in reducing power costs for less demanding applications. **You choose!**

Once installed and operational, the principle panel maintenance chore is the occasional wash with water and a soft broom! Wiring and circuit should be safely housed away from the weather, inverters have a long life if utilized within their limits, and only batteries, if installed, require a regular maintenance routine, yet even that is no more onerous than for automotive care! (Also see the [Wallchart](#) for quick-reference details of system care and maintenance.)

**Also, note that there are differing DC voltages that may be utilised. 24 volts, from 2vpc cells in appropriate conformation, is the usual Australasian domestic choice.** A household array should ideally produce at least 15-20 amps average charge, via the charge controller, thus limiting any need for more than occasional use of ancillary charging from a generator, (as in a hybrid system). Other forms of renewable energy may form part of a personal charging grid, generating electricity by wind, water, steam, etc. A bio-diesel generator for short-term intensive charging would at least be an improvement on the use of fossil fuels for the same purpose..?

Optimal auxiliary energy for individual solar power systems, if available, and always inferring optimal and planned usage of all sources, can be provided by gas, liquid fuel for generators, firewood, water, wind, plus biomass, or other plant biofuel generation. Another example of technological progress is the development of smaller scale **hydrogen fuel cell technology**. This may also mean that suitably equipped solar producers could maintain this energy source for auxiliary energy production as a byproduct of solar electricity generation. (**Fuel cell**: a galvanic cell in which the oxidation of a fuel is utilised to produce electricity. See also [Fuel Cell Systems Explained, Useful Books](#))

**Note:** The problem with the Hindenburg was as much the composition of the outer skin and sealing coat, as the inflammable nature of hydrogen, which requires the same common sense safety measures as any other volatile or gaseous inflammable fuels. The known brittling effect of hydrogen upon metals, and vessel permeability to such small molecules, is being researched and overcome as well. Hydrogen economies, however, are still very much in the future..?

**What is so new about understanding the solar principles applied to everyday living, skeptics might ask? Answer: Those principles have been used and proven for a long time now; but modern technology has simply added solar electric power, and/or other alternative energy, for more self-sufficient living environments!**

Most fundamental of all, for overall energy conservation, is **sound energy-optimising, and energy-saving, architecture**, utilizing suitable building materials, and the optimum siting of buildings, as dwellings or otherwise. Glass houses were the first, and still are, the purest form of solar architecture, with design features facilitating the original greenhouse effect, plus heat storage built into walls and floors. (See also [The Natural Solar House, Useful Books](#))

Planning **stand-alone** domestic solar usage is not difficult, and does not vary all that much from normal power conservation measures, differing only in appliances used, their size, order, or combination of usage, and the involvement of battery power storage and auxiliary power use. Learn the basics, and with a little perseverance, easily sustainable power use habits will develop. System maintenance is also part of sustainable energy production, and must be factored into any switch from, or parallel usage with, conventional energy.

At minimum, such basic needs as lights, TV, radio, computers and access to the Internet are all easily provided for by solar power, even in winter, with only top-up auxiliary charging required. Further energy usage is a matter of choice, cost, or convenience. Apart from normal power conservation, utilising smaller appliances such as low-wattage light bulbs, portable and b/w TVs, laptop computers, small-scale high performance stereos, etc., will reduce auxiliary charging requirements, especially if main usage is planned for sunny days.

Avoid incandescent lights where possible, and larger fluorescent lights which are not easily compatible with solar systems because of starters. **Plan concurrent usage** of appliances carefully, especially that of computers, switch off scanners and printers not actually in use. The average PC consumes 100 watts at 240 volts/50Hz, or, 4-5 amps DC, not including the ancillaries. All so easily learnt, and, deep cycle batteries are the very best in **UPS/SPS** (uninterruptible/standby power supply) technology, although note that a conventional UPS/SPS should be used with a grid interface PV system.

Water and building heating can be facilitated by solar hot water systems assisting LPG or firewood use. This is all part of good architectural planning that should account for optimum siting of heating panels, routing and lagging of pipes, ducting of air, etc., as well as building for climate and position. Use of a gravity tank ensures water on demand, and so reduces pump usage, as well as providing modular water storage that is a buffer against possible catastrophic loss of main storage.

With **smaller** solar systems, **secondary batteries**, ancillary to, and chargeable by, the main system, can be used for DC radios, security and comfort lights, etc., of low wattage, independent of the main inverter, which, although enabling the use of off-the-shelf appliances, does lose at least 10% of power through heat. Small-scale and uneconomical long-term use of inverter power can thus be profitably avoided.

**Larger**, more modern systems can absorb this low-level usage more comfortably, having high charge response, larger battery banks, and possibly two inverters. But main system backup is important, and, a supplementary DC power source will also allow for the resting of the main bank when only a small draw is needed for a light or radio. This will help to sustain optimal charge conditions for the main bank.

Modern regulator-monitors constantly display battery status, enabling easy reading, and, with history facilities, easy record keeping. Chargers with pre-set facility are especially useful in determining auxiliary charge progress and battery status, avoiding unnecessary charging. (See [Walchart](#) for further easy-reference details).

User-friendly technology makes owning and managing a solar power system increasingly easier. The future of solar alternative power generation is here now, and **working!** Actually, this is all not so new, since, as noted, the battery has been around for 150 years, and the solar cell for 50, and the sun for much longer, and now climate and resource exigencies mean that this technology should be part of everyday life. The economics of solar power should be emphasised, because, as well as just saving on grid reticulation and mains power use, the system will pay for itself several times over, and how much and how rapidly depends on the usage in relation to power generated.

**The solar power system will also concurrently pay for its own manufacture, as well as paying or off-setting power bills, depending on whether grid-interface or stand-alone. What other conventional mains power generation system will do this? Fossil fuel power generation is also less efficient, in terms of energy conversion, than solar, which is ever-improving. Even hydro-electric power has to have the capital cost and mass reticulation factored in, and there is all that continuing maintenance, wind power needs wind, and is high-maintenance. Being so low-maintenance, solar power generation over time is more cost effective than any other kind of power generation.** (See also [Appendix 2](#))

Any mass-produced alternative energy must also be reticulated, so smaller, independent or even district power generation centers make sense to avoid the problems and cost of main-grid dependence, yet benefit economically if there is grid interface and reverse-power purchase. Grid interface for the householder means that power sold in the summer will offset grid dependency in winter, or during less sunny periods, even if there is not actual cash return. There may be an installation subsidy for having GI. The bulk of power bills will be paid for by the solar generated power, including the line rental, and the grid maintenance is guaranteed by the utility company. All the while, any system batteries will provide an uninterruptible power supply, grid problems will not unduly affect your household, and ancillary charging will be minimal. **In fact, the more you 'eat', as the old maxim asserts, the more you get paid, rather than pay out, as for conventional power use..?**

**Stand alone** means that most power will come from the system, including stored battery power, with some ancillary generation if required. In both cases, capital cost of installation really means paying in advance for power, and getting a refund over time, as opposed to one long payout for grid power, and no "refund", and with the net loss of natural resources that fed the grid power generation. A business run on a solar system is even further ahead, as installation itself would be a tax deduction.

Investing \$A15,000 at **2003** prices, in a 1000 watt/pd system, and saving about \$1200 a year in power bills would mean a total payback in 12.5 years, and grid power would rise in relative terms. GI subsidy and credits would also contribute.

A stand-alone system with a **solar hot water system** and a generator would be worth \$A20,000, returned in 16 years, and with the concurrent benefits of an independent, uninterruptible power supply. Invest \$A15,000 to pay off main grid power bills, by interest, for 12.5 to 16 years, and watch it be eaten away, the payouts would start in 90 days from the investment date, and do not forget that there is no saving on fossil resources that power the main grid. (**2003** prices)

Certainly, as part of solar power capital outlay, there would be battery replacement, and panel augmentation with time, or even system upgrades, but batteries well cared for should last the entire 16 years, and panels would lose about 30% amps over 25 years, and only need adding to, rather than total replacement, and that could just be with secondhand panels. The **solar hot water unit** would last 25 years, and longer, if utilising good-quality filtered creek or river water, especially rain-water. System components would thus not need replacing all at once, so costs would be staggered.

The price of solar components will also fall as there are technological improvements and mass production. **The "refund" would still go on, depending on the extent of usage. The grid-dependent user just keeps paying out.** Optimum usage of solar, (and/with other alternative energy), just needs a move away from the switch-and-forget mentality of mains grid dependence, to better awareness and planning of power consumption, and good habits of management and maintenance. The following pages will help to explain how this may be achieved. Supporting the woollen industry helps as well..?

**Finally, good battery management, fundamental to successful domestic power storage, is very important, and this will also be described and explained.** In the following text, it will become evident that more should be known about care and management by every lead acid battery user. This basic information, not adequately publicised by the battery manufacturers and sellers, would ensure more efficiency over a longer lifespan, with fewer defunct batteries to be disposed of. Lead-acid batteries in vast numbers do constitute a disposal problem, with toxic and corrosive components, but these units are still the best we have for the jobs they do, and are gaining bad disposal publicity because they are unnecessarily produced in large numbers because of premature replacement. Good for manufacturers and retailers, but not good for common sense resource utilisation.

**Optimum charging regimes, plate reformation time, operating and ambient temperatures, fluid replenishment, depth of discharge, matching to load specifications, site suitability and safety, and BOS integrity and efficiency are all important for lead-acid battery health, (whether flooded or gel), efficiency, longevity, and, whether motive or stationary, all principles generally common to any secondary battery management.**

**Furthermore, modular flooded lead acid batteries, in particular, should now be manufactured that allow for easy and effective replacement of the principle consumable materials of acid and lead plate.** This would make for quicker and easier module transport, and easy restoration of power storage potential. Modern plastics can make this possible, and at changeover time, a complete discharge would mean only lead sulphate and weak electrolyte, (16% acid, also further dilutable, and then rendered neutral), would be removed, new plates installed, leaving only the stage of acid refilling to be carefully managed, with due safe-handling procedure. Another benefit would be the improved reputation of FLA batteries as to recycling management. Consumers, especially with decentralised and off-grid power, and the environment, would all benefit, and the ratio of resource use to overall benefit, and effective recycling, would improve also.

Most solar batteries see out their lifetime in situ, and there would still be second-hand value enhanced by better quality recycling materials that should attract a refund at source, or at recycling depots. Effective top seals of batteries should be easy to develop, and there is also a need for mechanical stirring to be incorporated for stationary, as in **motionless**, in situ FLA deep cycle batteries to reduce de-stratification charges, although, granted, stirring up of bottom sediments would need to be minimised by this activity. With a will, AGM and gel batteries could also be made more modular, with all the same benefits. An inverse temperature gradient, where this is possible or practicable, may help in this respect, see the **Unanswered Questions**.

**Note that for high-demand battery power use, especially when repetitive, FLA batteries are more suitable, if practicable, because excess heat and vapour formation in gel batteries can limit their effectiveness, and thus, their useful life. Also note that charge regimes for FLA and gel batteries are different for this reason.** (See also [Wallchart](#) and [Excerpt 2](#))

**There is, indeed, much to be done to further the utilization of alternative energy. This Manual is aimed at providing basic solar power information that will hopefully increase interest in, and demand for, home solar power utilization and, its effective management.**

**Your feedback to this website would also be much appreciated, even the smallest error or ambiguity needs attention, and, newer or better information is always welcome!**

**Conventions adopted for formulas and symbols** as used in this Manual are as follows:

**X:-y** means “divided by”, or **x over y** is used where practicable.

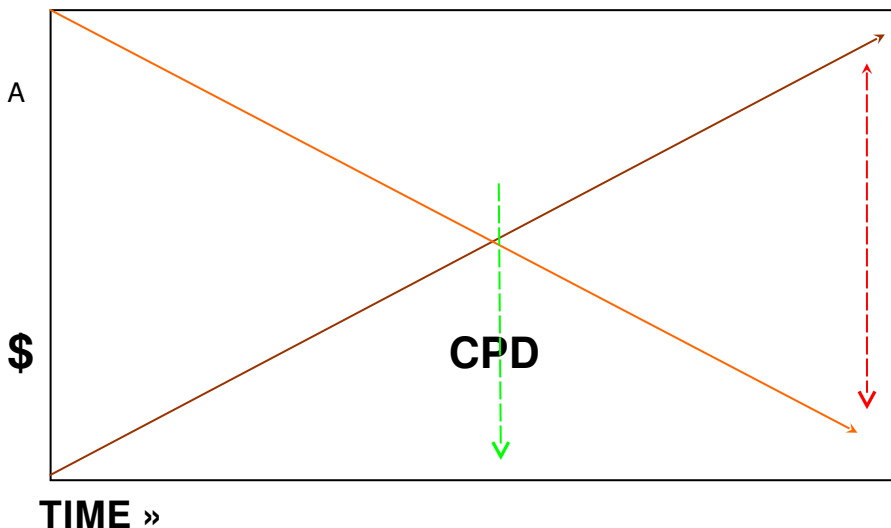
**/** is used as an abbreviation, hyphen, or as “per”, but not as “divided or multiplied by”.

**Amp-hours** = amps x hours, or a-h, similarly for watt-hours, w-h

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### Simple Solar Economics Graph:



<b>B</b>	<b>X</b>	<b>C</b>	<b>D</b>
1 year	>3 years (2008)	6-10 years 1995	(energy payback 15-20 years 1975)
<b>Start</b>	<b>energy payback</b>	<b>break-even</b>	<b>cost/payback differential</b>

**A** represents a solar purchase, money “up front” for power purchase in real terms. **B** represents the beginning of a bill-paying period for a power consumer on the main grid. **C** will be the break-even point for both consumers, and the steeper **B**'s cost-line is, the steeper the fall on **A**'s savings line, as that money was paid upfront.

**D** represents the difference between money paid by **B**, and, money saved by **A**, even to the extent that **A** will have repaid, in power savings, all the upfront purchase, and will be making a profit by this time. This is the **cost/payback differential**.

Both **A** and **B** will have ancillary costs that will cancel each other out, like a solar hot water, or firewood stove, gas, etc.

**A** will need battery replacement, at about 10-15 years, which will be a cost, and also panel enhancement by 20 years, but both of these costs will be lessened as the technology becomes cheaper, and **B** will be paying higher grid power prices, anyway. The break-even time will be passed before battery replacement time, most probably.

**Stand-alone** will see a smaller difference at **D**, **solar plus grid** will see a greater difference at **D**, because of the opportunity to sell power, or credits to off set any grid dependency. **Grid interface, without batteries**, just to sell power back, will see the biggest difference at **D**, most credits or refunds, and soonest break-even, reinvestment surplus, and then profit making. After gaining **break-even**, cost-savings will thus eventually go into profit, for all solar power users, even allowing for system upgrade reinvestment.

**Purpose-built solar houses, properly designed to be integrated with solar technology, including solar hot water, will provide the most CPD for consumers in the shortest time. Normal household high-draw power use is possible with a generator for back-up, or, by grid interface, with grid interface input canceling ancillary costs more quickly.** For stand-alone houses, possibly in remote areas, there no other choice but alternative energy for power generation independence; solar is the most reliable, and wind or water could also be ancillary power providers, as well as a backup emergency generator.

**The argument is sometimes put that investing equivalent upfront money will pay off bills, and make a profit for anyone already on the conventional power grid**, but the point must be made that the bills will come in the first quarter or so of the investment, and, at \$1200-\$1500 pa per average family, (Australia 2003), that would place high demands on any interest bearing account, and the money ‘saved’ is then gone for good, unlike the solar capital investment. As well, the environmental costs would not be lowered with continuing dedicated conventional power utilisation, one of the main reasons for initiating on-grid solar investment, and the investment money would have to be topped up, if not all upfront, anyway.

**Finally, the main grid itself needs backing up at times**, do not forget, and independence from blackouts, surges, and brownouts is worth considering, especially if electronics are in use! Solar standalone never has these problems, obviously, and grid-interface solar power farming can have a small battery bank and inverter for just such an emergency..?

**Therefore the most reliable main-grid backups are extensive hydro reserves, or else fossil fuel reserves if such hydro reserves are not available. A grid supported by extensive alternative energy inputs from solar, wind, or small-plant hydro-power generation, will thus help to conserve major hydro reserves, and limit the use of intensive fossil-fuelled power generation, where applicable, as well as conferring important environmental benefits.** (See also **Appendix 2**)

**As of 2008**, improved Solar PV technology has reduced manufacturing energy payback time from >20 years in 1975, to >3 years, as per ‘PV Energy Payback’, **Homepower Magazine #127** and HP main page, citing this significant PV EPBT/Estimated Pay Back Time reappraisal.

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## Sizing of Domestic Solar Power Systems:

Sizing depends on the decisions of whether the system is to be stand-alone, or connected to the grid. Connecting to the grid depends, in turn, on whether the grid is a back-up to the solar system, whether the solar system backs up the grid, or whether there is the intention to make money from selling surplus power back to the grid, with batteries as UPS, or perhaps even without battery storage involved at all.

Charging will always need higher-than-battery **volts** to be effective, as 30% extra charge is always needed to restore battery amp hour capacity. Storage-to-required daily watts ratio should remain fixed, and charging is then up to the main energy source and ancillary charging, but should always be regular, and optimum, for battery health.

**Having solar hot water, in any situation, is a cost saver, even in winter, as any heat contribution that overcomes the latent heat drain of water heating is important, and in warmer weather, the sun alone may provide all the hot water needed for most domestic purposes. Even winter season solar hot water will provide sufficient heat for temperature control of batteries, thus promoting optimal efficiency and health during the coldest part of the year. A solar hot water system utilising rain water will also have an optimum lifespan.**

Stand-alone systems will probably need a generator for high power draws, and for extra charge and/or equalization, depending on charge amperage and battery size. Having no generator will mean careful system power use, and sufficient panel to ensure full unassisted charge and equalization. There may be further ancillary alternative energy derived from wind, water or steam, but solar energy will always be the most predictable means of electricity generation, in any season. Water transport and pressure, if there are no mains, is best achieved by a gravity tank, with fewer pumping spells, and no small intermittent top-ups that would require an in-line pressure pump.

Thought and planning must go into alternative energy system sizing, and to possible system enlargement as time goes by, especially if there is to be more than one source of energy, and whether there is direct or inverted power use, and even if there is to be more than one inverter for high and low loads. A small independent back-up may also be utilised, sufficient for lights or radio in emergency, yet maintained and in regular use. Whatever the power source, or the application, batteries will be needed for storage when this is required, and they must be sized for effective and useful lifespan, **and** matched properly to the capacity and constancy of the generating source(s).

Solar sizing is simple, once the power consumption projection is known, whether a generator will be factored into the system, then a further decision must be made as to the size of the generator. To put this decision into simple perspective, a larger generator is needed for construction and/or welding, up to 6kva, and a smaller model, eg., 2kva for charging, or for higher draws unsuited to system use. As noted above, solar hot water, gas, or wet-back fire or combustion stove will be necessary for hot water, though the solar HW system will complement water heating in cooler periods, and probably render ancillary water heating unnecessary during long hot summers.

**NB, with new systems, batteries will gradually gain in capacity, and panels will settle down slightly, before achieving standard performance. Batteries could last up to 15 years, and panels up to 25 years, both will manifest gradual performance decline, easily tested. This should be factored into useful lifespan calculation.**

**The simple formula for panel and battery sizing is: Required daily wattage per annum average x efficiency factor to give optimum daily wattage, then divided by system voltage.** This will give daily amps charge required, multiply by 5 for 5 day storage, and/or divide by mean daily latitudinal solar hours p.a., to give hourly amps, and thus panel watts. This will give the nominal number of 12 volt panels to be used, and this, in turn, must be doubled for 24 volts, trebled for 36 volts, and etc. Note that battery size decreases as voltage rises.

**EG, at Latitude 35°South, with 4 mean daily solar hours pa, and daily watts of 500, and an efficiency factor of 1.5, that allows for 50% cycles of a 24 volt system:**

$500 \times 1.5 = 750$  :- by 24 = 31.25a :- 4 s/h = 7.8125 A-H  $\times 24 = 187.5$  watts panel, scaled to 240 watts on the [Tables](#) to panel sets producing 9.9 amps charge. 31.25 is  $\times 5$  for 5 days **nominal** storage, or a 20% daily recharged cycle, optimum for battery health and longevity. The 1.5% efficiency factor ensures that 50% only of the battery is involved in cycle calculations, thus 750 is the **required** wattage to ensure this.

**Easy 24v cross reference is 120 watts of panel to every 100 A-H battery storage, depending on latitude, grid interface, ancillary charging, new or second-hand, etc. This gives a ratio of 1.2:1 panel watts to required storage watts. Another simple ratio is required daily watts to panel watts is 4:1.**

**\*\*\* Note that similarly derived ratios apply to other latitudinal sun/hour calculations, eg for 3 s/h calculations, storage remains the same, but p/w:s/a will be 1.6:1, and r/d/w:p/w will be 3:1. Such ratios are useful to work out equations when matching components, and not just for calculating a full system \*\*\***

**Also**, 15.5 amps needs 320 watts of panel, 20a needs 480w/p, for a ready reference that will reduce any ancillary charge lag. Thumb-nail panel calculations could start at a minimum of 15.5 amps generating power, which would need 5x40 watt panels, generating 200 watts, for a 12V system, or 10x40 watt panels for a 24 volt system as a minimum, producing 400 watts, which would be sufficient for a 1000 watt daily requirement as well, at 3.5 to 4 daily mean solar hours. The amps would actually be 16.5, so there would be minimal use of ancillary power for boost and/or equalization, especially if the solar charge could be dedicated to this purpose when the occasion arose.

**Batteries bank sizing** is quite simple, and is the same regardless of the power source, solar, water, wind, steam, or even grid back-up. (See [Bill Darden's](#) FAQ 7.9 for a detailed survey of bank options).

**Daily storage** requirements are usually based on 50% battery use for cycling, derived as per the equation, from daily amperage  $\times 5$ , which determines battery size. This is expressed in respective amp-hours, based on an average manageable draw of

40%DOD, and multiplied to give useful days-of-storage margins, lesser figures perhaps more suitable to warmer latitudes, larger to cooler latitudes, and powered by lesser or greater panel capacities, respectively, or depending on ancillary charging.

Days of storage are nominal, really, as batteries should be optimally charged whenever possible, and operating within the 40%DOD for longer life, as per the wall chart. Lower storage requirements, as in lower, sunnier latitudes, means ad hoc. storage reduction, depending on need. Also, grid interface may mean maximum panels for \$\$ return, and minimum batteries for main grid outages or brown-outs, so the battery bank in that case, for practical purposes, is a temporary UPS.

**The formula for battery sizing is thus expressed as follows:**

Mean daily wattage requirement  $pa$  is multiplied by 1.5 (for efficiency compensation), then divided by the voltage, which will give the mean daily amperage requirement. This is then multiplied by 5 to give the nominal 5 day battery storage requirement, (if required), and thus the optimum battery amp-hour size, as well as the capacity to ensure 20-40% cycles between optimum charging regimes.

**The mean amperage requirement** is the charge that must be made up for each daily discharge cycle, so dividing this by the mean latitudinal solar hours will give the amp hour recharge required from the charging source. If this a solar array, then the amp hour recharge determines the actual panel size and number, depending on voltage. Whatever the panel size, numbers will be double for 24 volt, and so on, expressed as panel sets.

**Any recharge below 15.5 amps** will need to be complemented by external charge to achieve full recharge and/or equalization, utilising the C10 charge parameter, or 10% of the 10 A-H capacity, tapering as necessary. Any charge should be steady, and given optimum time, rather than being rushed. See the [Wall Chart](#), remember plate reformation time. Cooler latitudes will tend to larger battery capacity, but this should always be a factor of potential ability to optimally and regularly recharge the bank, by panels, or other higher amperage ancillary charging, to 15.5 amps and beyond. **Note that battery sizing by this method does lead to more precise panel and battery calculations, especially for small 12 volt systems. Scale up as per Tables, ad hoc.**

**Panels can be added to an array to boost output, as long as they are in the same units, singles, sets, etc., thus, size does not matter. This is not the case for batteries, which should all be the same bank number, based on same voltage, size and condition, at any stage of useful life. Any replacement(s) must fit these criteria.**

**Local or regional climate knowledge is useful also. Panel efficiency will decline by about 20% over 20 years, though supplementation is possible, preferably by second hand units. Batteries may last as long as 15 years, so major costs are staggered in well-managed systems. A standard performance reference test should be made and recorded for future reference after 1 month of operation, and this also would be useful with a partial upgrade or replacement involving new or secondhand components. Regular maintenance checks should account for efficiency changes over time.**

**Comparing nominal performance figures with empirical figures will indicate the state of system and component efficiency. Temperature control, fail-safe 20%-40% daily cycles, optimum charging, clean panels, BOS integrity, and de-mineralised water top-ups all contribute to longer and more useful system component lifespan.**

Upgrade as necessary, rather than overwork batteries by multiple daily cycles even assisted by ancillary charge, or risk damaging inverters. Good used batteries and inverters are worth money, and will offset the purchase of larger capacity units. Batteries may be replaced, but panels can always just be added to, and the BOS well cared for, especially inverters, will last indefinitely. Also, more than one inverter may assist with handling regular loads on differing wattage, eg., less power is lost to run safety lights with a smaller inverter.

Larger batteries are not wasted, making cycling easier, and allowing for some decline in performance with age, do the sums, and ensure optimal cycling and charging in system sizing. Remember, you pay in advance for a power generating system that will then pay for itself and concurrently pay you back over time, and the technology is also getting cheaper to replace. Those on fossil fuelled power just keep paying out as the reserves diminish, and greenhouse gases increase.

**Why panels and lead/acid batteries are the way they are:**

Some information on panel output, and why 12V is the basic panel voltage unit will help explain the foundation of sizing calculations. Solar cells individually produce, up to, or slightly more than 1.5 watts, 3+ amps, and .5+ volts. The cells, in strings, are configured for charging 12 volt battery systems, which are, in turn, **based on the original 2.2 volt single lead/acid cell**, on which other pre-existing lead-acid accumulator systems are based, especially in automotive applications.

The solar cells are usually in series strings of 36, which produces the single 12 volt panel of 18+ volts, 3+ amps, and 40 watts. The higher voltage is necessary to overcome resistance to battery charge, and panels are put in parallel to increase amperage, to facilitate higher current for full charge and beyond, to facilitate equalization, and optimum plate reformation.

24v will have double the panels of 12V, and twice the wattage, 36 volt will have treble the panels, and thrice the wattage, etc.

Panels in series units are then placed in parallel for amperage increase, depending in the system voltage required.

Larger 12V panels than 40 watts produce higher amps because of the multiplying wattage increment, as per the  $W=V \times A$  equation, so a 60 watt panel will produce 5-6 amps, an 80 watt panel 6-7 amps, and so on.

**The bigger the panel, the more efficient, and the less cost per watt.** (About \$A10 per watt for an 80 watt panel, retail, 2003.) Battery storage needs decline with greater system voltage.

Most importantly, solar batteries are similar to SLI automotive batteries, (**Starter, Lights, Ignition**), and especially to traction batteries, which solar batteries most resemble in performance, parameters and manufacture, **all being lead/acid, and based on the 2 volt cell.** AGM and gel batteries, whether low or no maintenance, vibration-resistant, or non leaking VRLA batteries, etc., are all lead-acid variations as well. Solar batteries are more correctly classed as more robust stationary batteries, possibly with characteristic scored/ribbed anode plates. Voltage is a product of series connection, and amperage of parallel connection

**Monitoring, generating, and appliance development are also based on this 2 volt standard, thus, energy storage for domestic purposes has been readily accommodated by developing existing technology, and the use of deep cycle batteries. Also, 2 volt lead/acid cells in series are the best configuration for safety and simplicity of domestic energy storage,** (more correctly, and when fully charged, 2.12/5vpc). The actual charge characteristic derived from the EMF is generated by the double sulphate reaction. **Hence automotive and storage batteries are in multiples of the original 2vpc cell, depending on unit configuration and application. Series only configuration is recommended for storage batteries in case of shorts or cell failure.** ([Solatron Technologies](#) has an excellent description of series/parallel connections)

All system components should have isolating switches or fuses, and even lightning conductors in some cases. Any part of the system should be accessible at any time, in complete safety, for performance check or repair. A further system back-up, especially for stand-alone systems is recommended, in the form of a simple lights/radio/12v TV system that operates from a separate battery and panel, most expediently 12 volts. A small 12v stationary battery would be optimum, but a good automotive battery would do, if not cycled below 20%. This means total independence for repairs, replacement, safety lights, or whatever.

**Advantages of 24 volt alternative systems over 12 volt are:**

**More watts for charging, and inversion to 240 volt, and also off-setting system efficiency factors**

**Smaller battery storage requirements, and, batteries declining before panels, offsets panel cost for 24 volt**

**24 volt inversion is more efficient for higher demands, and 240v means a wide range of appliances are also available.**

**Grid interface means power credits, and the more watts, the better.**

**12v appliances are cheap and numerous, so if no inversion is required, 12v suits a small primary or backup system**

**Summary of System Sizing Principles:** Firstly, note that the Manual is based on 24/240v stand-alone systems with ancillary charge, but appropriate management parameters are similar regardless of the size, voltage or application of the system, from electric fences and water pumps to large residences or businesses, and even to direct inversion that bypasses electrical storage.

Battery storage size is determined by the Daily Watts usage, however, panel size can be more a matter of how easily optimum charge cycles are achieved, whether the charge can be dedicated rather than shared, in that there is daily usage rather than just nightly, and also, whether there is economical ancillary charge available, either alternatively or fossil-derived. **The Multipurpose Solar Sizing Equation is, therefore, a guide to system matching, and a starting point for system planning, balanced or constrained by Daily Watt calculations.**

**Daily Sun Hours** are the minimum time required to fully charge the batteries, given optimum insolation, and maximum system efficiency, in ideal conditions. This may occur in late Spring, or in early Autumn, when skies are clear, and panel temperature is lowest, and insolation is approaching solstice maximum. Solar bursts would certainly provide optimum conditions, albeit of short duration. But, however, this obviously is not the case for all systems, given age and overall condition, or seasons or weather conditions, hence the need for factoring in dedicated charge, increased panel size for simultaneous charge and draw, and/or 20% flexibility in system capacity.

**Note also that peak sun hour insolation levels are not the same as average insolation levels, and that panel watts are listed at nominal peak watt capacities. Concurrent draw should allow for float charge to continue to maintain batteries in a charged state, for as long as possible, before any sustained draw that will not be directly replaced before insolation ceases, as will be the case with night-time use.**

**Economies of scale** will be the ultimate arbiter of system size and capability, but there should be that surplus generating capacity factored into the system, ideally 20% for batteries **and** panels, (and thus inverter), which will account for component aging, and allow for some flexibility of usage. **The Multipurpose Solar Sizing Equation, MSSE, factors in this surplus, and for the reasons why, see the end of the section on Managing a Secondhand System, also monitreg customisation.** Otherwise, reduce daily watts accordingly, if capital cost is a limiting factor, and settle for a smaller system. Enabling consistent dedicated charge during the day will reduce the need for larger arrays, **but, draw still must match battery capacity.**

**However the planning is done, it must be thorough, as system purchase must be based on sound decision-making, and the consumer has to literally live with the result. The final arbiters of your PV system's overall effectiveness will be the verdict of your voltmeter, and especially, that of your ammeter. Therefore, it is strongly recommended that you do some surveying of existing systems, if possible, to gain information about overall performance in relation to size, especially useful when proposing solar power system operation in a similar local or regional setting.**

**Asymmetrical systems:** If a system size is decided upon, and there are budgetary or logistical problems that do not allow full and complete installation, **the batteries should be purchased first, even if the solar panels units are not complete. As long as charge regimes for the battery can be maintained, by whatever means,** the solar array can be added to as practicable, but the batteries cannot be added to in the same way, as they are purchased in a matching bank units, which cannot be so easily substituted. Whenever the array does not match the battery, as in either less than or more than what charging power is required, maintaining careful usage and charge regimes means battery health and longevity will be maintained. Solar arrays, if properly installed, **do not require the same attention as batteries, which must always have daily attention/monitoring as to usage and charge regimes.** Similarly, this principle applies when ancillary generation of water or wind charging power is not optimum or consistent, battery health must nevertheless be similarly maintained.

**Note: Compass bearings for solar panel siting are opposite for Northern and Southern Hemispheres.** Go to [Solar4Power.com](http://Solar4Power.com) [Global Solar Maps](#) for more details of sun-hour tables.

**Finally, re the choice of panel types**, for longevity, **single crystal**, >16% efficiency, will give the best service and **the lowest decline in efficiency**, also reflected in price, and are the first choice for reliable home solar power.

**Polycrystalline** are slightly less efficient than single crystal cells, >10%, are less expensive, but do have shorter lives. Could be >30% efficient, but no more.

**Amorphous**, or thin film panels, are 30% larger in relation to output, more efficient in heat, are robust, work well in diffuse light, but have shorter lives, and actually suffer an efficiency drop, >30%, before stabilizing at >6%-7% efficiency, aka the **Stabler-Wronski Affect**, broken covalent bonds, aka **dangling bonds**, being present after manufacture. Amorphous panels are also more heat-tolerant as far as efficiency is concerned. They are most useful in small, temporary or portable systems. Their technology and useful lifespan continues to improve, and they are also proving useful for flexible PV formats.

**Self-regulating panels**, although cheap, can lose their efficiency with high heat affecting this regulation, and also have shorter lives than single or polycrystalline cells.

These available choices will suit most budgets for some time yet, although there are promising photovoltaic R&D developments that have yet to reach the open market. For information on the present state of this research, see **Practical Photovoltaics**, R. Komp, aatec 2001, ISBN **09374811X**; Ch. 3, **New Developments in Photovoltaic Technology**.

**As of 2008**, PV module manufacturing methods include mono- and multi-crystalline, string ribbon, and thin film. (See also PV Energy Payback, [Homepower Magazine](#) #127)



5 amp solar panel, supporting a 12 volt battery backup circuit, in an area of unreliable main grid power, NSW.



80W Flexible Panel 2025

### Solar Radiation Microbursts:

“A nearly constant 1.36 kilowatts/m<sup>2</sup> (the Solar Constant) of solar radiant power impinges on the Earth’s outer atmosphere. Approximately 70% of this extra-terrestrial radiation makes it through our atmosphere on a clear day. SW USA solar irradiance at ground level regularly exceeds 100 watts/m<sup>2</sup>. In some mountain areas, readings over 1200 watts/m<sup>2</sup> are often recorded, when average values for other areas may be lower.

Maximum instantaneous values of 1500 watts/m<sup>2</sup> can be received on days when puffy clouds are present to focus the sunshine. These levels seldom last more than a few minutes, the atmosphere is a powerful absorber, and reduces the solar power reaching the earth at certain wavelengths, as well, clouds move.

The part of the spectrum used by silicon PV modules is from 0.3 to 0.6 micrometers, approximately the same wavelength to which the human eye is sensitive. These wavelengths encompass the highest energy region of the solar spectrum.

Optimum angle of incidence to the panel, and cool panel temperatures, will further enhance this microburst effect, as will clear air, with lack of smoke or haze, as well as the wispy/puffy cloud effect focusing the solar rays at the time. The ideal regions to experience this involve altitude, mountains, plateaus, or highlands, and not necessarily in the middle of summer, which will have much to do with panel temperature and air quality. Any breeze across panels will aid cooling, and thus efficiency, also”. (SANDIA)

This phenomena also explains glare and sunburn being enhanced under these and other cloud conditions, in any region. Diffused insolation does not necessarily mean reduced insolation, as evidenced by sunburn, and by solar power generation even without direct sunlight. Heavy cloud is required to block UV rays, to the extent that mainly visible light rays penetrate.

**Circa 2002 PV technology, 1 m<sup>2</sup> of PV panel in full sun will produce approximately 14% electricity, 100-140 watts, 7% reflectivity, and the balance is heat accumulation, hence the need for heat dispersal when planning panel location to optimize PV efficiency.**

### Some useful definitions:

**Photon:** Posited particle to explain photoelectric effect, and other phenomena relating to light. Quantum of light of electromagnetic radiation of energy,  $E = h\nu$ , where  $h =$  Planck’s Constant, ( $6.626 \times 10^{-34}$  Joules-seconds). No zero rest mass, but has momentum  $h\nu/c$ , where  $c$  is the speed of light, and  $\nu$  is frequency in cycles per second.

**Photoelectric Effect, or Photo-emission:** Emission of electrons from a body’s surface, (usually an electropositive metal), due to incidence of light. Critical wavelengths of the spectrum may cause photo-emission from differing materials, when incident energy exceeds atomic binding energy. See **Quantum Mechanics**, also emission of X-rays with the impact of high energy on a surface is an inverse photoelectric effect.

(**UV wavelengths are from 400>4 nanometres: smaller than 200nm, they will knock electrons out of orbit, important for life forms.** Thus, shorter UV wavelengths, (B @ 290-320nm, C @ 230-290nm, and below), with lengthening exposure, will increasingly disrupt more molecular bonds. Hence resulting cell and tissue damage, and the importance of having a stable ozone layer within the stratosphere to absorb shorter UV wavelengths. Just ask the citizens of **Punta Arenas**, they know.)

**Photovoltaic Effect:** The production of an EMF across the junction between dissimilar materials when it exposed to light or ultraviolet radiation. **Note that increasing temperature potentiates this Effect due to added energy facilitating electron-band transition, while heat will also increasingly inhibit metallic conductivity, ie, by increasing system circuitry resistance**, so, optimal operating temperatures are needed to ensure optimal system performance for P-V installations. This means adequate air circulation, or, other more direct cooling measures, such as utilizing direct heat transfer with liquid cooling. An ideal system compromise would be a P-V installation that also incorporated water heating by direct heat transfer from the P-V panels, especially in tropic zones.

**Photovoltaic Cell:** A class of photoelectric cell which acts as a source of EMF, and so may be independent of a battery in the provision of power, and with suitable voltage excess, may also charge a battery.

**Photoelectron:** One released from a surface by a photon, with or without kinetic energy.

**Photoelectricity:** Emission of electrons from certain materials by quanta exceeding certain energy, ie, critical wavelengths, for those materials. (Observed by E. Becquerel 1839, H. Hertz 1887, P. Lenard 1902, and explained by A. Einstein, 1904)

(**Chambers’ Scientific Dictionary**, 1992, and **Oxford Dictionary of Biology**, 2000. **Quantum Theory and Quantum Mechanics**, qv, also describe and explain these phenomena, information available in any up-to-date college physics text.)

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**Solar Sizing Tables: Nominal data, verify by sampling of in-situ performance testing!**

12 Volt			24 Volt			
Panels	watts	amps	panels	watts	amps	sets
<b>40x1</b>	40	3.3	<b>40x2</b>	80	3.3	1
2	80	6.6	4	160	6.6	2
3	120	9.9	6	240	9.9	3
4	160	13.2	8	320	13.2	4
5	200	16.5	10	400	16.5	5
6	240	19.8	12	480	19.8	6
7	280	23.1	14	560	23.1	7
8	320	26.4	16	640	26.4	8
9	360	29.7	18	720	29.7	9
10	400	33.0	20	800	33.0	10
11	440	36.3				
12	480	39.6	<b>60x2</b>	120	5.0	1
13	520	42.9	4	240	10.0	2
14	560	46.2	6	360	15.0	3
15	600	49.5	8	480	20.0	4
16	640	52.8	10	600	25.0	5
17	680	56.1	12	720	30.0	6
18	720	59.4	14	840	35.0	7
19	760	62.7	16	960	40.0	8
20	800	66.0	18	1080	45.0	9
			20	1200	50.0	10
<b>60x1</b>	60	5.0	<b>80x2</b>	160	6.6	1
2	120	10.0	4	320	13.2	2
3	180	15.0	6	480	19.8	3
4	240	20.0	8	640	26.4	4
5	300	25.0	10	800	33.0	5
6	360	30.0				
7	420	35.0	<b>120x2</b>	240	10.0	1
8	480	40.0	4	480	20.0	2
9	540	45.0	6	720	30.0	3
10	600	50.0	8	960	40.0	4
			10	1200	50.0	5
<b>80x1</b>	80	6.6				
2	160	13.2				
3	240	19.8				
4	320	26.4				
5	400	33.0				
6	480	39.6				
7	560	46.2				
8	640	52.8				
9	720	59.4				
10	800	66.0				
<b>120x1</b>	120	10.0				
2	240	20.0				
3	360	30.0				
4	480	40.0				
5	600	50.0				
6	720	70.0				
7	840	80.0				
9	1080	90.0				
10	1200	100.0				

**A Rule-of-Thumb test of in situ panel output, at any insolation time, is to read peak amps in full sun, then x 1/2, then x effective sunshine hours.**

**EF 1.5 means that 50% DOD of net bank equals 33.3% DOD of total bank  
40% DOD net equals 26.2% DOD of total**

**watts:- voltage = amps charge  
panels/sets in series give volts  
in parallel give amps**

**12v in singles as a set  
24v in doubles as a set  
36v in trebles as a set  
48v in quads as a set**

	Single Panel Sets				Multiple Panel Sets				etc.
System	12v	24v	36v	48v	12v	24v	36v	48v	
<b>Volts</b>	18	36	54	72	18	36	54	72	
<b>Amps</b>	3.3	3.3	3.3	3.3	6.6	6.6	6.6	6.6	
<b>Watts</b>	40	80	120	160	80	160	240	320	
<b>P/set</b>	1	2	3	4	2	4	6	8	

**Small capacity banks, utilized as UPSs coupled with high panel watts for Grid Interface credits, need appropriate monitreg settings, charging at the C/10 rate. Rule of Thumb for all systems is charge at the C10 rate, and draw at the C20 rate.**

### Standard Multipurpose Solar Sizing Equation:

Daily watts x efficiency/1.5 = required daily watts :- voltage = daily amps  
 Daily amps x 5 = 5 days nominal storage, 2 'days' being equivalent to 40% DOD.  
 Daily amps :- latitudinal sun hours = hourly amps  
 Hourly amps x 24 = panel size, scaled up from sizing [Tables](#)

This standard equation can be manipulated to account for individual components, eg to match a set of panel amps to RDW, and/or storage, reverse the process. **Efficiency Factor 1.5 remains the same, but latitudinal sun hours, relative geographical location, alter other factors accordingly, as do differing system voltages.** The 1.5 E Factor ensures that of every 10% DOD, 6.25% would be available power, and 3.75% would account for system loss that would be made up by the extra charge in the subsequent charge cycle, approximately 30% of the recharge total. This is why staying within the Daily Watts total is important, especially for stand-alone systems, as **Required Daily Watts is Efficiency Factor plus Daily Watts.**

In the end, ability to maintain optimum charging cycles will determine battery use, but optimum usage cycles are also important to long battery life. Stay within 40% DOD, (25%+15%), and upgrade when necessary, while there is trade-in value!

### Simple thumbnail ratios:

These are relative to latitudinal sun hour zones, and for **24 volt systems** are expressed thus: required daily watts: panel watts, and panel watts: amp hour storage

2 sun/hours	RDW 2 : PW 1	PW 2.4 : 1 A-H storage
3	RDW 3 : PW 1	PW 1.6 : 1 A-H storage
4	RDW 4 : PW 1	PW 1.2 : 1 A-H storage
5	RDW 5 : PW 1	PW .96 : 1 A-H storage
6	RDW 6 : PW 1	PW .8 : 1 A-H storage

The panel watts:storage ratio is then expressed as panel watts :- storage x 100, so that at 4 latitudinal sun hours, which is mid-latitude, there should be:

60 watts per 100 A-H storage for 12 volt systems,  
 120 watts per 100 A-H storage for 24 volt systems,  
 180 watts per 100 A-H storage for 36 volt systems,  
 240 watts per 100 A-H storage for 48 volt systems, and so on.

### Battery storage ratios:

12 volt is 2x 24 volt storage,  
 is 3x 36 volt storage,  
 is 4x 48 volt storage.

### At 4 sun hours, and DW of 500 watts:

500x1.5 = 750:- 12= 62.5 x 5 = 312.5 A-H storage; 62.5:-4 = 15.65 x 12 = 187.5pw  
 scaled to 200 pw @ 16.5 amps, 5x 40 watt panels as singles.

500x1.5 = 750:- 24= 31.25 x 5= 156.25 A-H storage; 31.25:-4 =7.8125 x 24 = 187.5pw  
 scaled to 240 pw @ 9.9 amps, 6x 40 watt panels as 3 sets of 2.

500x1.5 = 750:- 36= 20.83 x 5= 104.16 A-H storage: 20.83:- 4= 5.20 x 36 = 187.5pw  
 scaled to 240 pw @ 6.6 amps, 6x 40 watt panels in 2 sets of 3.

500x1.5 = 750:- 48 = 15.62x 5 = 78.125 A-H storage; 15.62:- 4 = 3.90 x 48 = 187.5  
 scaled to 240 pw @ 6.6 amps, 8x 40 watt panels in 2 sets of 4.

2 volt cell resistivity, which may range from 7-8 ohms, resting, fully charged, will account for 3-4 amps of extra charge before raising the charge for full boost and/or equalization, (eg, for 24v :- 7.5ohm = 3.2 amps, adjust equation for other voltages), **to which must be added BOS resistance, plate condition, and heat etc.**, about 2 amps extra.

Thus, 15 amps of charge will be delivering 10 amps net for full boost/equalization, hence the 30% extra charge factor, and why 15.5 amps is the 24 volt charge optimum for panel amps for small systems, to minimise ancillary charging. **This translates to approx. 10+3.6a/12v, 10+5.2a/24v, 10+6.8a/36v, and 10+8.4a/48v to overcome system resistance, yet deliver float, or, charging amps when attempting high finishing charge.** Resistance is also lower in intermediate ranges of electrolyte replenishment, rising again with electrolyte depletion in discharged batteries, hence, early charge resistance. **Temperature control is important.**

NB, optimum **energy density** of an FLA battery is between 30°C-40°C, but 25°C maximum limits chemical aggression and self-discharge. Operating increasingly below 25°C, means a longer, but more sluggish life, as the electrolyte has increased viscosity with lowering temperature, which retards ionic transfer, and thus plate reaction. However, the more sulphate on the plates, again, the lower the rate of ionic transfer there is, as well as the sulphate, (either soft or especially the hard crystal form), passivating the reactive plate material. Thus, increasing cold and viscosity will only make the **performance** of a less-than-optimally charged battery even worse, although the decrease in potential

**voltage** will actually be only .05% per 1°C decrease in temperature. Warming a battery will still only be effective to the extent of usable reactive elements present to supply current on discharge demand.

#### Power Consumption Equations, all voltages, AC or DC:

$$W = V \times A \quad V = W \div A \quad A = W \div V \quad V = A \times R$$

$$VA = \text{Amps} \times \text{Mains}$$

$$R = V \div A \quad A = V \div R \quad W = A^2 \times R \quad R = W \div A^2$$

$$VA = \text{Watts} \times 1.6$$

$$A^2 = W \div R \quad W = \text{watts}, V = \text{volts}, A = \text{amps}, R = \text{ohms}$$

$$\text{Watts} = .66 \times VA \text{ or } 60\% VA$$

The most effective panel angle for utilizing sunlight has several variables, viz., the correct angle for latitude, the season and/or time of day, weather, sunlight intensity, and the possible degree of variation from any optimal angles, especially if a mechanized solar tracker is not used; hence the importance of correct data to enable a relevant MSSE calculation to be made.

#### Approximate panel efficiency v. sun incidence, relative to latitude:

Lat0°/90° incidence(100% efficiency, 25°/75°->95%, 45°/45°->75%, 60°/30°->50%, etc.

However, the final arbiters of your PV system's overall effectiveness will be the verdict of your voltmeter, and especially, that of your ammeter. Therefore, it is strongly recommended that you do some surveying of existing systems, if possible, to gain information about overall performance in relation to size, especially useful when proposing solar power system operation in a similar local or regional setting.

**Electrical Inversion Technology:** The inverter changes the DC current stored in the batteries into usable AC current which is the most common type used by most household appliances and lighting, irrespective of main grid voltage. Inversion is attained, in these days of semiconductor technology, by sophisticated transistor or thyristor oscillator switching, in an **inverted rectifier** circuit, converting continuous or direct current into alternating current that is then **transformed** into the specified AC voltage. The main component for this type of electrical conversion/inversion is the **rectifier**, which also turns AC into DC in a unit usually called a **converter**, although this term may also be, rather misleadingly, used interchangeably with the term inverter.

Older inverters are **square wave**, robust, heavy, useful with conventional appliances and motors if present, but not so compatible with modern electronics. A light may be needed to activate the circuit, and to quell noise or interference that will interfere with computers and televisions. **Stepped wave** or **modified sine wave** inverters have a square wave that is stepped to reduce this interference, and to facilitate switching. **Sine wave**, or **true sine wave** inverters are the most modern and sophisticated, with comprehensive electronic cybernetic circuits and programs, and are the most compatible with modern electronics.

Inverters carry two specifications, for **continuous watts**, and for **surge watts**, which is supposed to be momentary, and for appliances with transformers and, especially, electric motors. Motors will need extra starting power if they are out of sync with the current at switch-on, and also if directly loaded, with a lag before reaching efficiency in performance **after** starting.

There is also **energy loss as heat** to be accounted for with inverter function, about 10%, so this must be accounted for when sizing power systems, as with the 1.2 inverter loss factor used in the SSISE equation below. Thus, keeping an inverter cool and well-ventilated is as important as for panels and batteries, and an inverter should be permanently situated in a dedicated inverter annex, away from the potentially corrosive or inflammable vented oxyhydrogen gas hazard of a battery bank, which itself should have **separate, and adequate**, ventilation.

#### Standard AC-DC Inverter Sizing Equation:

1. Enter the total watts expected to be used by your AC loads running simultaneously. You most likely will not, should not, have all of your appliances and lights running continuously at the same time. **(A true sine-wave inverter is preferable.)**
2. Enter **measured** surges required to start any electrical motors.
3. Add line 1. and line 2. for total watts of power needed.
4. Multiply the sum of line 3. by 1.2 to account for inverter loss, (approx 10%). This is the power rating you need to match with your inverter specifications.
5. If you can afford it, you may want to increase the size of your inverter to allow for unanticipated extra electrical loads, **but only in relation to existing battery capacity. Remember, sustained discharge at C20 rate, charge at C10 rate.**

The foundation of inverter sizing is, therefore, battery sizing, based on load, DOD, ambient temperature range(s), and discharge rate, as per Peukert Effect, (Bill Darden, Appendix 3/15) These factors are based in turn on accurate and realistic calculations of usage requirements. This must all be factored into Daily Wattage for the MSSE to be valid, and thus the consequent inverter sizing. All these factors are interdependent, so spend optimum time on all aspects of system planning!

**Photovoltaic and ancillary electrical generation system charge controller:** Charge controllers/monitor-regulators/monitregs are included in PV systems to protect the batteries from overcharge and/or excessive discharge, and some panels are actually self-regulating. The minimum function of the controller is to disconnect the array or panel when the battery is fully charged and/or to keep the battery fully charged without damage, **regardless of the source of charge. The charging routine is not the same for all types of batteries, FLA batteries have specific chargers and charge regimes.** (See also [Easy User's Guide](#) and [Battery Wallchart](#)).

**The basic criteria for selecting a controller include the operating voltage and the PV array current, and a correct match must be made.** The controller must be sized to handle the **maximum** current produced by the PV array, and also for equalization of in situ batteries. Controllers are critical components in stand-alone or non-interfaced PV systems, because a controller failure can damage the batteries or appliance load.

There are two types of controllers: **series and shunt**. **Series controllers** stop the flow of current by opening the circuit between the battery and the PV array. **Shunt controllers** divert the PV array current away from the battery. Both types use solid state battery voltage measurement devices, and **shunt controllers** are 100% **solid state**. **Four-stage monitregs should be used for managing deep-cycle batteries.**

**Always carry out testing of monitreg performance at regular intervals, because even solid state may fail, for one reason or another, and prevent battery exposure to extremes of temperature to ensure longevity and reliability. Use of a digital multimeter and hydrometer will help to provide independent calibration data.**

**For Monitreg Sizing**, ascertain the peak panel or panel module amps, either as specified, or by using performance test data, by dividing rated watts by the peak voltage in full sun, or, where applicable, calculate peak amps based on panel and module configuration, or, simply utilize an amperage meter reading taken in peak sun.

The total solar amperage generated must be included, **because the monitreg will need to be no less than this in rated capacity**, and should ideally be slightly larger, **and also allowance could be made at this stage for possible solar array enlargement**. Too-small will still work, but, only at rated capacity, choking watts. (Note that amperage readings are taken along the positive wire in a circuit, not across as for voltage and resistance, and a dedicated amperage testing circuit is required.)

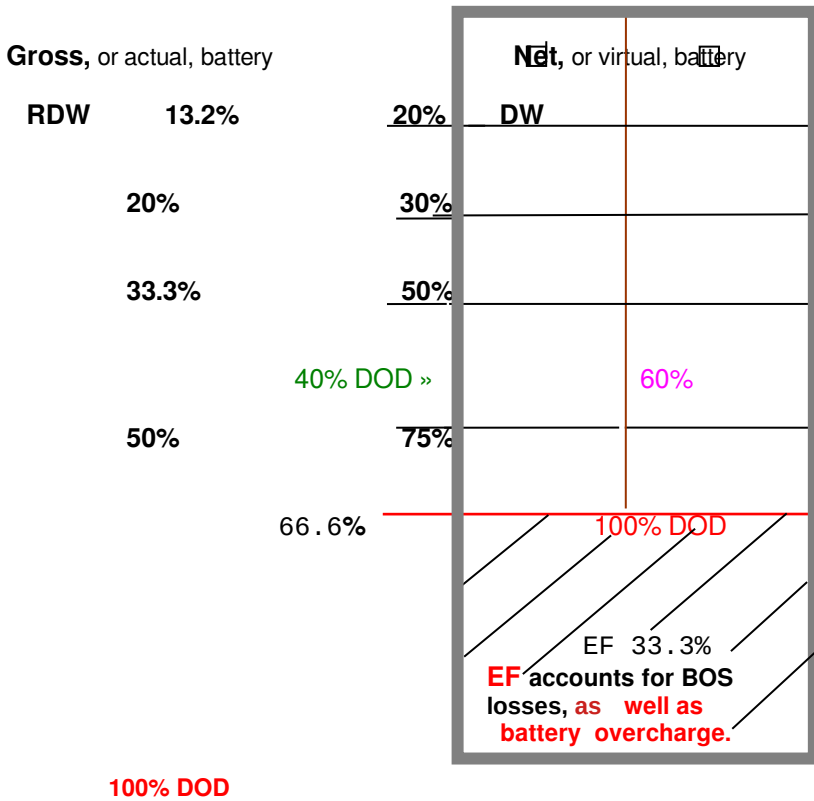
**Charger size and type** will depend on system voltage, and current needed to reach battery equalization voltage. If there is a sizable amp-hour battery, <75-100ah, a **dial-up charger** is recommended, usually with a preset system voltage selection incorporated, so that charge can be adjusted to circumstance as well as to system voltage. This is not only just for battery needs, but also if charge is concurrent with continuous shared **and steady** power use, such as with a generator, the charger can be adjusted for the net charge performance required at the time.

However, the monitreg will ultimately control the amount of charge to the battery, so the charger should at least match the monitreg capacity. Any excess charge will be ignored by the monitreg, so care must be taken to see that the dialled amperage is relevant to the charge cycle at the time. Unless there is a self-monitoring system in use, periodic checks during charging are necessary to co-ordinate charger and monitreg functions, to avoid overuse of ancillary charge. Even with grid interface, this proper co-ordination of functions should be monitored whenever it is necessary to recharge the battery from the mains.

**Wiring** and other BOS specifications will be according to local and regional codes, and solar installation will legally require licensed AC and DC technicians. The rule-of-thumb is that the smaller the wire for any given function, and distance traversed, the less efficient the flow of current, the more resistance, and the more power loss to heat. Similarly, other fixings, joints, and contacts should be of optimum size, all of optimum quality, and properly installed for safety, as well as for optimal system efficiency. There must be fail-safes, earthing, isolating utilities such as suitable diodes, fuses, corrosion prevention, and cut-off switches, built into the system as well. (See also **Solar Installation and Safety**) **Grid interface**, if intended, would only be permissible, and even advisable or possible, if the system installation was properly and legally performed.

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**Relative Usage Battery Chart:**



**Monitreg Readings**

**Unmonitored, DW calculation only**

**In relation to Daily Usage calculations:** For every 10 amps used, 13.3 amps must be replaced by charge, 33.3% as extra charge, due to resistance and BOS loss. This is factored in as the 33.3% EF. Monitor reads only RDW, so maintaining DW usage will automatically ensure RDW parameters are kept, ensuring easy cycles, easy management, lower maintenance, and thus battery health and longevity.

**W = V X A    V = W :- A    A = W :- V    V = A X R**

**VA = Amps x Mains**

**R = V :- A    A = V :- R    W = A<sup>2</sup> X R    R = W :- A<sup>2</sup>**

**VA = Watts x 1.6**

**A<sup>2</sup> = W :- R    W = watts, V = volts, A = Amps, R = ohms**

**Watts = .66 x VA or 60% VA**

**Thumbnail version of the Multipurpose Solar Sizing Equation, MSSE:**

1) Projected **daily wattage** needed first must be calculated, and expressed as watts x hours, (w-h), watts being a constant measure of power used, irrespective of voltage. **Read the wattage on appliances to be used with the basic solar system, (regardless of any concurrent sunlight), including batteries and inverter,** and multiply by the average number of hours or part-hours in use in each **full day**, ie, 24 hours.

**Remember that the projected load must be directly related to projected inverter capacity and battery size, expressed in amp-hours, and to a C20 discharge rate for that battery bank.** Any extra charge that you may need for an optimum charge routine within the 24 hours will need to be supplemented from ancillary charging sources, and **over-capacity draws will need to be directly supported by a generator overriding battery or solar input, although concurrent opportunity battery charging may be initiated, and monitored if necessary.**

2) **There will be a marked difference between summer and winter solar input in lower latitudes,** but the MSSE also uses average yearly sun hours for respective latitudes to calculate the optimum battery and panel size. **The MSSE has Efficiency Factor of 33.3%, plus a Usage Buffer of 20+% utilising given Global Solar Sun Hours.**

However, if you wish to base your overall system size on winter wattage consumption, then use those particular figures, if not just for determining the optimum solar system requirements, but also to get a realistic idea of ancillary generating demands, depending on the budget and/or meeting peak demands such as for a dwelling with only occasional short-term occupancy. This dwelling may then have a smaller than optimal system, **with direct power use at peak demand direct from a generator,** and normal solar recharge at other times.

**Remember that sun-hours reflect average peak sunlight hours only, under ideal conditions, hence the importance of conservative rates being used, to allow for less-than-optimal conditions at any time throughout the year.**

3) **A basic home solar system** will provide enough power for intermittent lights, small TV, computer, radio/cassette, and short-term use of a small motor such as for a blender. Other appliances such as microwaves, or those with motors, such as frigs or freezers, even if they have modern lower power demands, **must be matched to optimally sized solar systems to meet such demands, including an optimal inverter, with or without sunlight. Elements such as in kettles or toasters, or combination motor/element appliances such as hairdryers, most probably cannot be supported entirely by the average home solar system for any period of use. Consult!**

4) **The MSSE is as follows:**

$$\frac{\text{RDW}}{\text{DW} \times \text{EF}} = \text{V} = \frac{\text{S}}{\text{DA}}, \text{ DA} \quad (2 \text{ 'days' } = 40\% \text{ DOD})$$

$$\text{: - SH} = \text{HA}, \text{ X V} = \text{PC}, \text{ expressed as PW or PA, scaled ad hoc}$$

**DW** is Daily Watts, **EF** is Efficiency Factor, **1.5**, **RDW** is Required Daily Watts,

**DA** is Daily Amps/amp hours required, **S** is Storage in amp-hours, **SH** is Sun Hours,

**HA** is Hourly Amps, **V** is Volts, **PW** is Panel Watts, **PA** is Panel Amps,

**PC** is Panel Capacity, combined watts and amps, **subject to scaling up, see also Tables.**

5) **As an example for a 24 volt system, the MSSE would configure as follows:**

$$\frac{750}{500 \times 1.5} \times 5 = 156.25 \text{ A-H, scaled as necessary}$$

$$500 \times 1.5 = 24 = 31.25,$$

$$\text{: - } 4 = 7.8125, \text{ x } 24 = 187.5 \text{ scaled to 240 watts@ 9.9 amps}$$

'4' in the example is Mean Annual Daily Sun-Hours for Latitude 35° South

The **C20 discharge rate battery** is 1/20th of the 10 A-H rate, ie, X amps over a 10 hour period, **and will depend on given battery specifications**, consult your dealer to decide battery standards required, **but it would be advisable to allow a margin**, even if you never do intend any such degree of sustained discharge over such a period.

For a 24 volt system, 240 watts@ 9.9 amps would require 4 x 60 watt panels linked in 2 series sets of 2 in parallel, or similarly, 6 x 40 watt panels in 2 sets of 3.

Note that the MSSE can be manipulated to calculate all parameters from any given figures of DW, DA, S, or PC, as long as sun hours, SH, and volts, V, are relevant.

**Data re grid interface costs and benefits would be obtainable from regional grid electricity suppliers if this is a prospective component of the home solar system. Fiscal return from such an interface may enable the purchase of a larger system.**

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**STANDARD RESTING CHARGES, 2vpc cells, SLI and Deep Cycle @ 25°C** (.01-.05v vpc difference fully charged is OK, all vpcs drift over time, and cells will trickle discharge also, when not in use, hence float (volts), & trickle (amps), charging.)

SOC%	12 VOLT	24 VOLT	VPC	
100	12.70	25.40	2.12/5	max 2.583vpc @ 15.5v and 31v resp.
90	12.50	25.00	2.08	
80	12.42	24.84	2.07	20% SLI battery cycle maximum
70	12.32	24.64	2.05	
60	12.20	24.40	2.03	40% solar battery optimum DOD
50	12.06	24.12	2.01	50%
40	11.90	23.80	1.98	<b>RULES of THUMB:</b>
30	11.75	23.50	1.96	SG+0845 = vpc, resting charge
20	11.58	23.16	1.93	80% Ohms pc = 7.5, full r. charge
10	11.31	22.62	1.89	(both @ 25°C, normal acid range)
0	10.51	21.02	1.75	Full DOD

**24 volt deep cycle cells:** Do not discharge below 20-40% resting charge if possible. Battery (bank) will charge to 25.4v+ by PV or generator, (each day if possible), but for optimum battery health, a proper charging regime should follow, min. 2 hours per month. Equalize when there is a min of .2v difference between cells, regardless, smaller batteries will require less electrolyte de-stratification. Routine charging should extend into absorption @ 25°C and above, up to 28.6v; and beyond absorption, up to 29.6v, when below 12.7°C. (NB, for 12v halve 24v values) AGM and Gel VRLA battery maximum charge input is >2.35 vpc, use dedicated VRLA regulators!

**Boost** @ 20 amps to 30v, briefly, full charge @30v is 2.583 vpc, incl.  
**Absorption** 27.2v to 28.4v, charge rate may slow slightly. Then for  
**Equalisation**, Take to 31v, taper amps to maintain venting 30-31v, 30 to 180 mins.  
**Float** Drop amps, taper to 25.6v-26.4v, maintain 2.15-23 vpc.  
**Rest** Being fully charged, 25.4v, @ 2.12-15vpc, EMF/OCV

**IN DETAIL:** Advance charge, up to 20 amps, and raise only when needed to initiate **equalization** at 31 volts, and for **de-sulphation**, when amps are then tapered, to enable a vpc of 2.4/5v. Both may be concurrent. **Bubbling and venting at 30-31v will be sufficient for equalization.** Bubbling begins at 2.2vpc, so beware of overcharging beyond 31v, damaging and unnecessary, causing heat and plate breakage.

### TRUEST VOLTAGE READINGS ARE TAKEN DIRECTLY FROM THE BATTERIES, WITH A RELIABLE HANDHELD DIGITAL VOLTMETER

**HYDROMETER:** good SLI 1275 to 1300, DC 1220 to 1240 Test for SG peak during equalization then discontinue charging. Add or subtract .004 for each 5°C above or below 25°C for SG correction.  
 sat “ 1225 to 1250, “ 1200 to 1220  
 poor “ 1150 to 1200, “ 1100 to 1150

**Voltage and hydrometer readings should always be concurrently optimum.** Battery capacity is progressively limited with cold, factor this into winter usage calculations. Freezing point means 35% capacity reduction, plus the added limitations caused by age and condition. Heat and/or poor plate condition cause resistance, and cold limits capacity. Battery temperature and state will influence charging, by PV or generator. Battery life is halved by every 9°C over 25°C, if unregulated. **Temperature regulation for battery banks is strongly recommended.**

**Capacity to receive charge v temp: Fully charged & good SG; @ 27°C, 100%; @ 0°C, 65%; @-18°C, 40%.**  
**Battery temperature, 25°C for optimum performance, 25°C maximum for PV panels. The quicker and higher the charge return and hold, the healthier the battery. Allow adequate time for plate reformation, the key to optimum battery charging and long-term health.**

A brewstrip thermometer on the battery, plus calibrating wall thermometer, account for temperature lag. Ensure adequate ventilation of batteries at all times. Rotate end battery positions minimum once per annum, ad hoc, to maintain uniform condition.

Regular top-ups and/or trickle charging are needed when batteries are not in use, see FLOAT above, and the normal charge routine still applies. Always use 4-stage regulators to taper any charge, especially during unattended operations. When fully charged, anodes (PbO<sub>2</sub>) should be noticeably chocolate, and cathodes (Pb) grey, in colour.

Slow and steady C10 charge and C20 discharge best, 20-40% discharge optimum for longer battery life, with no large quick drains or shallow cycles under 5%. Use a generator at high demand periods, and for PV charge cycle lag and/or equalization.

Make a chart to track individual battery health, record readings regularly. Always check connections and wiring first when faultfinding, before more complex steps.

### Customise these Wallchart figures according to ambient temperatures, plate chemistry, manufacturer's specifications, and/or individual PV systems etc., when necessary. AGM and Gel VRLA battery maximum charge input is only up to 2.35 vpc, use dedicated VRLA regulators! ###

## An Easy User's Guide to Care & Maintenance of Solar Power Systems:

**Batteries:** Lead-acid 2vpc flooded systems are the optimum for domestic solar, connected in series, for safety and longer life, and ideally operated at 25°C. AGM batteries (absorbed glass mat), are the best, needing less maintenance, but are 2x the expense. Gel and low-maintenance batteries are for special safety-related or access applications, and have a shorter life, and both AGM and Gel batteries have specific charge regimes. **All FLA lead-acid 2v cells have similar SG, and charge regimes.**

Non-sealed batteries should be maintained at optimum electrolyte level, with mineral free water. Only test with the hydrometer once each time, carefully, as false readings result from disturbance of the electrolyte. Do not bubble air onto the electrolyte. Never add extra acid, **the normal ratio of 35% of H<sub>2</sub>SO<sub>4</sub>:65% H<sub>2</sub>O** is set at first fill. (Depending on climate and application, the acid range may be 28%-42%, but this Manual assumes the normal parameters apply, including for charge ranges. Consult battery manufacturers for more specific data.)

**The SG level should be maintained between 1220/1240 for deep cycle batteries, the H<sub>2</sub>SO<sub>4</sub> electrolyte being denser than water. (See [Wallchart](#)) Number all batteries, and record all readings. (Battery temperatures of range 60°F-70°F/22°C-27°C are ideal.) Note that there should concurrently be good SG and good uniform charge in all cells, and equalization must be regularly performed to maintain this balance.**

On newer systems, when normal usage and charging are maintained, SG testing should be done at least once a quarter. More frequent testing may be necessary for all systems when extra charging is required, as for age, or when a fault is suspected. Winter may give higher SG readings, which should be factored into performance observations.

**Remember TECSSS in relation to electrolyte condition: temperature, electrolysis, charge, stratification, sulphation, shedding. Temperature** affects density, **electrolysis** affects fluid and H<sup>+</sup> ion loss, **charge** affects reactant equilibrium, **stratification/destratification** affects electrolyte mixing, **sulphation** affects sulphate ions in solution, plus passivation of plate reactants with bond changes, and **shedding** affects useful plate reactant availability.

Do not test for 7 days after adding water, to avoid false readings. Test 6 hours after any generator charge, or after equalization, test any other time at rest and/or during solar charging. Leave dust caps loose to vent excess hydrogen, to keep out dust, and to provide a slight vapour layer above the electrolyte. More sophisticated caps reconstitute water from the hydrogen and oxygen gases. **Test during equalization only to determine de-stratification progress. Always maintain adequate ventilation, and the commonsense management of an inflammable gas, in this case, oxyhydrogen gas!**

**Charging:** Routinely monitor the system, during solar and generator charging, and during usage, for efficient use, maintenance, and long battery life. **RTFM!!!**, and/or follow professional advice. **USE A HANDHELD DIGITAL VOLTMETER ON INDIVIDUAL CELLS, AND BANK, FOR TRUEST READINGS. THIS IS MOST IMPORTANT, ESPECIALLY WHEN HIGH-CHARGING, AS DURING EQUALIZATION.** The voltmeter should be accurate to .5%, digital is preferred for ease of reading and exactness.

**Use longer slower generator charges to build to optimum levels when using a generator, high fast charging should be used sparingly, if at all. 15-20V SHOULD SUIT MOST 24v SYSTEMS, 15.5V will fully charge 2v cells, including to equalization.** Several such slow charges in succession may be needed if batteries are low, use SG testing to monitor progress. The battery may resist charge in cold temperatures, and slightly higher levels of charge may need to be programmed if possible.

Avoid surges and overloads on the charger if concurrently using more than one appliance, and monitor the charge rate regularly. The rate will drop normally as the batteries gain charge, so adjust charge, unless the charger has a preset rate system.

When solar and generator charge are consistently less than optimum, batteries should receive a maximum generator EQUALIZATION charge of 30-31v volts once per month, for >2 hours. For high tech monitregs, ensure enough charge to attain absorption and equalization phases. PV amps of 15-20 amps should enable equalization without the use of the generator in sunny periods, but check that programmable regulator-monitors can sustain their programs, and use the generator when testing indicates that this should be done. (RTFM and/or seek expert advice). Fully charged resting charge is 25.4 volts. Monitregs always should be of the 4-stage type for long-term battery health, and 3-stage for SLI and VRLA-type AGM and Gel.

Steady charge/steady discharge is the ideal regime for deep cycle batteries, avoiding extreme, rapid, or shallow cycles, especially 5% or less DOD. This ensures proper chemical reactions, optimum plate reformation, and stable chemical equilibrium stages, both of which ensure longer useful battery life. Note that FLA deep cycle and SLI batteries perform differently, and have different applications. (See [Appendix 1](#)) **There is no substitute for regular and consistent personal monitoring of your system with hydrometer and handheld voltmeter.**

The best solar charge is usually before 3pm, with winter charge correspondingly lower; although the panel efficiency will be greater when cool, the batteries will be more sluggish in winter. There will be some charge on most cloudy days. Any early am generator charging, when required, enables additional top-up charge to continue for the remainder of sunlight hours, at any time of the year. Latitude, geography, and weather patterns will differ from region to region, and may affect panel placement for optimum performance.

**If the batteries are not temperature-controlled, winter will require longer generator input, because of lower battery temperatures limiting charge-holding capacity. Also, raised temperatures are to be avoided, especially during summer high-charging, which promote chemical aggression, hard crystal formation if advanced sulphation is present, and water loss. Thus, battery storage (always ventilated), should be insulated, and maintained at 20°C-25°C during all seasons where possible, and/or practicable.**

Perhaps a loop from the HW system could be utilised, especially a solar hot water unit, set to ensure 60-70°F/20°C-25°C range, for optimal battery performance in winter. Cool temperatures will prolong battery life, even if performance is limited, **but battery life will halve for every 9C above 25°C, if sustained.** Annual temperature cycles will cancel themselves out, but sustaining optimal

operating temperatures will ensure consistent charging and power output, as well as longer life. Temperature extremes mean simple mechanical stress, usually limiting the anode life due to extra shedding of electrode material.

**New batteries should be fully charged, then record reference SG readings. Several cycles will pass before the batteries are performing optimally, after which benchmark performance readings may be taken.** (Panels may also take time to settle down when new, then reducing output slightly). **Never mix batteries of differing ages, capacities, or conditions**, and always install in series, rather than parallel, to avoid possible damage to the entire bank caused by one faulty battery, or a system short. Series also enables faulty cells to be identified easily and early.

**Note that, with optimal battery temperature, a quick charge, and hold, response, either solar or generator, indicates healthy batteries, and given optimum specific gravity. Do not discharge batteries below 40% SOC capacity if possible, aim for 10-20% depth of discharge. Continuous small cycles of less than 5% DOD are also damaging, so ensure an occasional drop to 40% DOD, followed by a complete charge cycle. 80% DOD is possible, but only in emergencies.**

Battery back-up sizing of a nominal 3-5 days capacity really just ensures that there will be no irregular deep cycling, and enables optimal charging to be easily facilitated. Boost charging **every** day, especially in winter, should be standard, regardless of system size, if there is daily discharge. **All boost charge cycles should be completed when undertaken, with equalization at regular intervals. Ensure that educated and effective back-up will monitor the system during vacation or non-occupancy. At a minimum, ensure checks for battery float charge, SG, and regulator function, even if there is no usage.**

### System Usage Details:

**Daily:** do not load the system beyond system specifications or go below 40% DOD, resting charge. Modern systems have cutout circuits. With small motors, plan transitory use only, preferably on sunny days. Start the generator for prolonged use. **Remember  $V \times A = W$ , et al. Respective system component specifications must be known for usage guidelines, ensure that these are recorded at time of installation.**

**A nominal 3-5 day battery capacity (without sun) should be factored into battery size, and the array should provide a minimum of 15-20 amps average for healthy charge, and 40% DOD cycles with the generator only as backup.** (see Sizing Tables.)

**Use the generator for all other high loads, to inverter specifications. Beyond this, use a generator directly, to its own specifications. (Welding requires a minimum of 5-6 KVA). Avoid sudden loadings or surges when using the inverter or the generator, and especially when using the generator for charging. Monitor the load if there is no self-regulating charger operation in use. Use common sense in these matters.**

Lights, computer and TV use as normal, but do not many appliances at once, use consistently, and **always monitor usage. Avoid using elements, motors, microwaves etc., through the inverter. Water pumps** (small), may have transitory use, if part of the original system design and specifications, otherwise utilise a gravity tank and/or generator power.

**Organising activities and generator usage for hybrid systems optimises battery power and generator use, and battery care.** E.g., using computers, small battery charging, hi-fi etc., on sunny days may postpone generator use, after initial boost charge, with careful system monitoring. Washing machines, power tools, ancillary charging, pumping-up, etc., should all be planned for concurrent and/or consecutive use with a generator, depending on generator capacity and consistent load. **Seek professional advice on all proposed usage when in doubt. See below re high demand usage.**

**Weekly:** Maintain consistent charge to ensure continuing SG of 12.2/12.4, and min 90% 25.4v charge using PV, test if necessary. Values will be lower in winter if the batteries are unheated. More ancillary charge input may be necessary, and the monitreg should be set accordingly

**Monthly:** Charge to maximum equalizing levels, as listed above, relevant to system specifications. Check SG, vpc, water levels, keep battery area clean and dry, check all other equipment incl. panels, wiring, etc. for any defects. **Check all battery readings and monitoring history for any signs of system defects becoming apparent, or any leaks or discharges. Test connections first when faultfinding, before more complex equipment modules.**

**Possible Faults:** Use a hand-held digital voltmeter to check voltages. A monitreg can freeze, absorb or block charge, and give erroneous readings. Check any programmable regulating equipment. Faulty battery cells may not be apparent during charging, only during repeated testing. **Serious battery defects will manifest in unusual charging requirements, but should be identified beforehand to protect other system components.** Make allowances for battery temperature fluctuations.

**Sulphation could be controlled by an electronic de-sulphator, but smart management will prevent this occurring!** Avoid leaving batteries in discharged state, as this increases sulphation reaction, especially in warmer conditions. **Records are important, and, with consistent usage, will both assist in fault finding. Habits of management should always be consistent.**

**In general, monitoring equipment may vary slightly in respective readings, but what is important is a consistent pattern of readings that indicate health and optimum system function.** Note that longer wiring to ancillary monitoring sites may show slightly lower voltage differences. Switch off all unused appliances at the wall to prevent low-level power loss, aka ghost or phantom loads. Switch off circuit breakers to test systems or to undertake maintenance or repairs.

**Think Safety, OK!**

**Fuses should be fitted to both the PV and the battery banks.** Check function of panel fuses or circuit breakers. Batteries in series also control any individual battery short circuits. Check for dampness and corrosion that may affect connections, and for panels that may need cleaning for optimum performance. A fungicide application may be periodically required in some climates. No shade should obscure the panels, at least during optimum sunlight hours. Quality panels have blocking diodes, but optimum panel insolation is the objective of the exercise!

When lightning threatens, disconnect all appliances, and panel array if this is possible, as well as the telephone, if in residence. A lightning conductor above the panels could be an option in high risk areas, seek advice.

Note that a small light may be needed at times for smooth switching of appliances, and to trigger low wattage lights, with early-model inverters. Some appliances with transformers may need this assistance to function properly, eg TVs and 240/12 volt battery chargers. Square wave inverters may also be incompatible with some appliances, however, sine wave inverters are becoming the norm in modern systems.

**The key words for effective management of solar systems are “optimum”, “consistent”, and “habituation”, ie, optimum charging and charge maintenance, and consistent patterns of usage within system specifications, and careful habituation of testing and maintenance.**

**Caveat Emptor:** Optimum panels combined with maximum+ capacity batteries, and 3-5 days sizing storage in average conditions, will ensure longer battery life. Less battery capacity, in relation to panels, will mean cycling more frequently, thus needing sooner battery replacement, whether optimally charged or not. Systems may be either 12/24/32/48 volt DC, all based on 2v cells, as well as incorporating inverted mains power, and can have ancillary batteries charged from the main system for specific uses, and back-up. **Be sure to examine these options and possible combinations carefully before committing to a new system.**

Plan for long-term viability, optimal charge and maintenance, consistent usage, and maximum life of all components. 24 volts with 2vpc cells in series is the most common Australian battery conformation, with inversion to 240 volts. Allow for 15-20 amps PV charging and maintain optimal charge, and operating temperature wherever possible. **Equate affordability with projected ancillary charging needs and means.**

Note that automotive batteries are not suited to deep cycle conditions, 20 deep cycles would usually cause severe damage, as they are built for short discharge, and quick recharge. So, if such batteries are used in a solar system in lieu of solar batteries, (in emergency or other temporary situation), such use should approximate their normal working conditions as much as possible, with limited uniform discharge, followed by swift, and regulated, recharge. The configuration of such temporary batteries must provide equal voltage as per system specifications, whether battery bank connection is made in series or in parallel. **ATTEMPT THIS ONLY IF YOU ARE SURE OF THE OUTCOME.**

**For the average user, system maintenance and monitoring need only involve monitoring the charge, observing optimal charge/discharge ranges, and percentage charge levels, as per their system specifications, while maintaining consistent patterns of use, clean batteries, correct electrolyte, and regular equalization**

However, variable and more demanding patterns of use will necessitate understanding the principle of amp-hour calculation in relation to battery capacity, charge availability, and projected demand based on appliance power draw. Knowing the wattage of appliances, the amps they will draw, and incorporating the time of projected use, will enable basic and useful amp-hour calculations to be made, ensuring optimisation of the system capacity, and making life easier for the batteries. This all must be factored into projected system sizing and purchase.

**KNOW YOUR SYSTEM SPECIFICATIONS, AND APPLIANCE REQUIREMENTS!** For example, a small 24/240 volt system will indicate, via the monitoring system, draws of 5 amps (DC) for a basic 100 watt computer system, with variations due to ancillaries to be accounted for. Similarly, a 100 watt TV+ aerial will draw 5 amps, a 700 watt microwave will draw 35 amps, a 40 watt stereo will draw 2 amps, a 300 watt blender will draw 15 amps, a 40 watt bulb will draw 2 amps, a 230 watt drill will draw 16 amps, etc. **In this example, DC volts are 1/10 AC volts and 10 x AC amps**

To these figures should be added the ancillary light that may be required for easier switching, and smoother power flow for older inverters. **Such readings should be made by testing each appliance in turn, when there is no other charge or discharge registering in the system, and noting each in turn for future reference. Either do such readings at night, or isolate the panel charge via the array fuse during daylight hours.**

Volts x amps equals watts, and remember the difference between AC and DC. Recharging requires extra charge of 30% to overcome resistance and any other BOS inefficiencies, so allow time for prompt and complete charge cycles, including equalization. **Storage should be calculated for purposes of 40%-50% DOD cycles, with 24-hour recharge cycles, NOT for days of functioning in partially discharged states.** Larger systems will take proportionately longer to charge, and ancillary charge will depend on climate, and panel optimal sizing, or less, as the case may be. Stand-alone systems with no ancillary charging will require very careful management to maintain battery health, regardless of panel size. **The bank is only as good as the weakest battery!**

**Once again, plan higher demands to coincide with optimum sunlight, or concurrent ancillary charge, and always ensure that no matter what power use was incurred during the day, that the batteries carry a reasonable 60% SOC resting charge in spite of the power draws that may be made in the interim before solar or generator recharge.**

**Remember that system specifications are based on optimum conditions of full sun, and ideal battery operating conditions. If your system battery bank is not temperature controlled, the effect of colder temperatures must be factored into high demand usage calculations. Consult your solar professional, or ideally, install temperature control for your battery bank.**

### **“Need to Know” Specifications of your solar system may include:**

VOLTAGE, eg. 24v, plus MONITREG CAPACITY, PLUS HANDHELD VOLTMETER FUNCTIONS  
 INVERSION TO 240 VOLTS, AND VARIATIONS AND COMBINATIONS OF POWER USE  
 WATTAGE OF PANELS, AND AMPS GENERATED FOR CHARGING  
 WATTAGE OF INVERTER, AND/OR BATTERY AMP-HOURS CAPACITY  
 AMPS RANGE OF AUXILIARY CHARGER  
 CAPACITY OF GENERATOR  
 CHARGE RANGES, USUALLY 15-20 AMPS STEADY CHARGE, REDUCE AS/WHEN 30/31V ARE REACHED  
 OPTIMUM BATTERY TEMPERATURE, AND, SIGNIFICANCE OF TEMPERATURE FOR PERFORMANCE  
 BOOST, ABSORPTION, FLOAT, AND EQUALIZATION PHASES OF CHARGE  
 SPECIFIC GRAVITY RANGES VERSUS CHARGE, RESTING CHARGES, AND TESTING PROCEDURES  
 DETAILS OF SYSTEM POWER OPERATION RANGE, FULL OR PARTIAL

**Wallchart details = minimum working knowledge!**

**Caveat Emptor #2:** As above, optimum panels combined with maximum battery capacity will ensure longer battery life, given optimal usage. Smaller battery capacity means the system must cycle more quickly, and more often, thus needing replacement sooner, whether optimally charged or not. The formula for balancing solar charge and storage capacity is, mid-latitude:

Battery banks should be 3-5 days storage without sun, or 5x maximum average daily use, with optimum 60 watts of panel per 100 A-H storage for 12v standalone systems, or 120 watts/100 A-H storage for 24 volt standalone systems. 15-20amps PV charge is optimal for any household system, ensuring that the array will provide equalization power. (See [Tables](#).)

**Panel and battery sizing** may be calculated as functions of:

Required daily wattage per annum average x 1.5 to cater for the 50% cycle maximum, divided by voltage, and then by the mean annual solar hours of that latitude to give amps required over those hours. This total is then multiplied by 5 for the 5 day storage, 120 hours, and so equates to the 100a-h rate of the prospective battery choice. Those solar amp hours also indicate the amps per hour required from the panels, which then may be referenced in the [Tables](#) provided to calculate panel size.

Lat 39°S, 500w/h average daily requirement p.a., 40 watt panels, 24 volt system:  
 500 w/h x 1.5 =750:- by 24 =31.25, x.5 =157.25 a-h storage, 31.25:-4, =7.81 amps p/h panel charge, which would require 6/40 watt panels in 3 sets of 2. Note that battery storage, and panel sets is determined by system voltage.

Ensure optimal installation, and angle of incidence for solar interception relative to latitudinal position, +/- 15% of northerly aspect, though this may differ region to region due to such variables as early morning cloud patterns. Local average conditions may necessitate customised angles of placement, use of solar trackers, or seasonal manual panel adjustments.

**Tilt angles for given latitudes:**

Lat 12-15, tilt@ 15°; Lat 15-25, tilt@ lat°; Lat 25-30, tilt@ lat+5°;  
 Lat 30-35, tilt@ +10°; Lat 35-40, tilt @lat+15°; Lat 40+, tilt@ lat+20°

**Approximate panel efficiency v. sun incidence, relative to latitude:**

**Lat0°/90° incidence(100% efficiency, 25°/75°->95%, 45°/45°->75%, 60°/30°->50%, etc**

In Australian or similar latitudes, the optimal winter panel setting is probably sufficient for all year, given the long summer days in most areas. (Depending on aesthetics, these same angle values should be utilised for solar hot water unit installation.)

**Note that MMPTs, or max power point trackers, are electronic compensation devices that maximise amp:volt ratios, depending on insolation conditions, and not to be confused with mechanical panel trackers. Authorities currently differ as to whether PWM technology, (power width modulation), which include desulphators and MMPTs, is good for battery health. Consult!**

**Further notes on winter conditions, and implications for optimum charging:**

Lower battery temperatures mean reduced capacity for accepting charge for charging to overcome. Specific charging functions like boost, absorption, and equalization are activated in the monitreg by voltage levels, and thus charges governed by the digital monitreg give seemingly “false” readings of high voltages, and optimum equalization is not achieved when required. This

also applies to hand-held meters. **Resting charges and SG testing** would confirm this, ref. **TECSSS** variables for optimum electrolyte health and SG. ( $SG + 0845 = SOC @ 25^{\circ}C$ , normal acid.) Yet, if the battery was warm, or warmed up, the regulating and monitoring systems would then synchronise, as charge is more easily accepted by the batteries. **Also, warming the batteries would “lift” the charge, regardless of input**, by increasing electrolyte activity, and thus ion conduction capacity, as per the old trick of warming a reluctant car battery by immersion in hot water for 15 minutes or so when starting a cold engine. (But, this is only an illusion of improved condition in older batteries).

Slightly cooler batteries will last longer, though relatively more sluggish in performance. Battery temperatures above  $25^{\circ}C$  are the danger to battery health, because of chemical aggression, hard crystal formation, and increasing resistance which will also contribute heat, even to eventual thermal runaway if uncontrolled. **All temperature extremes contribute to mechanical stress of plates.** Regular, and optimal, sulphate reversal at charge is important, as hard crystal formation will occur within 2-3 weeks in an unattended battery, including that initiated by self-discharge. Warmer temperatures intensify this trend.

The “truth” of the charge readings, therefore, is relative to the temperature of the batteries at the time. This means that resting charges, full, or partially discharged, are also relative to battery temperature, **so note that values given in the Wallchart for these voltages are for ambient temperatures of  $60^{\circ}F-70^{\circ}F$ , or  $22^{\circ}C-27^{\circ}C$ .**

**Remember, all TECSSS variables are important for electrolyte readings!** Using a generator to charge cold batteries will require a longer input to achieve optimum charge for a given temperature. Whatever the charge achieved, keep the working range of the batteries at 60% SOC, or above if possible, as for all operating conditions and temperatures, to prevent excessively deep cycling, and prolong battery life. A 40% DOD is optimum, 50% range of battery reserve use should be avoided, and never drop below this value if possible, ie, down to 12.06/24.12 volts, resting, when partially discharged. If possible, install a monitor that shows (calibrated) SOC levels, at least for resting phases, and take care with operating voltage levels.

Listen to the generator when charging cold batteries, as well as watching the display, the change of engine note will mean that optimum charge capacity for a given temperature has been reached, and scrutiny of the display will show the regulator refusing more charge. To continue engine charging beyond this point is a waste of fuel, unless the generator has concurrent work. 31v for equalization may not be reached, but maintaining any bubbling will aid equalization, anyway.

**You may be able to re-program modern regulator/monitor voltage ranges to compensate for colder temperatures if you do not have battery temperature control.** However, it would be prudent to take advantage of any warm weather in winter to try to achieve a higher charge as the batteries temporarily warm up. Whenever generator charging is necessary, regardless of the time of year, any early am charging ensures further solar charging to continue for the remainder of the day, although temperatures will build as the day progresses, perhaps enabling a late afternoon top-up of charge. See the **Wallchart** for seasonal charging parameters, re PV and generator. Use any manual system override facility on the mon/reg to enable boost, equalization, etc., if more hands-on intervention is required.

The solution to the problem of cold-temperature charging is to install battery banks in insulated, ventilated surroundings, with some means of mild heating to within the  $20^{\circ}C-25^{\circ}C$  range to ensure optimal charging and operating conditions.

Bypassing monitregs that react to charge resistance in cooler conditions, as well as volts for optimal temperatures, may not be advisable, as sudden battery warming would produce an overcharging battery, thus producing an over-correction of the problem. **Thus, bypassing the regulator for higher cold temperature charging would be inadvisable, as well as risking severe battery damage.**

Overcharge, apart from equalization, is damaging and unnecessary at any temperature. This is not to be continued beyond the 30% extra charge required over discharge to fully recharge a healthy battery at  $25^{\circ}C$ .

A solar system is expensive, but properly sized, monitored, and maintained, will provide good service over a relatively long life, for all its components. The batteries really are the heart of the system, and need care and attention to ensure optimal working life. Proper management is not for the faint-hearted, the slap-dash, or the absentee owner, so if you cannot care for your system consistently, ensure that there is available someone reliable who can do so, and on a regular basis. Practice consistent usage, within the system parameters.

**The astute and motivated human manager is the ultimate fail-safe device, regardless of the state, or degree, of system technology, or the age of the solar power system.**

### **Summary of Do’s and Dont’s of Battery Health Maintenance:**

Optimum temperature and normal charge/discharge cycles of battery use mean that the ratio of reactants to electrolyte is always optimum for any equilibrium stage of battery operation, and there are less mechanical stresses from extremes of temperature. **Charges are always true and easily maintained.**

Electrolyte concentration is more stable with respect to the overall reaction equilibrium, and sulphation of both anode and cathode is then only a matter of soft-crystal formation, and corrosion of the anode is minimised. Acid concentration should also be related to operating temperature, to optimise the balance of reactants. Water loss by electrolysis or evaporation is also minimised, SG is easier to read, and equalization schedules easier and shorter. Batteries consequently will have a longer, more useful life. **TECSSS** principles again apply.

**The ideal operating temperature is  $25^{\circ}C$ , +/-  $5^{\circ}C$ . Temperature control is recommended.** Colder means more sluggish performance, less active electrolyte/reactant interaction, reduced ionic conduction, and thus less charge holding capacity. Initial charge resistance is higher, and attainment of optimum charge is more difficult, especially in relation to battery capacity. Discharge states in very cold temperatures need to be monitored, to guard against freezing of the ion-depleted electrolyte, and reduce hard crystal formation. Colder batteries have longer lives than hotter batteries, all other factors being equal, but do so at below capacity,

which means potential value for capital cost is never realized in either case. A smaller battery operating at optimum temperatures would have been better value for money than a larger battery less than optimally managed.

**Hotter** means an overactive, chemically aggressive electrolyte, risking corrosion and halving battery life, mainly due to anode damage, by half for every 9°C over 25°C. Lack of electrolyte de-stratification will make the situation worse, due to more concentrated and active electrolyte reacting with both plates, especially the metal of the anode, at the lower levels of the plates. Self-discharge and hard crystal formation are increased. There is more water loss by evaporation, and any overcharge will induce more electrolysis. Rising operating temperatures will also create resistance, which may lead to thermal runaway in non-temperature controlled conditions.

**Overcharge, both by time and by rate**, means more heat when banks are not temperature controlled, as well as mechanical stresses from excess bubbling and venting beyond the minimum required for effective equalization. Overcharge at low temperatures will cause bubbling and venting to a lesser degree, but may result in a false reading, especially if attempted over a short period. In both cases, fuel is wasted if a generator is being used at higher revs than necessary. Overcharge to reduce hard-crystal sulphation may work somewhat, but at a mechanical stress cost to the batteries. **Prevention of large hard crystal sulphation is better than cure, so maintain optimum usage and charge cycles.**

**Undercharge** means sulphation is not fully reversed, battery capacity is reduced, made worse by hard crystal formation. Stratification not overcome by proper charging will mean uneven electrolyte concentration, and uneven reactant activity, with consequent plate damage. Battery life will be quickly reduced.

**Extra charge**, @ 30%, is what is needed to restore batteries and overcome resistivity, heat loss, and BOS efficiency, and this is more economically achieved by utilizing alternative energy such as from solar, rather than depending on generator or mains charging. A solar system may be complemented by water and wind generation contributing charge to the battery bank, as well as ancillary generator charge.

**Inactivity** can be balanced by float charge, but this should not be more than necessary to cause fine bubbling on the plates, and to prevent sulphation due to the tendency to self-discharge. High float levels may cause anode corrosion because of the higher activity level of the electrolyte due to the charge-driven reaction. **No battery should ever be stored without float charge maintaining some internal activity.** But excess float also means unnecessary electrolysis, and consequent water loss.

**Equalization must still periodically occur during extended float states.** This will also prevent partial electrolyte freezing where temperature control is not in use, down to about minus 30°C. **Any battery accidentally discharged, then frozen, must be thawed, and brought to some reasonable temperature, 10°C or so, before being recharged.** Long slow charges are not recommended as treeing of any dissolved metal in the ion-depleted electrolyte will occur on the cathode. Use a normal charge routine.

**Small cycles**, under 5%, cause damage by clumping of dioxide on the anode, which will later flake off, causing shorts, and also exposure of the anode metal to excess acid corrosion. **Deep cycles, whether 50%-80%**, will limit battery life more than operating consistently down to the 40% optimum.

**Rapid cycles** mean damage because the double sulphate reaction needs time, at any SOC or temperature, to be fully effective. Rapid cycles caused by large, abrupt downloads also cause mechanical damage such as plate buckling due to heat stress, potentiate hard crystal formation and anode shedding, and promote excessive electrolyte bubbling. Such excessive downloads also inhibit acid replenishment of the plates, so capacity to meet the demand is lessened until the battery is rested. The **Peukert Effect** applies in this case, (better slower discharge for longer amp-hour performance), and is the reason why battery capacity is listed, in amp-hours, as either short term or long term, and explains the differences in respective performance.

**Operating at extremes of temperature, due to lack of temperature control**, means that the battery is operating with an electrolyte that will be either too concentrated, (cold) or too dilute, (hot), dealing with the same given load, (this may be even more in winter), with only short periods of optimum operation when temperatures are anywhere near the optimum range for balanced battery performance. Heat offsets less dense electrolyte with greater chemical aggression, so **tropicalizing** batteries in warm conditions also complements temperature control. The battery will also be undergoing a wider range of mechanical stresses due to the temperature ranging, **and if less than optimum management is concurrent, then shorter battery life is guaranteed.**

**Vibration**, either consistent or short-lived, will affect any weak plates, even wiring, causing breakage, and possible shorts. **Avoid tapping or bumping batteries.**

**Dirt and moisture** can lead to tracking of charge, and possible reactive corrosion.

**Corrosion by acid mist** condensing on the outside of batteries may cause loss of contact, and even destruction of poles, especially if unsuitable fastenings, (i.e. optimum stainless steel shielded with Vaseline), are being used.

**Air circulation and/or ventilation** are important for safety, especially re explosive gas mixing, and to prevent moisture forming on system parts where this will cause harm, or even electrical tracking. This safety aspect applies also to sensitive human tissue like lungs, the electrolyte at full strength being very chemically aggressive toward biological entities! Also, homogeneous internal battery temperatures are better than temperature gradients, so store batteries on insulating materials, not on temperature-fluctuating materials. This avoids uneven chemical processes and stresses within batteries.

**Inappropriate architecture means that batteries may not be separated from any spark source, or from BOS equipment that may be damaged by acid mist, or be without proper ventilation, or temperature control, and be near a constant source of vibration, be sitting on concrete, and so on.**

**Try to give batteries a lifelong, permanent, quiet and temperature-controlled life from the first installation, and this is ever more important as they age, and become more fragile. This fragility is unavoidable, but may be postponed, and useful life prolonged as long as possible, by optimum care and management of the bank.**

**Note that SLI batteries have a shorter life** because they operate under extremes of temperature, vibration, many rapid high demand cycles, and have sponge lead cathodes for greater reactant interaction, which are inherently weaker than scored lead used

for deep cycle batteries. They certainly do not stand up well to deep cycling, as too much of the sponge lead is involved in the double sulphate reaction, and the plates soon become weakened by chemical action taking place which they were not constructed to withstand. Repeated mechanical stresses soon cause flaking and plate breakage of either anode or cathode during a normal operating life, and deeper cycling aggravates this. Perhaps the engine compartment is not the best place for an SLI battery to spend its useful working life either, elsewhere in the car would be cooler, if not less vibration free, and also probably harder to access. **Quick draw, quick charge, and no more than 20% DOD for SLI batteries.**

**Deep cycle batteries** require steady draw, and steady charge, with 40% optimum DOD. Deep cycle batteries have stronger plates, greater electrolyte volume, and more cycling capacity, and thus have longer, more useful lives if operating under optimum temperatures and charge/discharge cycles, and should last about three times longer than an SLI battery also operating under ideal conditions. The 40% DOD range is intended to be a failsafe parameter. (See [Feedback/11](#) for **Bill Darden's** "sweet spot" in battery discharge cycling, although this will vary with age and condition.)

The nature of FLA batteries, in relation to resistivity, heat capacity, solubility of reactants in the electrolyte, and depending on the SOC, means that the overall reversible double sulphate reaction must be charge-driven to function properly. This means, however, the slow self-discharge rate, hence the effectiveness of FLA batteries as electrical storage devices. Self-discharge is inexorable in unused batteries, but low float/trickle charge is all that is required to maintain battery health when not in use, with occasional equalization phases to level cell charges, and to de-stratify electrolyte if there are no mechanical means to do so.

**Load and charge are really controlled short circuits that drive the overall reaction, and the 30% extra charge needed to restore the system to full charge potential is a function of battery efficiency, 85-95%, plus any energy losses by heat, BOS efficiency such as resistance, and charging sources. Also, the bank is only as good as the weakest battery, so battery records are important, especially as the bank gets older, affecting charge regimes, and eventual replacement plans, full or partial.**

Power not used must be stored at any opportunity as chemical energy, and this is why batteries are so important for alternative energy systems, and also good battery management and maintenance. Solar, wind, or water power are the most economical passive means to maintain lead-acid batteries because of this extra 30% charge requirement, and solar is the most consistent in performance. Where demand requires, a hybrid system that also includes a generator is recommended for optimum power generation and storage. **Finally, new batteries should have customised cycling parameters accompanying them, as well as specifications of amp-hour performance. This is especially important for differentiating Gel or AGM lead-acid battery management from that of FLA battery management.** (See [Excerpts](#) for information re these other lead-acid battery types.)

**Management Tip 1:** You will most likely not need all the detail and technological facilities that are part of a modern solid state digital monitreg system, so, from extensive monitreg instructions usually provided, extract a **system management précis**, rendered in diagrammatic form, including your own relevant customised figures, all which should sum up the particular parameters of the system you are managing. Such a handy précis, written in chart form with a felt pen, will contain easily readable important information details and figures, and will complement the Battery Management Wallchart for quick-reference solar management when posted on a handy wall, in either your battery or monitreg/inverter annexe. (See also [Appendix 4\(?\)](#))

**A suggestion for deploying the Battery Management Wallchart to best advantage is to blow it up to A3 size with a photocopier for quick/easy reference when posted with your Monitreg System Management Précis.**

**Management Tip 2: Concurrent external charge and battery use values**, whether the charge is sourced from the PV array, generator, or mains, **must** be calculated correctly to be effective in preventing net battery discharge, especially below 40% for deep cycle batteries, or 20% for SLI. Charge that exceeds current draw will go directly to the load, and any surplus will contribute to overall battery charge if this is deficient. Conversely, charge that does not meet load requirements will be complemented by ongoing battery draw, and thus, net battery charge loss until a net charge is re-instated. In both cases, the current is flowing through the battery in one direction only, and the battery therefore functions as a current buffer.

With larger, fully integrated systems incorporating an advanced monitreg, such net battery charge loss is more readily accounted for and controlled, but smaller, more basic systems would have to be monitored if there is a possibility of significant charge deficit to be sustained for any length of time.

**Note also that neither of these battery use scenarios should exceed the normal parameters of battery capacity and charge limits for any given capacity of any system component. Excess charge should still be regulated, and draws of high amps through underrated circuits of charger, BOS or battery, will quickly result in overheating and probable damage, with a considerable fire outbreak risk!**



Know your system component specifications, plus specific prospective charge and discharge parameters, and do the **necessary maths!**

[Standalone solar installation, NSW Tablelands.](#)

## Solar Installation and Safety:

The table given for panel array placement and angles is only a guide, not taking into account climatic variations due to regional differences, altitude, topography, etc. Panels must be placed for the most uninterrupted or optimum sunlight. Obviously, trees, high ridges, or any other potential shadowing effects must be considered, as well as northerly aspect roof placements, or else have a free-standing differentially sited installation. For example, if your local region is subject to early mist or cloud, then a placement somewhat west of north should be considered, say  $10^{\circ}$ - $25^{\circ}$ , so that later afternoon insolation may be taken advantage of by optimising the westerly placement. In Australia, the optimum winter setting for PV panels would normally suffice, given the long, sunny summer days.

**Free-standing arrays must be very strongly built**, because of the sail effect of the surface area of the panels resisting the wind, causing movement, flexing and associated stresses, including metal fatigue, and even possible panel distortion. Dedicated frames, for whatever application, should be built, independent of any existing structures, of strong, non-corrosive materials, and the panels affixed to these, before the array modules are raised to permanent positions on strong structural bases. Plan the erection of a structurally modular assembly. Incorporate overall rigidity, wiring, panel placement and angles, weight distribution, bracing, and also accessibility of connecting boxes, fuses, wiring, bolts, etc. This will also enable easier maintenance and servicing.

**There should always be adequate ventilation behind panels**, especially when affixed above roofs, as they are sensitive to accumulated heat, which diminishes their photoelectric efficiency by causing resistance, by up to 20%, or 2% for every  $5^{\circ}\text{C}$  in temperature rise.  $25^{\circ}\text{C}$  is the maximum panel operating temperature beyond which efficiency, for the purpose of electricity generation, begins to fall away.

**Avoid vegetative or any other debris accumulation in or around the entire installation, as this will lead to corrosion, especially of roof fixings.** Maintain panels dust-free in long periods of no rain, and, in more humid areas, watch for mould or lichen that will interfere with solar reception. Prevent bird or insect access to sensitive areas, use mesh, sealant, or patches, and this applies to moisture egress as well. Even in your power box, take care to seal holes, and be aware of water leaks that may be wind driven. **Practice corrosion prevention, also.**

**For a maximum 5%-40% efficiency increase**, depending on the season, panels may be enabled to follow the sun by mechanical means. This type of system will have pivots or rails as potential weak points, plus motive means. Snug tracking is important, although this will mean more expense and materials. Better, probably, to have fixed base structures incorporating periodic angle changes, vertically and/or laterally, (say 4x per year, using seasonal insolation tables), with extra paneling if affordable, to provide optimum solar charging at any time of the year. Effective locking would still be important between moves. However, as above, in Australia, permanent optimum winter settings may suffice, given summer insolation and effective solar hours.

**When working around installations**, either building or maintaining them, be especially careful using tools or equipment either side of the panels, or near junction boxes, even use padding to protect them. A slip or blow could be very expensive! Likewise, allow some slack in any cabling, especially near connections, and secure cables strategically wherever necessary, and do not allow cable excess slack that could be worried by the wind, as unseen wire fatigue will result.

## Battery Installation:

Ensure correct wiring gauge for given voltages, matching fuses, and proper AC interface, ventilation, and temperature control. Install a separate state-of-charge (SOC) voltage meter that can be seen at a glance rather than being accessed with button-pushing. Also, a hand-held digital voltmeter and ammeter will give truest battery and charge readings, so important when equalizing charge, as other ancillary readings may be misleading. Wiring or other resistance may affect conventional readings, which may lead to overcharging. A hydrometer is important, too, as **good voltage and hydrometer readings must be concurrent.**

**Also, have a First Aid kit and protective clothing at hand!** Sodium bicarbonate is the neutralizer for sulphuric acid, and copious flushing with clean water as well. **A dedicated battery room is recommended**, free from monitoring equipment, and thus any spark sources, fumes, and also temperature controlled, either the entire room, or just by insulating the bank itself, ventilation assured in either case. (See also [Home Power Magazine](#) #33, March 1993, Battery Rooms, A Cellular Home)

**Generators must match projected usage requirements, and if bought secondhand, must be checked for mechanical and electrical soundness.** Brushless direct-couple drive types are the best. **Generators have fixed idle rate and throttle pick-up, set to avoid generator damage, and these should also be checked.** EG, a Honda 11 hp idles at 3,120 rpm, and will run a small portable welder, having enough throttle pick-up to strike and maintain the arc, 2mm rods, max., and should test to this limit easily. As for all small motors, pay attention to clean fuel, correct and clean oil, and air filters. Avoid running in the hottest part of the day, better early morning or later afternoon and evening.

Generators will suffer glazing of the cylinder walls if always run at constant speeds, so periodic power loading that makes the engine work is beneficial. Planning generator multi-usage will take this into account, but calculate watts in relation to generator capacity, and monitor any concurrent charging amperages. Monitoring generator function is also advisable, both for load, smooth current delivery, and any early warning signs of faults and malfunctions.

**Situate generators for use where there is shelter from sun, yet ample cooling air flow. Take care with proximity of buildings, gas hot water systems or electrical conduit. Generators take fuel, and there are always small spills. The best idea is a dedicated generator shed, fireproof, hard wired, and situated with regard to prevailing winds and/or noise. A dedicated, level-standing trolley or trailer would also be a useful option, enabling convenient and stable portability as needed. Never site a generator where vibration may be conveyed to a battery bank, as plate damage, and even wiring fatigue and damage will occur. For the same reason, do not tap batteries to make bubbles rise!**

Generators should be connected to the system in such a way that the batteries and inverter are isolated by a relay that senses the power input from the generator, so the AC system runs on the generator power alone while this is being provided. The AC battery charger should be enabled by this circuit, and disabled as the power flow stops, when the PV array takes over charging once more. However, switching may affect sensitive electronic equipment like computers, so if battery charging is required while they are used, charge directly to the bank via the monitreg.

Do not use the system when equalization charging is in progress, either, if direct draws of power are involved, to avoid damaging any equipment, and also slowing the equalizing stage. **Do not run high current draws through the inverter when using the generator, even if they are within rated limits, use generator AC power directly both for safety, and to avoid system stress. Likewise, never run high current draws through the batteries and inverter, even if within rated limits, use the generator to avoid battery and system stress.**

All power use creates heat and vibration, and inverters, though amazing, are sensitive to those stresses which will ultimately shorten their useful lives. Deep-cycle batteries are damaged by anything other than steady current draw-downs, and regular steady charge-ups. All system components will have longer and quieter lives given optimal steady usage and charging conditions. A hybrid system using a generator is recommended. **Transport or move batteries if you must, but only with due care and minimization of bumping or vibration, to maintain material integrity.**

Treat your own independent power system, whether AC or DC, with respect, as electricity can kill, injure, damage, or set fire to, and that can mean you, yours, and your system. **There are fundamental differences between AC and DC power systems, so seek advice if you do not understand these differences. There are separate qualifications required for AC and DC technicians.**

To reiterate, hydrogen and oxygen gases generated by battery charging are explosive if mixed with each other, or other gases, then ignited. Sometimes this can occur spontaneously. Keep all sources of sparks, or any other sources of flammable gases away from battery banks, which should be well ventilated at all times. Insulate and warm the battery bank by all means, rather than the actual battery room, if this will stabilise operating temperatures, while also maintaining optimal ventilation.

Have the system planned and installed, and even with the best advice and skill, maintain and service all aspects of the system when you become responsible for this. Fit, where necessary, isolating switches, fuses, and access panels for safety, and to facilitate inspection and repairs, extensions, and maintenance. Do not situate inverters in battery rooms, but have both in separate areas with separate outside ventilation, to avoid igniting vented hydrogen. For insulated battery rooms, ventilate every battery vent separately if necessary, and only remove such a hose, etc., individually when checking SG.

**More than one inverter may be utilised for high or low demands, or an auxiliary battery installed, usually 12V, to be charged via the main charging systems.** This separate back-up circuit for lights and radios, etc., is recommended, and 12 volts means cheap components and plenty of batteries to choose from. **Car batteries would be adequate as long as they are not discharged below 20%**, and can also be easily charged by an individual 12 volt panel as marketed for RVs and electric fences. Otherwise use a single deep cycle 12v battery. 12v emergency lights are a blessing when needed, and Murphy's Law should always be considered. Even a grid-interfaced system will or could eventually need that extra back-up, and the main bank will always benefit from a rest at night, or any other time, when all that is required is a light, or a 12v radio.

Certainly, there is much to learn about solar systems, and good habits of usage and maintenance must be cultivated. But the pay-off is independence from main grid failure, aka uninterruptible power supplies, custom-made systems, lower energy bills when pay-back time is complete, and use of a renewable resource. Also, a solar battery bank is the best possible computer UPS. So, if you have made the decision to utilise solar power as your energy alternative, persevere, it will be worth it, no doubt at all. **For other alternative energy generation, the same criteria apply to managing power storage with battery banks, whatever the power source.**

**Some common-sense safety precautions for installing solar electrical systems and solar photovoltaic panels are as follows**, however, the installation wiring of solar modules/panels requires a great degree of skill and should only be performed by a qualified licensed professional, so self-install at your own risk, and keep children at bay! Also:

- All instructions should be read and understood before attempting to install, wire, operate and maintain the photovoltaic components.
- Avoid creating electrical hazards when installing, wiring, operating and maintaining the installed system.
- A photovoltaic panel/module generates DC electricity when exposed to sunlight or other light sources, avoid wiring short-circuits. Photovoltaic panels/modules produce electricity whenever sunlight or other sources illuminate the front face.
- The voltage from a single module is not considered a shock hazard, but when modules are connected in series, voltages are additive. When modules are connected in parallel, current is additive. Consequently, a multi-module system can produce high voltages and current which constitute an increased hazard. Contact with electrically active parts of the module such as terminals can result in burns, sparks, and lethal shock whether the module is connected or disconnected.
- It is recommended that the module remains packed until time of installation. When installing or working with module wiring, cover the module face completely with opaque material to halt inadvertent production of electricity.
- Do not touch terminals while the module is exposed to light or during installation. Provide suitable guards to prevent contact with potential discharges. As an added precaution, use properly insulated tools only.

- Do not drop the module or allow objects to fall on the module, and avoid standing or stepping on the module. Never leave a module unsupported or unsecured. If a module should fall, the glass can break. A module with broken glass cannot be repaired and must not be used.
- Since sparks may be produced, do not install a module or wiring and contacts where flammable gases or vapors are present.
- Work only under dry conditions, with a dry module and proper tools and ladders.
- If not otherwise specified, it is recommended that requirements of the latest local, national or regional electric codes be followed, including wire size and quality. Shortest wire and lead lengths are recommended to offset DC current loss over distance, which should not exceed 2% in any circuit, for optimum current conservation.
- **Use the module as rated, and for its intended function only. Do not artificially concentrate sunlight on the module.**

## Personal Solar Battery Safety Precautions:

1. Someone should be within range of your voice if possible, to come to your aid when you work near batteries. Wear complete eye protection and non-floppy clothing protection, and restrain hair, jewelry, etc. Avoid touching eyes while working near batteries. Wash your hands when done.
2. If acid contacts skin or clothing, neutralize, (sodium bicarbonate in water), then wash immediately with soap and water. If acid enters eyes, immediately flood eyes with running cool water for at least 15 minutes and get medical attention immediately. Baking soda neutralizes lead acid battery electrolyte. (Vinegar neutralizes spilled NiCad and NiFe battery electrolyte). Keep a supply, as applicable, on hand in the battery vicinity.
3. **NEVER smoke or allow a spark, volatile flammable liquids or potential flame sources in the vicinity of a battery or bank of batteries.**
4. **Also employ caution when working with metal tools on or around batteries.** Potential exists to short-circuit the batteries or other electrical parts which may result in a spark which could cause an explosion.
5. Remove personal metal items such as rings, bracelets, necklaces, and watches when working with a battery. A battery can produce a short-circuit current high enough to weld a ring, or similar, to other metal surfaces causing severe burns.
6. If a remote or automatic generator start system is used with the system, disable the automatic starting circuit and/or disconnect the generator from its starting battery while servicing, to prevent accidental starting during servicing.
7. Plan intended work, organise the work area, account for children's whereabouts, and be sure you know what you are doing!
8. Keep up-to-date records of maintenance procedures that any system caretaker may need to access at short notice.
9. Safety also emphasises the need for proper regulation technology being part of the monitreg system for solar battery (or any lead-acid battery) charge cycles in any application. **#The regulator should be sophisticated enough to enable the 4 stages of boost, absorption, equalization, float, and rest, when the battery is ready for the changes!#.** System safety fail-safes must be factored in to planning and constructions.
10. Remember generator safety, site on a safe foundation away from any possible inflammable liquid, gas, or any other material. Take care with refuelling, and ensure good maintenance, including electrical connections. Wet conditions may be a hazard with unsafe or old wiring. Remove any wiring from possible damage in heavy traffic areas, especially extensions, permanent in situ wiring is preferable.
11. Batteries should be sited on wooden pallets with a sufficient buffer margin to avoid bumping or bodily contact, and BOS equipment should be similarly sited to avoid minor collisions and bodily contact, including wiring. This will also avoid system damage, and the need for unnecessary troubleshooting.
12. **No such list is exhaustive, so customise this one to cater for any other given conditions.**

**SOLAR INSTALLATION CHECK SHEET**

**SYSTEM DETAILS:** \_\_\_\_\_ **Type** \_\_\_\_\_ **Specifications:** \_\_\_\_\_

**Panels****Batteries****Monitreg****Charger****Ancillary monitoring**

Optimums: usage range

performance

loads

charging settings

**New/secondhand:** condition

projected life (with optimum usage)

system

batteries

Recent or current upgrades

Maintenance and records recommendations

Date of last professional check:

Next check due:

**Wiring and BOS:****Local solar professional:**

Reliable and quality professional installation ensures:

Matching of all system components, both to each other, and to projected occupant usage.

Optimum siting and connection of all system components, and ease of upkeep, ease of repair and upgrade, and safety of equipment of system and user.

Matching of generator to system, and to ancillary usage.

Education of user as to system function and usage, plus ongoing professional testing, advice, repair, maintenance, and warranties.

## Simple Solar Problem:

To match a 12 volt panel to a given set of used batteries, 6 x 2vpc FLA in a single bank, for charging purposes, plus other relevant site tips. (These notes were produced to help a neighbour to optimise a basic 12V lights-and-radio system, January, 2002).

The bank has been charged, but not tested for performance, having remained on constant mains charge, at 4 amps, so that charge has been artificially maintained in comparison to normal conditions of daily solar use. Solar hours in ideal conditions generally being, for ambit charge, 7-8 hours in summer, and 5-6 hours in winter, assuming the system is in working order, and able to receive and store charge.

Given that the optimum DOD is 40%, the proposed plan is to discharge under constant test with a 12 volt bulb, to about 50% DOD, so that the resting charge will then be 40% DOD when resting. (See the FLA Battery [Wallchart](#) for standard voltage readings in relation to charge.) This should be timed so that the switch-off is in late evening, and the battery rests and stabilises charge, during the remainder of the night, and at ambient night temperatures. This simulates what occurs during normal use, when a cooled battery is recharged by the panel in the normal charge cycle. A-H rating at 50% DOD: \_\_\_\_\_

One proposed panel is 80 watt @ nominal 6-7 amps charge, so the 4 amp battery charger would be able to simulate the charge satisfactorily, assuming average insolation in real time. Time of year for the test is October, El Nino, at 600 meters ASL, lat 35° South, good air conditions, official mean daily sun hours per annum are 4, for comparison purposes. (Ref. Multipurpose Solar Sizing Equation, p.17)

**Normal Charge Cycle**, daily, assuming battery temperature to be above 12.7°C:

Boost to absorption 13.6V-14.3V, then to 15.5V for 3 minutes, and back to float at 12.6-13.2V. Time to achieve this @ 4 amps constant charge: \_\_\_\_\_

If 4 amps are not sufficient to push to 15.5V, then note the optimum charge reached. This should go into absorption at least, during a period of 6-8 hours of spring sunlight, assuming no other power demands on the bank. Any gap must be made up by the generator, at 10-12 amps, and/or more panel used.

**Equalization Charge:** 1x per month, consists of the normal charge, but extended to 15.5V, for 1-2 hours, or until the SG on all cells reach a peak, whichever is easiest to monitor. Once again, the difference in charge must be made up by the generator, at 15-17 amps. Equalization rates would need to increase if the bank goes only to absorption rather than to float on normal charge. Time for generator-assisted equalization charge: \_\_\_\_\_

Readings from the test should be recorded as a standard to monitor the health of the bank in the future. Smaller or larger panels will give greater or lesser results. Optimum panel watts for the battery as is: \_\_\_\_\_

### Factors influencing panel performance, and thus battery charge:

**Air quality:** usually better in winter, clean panels, less haze factor.

**Seasonal differences:** viz, panels and batteries both function optimally at 25°C, batteries are more sluggish at cooler temperatures, panels are less efficient at higher temperatures, more and longer sun-hours in summer etc.

**Daily:** cloud, time of day versus sun angle, and panel position and angle

**BOS:** Cable size/length, connections, matched components, panel mounting, etc.

**Time** dedicated to uninterrupted charge cycle before any draw-down

**Condition of system components,** and of connection and cables

**Amperage optimum:** Min. 10-12 amps are needed to achieve 15-15.5v equalization charge in good time. Proposed panel should deliver enough amps to at least achieve absorption, the remainder is charge lag made up by ancillary generator charging.

### Fixed tilt angles of Solar Panel Settings, for Latitude 35° South:

Lat 30°-35° is Lat+10° = 40°-45° Angle of optimum northerly setting: 340°-345° NNW

Lat 35°-40° is Lat+15° = 50°-75°

High altitude, clear air, and long afternoon sun all contribute to 45° elevation tilt being optimum for 35° South on NSW tablelands.

### Sun Hours: Yearly regional averages of total sun and optimum solar hours:

Summer daylight: 14.52, with 7.18 as optimum solar (Global Solar is 4, pd, pa.)

Winter daylight: 9.80, with 3.58 as optimum solar

### Approximate panel efficiency v. sun incidence, relative to latitude:

Lat0°/90° incidence(100% efficiency, 25°/75° ->95%, 45°/45° ->75%, 60°/30° ->50%, etc

### Some extra tips on solar system installation and management for this site were:

Panels should have adequate rear ventilation, and sited away, or insulated from, heat reflective surfaces if possible. Optimum operating temperature is 25°C for best results. Allow the prevailing breeze across, and unrestricted, if possible. (The prevailing wind at this site is, fortuitously, mainly north-westerly.)

Battery capacity required should also be calculated as per the MSSE, and panels sized accordingly, using the [Tables](#). (See also [Feedback/15](#), Bill Darden.) The MSSE Solar Hours daily per annum for Lat 35° is 4 hours. When the battery amp hours are known, the ideal panel size as per the MSSE can be calculated, and the difference between that and the projected 80 watt panel will indicate, in relation to tested solar charge performance, how much ancillary charge will be needed to maintain optimum battery charge cycles, or whether another panel size is necessary.

Maximum charge to FLA batteries should be no more than 10% of the 10 A-H rate, 15.5 amps will fully charge 2 vpc lead acid cells. (Different charge regimes would apply to Gel and AGM batteries if they were to be used, consult.)

Shallow cycles under 5%, and rapid cycles, may damage the batteries, the optimum cycle is to 40%, never below 50% if possible, even though 80% is the maximum deep cycle parameter. Exceptionally slow charges, 20 days+, will damage batteries by causing treeing of any dissolved lead on the negative plates.

Any uncorrected, sustained discharge state, especially in warm temperatures, will cause hard-crystal sulphation of either positive or negative plates, difficult to reverse, and plate buckling may ensue. Also, discharging to very low levels will cause lead on the negative plate to be dissolved by increasingly purer water in the electrolyte.

25°C is the optimum battery temperature, with 35% acid solution. Sustained higher or lower temperatures in situ may require the acid solution to be adjusted accordingly, within the range of 28-42%. Positive plate loss damage, by corrosion of lead dioxide, will occur with high acid, high temperatures, and high float levels.

Equalization, in this case 30 minutes, should be at 15.5v, and a dial-up charger plus generator and monitreg are needed. Final amps required will depend on battery condition and resistance. Any sustained overcharging, beyond equalization time, will cause excessive bubbling, heat, water loss and possible plate damage, which is also caused by vibrations, poor handling, and too rapid cycling. Any bubbling during charge cycles will assist de-stratification within an in situ battery.

Battery cycles should always be within optimum ranges to avoid unnecessary material stress, especially that causing plate damage. (See [Walchart](#))

Daily charge cycles should be achieved as often as possible for battery health, and prevention of sulphation. Set the monitreg accordingly, and organise loading regimes optimally. Optimal operating regimes and temperatures ensure optimal chemical equilibrium at any state of the charge cycle, and thus optimal battery life. Opportunity charging must be followed by full daily charge cycles.

**Do not store batteries directly on concrete**, tracking of charge by a film of moisture or dirt will slowly cause discharge, and heat insulation is needed, especially in winter, with temperature control if practicable. Wood in pallet form as a base is an ideal insulator, also ensuring good air circulation. *Temperature gradients within a battery promote uneven chemical reaction, uneven plate formation and reformation, and thus, extra mechanical stress.*

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## Typical Faults and Problems When Inheriting a Secondhand Solar System:

**Background is the age and condition of the solar system, also stand-alone, with no records or Manual provided, and a local professional who would provide no satisfactory advice beyond the rudimentary, even when pressed for answers. In fact, the very reason this Manual was begun.**

**In detail:** Old 24v system, panels, wiring, and monitreg, about 20-25 years, and the PV underpowered in relation to the battery size, which meant equalization could not be achieved by the PV, without generator help. Testing revealed 25%-30% less than rated amps from array, which was, in nominal terms, 30% too small for the battery size, anyway. 240 watts/9.9amps, (giving 6-7amps), should have been 720 watts/28.12amps, for a 590 a-h battery bank. Actually, the system only supplied 160 watt at 6.6 amps.

The batteries were actually newish, 2-3 years, but damaged by faulty management, and the failing monitreg, which meant plate damage, shedding, buckling and sulphation. No checks had been made over 6 months of non-occupancy of the house. Electrolyte level was OK. There was a generator provided, but never optimally used.

The inverter, an old square wave, was actually too big for the batteries, so care had to be taken to ensure loads were related to battery, rather than inverter. capacity. A water pressure pump was in the circuit, too big, and too frequent in use for battery health. A gravity tank was installed, and the pump ran directly off the generator via house wiring to top it up.

The generator had no dedicated fireproof location, away from the house, later rectified by installation in a trailer, and hard-wired to the control box. The pump was wired to also run directly, when necessary, from the generator in time of fire.

System had no fail-safe, no solar panel fuses or isolating switches, no battery fuses or isolating switches, no lightning conductor, and no separate facility for the inverter and battery charger away from the batteries. There was a battery cut-out in the house generator circuit. The inverter was on a 3-pin plug to the house supply.

There was a very loose connection at the panel, (sabotage signs?), and a faulty earth connection in the battery room, reducing charge amps, which, along with the sulphation, faulty original monitreg and miss-programmed new monitreg, meant trial and error and time spent on solving battery charge problems. At least the original electrolyte level was ok, if not the SG.

The original faulty monitreg was "professionally" replaced with a new model which was not properly programmed, having no equalization time, as well as other errors, and also, the initial low PV charge, (3-3.5A), and low batteries combined would not "drive" the monitreg anyway. The batteries were direct charged by PV and generator for months before they began to respond as they should. PV charge was improved to 5-6A, which meant better battery performance with less generator input, and the new monitreg worked as it was meant to do, especially in relation to optimum charge regimes.

Handheld monitoring of battery performance was also begun, especially VPC's, supplementing normal SG readings. Sulphation was overcome by a regular high float regime, later reduced to avoid plate damage. Batteries are now numbered, and some swapping of positions has been worthwhile. There is also rudimentary temperature control for summer, but not for winter, which can go to -10°C, and the batteries would be below freezing point, if not to -10°C.

Panel angles were too far northeast, 10°, to be of real aid to charging. This was amended to 345°NNW, and the tilt angle lowered to 40°, although 45° would have been optimum, if achievable with materials available. Morning cloud is common in this region of the southern tablelands, at 34°S latitude, so a more westerly aspect for the panels makes good use of regular long afternoon sun, any season. Dust and bird droppings need regular washing from the panels. Solar bursts are common in this tableland region, giving an occasional and brief extra 1+ amp charge. The best result was 8.3 amps total during a strong solar burst, 10 minutes or so, Spring 2002, beginning of El Nino 2002/2003, observed by chance during system monitoring.

Research was begun to gain information to properly understand and manage the system, to extend its useful working life, and to anticipate further problems. After 18 months, the batteries are as good as they will ever be, but down about 15% of nominal capacity, with some visible plate damage, and VPC differences that are not being resolved by de-sulphation or equalizing charges.

At present, they only work on 20%-25% daily DOD, an easier life. 500 daily watts are cycled instead of possible 1900, and 500 daily watts needs 200 watts/7.81 amps, scaled to 240 watts/9.9 amps, of which the present 240 watt panels only provide 6-7amps, and full boost and/or equalization are catered for by ancillary charge as needed. (500dw is 26.35% of 1901dw)

**The 3 relevant equations, one ideal and two actual, are as follows:**

$1901dw \times 2.5 = 2852rdw$ ;  $2852rdw : 24 = 118.5x5 = 590a-h$ .  $118.5 : 4 = 29.5a$   $x24 = 708w$  scaled to 720 @27.7 amps. **This is the correct match of panels and battery.**

$500dw \times 1.5 = 750rdw$ ;  $750rdw : 24 = 31.25x5 = 156.25a-h$ .  $31.25 : 4 = 7.81a$   $x24 = 187.5w$  scaled to 240@ 9.9 amps. **This is the match of batteries to the actual panels that were present, if the panels were delivering the correct amps**

$422.4dw \times 1.5 = 633.6rdw$ ;  $633.6rdw : 24 = 26.4x5 = 132a-h$ .  $26.4 : 4 = 6.6a$   $x24 = 160w$  @6.6 amps.

**This third equation relates to the actual state of the panels at present, after 25 years, and this decline will continue.**

The difference between 720 and 240 is 3:1, and the difference between 720 and 160 is 4.5:1. So, the actual panel watts available are 4.5x smaller than they should be for optimum system use and performance. (In terms of battery amps,  $590x24 = 14160$ ,  $156.25x24 = 3750$ , and  $132x24 = 3168$ . Divide the lesser totals into 14160, and the ratios are 1:3.776, and 4.46 respectively.)

**400 pw @ 16.5amps**, ie 15.5 amps scaled up, would at least be enough to boost and equalize **with a dedicated charge**, and the ratio of 720:400 is 1.8:1. To make up this difference,  $400-160 = 240$ , or,  $400-240 = 160$ , **if the panels were in good condition.**

\*At this latitude, according to raw Met. data, average **summer** daylight is 14.52h, optimal 7.18h solar hours, (total 650), average **winter** daylight is 9.8h, optimal 3.58 solar hours, (total 250), and the average is **5.38** daily solar hours, per annum. The Global Solar Map gives a figure of **4** mean daily solar hours per annum, which by comparison is conservative, so **this** world standard allows for a realistic margin of error, (100%:74.3%) of approximately 25%, **using the MSSE.**

Certainly, the above multi-purpose equations **do** reflect the present system performance, and charge lags. 6-7 amps can only push the charge to 29.6v on the best solar days, and the ancillary charge needs to be 20 amps, tapered to 15-17>amps, as the equalization level of 31 volts is reached. The better the SG has become, as the battery condition is improved, the more final charge is needed to reach 31 volts with the generator, especially with cooler temperatures.

With the present rudimentary heat control of stored water and extra temporary roofing on the battery shed, the battery temps peak occasionally at 30°C on the hottest summer days, which may reach up to 45°C. Cooler temperatures will mean less battery capacity, without appropriate temperature control, but present 500 dw usage rates are not a problem in this regard, and the battery condition remains more than good enough to sustain this usage with reasonable charge rates, solar, or ancillary.

## The Least You Should Know to Properly Manage a Domestic Solar Power System:

- **The system needs to properly planned, for latitude, local or regional weather, for specific domestic power requirements, also for BOS specifications, and especially the monitor-regulator, which must be 4-stage. The batteries should be deep-cycle storage.**
- **Any grid interface must be officially approved, and all parts of the installation should be professionally certified as being of appropriate electrical standard.**
- **Safety and security are important, all structures should be strong and sound, also batteries and inverters need separate housing.**
- **Panels will require optimum latitudinal or regional angle settings, and need direct sunlight for as long as possible during daylight hours.**
- **Panels, batteries, and BOS must be kept clean, orderly, and with good electrical circuits. Batteries should not rest on concrete, but preferably on clean insulating material.**
- **Battery management procedures will predominate, and, if the system is asymmetrical, particular attention must be paid to the charging regimes if the panel size is less than optimum. Ancillary charging must be available!**
- **Battery manufacturers should be consulted for detailed charge regimes. Completely recharge every 24 hours when in use, and equalize/de-stratify at least every month. Ideally, do not discharge below 40%. Keep electrolyte levels at optimum, use only pure, distilled, and mineral-free water!**
- **Batteries may require temperature control in extreme conditions, or else adjustments to acid and charge regimes may be necessary. Panels should have good ventilation, and do not concentrate sunlight onto standard photovoltaic cells.**
- **Performance and maintenance records must be kept from the time of installation, and regularly maintained. Seasonal adjustments to the monitreg must be made if necessary.**
- **Batteries must be replaced as necessary, and should either be of the same age in individual cases, or completely renewed as a bank. Panels may be added to in appropriate increments to boost performance.**
- **Specific battery types have specific voltages, charges, and charge cycles, and batteries and battery banks must match these specifications, and vice versa! BOS and ancillaries must always reflect these specifications also!**
- **Delegate management to appropriately skilled caretakers if and when necessary, and only engage or consult with an experienced solar professional you can trust implicitly, there is too much \$\$\$ and personal safety factors involved to risk any professional incompetence or duplicity.**

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## Solar Manual Unanswered Questions:

1. The ohm/conductance test was done using a DIGITAL tester, on the 2vpc cells, (7.5), and on the 12v auxiliary, (13.40). Poles of tester and batteries were reversed, the readings would only proceed one way. Also, the assumption was made that the resting resistance/conductance reading of 7.5 ohms was valid and universal, metals and electrolyte being ohmic. Any expert comments are welcome..?
2. The Manual stresses, in **The Nature of 2vpc LA Batteries**, that batteries operate as electrolytic, as well as voltaic cells, and pole nomenclature needs verification. Also, this raises the question of what exactly goes on when there is load leveling during fluctuating charge and load phases? There is ionic conduction in either direction, which depends on charge threshold, **but does load levelling, using periodic and possibly irregularly fluctuating current, interfere with optimal plate formation, as with shallow cycles under 5%?** **Bill Darden's** FAQ/11.14, states 10%. This should be known for management purposes, especially if battery life could be extended by corresponding charge regulation, and programmed into monitregs. Modern separators and plate mesh-wrapping should also help to control uneven plate growth, as should proper charge routines. Where possible, consult with battery manufacturers for specific charge regulation details as necessary.
3. **If batteries are constructed as modular units**, then handling lead and acid electrolyte would be facilitated, by discharge before removal to 16% acidity, then by further dilution and then neutralization. At refilling with full strength acid care would be needed. Modular batteries would bring down costs, assist recycle, of metals and salts, and bulk or bank batteries especially would be so much lighter and easier to handle.
4. The Manual has only general facts re manufacture, especially plate coatings before forming charge. This is usually lead and lead oxide powder, PbO, with sulphuric acid and other necessary traces, and should be the same for both plates, before placing in diluted sulphuric acid and the forming charge produces PbO<sub>2</sub> on the -ve/anode, and Pb on the -ve/cathode, etc. Any scored/ribbed Planté-type anode plate should also be pasted before the forming charge. (See also **Bill Darden's** FAQ/ 2.1) Presumably, the older deep cycle batteries had two Planté plates, more modern Planté plates would only be for the anode. Also, there will be differences between motive, solar, stationary back-up and deep cycle storage battery plate construction. But, deep cycle batteries do have more robust anodes than SLI batteries, regardless of manufacture, and whether grids or solid plates are utilised. Questions need to be asked of individual battery manufacturers if more detailed information is required by a purchaser, of either construction, or of specific charge regimes.
5. In relation to charge and discharge, do oxygen and hydrogen vent from **opposite** poles during these respective states? Again, what happens with load leveling? Is there more of one gas than the other vented during respective activities, ie beyond the original proportions of water, is extra hydrogen vented from the electrolyte?
7. Is FLA battery charge/discharge a totally redox reaction, or partially a metal deposition/dissolution reaction? Redox appears in sources, but needs corroboration, and a bit more explanation. Does Pb metal pass temporarily into solution while PbSO<sub>4</sub> is formed, or broken down? (There are lead ions(?) that do dissolve in discharged electrolyte, that plate onto the -ve/cathode. See **Modern Batteries** p. 145, **Useful Books**) **More detail on plate surface interaction in general would be of interest to further understanding of these processes.**
- 8) Is 35%/65% electrolyte a 4.5 mol solution? **(Appendix 1)**
- 9) **Confirmation and chemical explanation are needed that warmer temperatures increase hard crystal formation, only passing mentions were found, although this information is very important for overall battery management. Emphasis must also be put on allowing time for plate reformation**, as the reaction proceeds in either direction
10. Do shallower batteries de-stratify more easily with controlled overcharge than deeper batteries? This should be confirmed, and why. Also, can mechanical stirring be utilized, as a time and energy saver, or is there a risk of stirring up debris from the bottom that may short, or clog, plate pores?
11. **New Question, 20.3.04: Would it be possible to initiate ongoing de-stratification, (where practicable and/or low-cost/low-tech), with an inverse temperature gradient within batteries, viz, warmer temperatures at bottom than above, to initiate and maintain ongoing convectional movement of the electrolyte? Temperature control could be designed to operate in this fashion, heating the batteries from below rather than ambiently?**

These questions are asked to gain clarifying information of interest to the battery-dependent layman, or, to educate technical, as opposed to tertiary, science students. Elementary principles of physics, quantum physics, chemistry, electrical engineering, AC and DC, solar engineering, metallurgy, electronics and common sense are all involved. For ordinary consumers, a general text, such as this humble Solar Management Manual, would be always needed at a ratio of 100:1 or better, over any high-tech professional course. There may be extra questions posed, or new information gained for future Manual revisions.

Meanwhile, no more can be done to enhance this Manual's content without further outside expertise such as that already gleaned from **Bill Darden's** Battery FAQ or from the Booklist, so any error correction, or new, especially expert, information would be most welcome, and will be incorporated in further updates.

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**Excerpt 1:** from *Electrical Technology*, T. Baitech, Wiley Int. 1972, ISBN 0471043699, pp.42 to 47.

## Lead-acid batteries, The Planté Cell:

"This type of lead-acid cell, historically the first secondary cell, consists of two sets of plain lead plates immersed in diluted sulphuric acid (H<sub>2</sub>SO<sub>4</sub>). First, the cell is charged from a direct-current source, then discharged, and this process repeated many times. During this process, the surface of the plates will become porous, and plates connected to the positive terminal of the charging source will turn brown (change into lead peroxide), while the negative plates will remain grey ("spongy" lead). The capacity of the cell depends on the surface area of the plates, and with a view to increase it, the lead plates are usually cast with deep ribs or grooves. Since the plates are being actually chemically processed or formed while already in the cell, this cell is also said to be fitted with "formed" plates.

This type of cell is now largely superseded due to its comparatively large physical size and high cost, but is still used in special applications where very high reliability, long life (in excess of 20 years) and great short-term overload capacity are required, eg, in power stations, while its use in telephone exchanges is declining. (What we could now call a stationary back-up deep cycle battery, similar to the present more robust solar battery, see [Bill Darden's FAQ](#), 2.1, and [Feedback](#))

The cells usually consist of large, individual, rectangular jars, made of glass or plastic, containing the plates immersed in the electrolyte (distilled water plus acid). The cells are normally accommodated on wooden racks or lead-covered tables, to prevent damage from spilled acid. The overall chemical process in a lead-acid cell can be expressed thus:

**discharge**  $\text{PbO}_2 + 2\text{H}_2\text{SO}_4 + \text{Pb} \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$  **charge**

While the processes on the individual plates can be described thus:

**positive plate: discharge**  $\text{PbO}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{PbSO}_4 + \text{H}_2\text{O} + \text{O}$  **charge**

**negative plate: discharge**  $\text{Pb} + \text{H}_2\text{SO}_4 \rightarrow \text{PbSO}_4 + 2\text{H}$  **charge**

(Note that in this example both plates are solid planté type, used in earlier batteries)

This shows, in effect, that the active material of both types of plates is being converted into lead sulphate on discharge. Sulphuric acid is thus being extracted from the electrolyte, which becomes weaker during discharge of the battery. The drop in acid-contents of the electrolyte, measured conveniently as a drop in its density, is a measure of the degree of discharge of the battery and is in direct proportion to this. During charging, the acid, (salt ions), are returned to the electrolyte, which thus becomes more concentrated and heavier.

It should be noted, that hydrogen and oxygen are being liberated at the plates during the charging process. While most of these gases will recombine into water, some will escape into the surrounding atmosphere as a highly flammable and explosive gas mixture. This accounts for the necessity to replace water lost from the cells at regular intervals (acid never requires replacing as it does not leave the cell), never to approach any lead-acid battery with a naked flame and to ventilate well any rooms containing lead-acid batteries. For this reason, it is not possible to seal a lead-acid battery.

### The Pasted Plate (Faure) Cell:

This type of cell, by far the most popular at present, has been developed from the Planté cell and is of an identical construction, with the exception that the plates do not consist of pure lead alone, but of a cast lead-alloy grid with rectangular holes. These holes are then filled with chemically active pastes, consisting of red lead (Pb<sub>3</sub>O<sub>2</sub>) and sulphuric acid for the positive (brown-coloured) plate and of litharge (PbO) and sulphuric acid for the negative (grey-coloured) plate. (Distilled water being added?). The chemical reaction is similar to that indicated for the formed-plate cell and therefore the remaining considerations do also apply here.

(Note that deep cycle batteries also can have a solid anode, and a pasted grid cathode.)

To increase the capacity of a cell, positive and negative plates are placed alternately side-by-side into the cell, the positive and the negative plates respectively bonded together to form the positive and the negative terminals of the cell. Separators in the form of acid-resisting, porous, rigid plastic sheets are inserted between the plates, to prevent internal short circuits between plates due to buckling or to dislodging of active material from the plates. It is also for the same reason that the plates do not rest at the bottom, but on supports near the bottom of the cell. Mesh-wrapping of plates will also help to hold shape, and prevent shedding.

Normally each cell consists of an odd total number of plates (there always being one more negative plate than there are positive plates) for best economy and electrical performance, and it is customary to speak of a 7-plate or an 11-plate cell, which also gives an indication of its capacity. Individual cells are generally combined into batteries containing three or six cells. This general-purpose lead-acid cell has found its greatest popularity in the automotive field as well as in the field of traction (mining locomotives, fork-lift trucks and, lately, electric road-vehicles).

## Charging and discharging of lead-acid batteries:

The nominal service voltage of a lead-acid battery is approximately 2 volts per cell. During charging, internal voltage-drop, (IR-drop), and polarisation will make it necessary for the charging potential to be of the order of 2.2 volts to 2.7 volts per cell. Charging is essentially a matter of causing a chemical conversion which is a function of current, so that the important parameter during battery charging is the charging current.

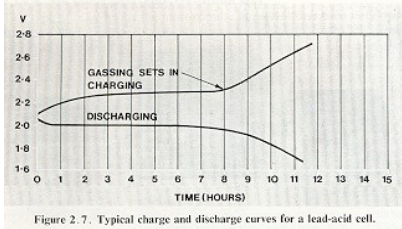
There are various methods of charging batteries, depending on whether the battery is permanently connected both to the load and to the charger (such as in telephone exchanges), or whether it is disconnected from the load during charging (emergency lighting etc.).

In the first case, the battery is said to receive a **float** charge (at a constant **voltage** application) or alternatively a **trickle** charge (at a constant **current**). This can be supplemented by short-time booster-charging (high-intensity "topping up") or by intermittent **float-charging**.

The most common methods of charging batteries which are disconnected from the load are the constant-current method and the two-rate charging or first-charging method.

In the constant-current method, the charging current is kept constant at a value which must not exceed the “finishing” rate for the battery, which is stipulated by the manufacturer and which is usually equal to one-tenth of the ampere-hour capacity of the battery. The battery must not be permitted to overheat during charging, nor must there be excessive “gassing”, due to the liberation of gas at the plates, towards the end of the charging period.

Figure 2.7 Typical charge and discharge curves for a lead-acid cell.



The two-rate charging method takes advantage of the fact that a battery can be charged at the beginning of the charging period with a current very much in excess of the finishing rate. This high current will charge the battery to as high as 90 per cent of its capacity within approximately 2 hours without damaging it, up to the point of severe gas-production (gassing) when the voltage of each cell rises to approximately 2.3 volts. At this stage the current is switched to the much-lower finishing rate either manually or automatically on the command of a voltage-sensitive relay.

A lead-acid battery may be discharged at any suitable current rate, as required by the prevailing service conditions. The potential will remain approximately 2 volts per cell for most of the duration of discharge, dropping gradually down to approximately 1.7 volts per cell. While it is possible to discharge the battery beyond this point, this is normally the limit of its useful range and frequent complete discharging of the battery will damage it, (causing buckling of plates and loosening of the paste). It is important that any lead-acid battery should be always maintained fully charged, if necessary by periodic topping-up charging, to compensate for normal internal discharge.

This is necessary, as the lead sulphate in a discharged plate changes its structure and becomes a white deposit on the surface of the plates. This “sulphating” of the plates reduces the capacity of the battery and can be removed only with difficulty (and only if it is not too old) by numerous cycles of charging and discharging.

It has also been mentioned before, that the ampere-hour capacity of a battery decreased rapidly with increase of the discharge current. This reduction is quite appreciable, typical figures being 80 per cent of the 10-hour ampere-hour capacity if the discharge current is twice that of the 10-hour discharge current, and 60 per cent with current at three times the 10-hour rate.

**Note that the preceding section emphasises the need for proper regulation technology being part of the monitreg system for solar deep-cycle, or any lead-acid battery charge cycles, in any application. The regulator should be sophisticated enough to enable stages of boost, absorption, equalization, float, and rest, when the battery is ready for the changes!**

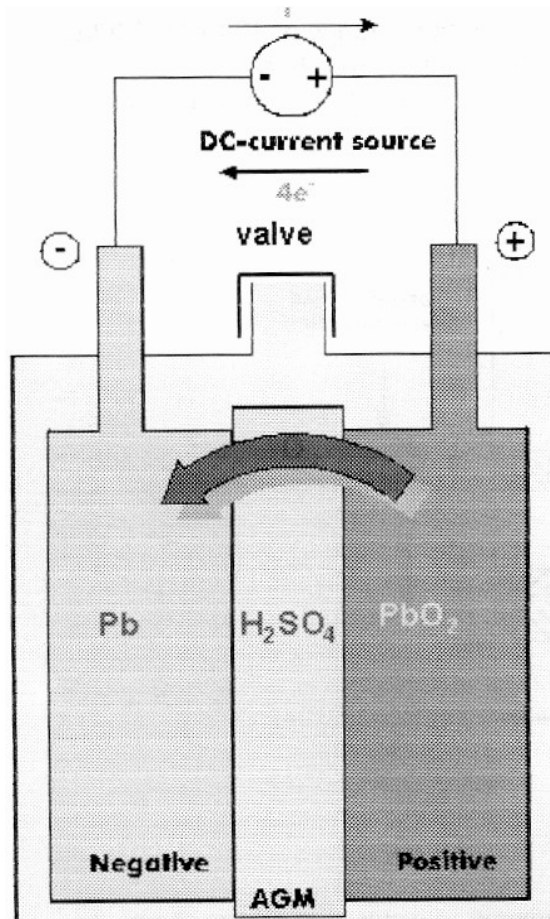
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**Excerpt 2:** from the [Accu Oerlikon](#) website, being a description of the oxygen recombination cycle as utilised in AGM and Gel lead-acid battery types:

**Lead Acid Batteries VRLA Types, (Valve Regulated Lead Acid), Definition:** According to the International Electrotechnical Vocabulary, (486-01-20), a VRLA battery is defined as follows: "... A secondary cell which is closed under normal conditions but which has an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The cell cannot normally receive additions to the electrolyte".

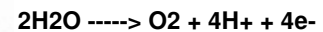
**Fundamentals: The fundamentals of operation of the gas recombination in a VRLA lead- acid cell are described below:**

(Schematic view of the oxygen recombination cycle in a VRLA cell in which the electrolyte is immobilized/absorbed in a glass mat (AGM), see the Web page for greater detail).



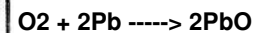
During float charge the current decomposes water and oxygen is evolved on the positive plate according to the reaction:

electrochemical oxidation of water with oxygen evolution:

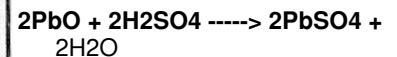


The oxygen is diffusing via the gas phase through unfilled pores of the glass mat separator to the negative plate, and reacts there chemically with the formation of lead oxide, lead sulfate and water:

reaction of oxygen with lead:

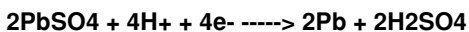


reaction of lead oxide with the electrolyte and formation of water:



The float current passing through cell then reduces, instead of evolving hydrogen, on the negative electrode the formed lead sulfate back to lead and sulfuric acid so that a closed cycle (oxygen recombination cycle) is obtained.

electrochemical reduction of lead sulfate:



The overall oxygen recombination reaction is hence:

$\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}$  Due to the oxygen recombination reaction essentially no hydrogen evolution occurs on the negative plate.

#### Heat generation:

Battery life and performance is influenced by temperature. Internal heat generation occurs in the lead acid cell during charge and discharge. The typical heat evolution in a flooded 588 Ah(C10) lead acid battery is shown below. Source: "**Blei-Akkumulatoren**", VHB

**In VRLA batteries** a lower end-of-charge voltage is used (**2.22 to 2.28 Vpc**). Hence a reduced heat evolution is expected. However **the internal oxygen recombination reaction is a new and additional source of heat**, generating approximately 0.09 Watt power per cell and 100Ah/C10 capacity. The heat evolution differential between a 100 Ah/C10 flooded and VRLA cell in float service is shown below. [AGM and Gel VRLA battery maximum charge input is generally only up to 2.35 vpc, use dedicated VRLA regulators, and always observe manufacturers specifications for charging regimes!]

The waste-heat generation Q is given by the following formula:

$$Q = 0.77 \times \text{number of cells} \times \text{current (A)} \times \text{hours (watt hours)}$$

Good operating practice of batteries requires an efficient heat removal (see Section 5) specifically with VRLA types.

Heat stagnation can cause thermal runaway. Thermal runaway is a critical condition arising during constant voltage charging in which the current and the temperature of a battery produce a cumulative mutually reinforcing effect which further increases them and can lead to the destruction of the battery.

### Corrosion phenomena of lead alloys:

An aging factor in lead acid batteries is the corrosion of the current collector grid. The choice alloys for VRLA battery grids are lead-calcium-tin and lead-tin alloys with the calcium level ranging from 0.03 to 0.09 % and the tin level from 0.3 to 2.0 %.

More exotic alloys containing lead-antimony-cadmium and lead-strontium-tin are also in use or have been proposed.

The grids of the positive plate of a lead acid battery are subject to a corrosion process in which lead (Pb) is transformed into lead dioxide (PbO<sub>2</sub>). The corrosion rate increases with temperature (doubling approximately every 10 °C), float voltage and acid concentration. The corrosion attack may be an area type attack or a grain boundary attack or a combination of both.

The corrosion product, lead dioxide, requires a 37% higher volume than the lead source material. This volume expansion induces mechanical forces in the grid which will become deformed and stretched. This deformation is called growth and reduces the contact of the current collector (grid) with the active material. A capacity decay occurs. The growth is not linear in time but accelerates rapidly toward the end of the design life.

At a growth level of 4-7%, grid fractures and capacity losses of the battery occur. In extreme case internal shorting and cell case rupture may ensue.

The transformation of lead into lead dioxide consumes also the water of the electrolyte (1g Pb = 0.17g water) which further impinges on the performance of the battery. In VRLA cells and monoblocs a chemically aggressive condition may occur on the surface of the negative plate lugs and straps. This condition is triggered by the oxygen recombination reaction and the presence of inorganic sulfate salts in the electrolyte.

This aggressive condition causes the so called sulfate rot, i.e., a catastrophic corrosion of the negative plate strap. An appropriate choice of high purity alloys (absence of antimony, arsenic) and tin levels at 1-3% together with a grain size modifier can prevent this corrosion to occur.

### Water loss in VRLA batteries:

A further life limiting factor is electrolyte water loss. VRLA batteries are designed to operate during their entire service life without any topping-up of the electrolyte with water. For this purpose, an oxygen recombination cycle is introduced so to reduce the loss of electrolyte water to a minimum. However water loss does nevertheless occur and has following magnitudes:

**recombination efficiency <100% approx. 0.016 g per 100 Ah cell and day,**

**excessive float current 0.336 g per ampere hour excessive float current and cell,**

**positive grid corrosion 0.17 g per gram of lead oxidized to PbO,**

**cell case transpiration approx. 0.06 g per 100 Ah cell and day at +40 °C,**

**self discharge reaction approx. 0.0336 g per 100 Ah cell and day at 20 °C.**

**Excessive water loss by one or more of the above mechanisms can cause the premature failure of a VRLA battery by a process called dry-out. Dry-out results in reduced electrolyte volume and capacity loss."**

Copyright 2001 [accu-info@accuoerlikon.com](mailto:accu-info@accuoerlikon.com) Reference to the [Accu Oerlikon](http://www.accuoerlikon.com) website is advised to ensure the accuracy of the text and diagram details of this excerpt, and, the latest updates.

**Do not equalise VRLA batteries unless specifically instructed to do so by the manufacturer! Remember to check battery manufacturers VRLA charge limits, and use 3-stage regulators.**

**Additional heat generation in VRLA batteries, due to the oxygen recombination cycle, means ambient and operating temperatures must always be monitored. Under an engine bonnet would not, therefore, be the ideal position for a VRLA battery if full working life is to be expected?**

**VRLA batteries are useful as emergency PV system backup, however, due to being sealed, and also low-maintenance. The battery cases and connections should always be kept clean and uncluttered to prevent current leakage or shorting.**

(For more technical references, see [Useful Books](#))

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**Internet Sites:** For solar PV and battery information, and other alternative energy, try these good sites. The information can also be complemented by utilising their links, and by using key search words in conventional search engines. For example, try battery chemistry, solar/battery technical data, deep cycle batteries/care and maintenance, or, solar research, solar/battery glossaries, etc. Glossaries and FAQs usually give good value. Note that some facts may differ, use your judgement, or suggest cross-checking with other sources, and also check with related conventional texts and dictionaries as you find them. **Put into Google, et al, or, use the links in the HSPM&W html version, via the Home Page Index:**

[Accu Oerlikon](#)

[Alternative Energy Association](#)

[Bill Darden](#)

[CREST](#)

[CSB Battery ?](#)

[Eaton Powerware](#) (International main grid voltages listing)

[Electrochemical Dictionary, Electrochemical Encyclopedia](#)

[ENSO Wrap-Up & SOI Index Graphs](#) (Pacific Ocean El Nino weather forecasts, graphs, and archival data)

[Homepower Magazine](#)

[HOMER](#)

[Independent Power and Light](#)

[Plasmatronics](#)

[PV FAQ](#)

[SANDIA](#)

[Shaka Desuphation, In The Light Desulphation ?](#)

[Solar4Power](#)

[Solar Panel Articles](#)

[Solar Power News](#)

[Solatron Technologies](#)

[US Battery Company](#)

[US Department of Energy PV Factsheets](#)

[New Scientist, CNN, BBC, & Physorg.com](#) (Useful mainstream information sources)

[WindSun](#), and any links from all of these.

**There are other battery types such as nickel-iron and nickel-cadmium which may be utilised for certain stationary backup or alternative energy uses. Their voltages, charge cycles, and management, are different to FLA lead-acid batteries, and they are not described in this Manual. Nofrillstech has found information relating to these alkaline batteries to differ according to sources, so consult the most up-to-date practical sources to be sure of data integrity if their use is considered.**

In general, the main differences between FLA and NiCad and NiFe batteries are that NiCad cell voltages are 1.30v-1.34v, NiFe are 1.37v-1.41v, they both have a 21% potassium hydroxide electrolyte, they are more cold than heat-tolerant, (NiCad are very efficient, and are especially cold tolerant, NiFe are the more inefficient when cold). Both store well without charge, withstand high discharges without the material stress of FLA batteries, and are of stronger construction. Their solid metallic plate material is not altered during redox reactions to the extent of FLA plates, being insoluble in the electrolyte, but they have higher internal resistance and also have shorter work cycles than FLA batteries. Their maximum charge is 16.8 volts, @ 1.6-1.8 vpc; SG is 1.3, although a hydrometer is not a reliable electrolyte test. 10 alkaline batteries make a 12 volt bank, and, 20 make a 24 volt bank, when connected in series.

They are more expensive, being less common, especially NiCad, (which are also potentially toxic), and, though lighter per unit than FLA batteries, are heavier overall, requiring more batteries per bank to meet the same voltage requirements as FLA batteries would. The 21% KOH electrolyte should be pure, have no dissolved CO<sub>2</sub>, and contain some lithium hydroxide when used in NiFe batteries, to ensure plate health. **DO NOT STORE NiFe & NiCad BATTERIES CONTIGUOUS TO FLA BATTERIES**, because of mutually deleterious vapour interactions.

These alkali batteries usually have much greater longevity than FLA batteries even if indifferently managed, but this still may not influence the economics of their usage. Although, perhaps they are to be recommended in place of FLA

**batteries when less-than-optimum management is expected? Your choice?** (See also the battery references included in the **Useful Books List** for other power storage possibilities) **Also note that:**

- 1) **Main grid voltages vary world-wide, allow for this while Web browsing. This Manual is based on inversion for 240v/50Hz grid interface and appliances. Standalone systems may vary from main grid standards, however.**
- 2) **Lead-acid batteries do not have real “memories”, only apparent, and caused by states and conditions that, if sustained, will lead to serious battery damage, especially by large hard-crystal sulphate formation.**
- 3) **The deeper or more intense the discharge of any batteries, the more material stress results, and, the shorter their useful working life, even with optimally-regulated charging cycles.**
- 4) **Putting automotive batteries beside engines may be great for convenience, but is retrograde in terms of optimal battery health and longevity, and use of original resources. All lead-acid batteries should function, or be stored both cushioned and protected, fully charged, in ideal temperatures, 20°C-25°C if possible, and, certainly away from any heat source, unless, of course, ambient heating to 25°C is required in colder climates.**

## Useful Books List:

**A History of Electricity**, E. Canby, Hawthorn 1963, ISBN 6310092

**Chambers Science & Technology Dictionary**, 1991

**Contemporary College Physics**, E. Jones & R. Childers, Addison Wesley 1993, ISBN 0201557215 (or similar)

**Crystal Fire**, M. Riordan & L. Hoddeson, Norton 1997, ISBN **0393041247**

**Electrical Technology**, T. Baitch, Wiley Int. 1972, ISBN 0471043699

**Electrical Theory and Practice**, Gov. Printer, Wellington NZ, 1977

**From Space to Earth**, J. Perlin, aatec 1999, ISBN **0937948152**, (an interesting history of PV)

**Fuel Cell Systems Explained** Ed. 2, J. Larminie & A. Dicks, Wiley 2003, ISBN **047084857X**, (qv Ch. 1 & pp. 270-275)

**Fusion**, G. McCracken & P. Stott, Elsevier 2005, ISBN **012481851X**

**Got Sun? Go Solar**, R. Ewing & D Pratt, PixyJack Press 2005, ISBN **0965809870**

**Marine Electrical Electronics Bible**, Ed. 3, J. Payne, Sheridan House 2007, ISBN-10:**1574092421**

**Modern Batteries**, Ed. 2, C. Vincent & B. Scrosati, Arnold 1997, ISBN **0340662786**, (q.v. Ch. 5 pp. 142-161)

**Modern Battery Technology**, ed. C. Tuck, Ellis Horwood 1991, ISBN **0135902665**, (q.v. Ch. 4 pp. 194-244)

**Penguin Dictionary of Chemistry**, 1990

**Power to the People**, M. Green, UNSW Press 2000, ISBN **08640554X**, (a beginner's guide)

**Practical Photovoltaics**, R. Komp, aatec 2001, ISBN **09374811X**, (more advanced, but not overly technical)

**Renewable Energy**, ed. G. Boyle, OUP 1996, ISBN **0198564511**, (q.v. Ch. 3 pp. 89-135, not overly technical)

**Solar Electricity Basics**, D Chiras, New Society 2010, ISBN **9780865716186**

**The Natural House**, D. Chiras, Chelsea Green 2000, ISBN **1890132578**

**The Physics of Solar Cells**, J. Nelson, Imperial College 2003, ISBN **1860943403**, (advanced)

**Tomorrow's Energy**, P. Hoffman, MIT 2001, ISBN **0262082950**

**Good references for information concerning climate change initiation and processes:**

**Climate Crash**, J. Cox, Joseph Henry 2005, ISBN **0309093120**

**Coal**, B. Freese, Perseus 2003, ISBN **0738204005**

**The Ferocious Summer**, M. Hooper, Profile 2007, ISBN **97881846680083**

**The Breakdown of Climate**, P. Bunyard, Floris 1999, ISBN **0863152961**

**The Ice Chronicles**, P. Mayewski & F. White, UNH 2002, ISBN **1584650613**

**Hothouse Earth**, J. Gribbin, Bantam 1990, ISBN **0552994502**, also [Epitaph for a Planetary Biosphere](#)

**Also, re the scope of fossil fuel resources remaining:**

**Out of Gas**, D. Goodstein, Norton 2004, ISBN **0393058573**,

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## Appendix 1: Definition of a Flooded Lead-Acid Battery:

A secondary lead acid accumulator, EMF of average 2V, positive electrode being of lead dioxide, and the negative being of lead, (sponge lead for quick SLI draw, and scored sheet lead or heavy pasted grid for deep-cycle), the normal electrolyte being of water 65% and H<sub>2</sub>SO<sub>4</sub> 35%, and 85-95% efficient in energy storage and discharge.

OR, an electrochemical device, (a voltaic pile), that converts chemical energy into electrical energy by use of a galvanic cell, which consists of anode, (oxidative electrode), cathode, (reductive electrode), and ion-conductive electrolyte.

OR, an electrical storage device, based on a reversible chemical reaction that restores PD/EMF between unlike poles, which are suspended in a conductive medium of electrolytic fluid, usually water 65%, sulphuric acid 35%, (possible 28%-42% range).

The reaction involves the double sulphate reaction principle, a reversible reaction driven by current flow, that is dependent on the cyclic liberation and recombination of electrons from the sulphate radical, and overall maintenance of the chemical equilibrium, with balanced reactants, plate reformation, and electrolyte integrity. The electrolyte is both ionic transporter, and active reaction participant, with the SO<sub>4</sub> radical reacting with PbO<sub>2</sub> and Pb at respective electrodes.

**Note that repeated shallow cycles, of less than 5%-10%, (ideal for SLI batteries, but not for solar batteries), can be damaging, causing dioxide clumping on the anode, which may shed due to mechanical stress, and remain dormant as sediment. However, modern separators and mesh-wrapping, plus appropriate monitoring settings and optimal cycling and recharge regimes, should prevent this occurring. Consult battery manufacturers for specific charge regimes as required.**

Excess and/or rapid discharging of deep cycle batteries also causes damage due to incomplete sulphate reversal and mechanical stress, though these are less damaging to SLI batteries if within normal operation parameters. SLI batteries should not discharge below 20%, or deep cycle batteries below 40%, despite ratings that purport to go to 80% DOD. Recharging cycles should always be as complete as possible for lead acid batteries, especially when equalizing. **Recharge should always be after every discharge cycle, or at least every 24 hours.** Interim opportunity charging, though useful, is not sufficient to maintain battery health, and a full charge regime should follow ASAP.

NB, sponge lead is used in shallow-cycle, quick draw batteries such as SLI batteries at .040"/1mm thickness, increasing plate porosity and thus reactive area. Sheet plates for deep cycle batteries are usually >.150"/.375mm, with >16% antimonial alloy for strength and durability. There are also low- and no-maintenance variations of lead acid batteries, using lead calcium alloys. Deep-cycle FLA batteries may have a solid lead anode for robustness, and a pasted lead grid cathode, and are generally more robust in construction when greater cycling life is required. They range in type from occasional back-up to industrial motive models, with deep-cycle storage solar batteries somewhere in between. There are also stretched lead and pasted grid versions, tubular grid plates, (usually for anodes), or stacked circular grid plates, and the choice will depend on application, and robustness or performance required. (See [Bill Darden's](#) FAQ 9.14 re plate types, and battery references in the [Booklist](#))

### Effects of Temperature on Battery Function and Charging:

The overall reaction in lead cell batteries is affected by **heat**, most importantly beyond optimum operating temperatures, by increasing resistance. The charge current is needed to push the discharge reaction back the other way, and this is then inhibited by charge resistance. Small-crystal lead sulphate forms on each electrode during discharge, is not an effective conductor, and passivates the active material beneath, which may undergo further bond changes, while contributing to even greater resistance. Heat energises the electrolyte, holding more ions in solution, and also increases the overall reaction, which must be regulated by amperage limits, and even temperature control.

Chemical aggression in **charged** batteries is increased by **heat**, also increasing self-discharge and hard crystal formation in unattended batteries, damaging the anode by increasing plate corrosion if there is exposed plate metal. This is worsened by excess acid, and overcharging or sustained high float. **Cold**, on the other hand, limits solubility and activity of salts in the electrolyte, limiting the de-sulphation stage of the reaction, which also contributes to slow sulphate hard (large) crystal formation, if the batteries are inactive. Hard (large) crystal formation takes 2-3 weeks, depending on temperature, if the batteries are not returned to optimum charge. Lead sulphate is not very soluble in the electrolyte, and the reactivity needs to be driven by electrical charge; hard-crystal sulphate is even less soluble, therefore prevention of the hard crystal formation by regular charge regimes is important. (See [Modern Batteries](#), p. 149, [Useful Books](#), for a description of hard crystal sulphation having a lower surface area.)

The dilute electrolyte and plate sulphation cause initial resistance as charging begins, and cold will limit charge-carrying capacity below optimum temperatures. Pore size of the plates and separators is also reduced by cooler temperatures, and ion conduction and cell recovery after discharge are also affected. Barrier sulphation in badly discharged batteries also clogs plate and separator pores, inhibiting electrolyte movement, and thus ion transport. **Severe hard crystal formation usually means battery replacement.** (See also [Shaka Desuphation](#))

Cold reduces the charge carrying capacity of batteries because less ions are being carried in solution, and ionic transfer is slowed. A fully discharged battery will freeze, as the SG approaches zero, much of the SO<sub>4</sub> component having been removed from the electrolyte. Note that SG will be apparently higher in winter, because the electrolyte will be denser, and compensation tables should be consulted. (See the [Wallchart](#)) A fully discharged battery will have 16% acidity by weight. ([Modern Batteries](#), p. 143.) Quick, heavy, discharge takes salts out of solution rapidly, and heat generated will promote mechanical stress and consequent electrolyzing and/or vaporization of the water component of the electrolyte, and promotion of possible hard crystal formation if there is no following recharge.

**In any discharged batteries, inactivity worsens the less reactive large-crystal stage of sulphation, reducing the chemical carrying capacity of the solution, and the charge-carrying capacity. Special sustained charge regimes are needed to overcome hard-crystal sulphation, causing more stress to the batteries. Better prevention than cure. Note**

that “sulphation,” used loosely, usually refers to large hard crystal sulphate formation. Thus, prompt recharging is important, at any temperature, as is maintaining an optimal discharge range, relative to battery type.

**Cold sustains small-crystal sulphation in partially discharged batteries, due to lowered ion-carrying capacity of the electrolyte at a lower temperature, and there is initial resistance to charge. Heat, in turn, promotes mechanical stress, chemical aggression, self-discharge, hard crystal formation and generates increasing heat-inducing resistance during operation, especially when charging. Optimum charging cycles, temperature control, and/or a de-sulphator permanently fitted into the charging system, are the easiest solutions. (There is still debate about high frequency pulses and battery health.)**

**Winter charging should be raised by 1V/24V, (or .5V/12V), see [Wallchart](#) figures. Basically, normal summer charge should go into short equalization, and in winter, somewhat longer. Large panel wattage or a generator will charge similarly, so set the regulator/monitor accordingly. Shorter, more numerous equalization times are now deemed sufficient, see [Appendix 3/9](#)**

**Equalization** is best carried out after a full day’s charge from the sun, lessening the time needed for generator charging. Anywhere between 30v-31v will do. Also, the shallower, or smaller the battery, the less bubbling should be required to mix the electrolyte, again a consideration when saving generator time when equalizing. If there is a large drain at night, start the generator for a short period, so that the battery bank does not “rest” with too low a charge, which is especially important if the bank is not temperature controlled to resist such temperature drops. **Better not to have this sort of situation, at least boost-charge opportunity cycles should always be completed at the time for optimal sulphation reversal and plate reformation.**

Engine heat maintains ions in solution in car batteries, though they are also affected by proximity to a hot engine due to chemical aggression and vibration, but any motion does promote electrolyte de-stratification. Hard crystal sulphation is inhibited as long as there is optimal charge, and as long as the battery does not sit idly for long periods, so that any partial sulphation will not revert to hard crystal formation. As with all lead acid batteries, charge drift, towards discharge, will occur, as the lead/acid reaction will continue on a small scale when the battery is not being used or charged. (Car batteries do have shorter lives because of mechanical stresses of shallow many cycles, expansion, contraction, heat, vibration, and less robust sponge lead anode, which also renders them unsuitable for deep cycles.)

**Hence the importance of trickle charge to offset charge drift when all lead-acid batteries are not in use, as well as maintaining some activity of the electrolyte until proper equalization can be carried out. This constant activity does, of course, inhibit hard crystal formation. Sustained bubbling at a high float 2.4-2.5 vpc is beneficial for existing hard crystal de-sulphation if a de-sulphator is not installed in the charging system, but is mechanically and chemically stressful.**

**Once again, prevention is better than cure, and this includes buying used batteries without signs of excessive hard crystal sulphation. Check used/secondhand batteries by voltmeter, [TECSSS](#), and a measured discharge/recharge cycle if possible. Only install batteries of similar capacity and condition in battery banks.**

**Summary:** A stable battery is one that is fully charged, or on a trickle/float/ maintenance charge, regularly equalized, and stored or operating in a temperature range of 25°C-27°C. Monitors that read charge at all stages are to be preferred to the simpler versions, and float should be just above the EMF fully charged, and electrolyte levels monitored.

**Boost/bulk charging as a matter of routine should at least go into absorption at temps above 12.7C, and ideally to 28.6v, and beyond absorption when below 12.7C, ideally to 29.6v, if not temperature controlled. These levels should be held for at least 30 minutes to benefit the batteries, promoting sulphation reversal, some electrolyte de-stratification, and optimum charge levels in all cells. Such a regime will then cut down on any equalization time as well, while maintaining healthy electrolyte SG levels. (29.6v is 2.4-2.5vpc)**

**In ideal conditions, a monitor-regulator will push PV boost charge, linger over absorption, then taper to boost maximum briefly, before returning to float. These settings can be customised for individual systems and operating conditions, and can also regulate generator charge, as well as periodic equalization sessions. However, do not push the boost amps beyond C10 in any season, (10% of 10a-h rate) and 15-20 amps would be optimum for any domestic system, either by generator or PV. Charge state is a function of healthy SG as well as good resting voltage.**

**[TECSSS!](#)**

**Also, electrolysis does inhibit reactions on plate surfaces due to gas bubble formation, but the battery should not be drawn on during high charging to prevent damage to sensitive equipment anyway. Ceasing draw-downs during equalization will also speed the process of controlled overcharge, and the dedicated activity will help to reverse any hard crystal sulphation at 2.4-5vpc and above.**

**Small discharge/charge cycles of less than 5%, if not prevented, will damage deep cycle batteries because the full range of chemical reactions does not take place, as is the case with rapid cycling by high current discharge. All charge cycles should restore full charge, with regular equalization following at least monthly. Cold battery temperatures prolong battery life, while limiting performance. Sustained heat reduces battery life by half for every 9°C over 25°C, thus, an operating temperature of 52°C if prolonged will reduce battery life to one eighth. Summer and winter temperatures may cancel each other out during battery life, but optimal temperature controlled conditions are recommended, to prevent the mechanical stresses of temperature extremes. Acid concentrations should be adjusted for cold or hot climates, so ensure battery acid is matched to climate, unless temperature control is guaranteed during operation.**

**Lead acid batteries do not have a “memory”;** the emphasis on completed boost cycles, whenever possible, is to do with optimum sulphate reversal, which is only achieved by completed recharge, as the anode also recharges faster than the cathode, complemented by regular equalization. **TECSSS!**

**As a matter of interest,** mechanical equalization is performed in large industrial battery banks, perhaps such tactics will be adapted to smaller installations? This would cut equalization time, especially by generator, to 20 minutes or so, usually sufficient for charge equalization, depending on battery size. Stirring any settled debris would need to be avoided, though.

**Included in the Wall Chart is a thumbnail charge measurement formula:**

**SG + 0845, at 25°C and with normal acid ratio = VPC charge**

To expand on this, a false high charge will show on a cell with poor SG, which means that the amp-hour performance will also be less than optimum, because full sulphate reversal has not occurred, plates are not fully reformed, and there may also be hard crystal sulphation present. Thus, in terms of performance, the thumbnail check, if carefully carried out, may be the truest SOC test in lieu of more sophisticated means such as a high-rate discharge test, or a timed set discharge. Any VPC thumbnail findings can be referred to on the Chart charge table, which will yield SOC as a percentage that can be factored into immediate usage calculations, or charge cycle planning. **Also, a battery should rest for a true reading after charging ceases, about 30 minutes or so, to disperse over-voltage.**

**Boost**, or bulk charge accounts for 15%-85% of charge, when utilizing maximum current, at the C10 rate.

**Absorption** charge accounts for 15%-25% of charge, 13.6/27.2V to 14.2/28.4V, as the charge tapers to 30/31V, when **equalization** takes place.

**Float** follows, 12.8/25.6V to 18.8/26.4V, to counter self-discharge, and inhibit sulphate reversal. **Sustained high float can cause damage, promoting chemical aggression and fluid loss, so conservative levels are recommended.** Excess gassing, due to high charge or high load, can also stress plate surfaces, and is a precursor of excessive heat buildup, especially with higher ambient temperature.

**Another Thumbnail Check for healthy electrolyte is that charged 2vpc LA cells have a resting resistance of 7-8 ohms.** (Metals and electrolytes are ohmic. See also **Unanswered Questions/1**). Less available discharge current means less sulphate ions in solution, and the increasing sulphate barrier covers and passivates the Pb and PbO<sub>2</sub> respectively. Thus, reactant involvement is decreased, and, as there are so few ions in solution, more **charge** current is required to ionize the water and drive the overall reaction, so that resistance in a deeply discharged battery will be relatively higher until ion transport is increased, hence the slow start to recharging flat batteries. **Prevention is better than cure, avoid low discharges, and use temperature control as well to aid charging performance.**

### **The Nature of 2vpc FLA Batteries, and Prevention of Damage:**

The balance of chemistry in flooded lead acid cells is transient, and equilibrium that may be gained at any stage of the charging cycle is never permanent, as the trend is to eventual discharge if the battery left without re-charge, however long that will take. External load also sends the internal cell reaction in the direction of discharge, so a corresponding re-charge, in the opposite direction, must take place, plus some 30% more charge to overcome cell and BOS resistance. The 2vpc FLA battery is about 75%-85% efficient, in good condition, the EMF/OCV varying slightly depending on electrolyte concentration, plate chemistry, and operating temperature.

**Thus, batteries are not simple capacitors, storing electrons after charge, but lead a quite different double life, in that when being charged, they are classed, and behave as, electrolytic cells, and when they are being discharged, they are similarly classed and behave as voltaic cells. Also, as **batteries** they have positive (electron deficiency) and negative (electron surplus) electrodes or poles, and as **electrolytic cells**, they have anodes, (electron donors), or cathodes, (electron accumulators), respectively. In this text, poles, electrodes and plates are interchangeable terms.**

**Batteries are, therefore, electrochemical machines, converting electrical energy into chemical energy when being charged as electrolytic cells, or vice versa, converting chemical energy into electrical energy as voltaic cells. A recharge surplus, >30%, is required to restore a voltaic cell to full EMF. The electrolyte is an active participant, as well as ionic carrier.**

In a voltaic cell, reduction is at the negative pole, and oxidation at the positive pole, and in an electrolytic cell, oxidation is at the cathode, and reduction is at the anode. **Metal components transport electrons by conduction, and the electrolytic component, average. 35% sulphuric acid and 65% water by weight, transports ions to respective plates, by diffusion, electromagnetism, and convection or forced convection/stirring.** Natural convection begins about one minute after discharge begins. **Resistance and conductance are opposites of each other, written as ohm, or mho, omega, or omega-1, or R for resistance, and conductance as S for Siemens.**

Plates form and reform as the reactions and cell classifications are reversed. Half-cells are formed at respective poles during charge or discharge cycles, the sum of whose potential equals the cell voltage at any stage of either cycle, see the equation below. Age, electrolyte state and plate condition also influence cell performance. Excessive current in either direction will cause water vapour gassing from heat or electrolyte disturbance, or by electrolysis of water, thus venting oxyhydrogen gas. When charging, oxygen bubbles from the anode, and hydrogen from the cathode, when discharging, it is vice versa.

**There are differing charging rates, (the anode charges before the cathode), and this is why equalization is important, plus for de-stratification, ensuring optimum charge and re-formation on both sets of plates.**

**Definition of PD, EMF, and OCV:** PD means Potential Difference, and is interchangeable with EMF, or Electromagnetic Force, and is the voltage available across the terminals. OCV, or open circle voltage can mean the same, but is the term used when the battery is connected to an outside circuit, with or without load.

**NB,** SLI batteries have sponge lead plates more suitable for shallow, rapid cycling, (maximum 20%), and deep cycle batteries may have thicker plates of scored/ribbed/stretched/alloyed lead or heavy grids for greater mechanical strength and longer life, and especially, more robust pasted anode plates, all for tolerating more regular deeper cycling, maximum 80%, although this should be avoided, 40% is optimum. Both flooded lead-acid types have the same basic chemistry. Plates are made to increase reactive surface area and pore size. SLI batteries usually have 5% more acid, so SG readings will vary accordingly. (See also [Excerpts](#) for a description of lead-acid Gel and AGM VLRA batteries, and their chemistry and maintenance specifications, and [Feedback](#) for **Bill Darden's** comments and link.)

SLI batteries are made from lead antimony grids, (or calcium alloy grids for less self-discharge and bubbling), packed with a paste of lead oxide, (reddish-yellow litharge, PbO), sulphuric acid, and additives, (the Faure Process), then measured electrolyte is added, and a forming charge administered. Both plates are sulphated by the reaction of the acid, then with the forming charge, the PbO on the cathode is replaced by lead, (grey Pb), in a spongy form, and on the anode the PbO is replaced by lead dioxide, (chocolate-coloured PbO<sub>2</sub>), and the battery is then fully charged. The negative grid may also have lead powder in the paste, plus the sulphuric acid and other additives.

Deep cycle batteries are made the same way, but have positive/anode Planté plates of scored/ribbed sheet or grids of lead alloy for greater strength and longevity, (increasingly lead-calcium for inhibition of self-discharge), although the overall reaction will be less rapid than with spongy lead, as there will be relatively less anode area. (See [Feedback/17](#) for details of usual conformation). The negative/cathode is made from a lead alloy grid, with PbO-based paste applied, when the electrolyte is added, the battery is discharged, and the forming charge produces Pb on the negative plate, and PbO<sub>2</sub> on the positive. (Earliest versions had Planté plates for each pole, see [Baitech, Excerpt 2.](#)) There is usually one more -ve/cathode than anode plate to provide extra reactive surface and storage of electrons in a fully charged battery in both kinds of batteries, SLI and deep cycle. Modern deep cycle batteries may now have pasted grids at both poles, but the anode or positive grid will usually be more robust. **(When a charged battery, as a voltaic cell, is discharged, electron flow is from -ve to +ve, but conventional current flow calculations are traditionally vice versa.)**

Deep cycle solar or stationary batteries may last 2 or 3 times longer than SLI batteries, with optimum cycles of twice the depth. But the cycles should always be steady up, and steady down, not less than 5%, and not more than 40%, at most at 50%. The 50% reserve means easier plate reformation with charge, the electrolyte still being relatively concentrated, and the electrode materials not so heavily stressed by the cycling activity. Avoid heavy sudden discharges, sudden overcharging, or using in a partially discharged state. **Larger batteries mean easier cycles, and longer life, so extra capacity is not a false economy at all.**

**The double sulphate discharge reaction, from negative to positive, is a redox reaction within an ionized liquid, aka an electrolyte, characterised thus:**

$\text{PbO}_2 + \text{Pb} + 2\text{H}_2\text{SO}_4 + 2\text{H} \rightleftharpoons 2\text{PbSO}_4 + 3\text{H}_2\text{O}$ , which is reversible by charge, and also involves atoms of ionised water in the electrolyte to balance the equation.

**On the +ve/anode:**  $\text{PbO}_2(\text{IV}) + \text{H}_2\text{SO}_4 + 2\text{H} + 2\text{e}^- \rightleftharpoons \text{PbSO}_4(\text{II}) + 2\text{H}_2\text{O}$  (1.685v)

**On the -ve/cathode:**  $\text{Pb}(\text{II}) + \text{H}_2\text{SO}_4 + \text{O} \rightleftharpoons \text{PbSO}_4(\text{II}) + \text{H}_2\text{O} + 2\text{e}^-$  (0.356v)

There is a half-charge at each pole, contributing to the overall net charge of 2.041vpc. The reaction will only proceed in one direction, current-wise, at a time, and this current direction depends on the external control and/or thresholds of circuit reversal, or, when resting with OCV. See also [Unanswered Questions/2.](#)

Either reaction proceeds until the electrostatically charged field produced by the opposite polar charges prevents further electron transfer. PD/EMF is then  $\pm 2.2\text{vpc}$ .

The 2 electrons, which are taken up and released by the reversible formation of the salt, are the source of the current in a battery, and charge or discharge are really their transport by a controlled short circuit via an external resistor/charger that drives the overall reaction in either direction. Roman numerals denote potential ionic bonds. (See [Baitech, Excerpt 1](#), for a description of **Planté** and **Faure** Plates).

Cessation of this current through the circuit means an equilibrium of reactants that is theoretically maintained until the circuit is again opened, although there is self-discharge over time, 2%-10%, that must be overcome by a float charge in unused batteries. There is sufficient resistivity in a lead/acid battery and BOS to prevent rapid self-discharge, as evidenced by the amount of extra charge, >30%, relative to discharge, that must be applied to fully reverse the double sulphate reaction. **Without this resistivity characteristic, the battery would be a poor storage facility of electrochemical potential, and would too easily self-discharge.**

Warm temperatures do promote self-discharge, hard crystal formation, mechanical stress and chemical aggression, hence good reasons for temperature control during battery bank working life. As well, prevent hard crystal sulphate formation through the correct float charge, and by equalization, and promote de-stratification of the electrolyte, thus ensuring optimum electrode integrity. **Resistivity of a 2 vpc cell rises with charge, to 7-8 ohms, as the electrolyte concentration is restored, another indication of battery health. However, the resistance will also rise with very low electrolyte concentration with fewer ions in solution, as well as the barrier sulphation increasing, so a concurrent voltage reading is relevant.**

There are separator plates between the +ve/anode and -ve/cathode plates, and these plates should remain free of any residues that will clog pores, disrupting electrolyte ion transport, between, and interaction with, the respective plates. Temperature will also affect pore size, on pole plates and separator plates. Newer batteries have fibre mesh envelopes to help prevent loss of electrode material due to mechanical stress. Expander materials **may** be incorporated in the plate paste, organic for the -ve/cathode, and

inorganic for the metal +ve/anode, to increase electrode strength and porosity, and to govern electrochemical activity **if that is required.**

Electrochemical reactions involve the transport of electrons, and in redox reactions, as in FLA batteries, reduction means the addition of electrons to the metal, as oxidation is reversed, and vice versa, ion transport being via the electrolyte, dilute sulphuric acid, and electron transport via the external circuit. Self discharge will occur, 2-10% per month in unattended batteries.

**Discharge should not exceed the ability of the electrolyte to circulate and make contact and react with respective plates. Temperature is important in this respect as well.**

**Pure distilled mineral-free water** must be used to top up the electrolyte, acid must never be added, as the concentration (usually 35% sulphuric acid, for normal operating temperatures), was set at first filling. Any added impurities that can ionize will interfere with the battery chemistry and efficiency. Acid concentration may range from 28%-42%, depending on brand, type, operating temperature, etc., but 65%:35% is the norm for effective operation at 25°C.

**SLI batteries usually have 5% more acid, SG 1.270-1.290 v. 1.220-1.240 SG for deep-cycle batteries.** (See **Modern Battery Technology**, op cit, p. 202, for a comparative battery SG table, including for the tropics.)

**The function of batteries is reflected in the nature of the chemicals and construction materials utilised in their manufacture, and how they may react together, as well as other factors like temperature, loads, and charge regimes, internal and BOS conductivity, ionic states, and source of charge.** Charges should be tapered sooner in warmer climates, if there is no temperature control, and monitregs should be set accordingly. **Taper begins at the end of the absorption phase.**

As above, basically, batteries work rather reluctantly, needing a current, as load or charge, to drive the overall reaction in either direction. **They operate by what is known as the Double Sulphate Principle, whereby lead sulphate is formed as a transient substance on either pole during operation to produce the 2v emf difference that powers the amperage load, or is the restored charge as the reaction is reversed.** Electricity flows at light speed, but ionic transfer does not, hence, sustained draws need relief to allow electrolyte re-distribution and enabling of optimum plate contact by the electrolyte to be sustained. However, such high draws should not be allowed to occur in deep cycle or SLI lead-acid batteries, to preserve battery health and longevity.

**Battery life and usefulness is a function of relative equilibrium at any given stage, being a balance of ions in solution, temperature, charge or discharge rates, and the buildup and transport of the electrons that provide the current, via an external circuit in the charge/discharge cycle. Temperature control is important!**

**For battery longevity**, the changing states of this equilibrium must occur under optimal conditions. Imbalances of components, especially of sulphate, are difficult redress. A certain ratio of all reactants is involved in the charge/discharge cycle, relative to temperature, and if this balance is distorted, then some of the reactants will remain outside the electrochemical cycle, perhaps permanently, with damage to the battery resulting. +ve/anode shedding and hard crystal formation are the main causes of reactant imbalance, and the +ve/anode will tend to expand >5% over the battery lifetime. PbO<sub>2</sub> has a greater expansion co-efficient than PbSO<sub>4</sub>, which adds to material stress during plate changes. Solid (or stretched lead) sheet anodes, as in the Planté model, are more robust than grid anodes, but less efficient. **Any exposed metal of the anode will also be corroded, especially if acid concentration in relation to temperature is not correct.**

**Full EMF/OCV represents the full complement of reactants returned to full potential for discharge within normal parameters. Full discharge, (not recommended..!) represents the plates having no more reactant material in a form suitable to continue discharge, and requiring a current reversal, from a charger, to return to a charged state. Full discharge will mean electrolyte of approximately 16% acidity.** Optimum charge is at 10% of the 10 A-H rate, and optimum discharge is at C20, 5% or 1/20th of the 10A-H rate. 15.5V is sufficient to fully charge a 2vpc EMF lead acid accumulator cell, given time, and sufficient charging amps. (See [Wallchart](#) for FLA operating ranges, including for different temperatures.)

**The Peukert Effect** means that there is less power available over time with a rapid discharge than with a slower one, hence the differing nominal 10 A-H rates versus 100 A-H description of battery capacity. Circulation of the electrolyte needs some time, and higher discharges also cause heat, which in turn raises resistance. Deep cycle batteries perform more steadily than SLI batteries, so observe the specific operating parameters set at the original system sizing during operation.

When first charging FLA batteries, there is, to begin with, marked resistivity of electrolyte states and reactants to be overcome, compared to the resistivity of pure copper or silver, and this resistivity causes heat, which will build to high levels without an even and controlled charge or discharge cycle, or temperature control.

**Heat capacity of battery materials is considerable, especially that of water, but this heat retention is also only slowly released. Heat capacity is therefore proportional to battery mass, and overheating will result in eventual thermal runaway if not controlled.** FLA batteries are comprised of materials with considerable heat capacity, undergo cycles that produce heat, and are housed in cases that act as heat insulators. These are conditions that may lead to thermal runaway, and consequently, any tendency for rising temperatures should be accounted for in battery placement, operations, and operating conditions. **Water has the highest specific heat known, and is a large proportion of the electrolyte, note!**

Electrolyte concentration, reactant state, and temperature all affect resistance. Battery temperature control, especially, is an important part of good management, as temperature affects the reaction and equilibrium at any stage of operation. Left alone, lead-acid batteries will discharge at 2-10% each month, depending on type, age, etc. Heat will increase this self-discharge rate, and aggressive sulphation will result, changing to the hard crystal form over time, especially with an unattended battery. **Trickle or float charges maintain activity on the plates, and prevent hard crystal formation at any temperature.**

However, lack of heat will mean a sluggish performance, and a denser electrolyte with less ionic activity, and thus limited capacity to receive charge, and also a tendency to large hard crystal sulphation if left discharged. **Never charge a frozen battery,**

**defrost and warm it first to some reasonable operating temperature.** A frozen battery would be one that was discharged, and left in that state, at below zero temperatures, with diluted electrolyte, with most or all of the sulphate deposited on the plates and not retained ionised in the electrolytic solution. **No excuses!**

**NB, optimum energy density of an FLA battery is between 30°C-40°C, but 25°C maximum limits chemical aggression and self-discharge.** Operating increasingly below 25°C, means a longer, but more sluggish life, as the electrolyte has increased viscosity with lowering temperature, which retards ionic transfer, and thus plate reaction. However, the more sulphate on the plates, again, the lower the rate of ionic transfer there is, as well as the sulphate, (either soft or especially the hard crystal form), passivating the reactive plate material. Thus, increasing cold and viscosity will only make the **performance** of a less-than-optimally charged battery even worse, although the decrease in potential **voltage** will actually be only .05% per 1 °C decrease in temperature. Warming a battery will still only be effective to the extent of usable reactive elements present to supply current on discharge demand.

**New batteries should be cycled several times before standard readings are taken, as their initial performance will improve.** (PV cells give a higher initial charge, then settle down.) Optimal battery charge should thus be achieved, after several cycles, and voltage and SG taken to set the benchmark for future operation. Note that differing concentrations of electrolyte will affect the charged EMF/OCV. Load cycles should not exceed specifications, or this will cause heat and forced electrolysis and plate damage, just as overcharge will do. Optimum operating temperatures facilitate acid reaction and electrolyte replenishment at the plate faces, and thus maintenance of overall reaction equilibrium.

**The larger the cell, the more amp hours, but volts remain the same. Solar batteries should be connected in series only. With panels this is not a problem. VRLA, GEL, and AGM batteries, though also lead-acid, differ in nature and performance, using the oxygen recombination cycle, rather than the double sulphate principle.**

**Principle Materials in Detail:** All the FLA collector plates, poles, and connecting bars in a battery are made from a lead foundation, now more usually alloyed lead for strength, with separator plates between, incorporating pores that allow the passage of the ionic solution that is the electrolyte. (Lead-antimony batteries tend to need more water as they age, lead-calcium alloys have less self-discharge and bubbling.) The +ve/anode is coated with lead dioxide, PbO<sub>2</sub>, over the plate grid, as a result of the forming charge, and the -ve/cathode is coated with lead crystals, or sponge lead in the case of SLI batteries. Modern batteries have mesh-wrapped plates and separators to limit distortion and breakage, the anode always ages faster than the cathode, but good management can extend this anode life, and the battery life as a whole.

**Lead dioxide, PbO<sub>2</sub>, (aka peroxide, lead oxide 1V),** electrode material of the +ve/anode, darkish brown in colour, is insoluble in water, and not very soluble in the electrolyte solution of sulphuric acid and water, (28-42% range), depending on sustained ambient temperatures in situ, and the chemical equilibrium at any given time. It is a strong oxidising agent, with a valency of 4, a useful property in the double sulphate redox charge or discharge cycle. Lead dioxide, at forming charge, is deposited on the +ve/anode, which becomes weakened by repeated cycling and recharging, higher relative concentration of the electrolyte, high temperatures, prolonged overcharge or high float levels, and vibration. Mechanical failure is also more likely with temperature extremes. Heat, high acid concentration, prolonged high float, and rapid shallow cycles under 5%, (which worsens corrosion and dioxide clumping), and any plate buckling, with resultant uneven plate activity, all weaken the dioxide-coated +ve/anode. **Corrosion of exposed +ve/anode doubles for every 9C above 25°C.** The +ve/anode will also expand >5% over its useful life, and PbO<sub>2</sub> has a higher co-efficient of expansion than PbSO<sub>4</sub>.

**Lead alloy of the +ve/anode base,** ie the exposed lead plate at the edges, or beneath the dioxide, can be dissolved by excess acid concentration, overcharging, or heat, to form excess **sulphate**, (chemical aggression). Excess acid concentration may be due to lack of electrolyte water, or acid levels that were more suitable for a colder temperature of operation. (Temperature control is the better alternative, limiting chemical aggression.) **The normal dioxide and soft crystal sulphate deposition and re-deposition cycle along with any hard-crystal lead sulphate formation, also slightly weakens the +ve/anode over time.** Normal sulphate is oxidised by charge as part of the normal cycle, to form extra dioxide in clumps, ("growth", or corrosion of the +ve/anode), whose expansion at deposition, (37% more than the lead base), has further weakened the outside of the dioxide layer on the +ve/anode, which then flakes or powders off, exposing the bare anode metal.

This flaking may expose more and more bare metal to further add to corrosion. Some of these flakes may cause shorting of plates, either directly, or by buildup from the bottom, and also blocking of separator pores. Excess sulphate from the discharge cycle will lie on the dioxide layer as well, with yet another rate of expansion at formation, obstructing ionic contact with the +ve/anode, especially when in the less reactive large-crystal form, further limiting battery efficiency.

Hard large-crystal also sulphate binds more strongly to itself and the electrode than does soft crystal sulphation, causing more material stress. Heat, incorrect acid, overcharge, high discharge, excess gassing, and vibration or bumps all weaken the +ve/anode and its primary coating. Sulphation and corrosion of the +ve/anode show as a lightening of the brown colour, due to sulphation, under the blackish peeling scale of re-deposited dioxide. +ve/anode deterioration is more likely with poor management of operation and maintenance. A vicious cycle of +ve/anode corrosion may ensue from earlier damage initiated by improper management in secondhand batteries. **The +ve/anode is thus a key factor in battery longevity, emphasizing the importance of optimal operation and management care.**

The +ve/anode is thus the most likely part of any battery to fail over time, as oxidation, being a transient product of the reversible reaction, is necessary for sulphate formation, excess sulphate in the form of corrosion can never be entirely prevented, and the healthiest of batteries will have a gradual +ve/anode shedding, visible as a lightish brown powder deposited on the floor of the casing. This shedding may also produce shorting if excessive build-up occurs, either from the battery floor, or across plates. Newer fibre envelope and expander additive technology help to prevent this shedding, **but good management is always necessary.**

**At the -ve/cathode,** there may also be damage caused by any excess dissolved lead metal being deposited, causing dendritic treeing, especially at long low charge. This lead in solution originates from lead dissolved in ever purer water of the electrolyte, in the presence of oxygen, at very low discharge. Also, dioxide which has flaked off the +ve/anode may be also carried to the -ve/cathode, where it is reduced to lead metal by the charge cycle. Less likely with modern battery separators and mesh—wrap.

**Lead**, Pb, base of the anode, or +ve pole, and grid base of the -ve/cathode pole, is light grey in colour, with a valency of 2 or 4, is soluble in pure water, in the presence of oxygen, and is soluble in boiling sulphuric acid, **a situation simulated in the battery by the passage of current. The comparative electrical resistivity**, in u-ohm metres, at 20°C: of lead is .2065, of copper .0167, of silver .0162, and of iron .0980. **This resistivity then translates as lead being 2.1 x more so than iron, and 12.7 x that of copper and silver. Note that the overall resistivity of a healthy battery is 4-5 ohms, resting.**

**Cp, or heat capacity of copper** at 20°C, in cal/gm/C, is .092, and of lead .031, 2.96 x that of copper. So lead is not a very efficient electrical conductor, but is a relatively good absorber of the heat generated by the load/charge cycle, **although slower to lose stored heat as a result. Water** has a Cp of 1.0, (4.186kJ/kg), and is a relatively slow absorber of latent heat, (highest specific heat), but eventually will also contribute to battery heat build-up, ie **increased thermal mass**, and even **thermal runaway**, if temperatures and/or charge/discharge are not regulated. **Beyond initial latent heat absorption, water heats more efficiently, the key principle of supplementary solar water heating.**

**Beyond optimum charge, 1 amp-hour of overcharge will electrolyze .336 gms of water** into 2L of oxygen, and 4L of hydrogen, and hydrogen is explosive in ranges of 4-94% concentration in air. Overcharge is necessary for equalization, but should not be overdone in a properly regulated system, and the float charge should be slightly above the EMF/OCV fully charged. **Checking electrolyte levels is thus important, as water some loss is part of normal operation of any FLA battery.**

**Sulphuric acid, H<sub>2</sub>SO<sub>4</sub>**, has an SG of 1.85, and is diluted with pure water for battery electrolyte: ranging from 28%, 1.20gm/cm<sup>3</sup> at 3.4mol/L; to 42%, 1.32 gm/L 42% at 5.6 mol/L concentration, and **freezing at -30°C and -70°C respectively. Dilute, discharged electrolyte may freeze as high as -0.5°C-5.0°C. 20% charged, ie DOD 80%, electrolyte will freeze at -2°C** Equilibrium stage acid concentrations depend on operating temperature ranges, and battery technology. Note that battery resistivity is relative to electrolyte concentration. The most common SG is 35% at SG 1.260, 4.5mol/L, for operating at optimum 25°C. Temperature controlled operation means more stable cycle equilibrium. (1 mol= number of atoms in 12 grams of Carbon 12) PbSO<sub>4</sub> is a poor conductor of electricity, and with ongoing discharge, increasingly passivates the active material on the plates, hence the need for regular re-charge, especially to prevent large hard-crystal formation if the battery is left unused after discharge for 3 weeks or more, especially in warmer temperatures.

**Importance of maintaining float charge:** Solubility of lead in pure water, in the presence of oxygen, is significant because the more batteries become deeply discharged, the more pure metal begins to go into solution in the ever more pure water of the electrolyte, later to be deposited as "trees" or dendrites on the cathode, as charge is restored. Also, low charge, even with cooler temperatures, will contribute to hard crystal over several weeks. **Any sulphate formation, even soft crystal transient, means some dilution of the electrolyte before full or partial restoration by charge. False high charge may then ensue if the charging rate is excessive relative to the chemical equilibrium. 15.5V will fully charge sound 2V FLA cells given time.**

Hence the importance of maintaining an optimal float charge when the batteries are inactive. Float should be to the extent of very fine bubbles forming on the plate, 2.2-2.3 vpc, sufficient to counter natural discharge, and to hold the reaction of all components in a relative equilibrium when not being loaded or recharged. **FLA batteries will self-discharge at rates of 2-10% per month if left unattended. High float charge (volts), is technically an overcharge, and will be damaging if prolonged.**

**Lead sulphate, PbSO<sub>4</sub>, a normal dibasic salt**, is also formed on the -ve/cathode and +ve/anode poles as part of the reversible reaction, and in excessive amounts will show as a whitish powder on the darker gray of the metal, or on the brown of the dioxide. **Lead sulphate is not very soluble in water, (1:2225), or in sulphuric acid, and is potentially only to be a transient product of the overall reaction, whose formation is supposed to be entirely reversible when in the soft-crystal state. It is also a poor electrical conductor, hence higher resistance at the beginning of a charge cycle, and increasing passivation of plate material as discharge increases.**

**Because of its relative insolubility, once formed in excessive amounts relative to any chemical equilibrium, it is difficult to decompose, especially in the hard crystal form. Anglesite, the lead sulphate mineral, is found in orthorhombic crystals, with 3 axes at right angles, of varying lengths, reduced surface area of large crystals, hence the durability of large hard crystal sulphation in batteries, necessitating special charge regimes to overcome formation, and/or the use of de-sulphating technology, which uses high current waves to help to breakdown the crystals, much as ultrasound works on kidney stones.**

Prolonged battery inactivity, especially at warm temperatures and higher levels of molecular activity, causes this formation of the larger, hard crystals of sulphate. This is more difficult to re-dissolve, thus clogging the pores of plates, and buckling or damaging them because of its thickness of deposition and relatively higher expansion coefficient. Any subsequent change of crystal form results in further expansion damage on both +ve/anode and -ve/ cathode plates, and electrode/plate shedding.

**Hard crystal lead sulphate formation on either plate takes 2-3 weeks with no recharge, and depending on ambient temperature. Using batteries continuously while in a partially discharged state will also add to the problem, as they become warmer in operation. Optimum charging routines, including float and temperature control, mean the balance, ie equilibrium, of electrolyte and reactants during any stage of the battery's extended useful life. A float charge, of constant voltage, maintains a charged state equilibrium, keeping sulphate ions within the electrolyte. All small-crystal sulphation should be reversed by charge as often as possible, with optimum plate reformation.**

**To summarise:** Normal small-crystal sulphation is a necessary part of the overall reversible reaction on either plate. But, and especially on the +ve/anode plate, conversion, by the electrolyte, of dioxide coating into any excessive amounts of (almost) non-reversible **hard crystal sulphate** due to battery inactivity also weakens those plates, and these deposits also cause loss of electrolyte contact with the remaining dioxide by the electrolyte, which has, in turn, been weakened by the loss of sulphate ions by deposition on either of the poles.

This buildup also causes increased electrical resistivity of weakened electrolyte, which slows recharge, especially at lower temperatures. Sulphate, in either form, thus clogs pores on both plates, disrupting electrolyte action, and affecting recharge levels and rates. Hydration of metallic lead and/or alloys at low electrolyte concentration in neglected batteries produces another barrier deposit of indeterminate chemical identity, further contributing to resistance to charge.

**Excessive amounts of large-crystal sulphation** are not easily reversed by normal charge cycles, and also increase electrical resistivity, and thus heat, which will in turn produce more resistivity. Prolonged charging may overcome this excess of LC sulphation to a certain extent, at 4.4-4.5v vpc, but this imposes strain on the battery as a whole, especially the +ve/anode pole, as above, reducing the lifespan of the battery. Long charge cycles should be avoided, slightly longer normal dedicated charge cycles, over time, may overcome the problem without limiting battery life so much. Improve panel watts and/or ancillary charging to ensure optimum amps restored. Allow for temperature, or install temperature control. Care with concurrent wattage use calculations is also necessary to prevent over-discharge.

The use of distilled water, (which will initially tend to dissolve the lead -ve/cathode anyway), or addition of other chemicals to the electrolyte may be resorted to, again with extra charging, replacement batteries would be the sensible option. Prevention is better than cure, by good management, by temperature control, correct electrolyte concentration and levels, and optimum load/charge cycle management. (See also [Bill Darden's](#) FAQ/16.) Charge regimes are as per the Wall Chart, but rule of thumb for all deep cycle batteries is to charge at the C/10 rate, or 10% of 10A-H of the battery, or, using the 15.5A optimum, divide the 20 A-H by 15.5A to get the C rate.

**Rule of Thumb: Maximum discharge short-term at no more than the C10 rate, or 10% of the 10 A-H rate, normal ideally at the C20 rate, 1/20th of 10 A-H rate, and more sustained discharge would be at half of that rate or even less, especially if the batteries are used continuously, such as at night. In that case, the discharge may be as low as 2-3% of the 10A-H rate. These figures are general, and should be customised for each system.**

**Deep cycle batteries charge and discharge at lower, steadier rates than SLI, and 15.5amps will charge deep cycle batteries completely, given time. All cycles should be between 5% and 40% DOD, hardly ever to 50%, and to 80% only in emergencies.** (Note that for gel cells, the charge rate is C20, or 5% of 10 A-H capacity, as well as to a lower peak, about 28.4V) **Pore size** of plates or separators increases with heat, but this is only effective to the point where resistance increases, so **maintain 25°C operating temperature to optimise electrolyte activity and integrity, pore size, and control of the thermal mass.**

**If battery plates are ever exposed to the atmosphere** due to non-replacement of water lost from electrolyte, more damage is caused, by swelling of plate deposits, and buckling. Chemical reactions with exposed plates involve atmospheric impurities, especially corrosive acid or alkalis, all of which will rapidly damage exposed plates, and contaminate the rest of the battery. **No excuses! Battery caps also promote a vapour layer above the electrolyte, as well as allowing for venting of gases. This barrier minimises atmospheric contact, limits electrolyte evaporation, and blocks the entry of airborne particles. Use them!**

**VRLA Batteries, viz, AGM and Gel, though lead-acid, utilize a different chemical reaction, called “oxygen-recombination cycle”, with no hydrogen production on the negative plate. They also have different and respective charging cycles, and greater care must be taken to prevent overcharging and vapour loss, (especially gel batteries, as vapour cavities will occur within the gel), thus affecting battery efficiency.**

The plates are made from lead-calcium alloy, which limits gassing and water loss. No replenishment of electrolyte is possible. These batteries are useful where motion or other disturbance is common, and where ventilation is limited, because there is a minimum of vapour emission. AGM, or “starved electrolyte”, are very efficient, and have a long life, even compared to FLA, but are very expensive, and plain gel batteries, a shorter life compared to FLA, efficiency about the same. (See [Excerpt 2](#))

**However, bulk power storage, and longer cycle life are better provided by FLA deep cycle batteries where these can be installed.** VRLA batteries are very useful and convenient for emergency use, being sealed, and requiring low maintenance, if properly charged. AGM and Gel VRLA battery maximum charge input is >2.35 vpc, use dedicated VRLA regulators! (Note that **low-maintenance** batteries are not the same as VRLA batteries, but have special alloys that inhibit vapour formation, and resist material fatigue that is due to plate formation and reformation changes.)

**Note that VRLA: Valve Regulated Lead Acid, FLA: Flooded Lead Acid, AGM: Absorbed Glass Mat**

A fuller description of manufacture, function and application of these lead-acid batteries is outside the scope of this Manual, which concerns conventional FLA batteries. See [Excerpt 2](#) for introductory explanations, and other details also obtainable from the [Accu Oerlikon](#) website. In general, and given proper applications, deep cycle motive batteries, especially if motionless in situ, will of necessity be more robust, and more resistant to functional vibration and rapid cycling, although, on the whole, they will not last as long as well-managed stationary backup or solar deep cycle batteries, even if their service life specification may suggest otherwise. (See [Bill Darden's](#) FAQ/2.1.)

**The difference between stationary back-up, and what could be called stationary solar, is the potential for cycling, which will mean more robust construction for the conventional solar battery. Both would be motionless, in situ, flooded, (though not necessarily FLA?), and, if FLA, have 4-stage monitregs, and accordingly their respective 4-stage charge regime.** (See also 17/18 in [Bill Darden's Feedback](#) for reasons why these distinctions should be made to avoid unnecessary confusion about FLA deep cycle battery types.)

“Stationary” is apparently an older term used for standby batteries designed for occasional cycling before more multiple-cycling solar batteries became widely used, but both types are stationary, as in motionless, in situ, and not supposed to be moved by virtue of construction and chemistry. However, including deep cycle solar and deep cycle standby within the category of stationary, or deep cycle stationary batteries, would solve this problem of nomenclature, surely?

**Some Electrical Definitions** related to battery function:

**AMP: I/A, SI unit of current, or rate of flow of 1 coulomb for 1 second. Analogous to current in liquid terms.**

**AMP-HOUR: SI unit of charge, 1 amp for 1 hour, transporting 3600 coulombs. Analogous to volume in liquid terms.**

**BATTERY CHARGE STATE: functioning as an electrolytic cell, and,**

**BATTERY LOAD STATE:** functioning as a voltaic cell, the two states/cycles in sequential combination constitute a secondary or re-chargeable cell, thus combining ionic and metallic reciprocal transfer of electrons, the moving physical components of electricity thus utilised via an outside circuit.

**CONDUCTANCE:** see S, Siemens.

**COULOMB:** C, SI unit of electrical charge, transporting 1 amp for 1 second.  $C = A \times T$  (in seconds). Analogous to volume in liquid terms.

**CGS:** centimeter/gram/second system, superceded by the SI system.

**ELECTROLYTIC CELL:** in a charging lead-acid battery, reduction of  $PbSO_4$  at the cathode/negative pole,  $O_2$  vented; oxidation at the anode/positive cell,  $H_2$  vented. Excess current promotes heat production and venting, rather than reactant recombination/plate reformation. TIME is also important for rr/pr while charging. (Anode/cathode are correct pole terms for electrolytic state/cell)

**ELECTROLYTIC TRANSFER:** ions only, carrying electrons, in a liquid conducting medium

**EMF:** electromotive force, difference of potential driving current through a circuit.

**ENERGY DENSITY:** potential energy:unit weight ratio of an FLA battery

**EQUATIONS:**  $W = V \times A$ ,  $V = W:-A$ ,  $A = W:-V$ ,  $V = A \times R$ ,  $R = V:-A$ ,  $A = V:-R$ ,  $W = A^2 \times R$ ,  $A^2 = W:-R$ ,  $R = W:-A^2$

**HEAT:** causes increasing electrical resistance as electrons/ions collide with atoms/molecules of the conducting material or electrolyte, and vice-versa. This can become a vicious and cumulative cycle in unregulated thermal masses such as batteries, with ever-increasing inefficiency, component damage, and possible ultimate failure.

**INSULATION:** non-conducting materials, obstructing of/impervious to, the passage of electrons, c/f semiconductors, et al. Also, c/f containment of electrolyte.

**JOULE:** J, SI unit of work/energy/heat, amount of power to move one newton through 1 metre, the product of resistance, R.

**METALLIC TRANSFER:** electrons only through a solid metallic conducting medium

**MONITREG:** combined monitor and regulator of battery state and system function

**NEWTON:** N, the SI unit of energy required to accelerate 1 kg through 1 metre.

**OHM:** R:-O, SI unit of resistivity, proportional to voltage drop. One amp through a resistance, R:-O, produces a drop of 1 V across the circuit.

**PD:** Potential Difference, see EMF

**PRIMARY CELL:** a non-rechargeable battery/cell with a one-way reactant process.

**RESISTANCE:** R:-O, impedance of the passage of electrons, through a solid conductive medium, and/or passage of electron-carrying molecules through electrolyte; a function of overall molecular and atomic activity/collision rates at a given time, affected by temperature, and nature of conducting materials.

**SI:** System International (d'Units), modern system of electrical nomenclature.

**SIEMENS:** S, SI symbol of electrical conductance, the reciprocal of R, aka MHO (CGS), or  $O \times -1$ ; the degree to which electrons will pass through/via a conducting medium.

**VOLTAIC CELL:** in a lead-acid battery under load, oxidation of Pb at the negative pole,  $H_2$  vented, reduction of  $PbSO_4$  at the positive pole,  $O_2$  vented. Excess current promotes heat production and venting rather than reactant recombination and plate reformation. (Positive and negative are correct pole terms for voltaic cell state)

**VOLT:** V, SI unit of potential difference, PD/EMF, equal to 1 watt at 1 amp of power, or 1 coulomb charge gives 1 joule of work with a PD/EMF of 1 volt. Analogous to pressure, or head, in liquid terms. Vpc = volts per cell.

**VOLT/AMPERE:** rms current x voltage, when rms = root mean square, and, **safely regard watts as being 60% VA**

**WATT:** W, SI unit of 1 joule for 1 second, 1 watt/hour = 3600 joules.

**WATTMETER:** measures active power in a circuit. Also, the rate of joule expenditure. Solar panels carry a wattage rating, divide by circuit volts to obtain amps charge, or coulomb rate.

**Also, be familiar with the following common usage terms:**

Absorption Phase, Absorption volts

Alternating Current, Alternator, specific definition

Amps, op. cit.

Amorphous v. Single Crystal v Polycrystalline

Auxiliary Power

Boost phase, Boost Frequency, State of Charge, Charging, Opportunity Charging, (see [Bill Darden's FAQ/9.8,12](#))

Deep-Cycle Battery, Battery Capacity

Direct Current, Generator, specific definition

Electrolyte, Electrolytic, Electrolysis

Energy Density

Equalization Phase, E. Frequency, E. Time

Float Phase, Float Volts

Floating Charge v. Trickle Charge

GeL/AGM as for VRLA batteries v. FLA Batteries

History

Hysteresis, also Cybernetics, Lag Time, Switch Lag, etc.

Ionic/Electrostatic v. Covalent Bonds, Ionic Transfer

Inverter DC to AC, v. Converter, AC to DC

Latent Heat v. Heat Capacity, also Specific Heat, especially of water.

Load

Monitor, Monitor/Regulator, Battery control, Charge v. Current Limit

Motive v. Stationary, as in Battery Type; also Deep Cycle, SLI, etc.

Ohms, op. cit.

Over-ride v. Reset

Program, P. Customising, eg., Event Control, Current Limit, Regulation Cycle etc.

Photovoltaic v. Photoelectric Effects, Photoemission,

Porosity v. Diffusion v. Viscosity

Pulse Width Modulation, PWM

Resistance & Reciprocal, Conductance

Resting Charge v. OCV, open circuit voltage

Semiconductor, Semiconductor Effect,

Specific Gravity

Volts, op. cit., Battery volts, Solar Volts, Voltage Drop, Open Circuit Voltage, vpc

Watts, op. cit.

[Solar4Power.com](#) also has an excellent **Solar Power Glossary**

**For the more technically minded**, refer to **Electrochemistry** and **Electroplating** for useful data. Meanwhile, try **charge carriers, stationary states of metals and nonmetals, conductors and insulators, decomposition voltage, concentration over-potential, charge-transfer reaction, kinetic over-voltage, Photoelectric Effect, semiconductors, conduction and valence bands, energy levels, N/P-type doping, electron-donor impurity**, and **Quantum Physics** in general if so inclined..! These concepts and properties, and more, are fundamental to understanding the science behind solar electricity, and its continuing R and D.

**For those wishing a glimpse of the more technical aspects of solar cells**, here is an extract from Selinger, B., **Chemistry in the Marketplace** 1991, Harcourt, 0729503348, p. 366, in a passage about solar cars:

"Silicon makes up 25.7% of the Earth's crust, by mass, and is the second most abundant element, being exceeded only by oxygen. Sand is just silicon combined with oxygen. However, to have silicon pure enough for solar cells, it must have impurity atoms of vanadium, titanium and zirconium below  $10^{13}$  atoms per  $\text{cm}^{-3}$ ; ie, one impurity atom for 10 billion silicon atoms is allowed.

For iron, manganese and chromium we can be 10 times more generous, whereas for copper and nickel, one in a million is permitted. Purification of substances to such a degree requires the art to be taken to its ultimate perfection. It is also highly energy intensive. (.but, the technology is ever-improving, and the cells will, of course, more than in their lifetime the energy expended to make them, ref. PV Payback, [Home Power Magazine](#) #127, by 2008, this payback is effected in 3 years or less.)

The solar cells are manufactured from pure silicon, (valency 4). This is doped with a tiny amount of phosphorous, (valency 5), to provide an extra electron, and give an N-type (negative) semi-conductor. The silicon can also be doped with boron, (valency 3), to provide the absence of an electron, (called a positive hole), and to give a p-type, (positive), semiconductor. These two types of silicon are layered in a single cell, forming an n-p junction. (Note that other dopants can be used.)

Diffusion of electrons across the junction sets up a voltage difference which then opposes further diffusion. However, the photons of the blue and ultraviolet section of sunlight, which causes sunburn, are also energetic enough to “promote” an electron in the n-p junction to a higher level, where it can move freely, (a conduction band), at the same time leaving a hole behind, which is now also free to move, (in the valence band). This movement apart constitutes the flow of an electric current which can operate a motor.

A silicon solar cell generates about half a volt, but its current depends on its surface area, and the amount of sunlight. The more expensive single crystal cells are more efficient in direct sunlight while the cheaper amorphous cells seem to work better in diffuse light.” (..thus these cells can be used in an efficient combination, etc., an example is given in the text.)

(See also **Basic Principles of Semiconductors**, I. Gottlieb, Prompt 1995, ISBN 987654321, or similar)

**Appendix 2: Fuel efficiency is not the same as energy efficiency.** To properly present the case for investment in, and, increasing the use of, alternative (or supplementary) energy, **the difference between fuel efficiency and energy efficiency must be made clear:**

**Fuel efficiency is more a relative term, and energy efficiency is more an absolute term**, the first, **fuel efficiency**, is relative because it is a comparison only concerned with economics of energy consumption, efficiencies measured by energy input relative to work output of comparative technologies. The second, **energy efficiency**, is absolute, describing the actual entropy of energy use, the order to disorder change of energy, the extent to which energy is available for work, or conversely, the extent to which the energy harvested has been degraded, or lost.

**Fuel efficiencies are less relevant when the actual overall energy consumption increases, because this also increases entropy and ultimately total resource loss, at least on the scale of human technology.** This is important when non-renewable, (on a human time-scale), energy-generating resource is being depleted. “Energy” for our human societies means net energy **actively** harvested from resources such as coal, oil, gas, oil shale, peat, and even refined into forms such as chemical and/or stored energy, but all consumed by less-than-efficient technologies to meet demand. As the “cleaner” resources are being depleted, there is atomic power, of course, but unless there is a technological breakthrough in the form of fusion power, the “dirtier” form of fission power would need to be used in the future, as energy needs grow.

**# Hydroelectric dams do provide passively harvested energy, but the bigger the dam, the bigger the infrastructure and maintenance costs, and the greater cost to the environment, even including greenhouse gas emissions. Plus, the rain and snow must continue to fall, so the net energy gain, therefore, in this time of Greenhouse, may be variable and questionable? Firewood, and similar products, qualify as a mainly passive renewable resources, after planting and tending, and when used, good combustion technology should give better fuel efficiency and less greenhouse gases produced per energy benefit derived, even if there is a degree of inefficiency and almost total entropy of energy harvested. (There are residues that may be useful if clean product is burned.) However, ‘firewood’ gathering qualifies as active energy production, with some unavoidable consequent greenhouse gas production from burning what was so garnered. Biofuel production begins to cause agricultural resource problems, and the end product of their uses are still greenhouse gases, as with ‘clean’ burning of coal and of whatever fuel-oil reserves may remain. #**

The need for less human population, more efficient end-user technology and architecture, more shared transport, more individual responsibility, etc., are all known and understood. (We consume therefore we are, and can “afford” to do so?) But still, there remains the fact that human energy needs are always dependent on some finite resource or other, which already means eking out what is left, not least because of the “harvesting” infrastructure and maintenance costs, whatever the technology involved, even before end-use, that so characterize our **active** energy-based technology.

**Active** energy production is typified by the active steps of mining or drilling, transport, refining, reticulation, and repair and maintenance of equipment during all these stages, with a greater gross energy loss before end-use. Actual appliance use and attendant entropy is similar, irrespective of energy source. When there is an interface between alternative (more passive), and conventional (more active) energy, **all** appliance technology, **and energy end use**, should be as efficient as possible.

**Even alternative energy technology must have its origins or foundations in intensive energy utilisation that would be based, in whole or in part, on non-renewable energy resources. However, irrespective of technology origins, the more energy efficient systems, therefore, are those with a higher passive energy component than active energy component.** This means that some degree of the energy end-used has been passively accumulated, as is the case with alternative energy technology resources such as solar, wind, water, geothermal, biofuel and biomass, with a consequent lower gross infrastructure energy cost in manufacture and maintenance **before** end-use. (Again note, plant **biofuel** production and use will require sensible management because of potential greenhouse gas emissions, as well as competition for agricultural resources. **Biomass**, at least is often organic waste that produces combustible gases such as methane, but again, CO<sub>2</sub> is a byproduct of end-use.)

So, alternative energy technology, as noted, has a share of infrastructure-related energy use in manufacture that has been provided by fossil fuels, of course, but the purpose of such technologies is to harvest energy passively, when installed and operating. Of the passive energy technologies, dams would be the most expensive, and solar power the least expensive, especially because of the major solid bulk component. In between would fall the other more passive energy technologies, (passive infra-red solar energy harvesting would be one of these). Geothermal energy is constant, as would be biomass energy when accumulated, although biomass, of course, generates methane, (as do biofuels), which can leak directly into the atmosphere, or, has an end-use byproduct of carbon dioxide, as well as other greenhouse gases. Deep-water thermal gradient power generating technology is still under development, and will still require ideal geographical locations, and this also applies to solar updraft turbine generators in large chimneys, although, of course, we wish them both well, we **must**, after all..?

Solar, tides and winds would be predictable and reliable, if episodic, and of these, solar would be the most reliable; there will always be day, night, and overcast, but as long as there is sufficient light, there will be useful current generated, even if this only supports a

float charge for batteries. (For the sake of brevity, electrical, heating, and mechanical energy **end use** and their overlaps are not here differentiated, a couple of pages is, after all, standing in for what could amount to a book on the subjects of fuels, energy sources, and energy efficiency, **and** all their respective technologies.)

**To summarise** so far, fossil, or other non-renewable energy consumption, **actively** utilises non-renewable harvested resources, at least by human time-scales, whereas alternative (or supplementary) energy passively utilise renewable harvested energy resources, to a greater or lesser extent, either as stand-alone, or interfaced with any other energy production systems.

**When energy output is combined, the energy derived from a passive source will offset, and/or partly replace, that from a non-renewable source. Energy, whatever the source or resource, will all ultimately be destined for entropic loss or degradation as heat and/or friction loss, either during first stage mechanical use, or second stage, such as electricity for end-user appliances.** What should be a priority is that more and more passively harvested energy should be utilised, offsetting and eking out energy from non-renewable sources, especially as the high-demand energy is still provided by non-renewable active energy resources, and will be so for the foreseeable future. This will, in turn, decrease greenhouse gas generation, which is becoming as important a factor in energy consumption as dwindling finite resources. **Ultimately, Entropy Rules, OK, for local grids, planets, galaxies, and universes! That Entropic Rule must be made as benevolent as possible, on this particular planet, at least..? So many terrestrial life forms now depend on sensible future human energy use, including ourselves..?**

So, after that rather lengthy preamble, **where does solar fit into the ever-evolving energy scheme of things?** Best-of-technology solar panel efficiency at present is about 17%, with up to 40% projected, we are told. However, the insolation required is periodic in nature, as we all know, but as long as the sun shines, or even indirect sunlight is strong enough, panels will provide power, and that includes at the Poles, and even further reaches of the Solar System.

A more realistic efficiency would be, (circa 2003), about 15%; ie, of the average 1Kw/m<sup>2</sup> of convertible cosmic rays, aka sunlight, that falls on current silicon solar panels at any level of useful insolation, 15% is actually passively harvested for conversion into electricity. **This rate of conversion efficiency will always be the same, but the current generated will, of course, vary with the insolation intensity, hence the importance or peak-sun-hour data for respective latitudes.**

Of this 15%, in a stand-alone system, about 10% will be lost in the system by inversion or other resistance, and 33.3% will be lost by necessary battery overcharge, a passive energy efficiency total of about 50%, before final end-use. With grid interface, and direct inversion to main grid power, this energy efficiency will be much higher, perhaps 80%. Once in the grid, electricity will be subject to the same entropy as power from other sources. In their right context, these are very good energy efficiency rates, from a passively harvested resource, and, solar technology is still improving, though like any other human energy technology, "perfection" is a standard at least to strive for, if not to actually achieve.

(Does anyone really know how active energy efficiencies compare? Of the active energy 'harvested' from respective technologies, what, of the net percentage, could be termed truly energy efficient? Serious unbiased definitive studies are required, but common sense says that renewable energy should play a prominent role in future human affairs..?)

**So, although supplementary in nature, and with manufacturing foundations in non-renewable intensive energy technology, solar energy easily proves its worth as a passive energy technology that should be invested in, developed, and extensively used wherever the sun may shine. Directly based, as it is, on the entropy of the Sun as a renewable energy resource, solar energy, both infrared and ultraviolet, has a good future for humans, as long as, and wherever, sunlight may fall on our photo-voltaic or infrared panels.**

For the actual production costs of solar technology, see PV Payback, [Home Power Magazine #127](#), to debunk that particular counterproductive argument. Otherwise, stand-alone systems with batteries, that have a back-up generator, will rely on this for ad hoc supplementary charging, or, periodic intensive energy usage. But the panels will always produce, in total, more power passively than was needed for active energy supplementation in a well managed system, and there is independence, savings on main grid reticulation, whether available or not, and on greenhouse gas emissions.

**The value of solar increases with the passively generated power used, (ie, the more you "eat", the more you get paid), and this is a factor of both effective system planning, and effective ongoing system management.** Even extra costs, in active energy and materials for maintenance and periodic upgrades, will be subsumed within the overall net energy gain. Grid interface power-sharing, as another type of hybrid system, further enhances the value of this passive energy. **Any intensive energy use may be replaced by payback of surplus solar energy as this occurs.** The energy efficiency of direct grid interface, either single household or solar energy farm, of course, speaks for itself.

**Finally**, there should be no disagreement now, at least between impartial and sensible people, that active, non-renewable energy must be supplemented, to eke out what remains of fossil fuels, and to decrease greenhouse gases. Technological options and time are both limited, and the boundaries of new technologies are expensive to explore. There are effective passive energy alternatives available **now**, of which solar is the most energy efficient, and they must be developed and used, with utmost priority, along with better end-user technology and consumption habits, economies of scale, and a healthy universal vested interest in shared responsibility in long term energy savings and diminished greenhouse gases, rather than short term financial, or electoral, gains.

The oil crisis of the 70s, before climate change and energy reserves became such issues, prompted a concerted effort to develop alternative energy technologies. But the irony is that now, when the need for such a technology switch is even more imperative, no such sense of urgency has yet again to really drive active alternative development. **Beating OPEC, apparently, was then more of a goad than the now, far more serious twin threats, of accelerating Greenhouse Effect and concomitant climate change, and, dwindling reserves of non-renewable energy.**

There is also no point in waiting for some possible future "perfect" energy technology which, even if achievable, may be too late to be effective in maintaining any reasonable universal human living standards, or in saving active, non-renewable fuel reserves. Neither can we dilly-dally over matters such as the Kyoto Protocol, which should, rather, serve to unite us and direct our efforts to decrease greenhouse gases, eke out those non-renewable energy resources, and to support and get the best from our current technology in case there will be nothing technologically "better" in the foreseeable future.

Global Warming is **real**, and will become increasingly exponential, just like human population growth, if greenhouse emissions not controlled by improved energy use habits, and more passive energy utilisation. Those making the energy technology transition, from wood fuel and animal transport to main grid access and personal automotive transport, are also placing ever-greater demands on finite energy resources, demanding the same access to energy that more developed nations already flaunt, and exploit, so recklessly.

**Indeed, even if discovered, a 'perfect' energy technology is a potentially exploitative tool that the human race has not served an apprenticeship to have control over, given our poor record, past and present, of energy or other resource conservation.** All resources would then be under greater threat as the perfect tool of exploitation was utilised, thus triggering yet more exponential patterns of exploitation, impelled by even more inexorable human population growth, 9.5 billion of Us by 2050. Doing better with what humans already have, and also limiting our numbers, are thus optimally sensible and logical energy solutions..?

**In the meantime, all over the world, any form of proven passive alternative energy generation should be fostered** to support individual needs as well as to support main grids, to diminish greenhouse gas emissions, and to aid in eking out remaining fossil fuel supplies. However, the sun does not always shine, the wind does not always blow, and water does not always fall or run. The great hope of tidal power generation may be subjected to collisions, sea and/or river bed changes, or damage from marine flora or fauna, and, in addition, all passive generating technology may suffer at some stage from the extreme effects of storm damage, earthquakes, fires, or whatever other possible natural disasters. Global warming management which necessitates the use of passive energy generation carries its own functional hazards, and these must be planned for.

**So, it follows that the growing network of alternate power generation should be varied in scope and geographical dispersal** in order to take advantage of any possible passive energy source, and also this must be comprehensive enough to still sustain even and stable power generation should any part of the network need to be closed down. As well, the usual **load leveling**, influenced by seasons, peak hours, holidays and weekends, and even unforeseen transient emergencies, continues as a constant challenge for any power generation network.

**Vast FLA battery banks** have been used in the past, when power demands were more modest and population was smaller, but would have limited application today? Fossil fuel was, (and still is), a generating mainstay, or, a standby energy system component where utilizable, even unto the humble portable generator, using biofuel, of course! Surplus power generated by means of hydro power generation could also lift hydro water back to higher storage **when** water was abundant enough to meet ongoing power demands. These (potential) power storage measures have been taken for granted in the past. **The great unanswered question now, more than ever, as alternative energy is increasingly used, is how to accumulate and sustain the stored power that copes with load leveling**, so much easier in past times when the easily managed **potential** power of fossil fuels or stored hydro water mass could be quickly called upon? (Battery banks at local power installations may yet be practicable, but the population will need to learn new energy saving!)

There is still the problem of supplying intensive energy for industry that smelts, welds, or must otherwise run constantly with high power consumption demand, such as hospitals, water distribution that requires constant pumping, regardless of power generation resource, and all these despite any projected improvements in revised energy usage behaviour. Alternative energy that will, in turn, produce greenhouse gases, must also be carefully used for power generation, whether sent directly to the grid or not, even if it was originally intended to more directly supplant more polluting fossil fuel use, such as in automotive application.

**Is the future for actual power storage now to be vast arrays of hydrogen fuel cells**, fed by hydrogen, (and oxygen), that is obtained by electrolysis of water utilizing spare passive electrical energy, especially that from solar electricity generation? In the 'hydrogen' fuel cell, hydrogen is the reducing agent, oxygen the oxidizing agent, both of which can be supplied by the controlled electrolysis of water, and/or, simply utilizing free oxygen, as oxidizer, from the atmosphere.

**The EMF produced by such cells is up to or about 1 volt, with a theoretical maximum of 1.23 volts.** A very real energy balance, indeed, if passive generation such as solar power is used? Certainly we would be much more in sync with plant photosynthesis and CO<sub>2</sub> binding. **Biogenic production of hydrogen is also improving.** (Other reducing agents may be used, e.g., derivatives of fossil fuels, but these are diminishing in supply, as well as being sources of greenhouse gases as combinative byproducts. (See also **Fuel Cell Systems Explained, Useful Books.**)

**Potential** power storage as readily available backup will never again be so easily assured as in the past. Fusion power seems to have petered out, atomic power is ill advised anyway, as well as having a limited ore resources. **Magic energy bullets** generally seem in short supply, and exigencies of other resources, such as hydro potential affected by rapidly developing global warming, indicate that research funding should be very carefully delegated for sensible projects. **Fusion power** will always be 'the energy of the future', as the skeptics say. **Quo vadis, homo sapiens sapiens? Do well with what we now have, and know..?**

**Economies of scale of all resource utilisation have yet to be learnt by Us, and subjective personal and social creeds, and expedient cultural and social doctrines of resource exploitation, still hinder that necessary learning. Our peak human energy efficiency achievements, thus far, are still the water wheel and the bicycle, agreed?** An enforced period of extensive **passive** energy usage, slowing active energy and other resource exploitation, would certainly enable us to gain some valuable time in order to serve that overdue apprenticeship of economies of scale, while concurrently curbing our exponential population trend.

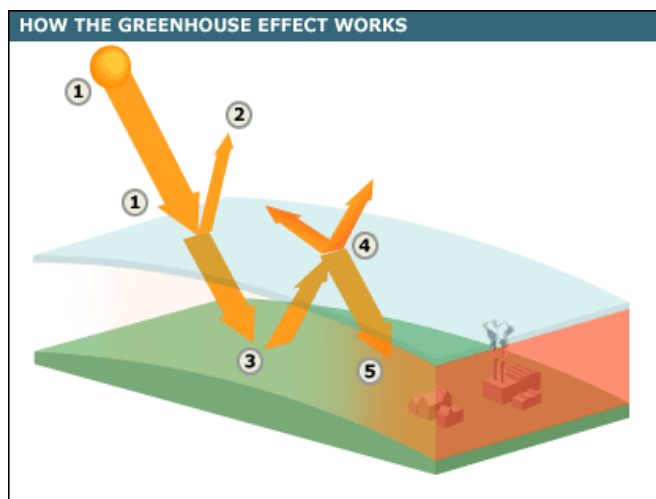
**Otherwise, that great darkness, literal and figurative, that we have striven for so long to overcome, and keep at bay, will fall once more. Time is not on our side, and if this fact is not heeded, The Club of Rome will, most certainly and conclusively, finally have their day!**

**Defining the Greenhouse Effect: "Greenhouse Effect:** The general warming of the lower layers of a planet's atmosphere caused by the presence of carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) molecules. As happens on Earth, the greenhouse effect occurs whenever a planetary atmosphere is relatively transparent to visible light from the parent star (typically 0.3 to 0.7 micrometer wavelength) but is opaque to the longer-wavelength (typically 10.6-micrometer) thermal infrared radiation emitted by the planet's surface. Because of carbon dioxide in the atmosphere,

this outgoing thermal radiation is blocked from escaping into space, and the absorbed energy then causes a rise in the atmospheric temperature. In the case of Earth, this atmospheric warming effect tends to increase with increasing atmospheric carbon dioxide content. (See fig. 1.)

In fact, some environmental scientists now warn that as we continue to burn vast amounts of fossil fuels, we are also dangerously increasing carbon dioxide levels in the Earth's atmosphere. We may even be creating the conditions for a runaway greenhouse, like that on Venus. Such an effect is a planetary climatic extreme in which all the water has been evaporated away from the surface of a life-bearing or potentially life-bearing planet. Scientists now postulate that Venus's present atmosphere allows some sunlight to reach the planet's surface, but thick clouds and a rich carbon dioxide content prevent surface heat from being radiated back into space. This condition has led to the evaporation of all surface water and produced current surface temperatures of approximately 485 degrees Celsius (900 degrees Fahrenheit)-temperatures hot enough to melt lead."

From: **The Extra-Terrestrial Encyclopaedia**, J Angelo  
Facts On File Publications, NY 1985 ISBN 0871967642



- 1 Energy from the Sun beats down on the Earth.
- 2 Some energy is reflected into space, the rest enters the atmosphere.
- 3 The Earth absorbs the energy and emits heat.
- 4 Unlike other gases, greenhouse gases absorb and re-emit the heat energy - some is emitted into space and some back to Earth.
- 5 The heat is effectively trapped and warms the Earth.

From BBC NEWS, [bbc.co.uk](http://bbc.co.uk), Guide to Climate Change 2005

#### March 20, 2004, CNN.com - Report: Carbon dioxide buildup accelerating -

MAUNA LOA OBSERVATORY, Hawaii (AP) - "Carbon dioxide, the gas largely blamed for global warming, has reached record-high levels in the atmosphere after growing at an accelerated pace in the past year, say scientists monitoring the sky from this 2-mile-high station atop a Hawaiian volcano.

The reason for the faster buildup of the most important "greenhouse gas" will require further analysis, the U.S. government experts say. "But the big picture is that CO<sub>2</sub> is continuing to go up," said Russell Schnell, deputy director of the National Oceanic and Atmospheric Administration's climate monitoring laboratory in Boulder, Colorado, which operates the Mauna Loa Observatory on the island of Hawaii.

Carbon dioxide, mostly from burning of coal, gasoline and other fossil fuels, traps heat that otherwise would radiate into space. Global temperatures increased by about 1 degree Fahrenheit during the 20<sup>th</sup> century, and international panels of scientists sponsored by world governments have concluded that most of the warming probably was due to greenhouse gases. The climatologists forecast continued temperature rises that will disrupt the climate, cause seas to rise and lead to other unpredictable consequences—unpredictable in part because of uncertainties in computer modeling of future climate.

Before the industrial age and extensive use of fossil fuels, the concentration of carbon dioxide in the atmosphere stood at about 280 parts per million, scientists have determined. Average readings at the 11,141-foot Mauna Loa Observatory, where carbon dioxide density peaks each northern winter, hovered around 379 parts per million on Friday, compared with about 376 a year ago. **That year-to-year increase of about 3 parts per million is considerably higher than the average annual increase of 1.8 parts per million over the past decade, and markedly more accelerated than the 1-part-per-million annual increase recorded a half-century ago, when observations were first made here.**

Asked to explain the stepped-up rate, climatologists were cautious, saying data needed to be further evaluated. But Asia immediately sprang to mind.

"China is taking off economically and burning a lot of fuel. India, too," said Pieter Tans, a prominent carbon-cycle expert at NOAA's Boulder lab.

Another leading climatologist, Ralph Keeling, whose father, Charles D. Keeling, developed methods for measuring carbon dioxide, noted that the rate "does fluctuate up and down a bit," and said it was too early to reach conclusions. But he added: "People are worried about 'feedbacks.' We are moving into a warmer world." He explained that warming itself releases carbon dioxide from the ocean and soil. By raising the gas's level in the atmosphere, that in turn could increase warming, in a "positive feedback," said Keeling, of San Diego's Scripps Institution of Oceanography. The Intergovernmental Panel on Climate Change projects that, if unchecked, atmospheric carbon dioxide concentrations by 2100 will range from 650 to 970 parts per million. As a result, the panel estimates, average

global temperature would probably rise by 2.7 and 10.4 degrees Fahrenheit (1.4 to 5.8 degrees Celsius) between 1990 and 2100.

The 1997 Kyoto Protocol would oblige ratifying countries to reduce carbon dioxide emissions according to set schedules, to minimize potential global warming. The pact has not taken effect, however. The United States, the world's biggest carbon dioxide emitter, signed the agreement but did not ratify it, and the Bush administration has since withdrawn U.S. support, calling instead for voluntary emission reductions by U.S. industry and more scientific research into climate change." (Copyright 2004 Associated Press)

**April Fool's Day, 2004**, the pending US Presidential Election Campaign has sparked debate between the major parties about fuel prices and the US economy, nothing so far said about energy conservation, alternative energy, or Kyoto, and from a country with 6% of the world's population, responsible for 25% of world CO2 emissions. Mind you, the present Australian Government is no better, spruiking solemnly about drought preparedness, without acknowledging their own lack of action in regard to fundamental Greenhouse causes, Australia being the highest per capita producer of greenhouse gases. Calling the present climate problems "a 40-year drought" clumsily side-steps the issue of global warming, and thus, having to actually do anything about it. \$A500 million recently set aside (June 04), for "alternative energy development" is also meaningless if fossil energy use is not purposefully diminished, although, understandably, the main purpose of any government is never to jeopardise re-election, of course. No example for the developing world to follow.

**April 14, 2004**, CNN.com - World energy demand to soar - Strongest growth forecast for China, India Thursday, April 15, 2004  
Posted: 0156 GMT (0956 HKT) World oil demand may reach 121 million barrels a day by 2025.

"World demand for all forms of energy is expected to grow by 54 percent over the next two decades, with oil consumption alone jumping by 40 million barrels a day, the U.S. Government says. The U.S. Energy Information Administration's long-term forecast to 2025 projects the strongest growth in energy use from developing countries, especially China and India, where buoyant economies will boost demand. Energy use in developing countries is forecast to soar by 91 percent over the next two decades, while rising 33 percent in industrialized nations. "Generally, the nations of the industrialized world can be characterized as mature energy consumers with comparatively slow population growth," the EIA, the Energy Department's analytical arm, said Wednesday. These countries are also shifting from energy-intensive manufacturing to service industries, which means slower growth in energy use, it said. World oil demand is forecast to rise from 81 million barrels per day (bpd) this year to 121 million bpd in 2025, with the United States, China and the rest of developing Asia soaking up almost 60 percent of those extra barrels, EIA said.

"Over the past several decades, oil has been the world's foremost source of primary energy consumption, and it is expected to remain in that position," the agency said. To meet that demand, global oil production capacity would have to rise by 44 million bpd over current levels, it said. OPEC is expected to be the major supplier of the extra oil, with the cartel's production at 56 million bpd in 2025 compared to 27 million bpd this year. Additional non-OPEC barrels will also come from offshore wells in the Caspian Sea, Latin America and West Africa. Average annual oil prices are expected to decline after this year to \$25 a barrel in inflation-adjusted 2002 dollars, and then rise slowly to \$27 in 2025, which would be \$51 a barrel in nominal dollars, the agency said."

#### **Other highlights of EIA's long-term energy forecast include:**

Natural gas is the fastest growing primary energy source through 2025, increasing 67 percent to 151 trillion cubic feet (tcf) a year. That would be down from the 176 tcf forecast in last year's report, because of slower projected declines in nuclear power generation and concerns about long-term gas production. World electricity demand will almost double by 2025, growing 3.5 percent a year in developing countries from newly purchased home appliances and air conditioning. **Coal use** will grow by 1.5 percent a year, with demand increases in all regions expect for Western Europe and the former Soviet states in Eastern Europe, where coal will be displaced by natural gas. Nuclear power use will increase because of higher generating capacity rates for existing plants and fewer facilities will be retired. In the developing world, consumption of electricity from nuclear power increases by an average 4.1 percent a year during the forecast period. **Carbon dioxide emissions** will rise from 23.9 billion metric tons in 2001 to 27.7 billion tons in 2010 and 37.1 billion tons in 2025. The developing world will account for 61 percent of the increase because of reliance on coal and other fossil fuels." (Copyright 2004 Reuters)

**June 2004**, three weeks before the shortest day, in the NSW Southern Highlands, trees were showing leaf buds already. In passing, calling that 500 year drought in the Western US a "drought" will not make that go away, either.

**September 14 2004**, another El-Nino looms, hurricanes are lining up to lash the Caribbean and the southern US, Australian farmers face low crop yields, wool clips are down, water is increasingly scarce, and the price of meat ever rises. **No small irony** that two of the key players who refuse to sign the Kyoto Protocol are so seriously affected by global warming, which they choose to ignore beyond mere lip service. You have to feel sorry for the Caribbean Islanders, though, considering the relative insignificance of their contribution to global warming?

**Geo-sequestration of carbon dioxide**, the latest token anti-Greenhouse scheme in the news, is only an attempt to buy time while continuing to support high energy consumption, and thus, corporate support and continuing popularity at the ballot box. There will be another 10 years of "good" energy times until this technology is in place, if indeed it will ever work successfully or effectively anyway, and it will be energy intensive to set up, as well as to run.

**Which means greenhouse gases will continue to rise in the interim** at ever-increasing rates, from this stop-gap technology, as well as from the usual sources. Right-wing governments, proclaiming "Progress", hounding the usual political or economic scapegoats, and believing that Might is Right and "God" is on Their Side, all the while prosecuting pointless wars, are not likely to show real commonsense in dealing with the most serious problem that the entire world now faces. **The Bonfire of the Vanities, indeed ... Even the ultimate BOTV? Murphy's Law of Climate Change: Whatever can happen, will happen...?**

**December 2004**, The Phillipines reel under a succession of typhoons and torrential rain storms, with many deaths and widespread destruction. Their 2004/5 typhoon season is just beginning. In Australia this summer, a hot consumer item and status symbol is a fossil-energy powered "energy-saving" air conditioner. Power outages are already occurring, and new gas- and/or coal-fueled power generation plants are planned. The Coalition Government still refuses to sign the Kyoto Protocol. Even if an El Nino does not eventuate, it will be a long, hot, and even turbulent summer. **The Antarctic Ice-Shelf** is now melting 8 times faster than originally projected as being due to global warming. Decisions made internationally thus far, about dealing with global warming, are mostly about planning to make decisions about this decision-making. The evidence for global warming was incontrovertible by **1985**, and now that we are in **2005**..? Also, re the **Asian Tsunami**, how much was this enhanced in volume and effect by the rising ocean levels and lessening of land-lock frozen water, and how much does this also contribute to increasing crustal/tectonic instability? **Global erosion alone will affect plate tectonics, note.**

**Monday 6 June 2005**, was **World Environment Day**, ice is melting from the Greenland ice-cap more rapidly than ever, and the hurricane season in the Atlantic is just beginning. The Pacific will have another dry summer, if not a full-blown El Nino. Humans are betrayed by their primitive origins, thus our companion feeding, and mob psychology, hinder the realization of ours, and the world's, collective predicament?

**Tuesday 9 August 2005** The hurricane season in the Atlantic is predicted to be even more severe than in 2005, and glaciers in Greenland are melting 3X faster than predicted. USA, Japan and Australia have opted for hi-tech carbon emission and greenhouse gas fixes to buy more fossil fuel time, including using nuclear power. A current saying that sums up the hopes for fusion technology: **an energy technology of the future, and always will be.**

**Global dimming** due to pollution, >20%30%, is now recognized as masking the effects of global warming, so greenhouse gases must be reduced as pollution is decreased, or there will be an even greater heat sink problem, with major changes affecting the stability oceans and Antarctica beyond those already identifiable now. When the pollution is reduced, solar power will literally have an even brighter future, especially in the higher latitudes. As oil reserves diminish, resorting to coal and wood burning, however 'clean', is still not climate-friendly, and bio-fuels have their own drawbacks as well. **We urgently need commonsense energy decisions, not just politically expedient decisions!**

**New Zealand** has signed the **Kyoto Protocol**, but continues to export dirty coal to China, and the population would rather use the energy grid for heating than support their own woolen industry, and wear more woolen garments. Winter power use is at an all-time high, **June 2005**, the predominantly hydroelectric grid is to be further supported by planned coal-derived power generation. The question should be asked: is the Kyoto Protocol, in its present form, no more than an expedient self-serving token gesture? Will greenhouse gases really be significantly lowered, as opposed to merely reduced, or at best only stabilized, using present "guidelines"? Stabilisation at present levels will still continue to have serious climatic effects before world climate itself stabilizes, a 70%-80% reduction in human-related CO2 production is necessary just to attain this stability. The Grand Experiment goes evermore out of control!

**Monday 19 September 2005** Hurricanes/typhoons/cyclones are growing in intensity and strength; over four years September Arctic sea ice has had a net reduction, and vegetation is increasingly unable to sequester CO2 due to shifts, heat stress, burning, and land clearing. These phenomena are strongly indicative of accelerating and irreversible climate change.

**Thursday 26 April 2007**, by 2050 the world population will rise to 9.5 billion, more than 50% in 40 years, which makes an even greater mockery of greenhouse gas reduction. In Australia, nuclear power generation and water de-salinisation are planned, while 2.2 million acres of bushland and National Park went up in flames in the summer. In NZ, solar power is being ignored in favour of hi-tech wind and water electricity generation, which will both be endangered by increasing climate turbulence.

**World sea levels** are rising by 3mm per year, and that curve is steepening. **Also, 2007 CO2 emissions** are increasing, as doubtless so are all the others, nations equivocate and procrastinate, the distracting pointless military wars continue, and the cold Southern Ocean can no longer absorb CO2. High-efficiency plastic solar cells are being developed, (just ask Google, re this subject and any other related issues), but the technology still must be supported, refined, mass-produced, and then actually deployed, vested interests notwithstanding, and so on...

**June 2007** The Sun is now 'officially exonerated' of being the cause of present global warming and climate change, presently entering a cooler phase, with less sunspot activity. However, an 'imminent' N/S magnetic pole swap is touted as causing global warming, rather than anthropogenic warming, thus unsettling the Earth's crust, and warming the oceans by increasing hydrothermal activity in deep ocean trenches, where this posited activity cannot possibly be monitored...

**July 2007** Hurricanes bear down on the Caribbean, and an unusually prolific rain and flooding is forecast for vulnerable regions in the world as a La Nina strengthens across the Pacific. Mass biofuel production planning begins to cause controversy as regards competition with food crops for land use and water resources...

**September 7 2007** the current APEC Summit Meeting in Sydney talks up atomic power and 'aspirational' greenhouse gas reductions, and the next bushfire season, anywhere in the world, will be the biggest and brightest yet...?

**October 10 2007** The NZ Government announces a new green power generation supplementation plan, which relies on heavily on wind-power generation, and, although solar hot water and dwelling insulation subsidies do rate a mention, solar power receives no mention...

**October 12 2007** Al Gore and the IPCC share a **Nobel Peace Prize** for publicizing and education re global warming issues, the day after Gore was castigated by a British High Court Judge to the effect that his documentary '**An Inconvenient Truth**' had made 'unproven allegations' in regard to climate change. This castigation reflects attempts to water-down the climate change message in British schools. So-called Bio-Fuels are now increasingly cultivated on land originally used for food crops...

**2009 Germany** invests heavily in solar energy despite latitude and climate, (see **Appendix 5**), yet, other countries better endowed with year-round insolation, such as Australia and New Zealand, are lagging behind...?

The graph speaks for itself, but who is listening? An increasingly exponential curve, and unchecked exponentiality, can only lead to biosphere chaos, see below, re "Melting Ice, The Threat to London's Future", for an example of what we can expect.

As well as just loss of ice, with unchecked global warming there will be loss of habitat for many species including for us, and all of whom, including us, will also experience massive population culling, and, for many unfortunate species, final extinction.

Humans thinking seem to be affected, and even hindered, by a combination of companion feeding and mob psychology? We are ultimately betrayed by our origins, and the fact that we cannot seem to leave them behind.

Diagram from *New Scientist*, 30 November 2002, p.28. See also *New Scientist* Special Topics, and Archives.

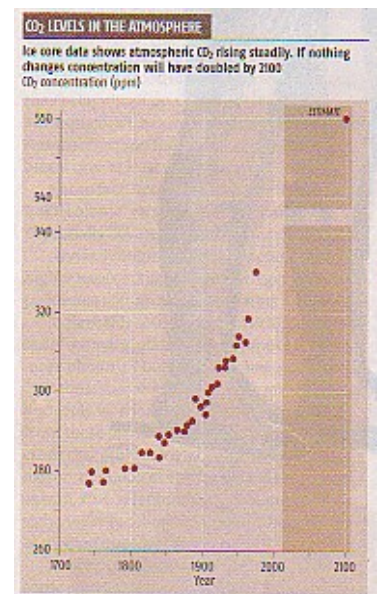
An example of solar R&D that should be supported by Thinking Governments everywhere, in this case expanded utilisation of the total solar spectrum for PV solar electricity generation.

We have always managed to rise to major physical and technological challenges before, albeit with collateral damage involving ourselves, the environment and other species, but now the odds are greater than ever before, including our inability to co-operate, and to lower our own population numbers.

May 2006: Currently, how much energy and resource has been lost in pointless Middle East conflict? Indeed, energy and resource that would have been far better directed towards alternative energy development, public education, and human population control?

*Homo Sapiens Sapiens*, wherefore art thou?

Diagram from *New Scientist*, 17 December 2002, p. 26



Extract from "Melting Ice: The Threat to London's Future" by Paul Brown, Environment Correspondent, Wednesday July 14, 2004, *The Guardian*

"There is more carbon dioxide in the atmosphere than for 55m years, enough to melt all the ice on the planet and submerge cities like London, New York and New Orleans, Sir David King, the government's chief scientific adviser has warned.

Speaking on his return from Moscow, where he has been acting as the prime minister's "unofficial envoy" to persuade the Russians to ratify the Kyoto protocol to fight climate change, Sir David said the most recent science bore out the worst predictions. An ice core 3km deep from the Antarctic had a record of the climate for 800,000 years and showed the direct relationship between the amount of carbon dioxide in the atmosphere and warm and cold periods for the planet.

Critical in climate records is the quantity of ice at the poles and in glaciers. Records show that at the peak of the ice age 12,000 years ago, the sea was 150 metres below where it is now. "You might think it is not wise, since we are currently melting ice so fast, to have built our big cities on the edge of the sea where it is now obvious they cannot remain. "On current trends, cities like London, New York and New Orleans will be among the first to go.

"Ice melting is a relatively slow process but is speeding up. When the Greenland ice cap goes, the sea level will rise six to seven metres, when Antarctica melts it will be another 110 metres," he said. Records of the 3km deep Antarctic ice core showed that during ice ages the carbon dioxide in the atmosphere was around 200 parts per million (ppm), and during warm periods reached around 270 ppm, before sinking back down again for another ice age. That pattern had been repeated many times in that period but had now been broken because of the intervention of man. Carbon dioxide in the atmosphere had reached 360 ppm in the 1990s and now was up to 379 ppm and increasing at the rate

of 3 ppm a year - reaching a level not seen for 55m years when there was no ice on the planet because the atmosphere was too warm.”

#### **CNN.com - Mussels near North Pole hint at warmer Earth - Sep 20, 2004**

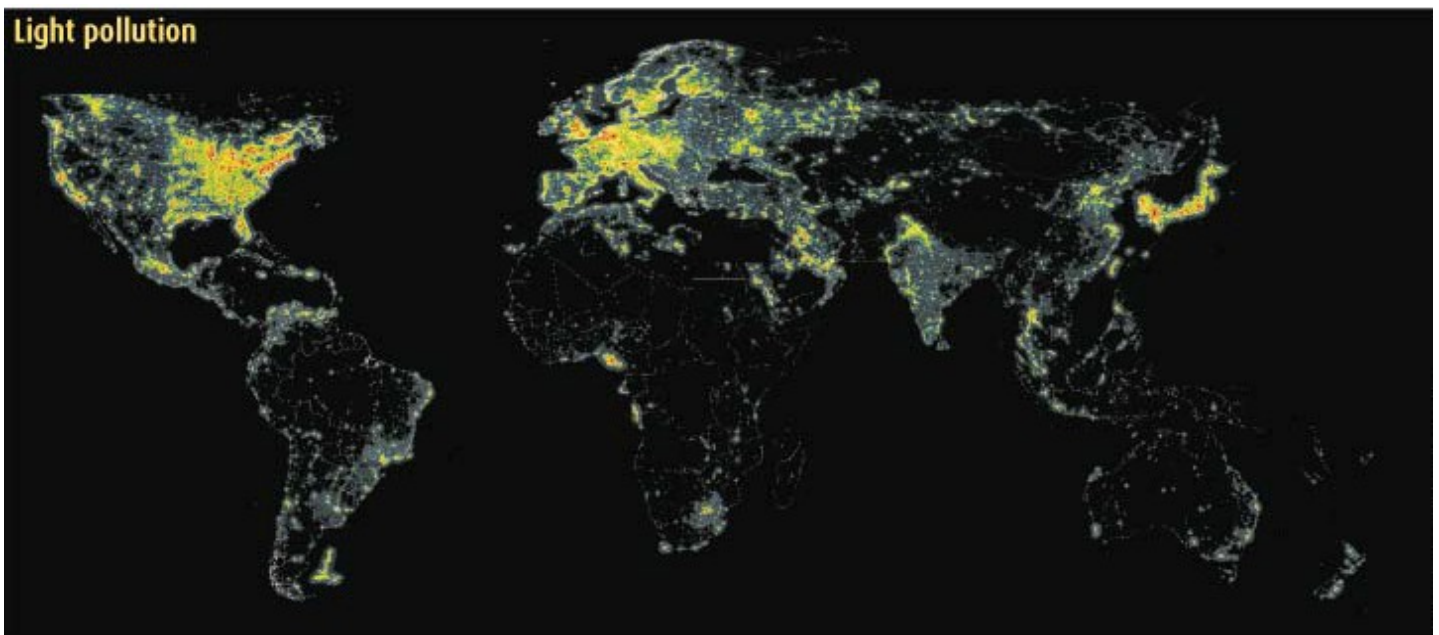
OSLO, Norway (Reuters) – “Mussels have been found growing on the seabed just 1,300 km (800 miles) from the North Pole in a likely sign of global warming, scientists said on Friday. The blue mussels, which normally favor warmer waters like off France or the eastern United States, were discovered last month off Norway’s Svalbard archipelago in waters that are covered with ice most of the year.

“The climate is changing fast,” said Geir Johnsen, a professor at the Norwegian University for Science and Technology who was among experts who found the bivalves. Mollusks were a “very good indicator that the climate is warming,” he said. “It seems like the mussels we found are two to three years old,” he told Reuters. Such shellfish have not been recorded off the islands since Viking times 1,000 years ago during another warm period. U.N. scientists say the Arctic is now warming faster than any other region because of human emissions of carbon dioxide and other greenhouse gases released from burning fossil fuels in cars, factories and power plants.

As the white ice and snow melts, it exposes darker ground or water that soaks up heat and so accelerates warming compared to regions further south. By comparison, ice in Antarctica is thicker and acts as a deep freeze resisting global warming. Inuit peoples in Canada, for instance, are seeing robins for the first time and hunters are falling through previously solid sea ice. In Scandinavia, birch trees are moving northwards into previously icy areas used for reindeer herding. The scientists monitoring Svalbard also said they had found seas free of ice further north than for 250 years at one point this summer.

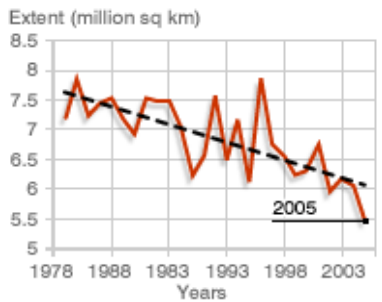
**“The climate has been warming,”** said Bjorn Gulliksen, a professor at the University of Svalbard. **“The ice limit...has not been as far north since 1751.”** Copyright 2004 Reuters.

**2020: A climate state of Emergency declared by the UN Secretary-General...**



**Our World by Night (NASA)**

## Arctic Ice Decreases 8% in a Decade:

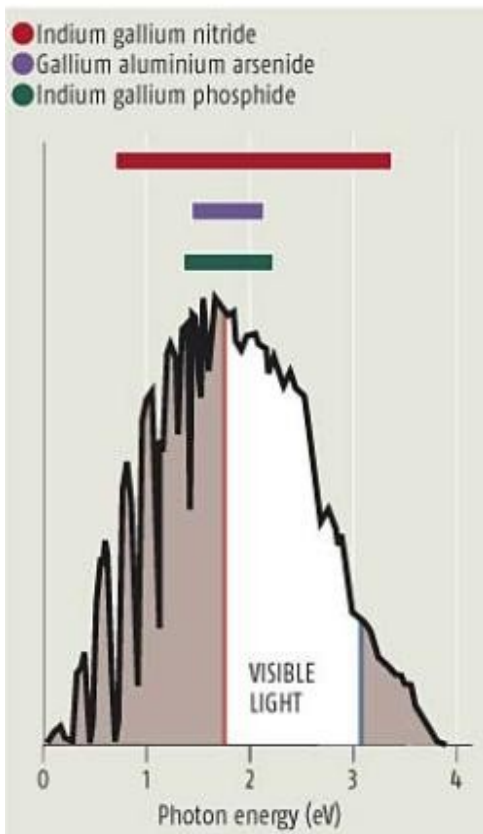


SOURCE: National Snow and Ice Data Center (NSIDC)



## THE SOLAR SPECTRUM

Indium gallium nitride absorbs more of the Sun's energy than today's best alternatives



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The Manual has generated replies which contain views and information that are now presented FYI, and thanks to those who have taken the trouble to help enhance and expand the information base.

**General Comments:**

- **The Preface, Introduction, and Appendix 2, are included because the points raised, in a general sense, are part of the Why of any solar energy management program.** Also, applying this technology does require thought, planning, power usage management, and perseverance as to routines and self-education for those who wish to utilise this energy-saving technology. The information all free, take whatever you want or need, and feedback is most welcome.
- The detailed section, **Definition and Nature of Lead-acid Batteries**, will eventually be available as a separate page when sufficient corrections and updates are made to the original, so keep feeding back..! **Now Appendix 1 as of 20.3.04**
- Thanks to **Bill Darden** for pointing out the oversight re 3-stage regulators, this should, of course, read as 4-stage regulators for FLA solar batteries.
- Also thanks to Bill's attention to detail, the **Wall Chart** has an alteration to the final recommendation:

**### Customise these Wallchart figures according to ambient temperatures, plate chemistry, manufacturers specifications, and/or individual PV systems etc., when necessary ###**

- and SLI is fully defined as **Starter, Lights, Ignition**

Here are excerpts from Bill Darden's most welcome email, with comments in non-bold:

- 1. You have presented a very detailed and scientific description of a lead-acid battery from page 26 to page 34. I would suggest that you make this a separate document or put it in as an Appendix.** See above, others have suggested this too, and there are now five **Appendices**, no less!
- 2. I would suggest that you add more information on inverters and how to properly size them.** Good idea, but at this stage, I do not have the expertise, and hence defer to other sources. Any paper on inverters that can be linked, or included and attributed will be most welcome, of course. But Bill's comment on battery sizing factors, see **15** below, should be the foundation of any inverter sizing.
- 3. The definition of "OCV" is Open Circuit Voltage. Measuring the OCV of a battery can be very different than measuring the terminal voltage with a load based on the diffusion rate within the battery. Your SoC table will change based on the discharge current.**
4. Since you are recommending that the solar batteries be operated in temperatures from 60 to 70 degrees F, as I recall, OCV temperature compensation is not as important to determine the SoC, but does matter as the batteries are cooler or warmer. (Please see the new TC table in Section 4.4, **Bill Darden's** FAQ.)
- 5. I suggest that you recommend that the "handheld voltmeter" be digital and have a basic DC accuracy of at least .5%.**
- 6. I believe a good temperature compensating hydrometer is more accurate than a digital voltmeter in determining the SoC or condition of a cell or battery. You clearly require both.**
- 7. Your SoC table, like mine, is based on a specific plate chemistry. I suggest that you more clearly point out that different plate chemistries will produce different SoC values and might need to be adjusted for temperature. Charging voltages also need to be adjusted by plate chemistry and temperature.** (The **Wallchart** has been altered accordingly, TVM. See also **Bill Darden's** **FAQ 9.14** for more plate types.)
8. More precise meanings for the terms, stationary, motive, solar, and deep cycle, have been noted, and the text altered accordingly, see **17** and **18** below.
- 9. I would suggest that you check some of the more recent research papers posted at Sandia. I think that you will find that the current thinking is that short (30 minutes or less) daily equalization of flooded batteries is better than a long equalization once a month.** Thanks for that, a welcome finding..!
- 10. For longer service life, I recommend that four (bulk, absorption, float and equalization) stage chargers be used with flooded batteries and three stage for VRLA.** Glaring proofreading oversight corrected, no excuses, thanks Bill!
- 11. For average DoD, I recommend discharging to the "sweet spot" rather than a range. (I believe you used 20% to 40%.) The sweet spot is the point that the battery will produce the greatest amount of total power by taking the number of life cycles times the DoD and will vary by plate chemistry. I have an example for an AGM battery in Section 11.3.** A pertinent and very useful concept. However, the sweet spot will vary (more shallow?) with age and condition. The Manual's range is meant to be a failsafe operating parameter for the less technical among us, myself included.
- 12. Normally, flammable gas (hydrogen and oxygen) is produced only during the absorption and equalization charging phases. It is my understanding that high discharge rates can produce stream from the excessive heat. Other and more deadly gasses can be produced when the battery has completely dried out or is burning.**
- 13. Warmer temperatures will significantly accelerate self-discharge rate and colder temperatures will slow the rate down, but not eliminate it.** Warmer temperatures also exacerbate hard crystal formation?
- 14. The 35% acid concentration of the electrolyte of a fully charged battery is for a specific plate chemistry and is different for other plate chemistries. The concentration value is basically a trade-off of capacity vs. positive grid corrosion.** Actually, I wanted a verification of the mol value for 35% sulphuric acid solution, just to be exact. The overall normal acid range is apparently 28%-42% depending on ambient and operating temperatures, eg 28% is more suitable for the tropics.

**15. The main factors in battery bank sizing are based on average load, DoD, temperature, and discharge rate (Peukert Effect).** Well put, and thanks for that, and these factors also influence inverter sizing, so finding their true value is important for a well-rounded system, see **2** above.

**16. I suggest that you compare using parallel, parallel, or serial-parallel wiring and one, three and six cell batteries. My comment about using single cell batteries, was prompted by cost. I come from a telecommunications background and all we used for years were wet (flooded) 2-volt batteries in a series or series-parallel configuration to power central offices. These batteries were very expensive and designed to last 20 to 25 years in float service. Six or 12-volt batteries, for the same capacity, can be less expensive, but do weight considerably more. Almost of my readers that have written me about solar charging and battery problems, use six-volt batteries because they were more readily available and less expensive. AGM separators have made the batteries a lot more reliable.**

The practical info, as much as possible in the Manual, including for batteries, is based on personal experience only, and 12v batteries/24v system also is the most common configuration here in Australia and NZ. In addition, simple series configuration is a safer operating proposition than parallel, should any accidental shorting occur.

**17. Solar presents a more complex situation, because, if the load occurs when the sun is unavailable, the discharge is cyclic. If the load occurs, say in a office building or school during sunlight, and the panels are sized at 130%, then the discharge on the batteries is shallow or “float”. Another example of this is for satellites where there is constant sunlight. Vehicles and “live-aboards” on boats have a similar challenge when their primary power source is the vehicle’s charging system or shore powered battery charger. The batteries are in a float service rather than deep cycle. Deep cycle batteries designed for motive or cyclic operations are different than the ones designed for stationary or “float” applications. The operative word here is application and not motive or stationary. Also, normally if a battery has solid plates, they would be the positive plates and the negative plates would be pasted grid.**

What are the actual manufacturing differences, apart from the detail re positive and negative plates, although this is in itself an important item of information? This is the hardest sort of info to find, as per the Unanswered Questions. No doubt there must be a trade-off between robustness, size, weight, effective plate area, and overall performance for given application, be it SLI, deep cycle motive or stationary, or in situ solar, which seems to be somewhere between. **Bill Darden’s FAQ 2.1** gives interesting extra details on construction. Perhaps “stationary” could have two categories, viz., stationary back-up, and stationary solar for clarification purposes, both motionless as well as in situ?

**18. As near as I can determine, the battery manufacturers are trying to be competitive so they build different batteries for different applications. For example, motive deep cycle batteries have to withstand a great deal more abuse (vibration, deep cycle charging, etc.) than do stationary deep cycle batteries for the same service life design; thus, cost more to build. I would recommend that you suggest for optimum service life to match the batteries to the cyclic or float application, to match the batteries to the charger or visa versa, and to follow the battery manufacturer’s charging and discharging recommendations.**

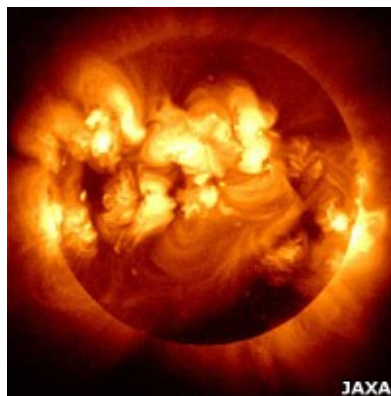
By this definition, in situ solar batteries undergoing regular cycles would be classed more as motive batteries, rather than stationary or back-up batteries. See Bill’s **FAQ 7.1** for this explanation.

Once again, two types of stationary classification, (ie, in situ, fixed, immovable), back-up and solar, would aid clarification? “Solar” and “solar backup”, (the difference being cycling potential), would also imply flooded batteries principally designed to be charged by the sun and/or ancillaries, and needing 4-stage monitregs to regulate charge cycles? Motive batteries would, therefore, more likely be SLI and/or deep cycle VRLA, and not fixed, especially in the sense of being subject to possible motion, which stationary FLA batteries should not be, and whether principally charged by the sun, or not?

**FYI: float charge utilises a constant voltage, and trickle charge a constant current, see the [Electrical Technology](#) excerpt.**

**See [Bill Darden’s Battery FAQ on www.batteryfaq.org](http://www.batteryfaq.org), well worth your time and effort to read all of it!**

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## Appendix 4: Customising monitreg data for easy reference.

An advanced monitreg will have a series of programs which may be accessed by various push-and-pause codes, depending on make and model. If the entire program inventory is not required to be used, the suggestion is to extract only the optimum information needed for managing a particular system, making a small flow chart of this for easy day-to-day reference. In this example, each block opens as a new sub-list in the LCD window:

**BATV** battery volts, interim, see manual over-ride below  
**CHGE** charge rate, also interim, includes generator controls  
**LOAD** if any at that time, also low battery disconnect  
**IN** amps collected since midnight  
**OUT** amps used  
**DATA-----àVMAX** battery volts max since midnight  
**SET** ->**VMIN** battery volts min “ “  
 ->**FTIM** float activation time  
 ->**SOC** state of charge, interim  
 ->**TEMP** external temperature  
 ->**SLRV** solar volts, interim  
 ->**HIST** history, monthly increments

**SET---à Time-> Volt-> Program-> Regulate-> Mode-> Event-> 24v-> 4**

### Regulate

-> **BMAX** boost max, 28.6v summer, 29.6v winter  
 -> **EMAX** equalization max, 31v  
 -> **ETIM** equalization time, 1 hour  
 -> **EFRQ** equalization freq., 20 days  
 -> **ABSV** absorption volts, 28v  
 -> **ABTM** absorption time, 30 min  
 -> **FLTV** float volts, 27.2/6, s/w  
 -> **HYST** hysteresis, 0.8v  
 -> **BRTN** boost return, 25v  
 -> **CMAX** charge max, 20amp  
 -> **BFRQ** boost frequency, 1 day  
 -> **TCMP** temp. comp. profile Code 8

### Mode

-> **BCAP** battery capacity, 100 a-h rate  
 -> **PWM** pulse-width modulator on/off  
 -> **RSET** reset processor/system performance settings

Also in **BATV** sublist:

### as manual over-ride controls

->**BOST** boost on/off  
 ->**ABSB** absorption “  
 ->**EQUL** equalization “  
 ->**FLOT** float “

Example derived from **Plasmatronics Model PL20**, <http://plasmatronics.com.au>

**Concurrent external charge and battery use values**, whether the charge is sourced from the PV array, generator, or mains, **must** be calculated correctly to be effective in preventing net battery discharge, especially below 40% for deep cycle batteries, or 20% for SLI. Charge that exceeds current draw will go directly to the load, and any surplus will contribute to overall battery charge if this is deficient. Conversely, charge that does not meet load requirements will be complemented by ongoing battery draw, and thus, net battery charge loss until a net charge is re-instated. In both cases, the current is flowing through the battery in one direction only, and the battery therefore functions as a current buffer.

With larger, fully integrated systems incorporating an advanced monitreg, such net battery charge loss is more readily accounted for and controlled, but smaller, more basic systems would have to be monitored if there is a possibility of significant charge deficit to be sustained for any length of time.

**Note also that neither of these battery use scenarios should exceed the normal parameters of battery capacity and charge limits for any given capacity of any system component. Excess charge should still be regulated, and draws of high amps through underrated circuits of charger, BOS or battery, will quickly result in overheating and probable damage, with a considerable fire outbreak risk! Know your system component specifications, plus specific prospective charge and discharge parameters, and do the necessary setup maths!**

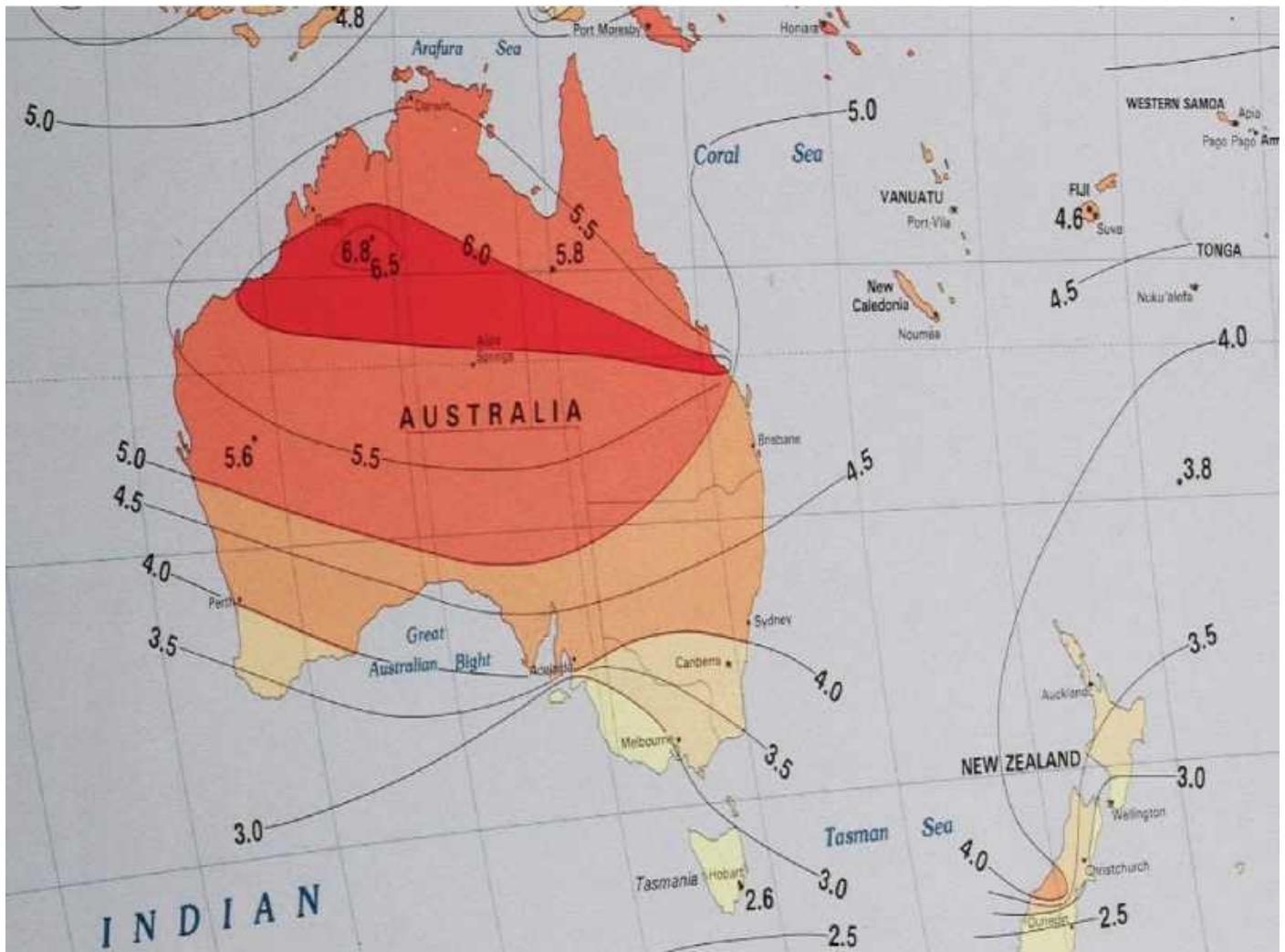
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## Appendix 5:

Global Solar Power  
Map #8  
Australia and New  
Zealand



Advanced Energy Group  
Contact us today for a solution using solar power!  
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Please see [Solar4Power.com](http://Solar4Power.com) for the full range, in colour, of all their Global Solar Power maps.

### Tilt angles for given latitudes:

Lat12-15, tilt@ 15°; Lat15-25, tilt@ lat°; Lat25-30, tilt@ lat+5°;  
Lat30-35, tilt@ +10°; Lat35-40, tilt @Lat+15°; Lat40+, tilt@ Lat+20°

### Approximate panel efficiency v. sun incidence, relative to latitude:

Lat0°/90° incidence(100% utilizable efficiency, 25°/75°->95%, 45°/45°->75%, 60°/30°->50%, etc

The most effective panel angle for utilizing sunlight has several variables, viz., the correct angle for latitude, the season and/or time of day, weather, sunlight intensity, and the possible degree of variation from any optimal angles, especially if a mechanized solar tracker is not used; see also p. 25; hence the importance of correct data to enable a relevant MSSE calculation to be made.

However, the final arbiters of your PV system's overall effectiveness will be the verdict of your voltmeter, and especially, that of your ammeter. Therefore, it is strongly recommended that you do some surveying of existing systems, if possible, to gain information about overall performance in relation to size, especially useful when proposing solar power system operation in a similar local or regional setting.

### Global Solar Power Map # 11 Europe and Eastern North Atlantic



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 Contact us today for a solution using solar power!  
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Please see [Solar4Power.com](http://Solar4Power.com) for the full range, in colour, of all their Global Solar Power maps.

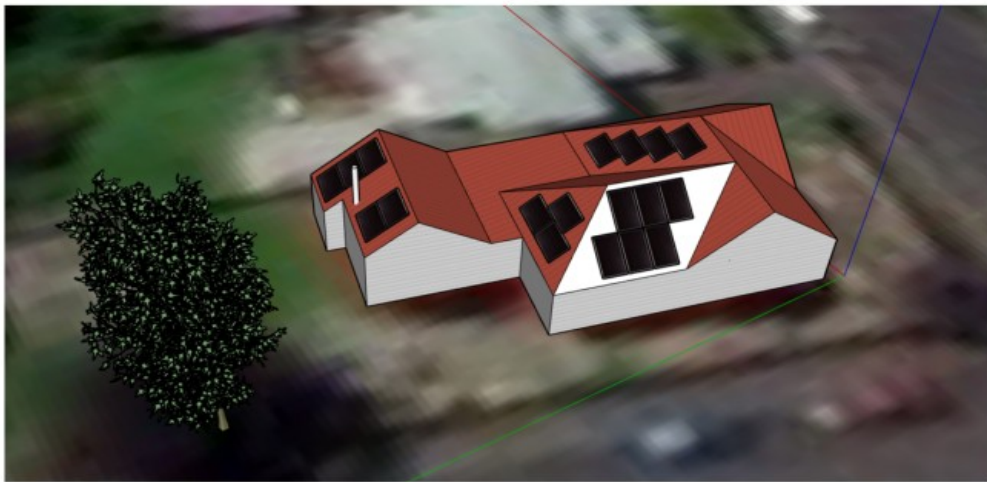
## Appendix 6:

<https://interestingengineering.com/energy/electrified-house-with-solar-and-thermal-energy>

### Modern 2024 Domestic Solar System Example, Grid Interface:

## Solution Design - 6kW System

18 SunPower 415W solar panels totaling 7.47kW,  
Coupled with a 6kW inverter.



Expected Annual Generation - 7620kWh

$E_d$ (kWh/day)												
Group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	7.88	8.72	6.68	5.45	3.66	2.77	3.60	4.60	6.47	7.51	8.54	7.70
2	6.60	7.18	5.39	4.30	2.83	2.13	2.76	3.59	5.19	6.16	7.10	6.47
3	4.72	5.26	4.07	3.36	2.28	1.72	2.24	2.85	3.95	4.54	5.12	4.60
4	9.52	8.88	6.43	4.70	2.80	2.00	2.77	3.73	5.90	7.86	10.06	8.62
$\Sigma$	28.72	30.04	22.57	17.81	11.57	8.62	11.38	14.77	21.51	26.07	30.81	27.39

$E_m$ (kWh/month)												
Group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	244.39	244.21	207.09	163.58	113.42	82.98	111.51	142.59	193.99	232.87	256.20	238.63
2	204.61	200.96	167.04	128.92	87.69	63.90	85.65	111.22	155.58	190.84	212.87	200.54
3	146.20	147.41	126.31	100.84	70.54	51.72	69.55	88.33	118.63	140.83	153.48	142.73
4	295.22	248.66	199.36	141.09	86.88	60.03	85.97	115.77	176.97	243.71	301.88	267.14
$\Sigma$	890.42	841.25	699.81	534.43	358.53	258.63	352.68	457.91	645.17	808.25	924.43	849.04
							228	310	563	701		

Assumptions



## Some thoughts Re Community and Household Natural Disaster Preparation:

Small modular AE units, for the average household, such as solar/PV, should be on the market..\$500 or so, standard and mass-produced(?) Units with a PV panel, regulator, inverter, and, powering both wifi/phone and Internet, plus, charging mobiles, thus, keeping lights on at night, and, outside contact open. (Landline cables may be damaged, or unpowered.) Solar-powered caravan in the driveway would be a handy asset in these circumstances! Gel L-A batteries are fine, just keep them cool, well-ventilated, and, keep optimum charge topped up with the PV panel. *Small wind generators also..?*

**Note that deep cycle batteries are slow down, and slow up, re discharge/charge cycle, and automotive batteries are fast down, and fast up, so, automotive batteries are not suited to maintain emergency power beyond brief interim usage. Avoid ghost discharges if possible, especially with automotive batteries. LI-ion certainly has greater energy density, but, must be used with care, plus, the batteries situated away from buildings. This battery technology is still evolving, note. FLA/Gel L/A have a long history of development and use, plus, electrolytes that are water based. Just keep unit maintenance at optimum, re correct wire gauge and insulation, clean contacts, plus clean well-ventilated storage sites.**

Standby gas, for either low or high pressure stoves, is sufficient for cooking, and, hot water as required. Traditional burning fuel also.

As well as phones and lights, there must be power for fridges and freezers, certainly, plus, a few community-owned diesel generators, or, private enterprise, on trailers, doing the rounds within the community, or , private enterprise at an hourly rate, would cope. Diesel is recommended, because this fuel can be grown and produced locally, plus, the motors are more robust and longer lasting than petrol motors. Also, petrol does not store past a couple of months in prime condition, and needs stabilisers, thus, cannot be stockpiled like diesel/diesel-compatible fuel can be...which is decades, at the least. (Petrol combustion engine days are now numbered, as well?)

LED lights are now ubiquitous, and, a budget gift for emergency lighting, with their low energy requirement. Magnetic battery-powered LED lights are a boon for emergency lighting, before major battery power switch-over, if/when there are power cuts at night. Rechargeable batteries for these lights, and portable radios, are recommended, thus, in turn, being rechargeable via the solar unit.

**Always have a buffer of water and/or ice in fridge or freezer, that will maintain adequate storage temperatures, for days if necessary, and, leave unit doors closed as much as possible. Keep ambient temperatures low, as well, with moving air and no direct sunlight.**

**Maintain a cool provision store of dried and other non-perishable food, plus potable water, for emergency use.**

**Prepare for power cuts by practicing coping protocols....even going bush for a few days would be ideal, to re-create conditions of life without electricity readily available. Take a small portable solar camping unit to add to the experience! Do not expect life without mains power to go on just as before, unless you are prepared to meet the required costs, for AE, and/or generators, note...OK!**

### General notes:

**Re \$500 PV unit cost....** if enough consumer business was generated, with uniform/standard specs and bulk-buying, the price could come down, hopefully to circa \$500, to be within easy range of the average household. Maybe Govt. could chip in..? This would also ease emergency grid repairs somewhat, as far as time was concerned. Special power needs would have to be catered for by full solar installations, or, generator power.

**Re diesel generators...***just looking well ahead to the days when gasoline will be very hard to obtain, and diesel piston engines will be the mainstay of transport, portable power generation, and major power backup, for hospitals, et al. EVs must also still be charged, one way or the other, if mains power is not available...! Railways run on diesel-electric, too. Sharing a diesel generator, or, private enterprise operating at at an hourly rate...either option would fill the standby gap, till the mains were repaired. Plus, a whole lot more oil-seed cropping will be needed... (Note that diesel engines will never be cheap because of extra robustness due to required compression ratio.)*

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## Appendix 7: Countering Alternative Energy Misinformation Extant in NZ

(Notes from conversations, OU 2009) Updated June 2026

There are various types of misinformation about the type and uses of alternative energy suitable for interface with, and complementing of, the main power grid in NZ. Some of the misinformation is a matter of vested interest, some is politically expedient, some just mischief and urban myth, and some just generational. The following file will describe, in a short information package, the status quo of alternative energy use in NZ, and also in view of present and future climate change trends. Climate Change is a purposive misnomer, along the lines of 'the climate is always changing', a handy cop-out for Deniers. The full title should be CC/GW/OW/AW, aka climate change/global warming/ocean warming/atmospheric warming, to show the full extent of what is happening.

**1)** NZ's primary electrical power source is at least renewable, in the sense that, once built, hydro dams do hold rainwater for power generation, and, should be of sufficient capacity to do so regardless of season. South Island hydro, ironically, is located within an Alpine rain-shadow, which does not auger well for climate change, as most of the water reserves that will enter the dams are held in snow and ice. North Island dams are dependent entirely on rainfall, and consequent river levels, to be sustainable. Hydro potential in NZ is being further reduced to smaller and smaller installations in more regional areas, especially as there will be increasing competition for water for other purposes, such as irrigation and potable water. Thus, use of alternative energy is becoming more important, not least because insufficient regard is being shown for optimal NZ population numbers, and population nodal balance. The North Island is unbalanced regarding present power generation potential versus population numbers, thus requiring South Island grid supplementation.

**Dams themselves are not so green** when the initial cost of construction is considered, with heavy reliance on fossil fuels for construction, and, the major power reticulation and maintenance costs that also must be met. Dams also may cause earthquakes in susceptible areas, (eg Benmore), even with the most carefully planned siting and construction. As well as interrupting land use due to raised water levels, and the natural carbon cycle of the original land that becomes submerged. Methane is a major greenhouse gas that is generated by both natural anoxic decay, as well as by methanogens in oxygen-deprived environments, so, original vegetation breakdown, as well as the ongoing accumulation of water-borne organic debris, silt, and mud, means that an endless supply of methane-producing deposits continues to accumulate, as well as a gradual loss of storage capacity resulting if flushing mechanisms are not present. This has occurred at the Aswan Dam, and will occur in the Three Gorges Dam. NZ North Island dams are also susceptible to this shallowing, unless careful land-use is practised.

**As for nuclear power, forget it**, especially in a country that is one long earthquake zone, with no significant economic reserves and/or flexibility, and, dependent entirely on overseas markets for nuclear fuel, technology, and toxic waste disposal, plus, being remote from many such markets for products and services. Nuclear power, by its very nature, is dirty and dangerous, and can never be completely safe, which is a definite priority, considering the previous history of nuclear power use. Even moored atomic submarines, as once mooted for Darwin's power generation, would be impracticable, hazardous, and politically very unpopular...! The Fukushima accident, also on the Pacific Rim of Fire, has served as a timely example of such hazards. Given NZ's alternative energy alternatives, nuclear power is simply unnecessary, and proponents politically dismissive of development of Alternative Energy and a distributed grid/mixed energy power grid.

**2)** Thus, properly planned alternative energy can be of great value in complementing all stored water reserves, as well as relieving the need for more dams, or, coal-fired power stations such as Huntly, at a time when GHG emissions are subject to world scrutiny. Keep the water behind the dam walls by optimising alternative energy power generation. The present dams, fortunately for NZ, serve as the 'battery storage' facilities that so many other countries do not have. However, climate change/ CC/GW/OW/AW means that careful water conservation must be ongoing for optimum storage, and this can be maintained by educated power usage, supporting the woollen industry, and, most importantly, by alternative energy generation that pre-empts excessive release of stored water.

**3)** Geothermal power is very useful, although always dependent on careful management, and, geological stability of the geothermal fields that supply the steam energy. Wind and wave power utilities are, by their very natures, also exposed to the extremes of the elements that provide their generating energy, thus being susceptible to storm damage, are also capital intensive, and, require continuous maintenance.

**4)** Solar power is also capital-intensive, but, once arrays are set up in optimally-sheltered north-facing locations, (vice-versa for the N. Hemisphere), they will function efficiently for 30 years or more, even then, panel decline is only gradual, and extra panels can be added to an array, or, older panels can be sold off for less demanding functions. The only moving parts are electrons, and the only large-scale maintenance is panel-cleaning as required. (Mostly dust, and bird droppings, good thing cows do not fly..!) Warranties issued with new solar PV technology are currently valid for 25-30 years, and older panels that lose efficiency still generate the same wattage, only amperage declines. Earthquakes and weather turbulence are not major problem for solar arrays, either, though attention must be paid to shelter from potential high wind gusts, and, panel frame construction should be accordingly robust.

Furthermore, the longitudinal spread of NZ, as well as its geomorphology, make any season a good season for solar power generation, as there is a long Indian Summer in the South of NZ, even if not optimal winter

performance in all regions, and, there are adequate solar hours all year round in the North Island. Solar farming is also ready-made multimodal, just utilising any existing and/or adjacent grid for interface, thus having easy input into country-wide power generation networks, which also means optimal spread of panel insolation is possible, regardless of any regional weather or seasonal differences. PV panels on every roof in NZ, connected to the main grid, would then save a lot of dam water from unnecessary release during daylight hours, even on cloudy days. In particular, solar panels on every roof in the North Island, including for hot water, would be a most sensible solution to the present power generation imbalance that subsists in NZ.

Please also refer to [Global Solar Atlas](#) World Solar Maps for detailed information re World Solar Hours; firstly, note that the hours are conservative, (not necessarily accounting for phenomena such as Indian Summers), and secondly, that Northern Hemisphere countries like Germany, with fewer solar hours than Australasia, are spending more per capita on solar power research than we are. China is now becoming a major solar PV producer, and, with 'solar grade' PV silica being less expensive than silica refined for conventional electronics, panel prices will continue to fall.

Regional solar farms would could also support the grid, especially at some elevation, and cause less controversy, re environmental impact and noise, than wind power. The best annual insolation in NZ is actually in the Otago region, and, the Mackenzie Country is a case in point, with high elevation, clear air, suitable north-facing slopes, yet still close to the main grid, although there are plenty of well-elevated positions of similar potential anywhere in NZ. Solar PV and thermal hot water will also produce results during cloudy days, and this counts when the main grid is being supplemented, or, just for standalone installations. Note that 'savings' of dam water thereby should be calculated on a yearly basis, and for the whole country.

**5) Mixed alternative power generation is the optimal solution**, plus, utilising a distributed energy grid, but, solar power, of the all power generation alternatives, will always be more ubiquitous, and more reliable, and that **must** include solar hot water. Even remote stand-alone power generation benefits from mixed power generation, but, solar is the main reliable low-maintenance solution, and, even with wind and water potential available, stand-alone plant users may choose not to use them, preferring higher investment in solar PV and solar hot water, because of the trouble-free nature of solar power usage. Water movement and storage is also possible using portable solar pumps with a dedicated panel, remote telephones can be solar powered as well as other remote uses of solar PV, with or without battery backup. Noise, maintenance, proximity, and/or reticulation, etc, are all factors to consider with wind and water power supplementation.

**Even businesses or homes on a main grid can both benefit from a small backup solar installation**, especially when power cuts are probable, with current grid stability an issue. Main grids in Australia and NZ date from the 1950s and 60s, and there are population increases placing and added burden on these older grids at a time when upgrade is well due. Balanced input of any alternative energy to the grid can be economically implemented, excess could be directed to water heating, large-scale battery charging, especially vehicular, etc., and, power prices should also be adjusted during times of peak AE input.

**6) Much is made of power costs versus efficiencies**, and, solar gets bad press in this regard by lobbies pushing for complex technical and mechanical power solutions, or, protecting some other outdated economic status quo. Present PV solar technology, at about 27% efficiency, will peak at about 30%, the average off-the-shelf for stand-alone purposes is presently about 20%. But, the price of manufacture has been NZ/AU\$10 per watt for more than 30 years, and will continue to fall in relative terms. As well, there is ongoing R&D improving solar technology, especially involving wider utilisation of the solar spectrum. Solar power should be seen as a major power supplement for most installations, unless very large panels and batteries are installed in standalone situations, and, in the case of grid interface, the main grid will support on-demand intensive power needs, then, the solar power unit will farm back solar-generated power, at other times, for a cash return. Note that grid power to a wall-switch is only about 30% of initial power generated, the rest being lost to heat, distance, resistance, inversion/conversion, regulation, metering, et al.

**New solar technology also means a healthy market in used solar equipment**, so, larger budget-priced arrays can be installed, especially for standalone use. Improving climate-related architecture, improving home appliance technology, utilising thermal hot water, plus, careful supplementation of heating and cooking by other means, such as main power, (not including standalone situations), plus efficient wood-burning, or, of natural gas, (which can be supplemented by biomass production as well), all make solar power more attractive and cost effective. All types of AE power generation can benefit from similar considerations of energy conservation and careful usage. Note that solar PV power can also provide hydrogen generation for fuel cell use, as well as for main grid or standalone use, outside of peak usage periods.

Meanwhile, the average combustion engine is no better than 30% efficient, as well, and that does not take into account the gross energy expenditure to actually bring fuel to the pump, as well as the energy, and the cost, being non-recoverable, once expended. Likewise, apart from capital cost, dams expend water one-way only, depending thence on replenishment that is climate-dependent, and, there are efficiency penalties and costs in turbine use, plus major unimodal power grid reticulation that loses some 60% efficiency as well. **Note again, that grid power to a wall-switch is only about 30% of initial power generated**, the rest being lost to heat, distance, resistance, inversion/conversion, regulation, metering, et al. Geothermal and fossil fuel power can be similarly subjected to cost /efficiency scrutiny, and when this is done properly, solar power, both PV and Thermal, look much more worthwhile, especially when GHG emissions are considered, and, low maintenance and long working life are included.

**Solar PV power farming will ensure the quickest return of manufacturing costs** in a way that no other power source can possibly do, (5 years is quite realistic, the less so as power prices will continue to rise), and, there really is 'power for free' until PV efficiency declines after 30 years or so. Capital investment is thus returned, and then exceeded, whereas power paid by the usual grid consumer is money that is lost forever. With solar power, both PV and Thermal, the old adage, 'the more you eat, the more you get paid', really does apply in the full economic sense of limitless power returns. Solar farming can connect to any part of a main or regional power grid with simple DC-AC inversion, plus interface technology, and there is consequently less loss of power efficiency to 'The Grid' compared to reticulation from major conventional power-generating plants.

**Note that batteries are usually only necessary for standalone applications**, and, these are the same batteries that would support wind or water power as well, most commonly flooded lead-sulphuric-acid, and for ultimate low maintenance, nickel-iron-sodium-hydroxide. Lithium-Ion batteries are now in common use, with high recharge cycle rates, and Calcium batteries show even more potential for similar efficiencies. (See also [Nofrillstech.net](http://Nofrillstech.net) re battery management information.) Large scale FLA battery piles have been used to support main power grids in the past, eg, at Niagara Falls, but, **the water actually held in the dams is always the optimal power storage solution**, so, any alternative energy source that complements and supports this should be used. Solar power is thus mooted as the best alternative solution, with potential for ubiquity, easy grid interface, and, an energy efficiency that compares very favourably with other energy sources, if gross and net energy costs are factored into efficiency equations, especially solar hot water production.

**Most importantly, solar power, whether PV or thermal, is infinitely renewable**, gives an early refund, and more, on investment, does not involve serious environmental siting considerations, and, is very low maintenance. Plus, solar power is endlessly ubiquitous in application, even within the far reaches of the Solar System, or, during Polar Summers! Grids with time zones, as well as longitudinal spread, that would utilise solar power, are particularly well favoured because of the continuity of insolation within the grid, plus, staggering of peak usage, and this should always include solar hot water temperature boosting, which also eases grid demands.

Thus, solar power is a potential agent for regional co-operation, as well as for national and even international co-operation. Consider Pan-Eurasian, Pan-African, or Pan-American power grids supported by solar power, and any other utilisable energy source, which will now increasingly be the Australian grid supplementation model, as a further example.

**Solar Power for World Peace...?** Not least to prevent looming World Water Wars..?

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**Notes:**