ENERGY FOR HUMANITY_

# SOLAR PHOTOVOLTAICS

Rick Jefferys

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Solar PV prices have dropped dramatically in recent years, albeit from a very high level. In very sunny places and/or with high retail power prices, such as southern Europe, US, Middle East, the unsubsidised levelized cost of solar power is competitive with retail power prices and in some areas is competitive with wholesale power. But as the share of solar on the grid becomes significant, wholesale electricity prices drop when solar peaks, reducing returns to projects that see time of day pricing.

Utility power prices include a cost of energy component and a share of overall grid costs which is spread over all the energy sold; retail/commercial solar saves the consumer both the energy cost and their related contribution to grid costs, which are then loaded onto the remaining energy sold by the utility This is not entirely fair, given that solar generators without sufficient storage will need the grid at night / in cloudy weather - and they will all need it at the same time. This can be remedied by charging PV owners a daily flat price, based either on their generating capacity or their peak demand during periods when they need grid supply.

In many markets, domestic PV installations can sell excess power to the grid at retail power price (net metering). This is another subsidy, since the utility is paying retail rates for power which usually could be sourced at a much lower price. This can be handled by real time pricing or a meter which pays a wholesale price for power put back into the grid. Typically, fossil fuel generators are not paying enough or at all for $CO_2$ emissions, so some solar subsidy, direct or otherwise, is reasonable. For those in the developing world who have no access to grid power, solar combined with battery storage (provides 2-5 hours of backup) is life changing and typically less expensive than kerosene for lighting and perhaps diesel generated electricity.

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Solar plus batteries are much less expensive than providing transmission and grid power for small and remote consumers and can be installed at will. Once consumers want more power - perhaps air conditioning as well as lighting and phone charging - and higher reliability, solar plus storage begins to look quite expensive - and very expensive in areas with winters or serious seasonal clouds and rain, which can reduce solar panel output by 65% to 90% for days at a time, requiring much larger volumes of storage to maintain service.

Grid integration becomes a big issue once solar becomes a significant portion of supply. In most markets, solar panels face south to maximise energy output, since this is what subsidies reward; output peaks at mid-day, while power is usually more valuable later in the day. In UK, Germany and similar markets, solar output peaks in mid-summer when demand is relatively low. In other countries, such as the US, solar tends to peak on hotter days, so there is some match with air conditioning demand, but this stays high and can increase into the evening while solar output is diving to zero. Storage and/or other grid assets must work hard to handle the decline in solar at a time of rising demand. PV output can drop by 65% to 90% due to clouds, creating strong local variation.

Dispatchable demand may be a cost effective ways to handle this issue (see Energy Storage briefing). New options include electric vehicles and cold storage, where spare power is used to make ice which can then be used for air conditioning later in the day. Grid integration costs are imposed on the grid and must be paid by consumers and/or the solar installation owner.

While PV has been around for a couple of decades, the technology is still maturing, with continuing advances in efficiency (20% solar to DC electric is routine in garden variety cells), manufacturing cost, DC-AC conversion and installation methods.

Efficiency (not to be confused with load factor!) is one aspect of cost effectiveness and is very important where space is at a premium. More efficient systems need less racking and wiring to install so are generally desirable, but not at any price.

This note will not provide details of the multiple technologies in the running; crystalline silicon dominates by volume but thin film, historically less expensive and less efficient, is approaching silicon efficiency. Gallium Arsenide is the efficiency (31%) and weight leader, but is still too expensive other than in space applications. Focusing systems can use very efficient, very expensive, multi-junction cells, but usually need trackers to follow the sun, adding cost. Perovskites are the hot new conversion technology, efficiencies are high, material is very low cost but life / robustness may be an issue. Longer term, Perovskite solar may be built into laminated glass, greatly reducing installed costs.

In many markets, there are less expensive, though unfortunately less glamorous routes to $CO_2$ emissions reductions and energy security. Levelised cost of power to the owner is not the whole story; it is quite possible for solar to have the lowest cost of any generating technology, but still be undesirable at the system level, which has to provide backup capacity for solar, often without adequate reward.