Efficiency—

Ratio of Energy Out to Energy In

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Derivation: From Latin efficere, *to effect.*

In terms of energy generation and use, "efficiency" is the ratio of energy input to energy output. If I put ten units of energy into a device and only get seven units of useful work out, the device is 70 percent efficient. This means that 30 percent of the input energy is lost. This "loss" is usually waste heat.

Losses are inherent in any transfer and use of energy. The goal is to keep these losses to a minimum. But concern about efficiency may vary depending on what sources of energy we're talking about, and what devices.

In the case of solar-electric modules, the quest for higher efficiency sometimes seems a bit misplaced. Sure, we'd all love very efficient modules, and progress in this area of technological development is welcome. But we're dealing with a free and abundant resource—sunshine. It's not as if we're wasting sunlight by not converting it to electricity more efficiently.

What's needed most with PV development is lower cost. If given the choice between cheaper PV modules and more efficient PV modules, I'd take the cheaper ones (assuming the same warranty). Less efficient modules do take up more space on your roof, and require more racking structure. But the fact that today's best mass-market solar-electric panels are "only" about 15 percent efficient is not something to lose sleep over.

It's a similar story with wind turbines. Sure, we want very efficient blades and alternators. But as long as you site your wind generator properly, it will have no shortage of wind, which blows by at no charge. A higher priority is to make durable, long-lasting turbines that we can afford.

The situation is a bit different with hydro turbines, at least in most cases. Often, hydro system owners have a limited amount of head (vertical drop) and usable flow, the two ingredients that make hydro-electricity. So it's important to make the most of the resource. By increasing the efficiency of the turbine, you can make more electricity from the same resource. With sun and wind, you can always make your array or wind turbine larger to catch more of the free and abundant resource. With a hydro turbine, it's the resource that is limited.

Once you've generated the renewable electricity, efficiency becomes *very* important. Renewably generated electricity is not cheap. It makes no sense to waste it with inefficient balance of systems (BOS) components or with inefficient loads.

Batteries are essential in virtually all off-grid RE systems. But there is an efficiency cost. For new batteries, we generally assume that 10 to 20 percent of the energy put into a battery is lost in the electrochemical energy conversion process. That's the price off-grid folks pay for needing energy when they aren't making any. Improvements in storage efficiency would be very welcome, though again, at what cost?

Inverter efficiency varies depending on the load on the inverter and can range from really poor (say, 50%) to quite good (95%). Remember that inverter manufacturers like to advertise the *peak* efficiency, but actual efficiency spans a wide range, depending on the level of energy usage. I've seen battery-based, grid-tie PV systems in which the inverter/battery system eats up 40 percent of the production!

Charge controllers have an efficiency penalty too. You just can't do much with electricity without paying an energy price. But these percentages are generally minor with modern charge controllers, which are typically better than 95 percent efficient.

With all the BOS components, we're looking for electricity out compared to electricity in. With loads, the output takes different forms. We put electricity into a lightbulb and we want light out. Inefficiency takes the form of heat, something we aren't looking for from a lightbulb. An incandescent lightbulb, for instance, is a fairly efficient heater, but a very inefficient source of light. Compact fluorescent bulbs, on the other hand, give the same amount of light for one-third to one-quarter of the energy input of incandescents. Much less energy is wasted in heat.

Every load in your home can have high or low efficiency. Your pump may pump more water per kilowatt-hour of electricity than your neighbor's pump. Your washing machine may use more electricity to wash that load of jeans. Choosing efficient appliances is critical to making the most of your energy, whether you buy it from a utility or make it yourself. See the fine publications of the American Council for an Energy Efficient Economy (www.aceee.org) for information on choosing efficient appliances.

There's still a cost vs. efficiency balancing act with appliances, but the closer you get to the end use, the more important efficiency is. If you use incandescent bulbs instead of compact fluorescents, you'll be spending three to five times as much on solar-electric modules to power them.

Efficiency at the appliance end is much more important than at the generating end of the system, and money invested there will do the most good for your pocketbook and for the environment.

Inefficiencies in a system don't just add up, they multiply. If you use four times the energy to do the work, you'll have four times the losses in the conversion process. Your generating sources will have to make more energy for your inefficient loads, multiplied by the inefficiency of all the conversion components.

So another way to look at efficiency is that the most efficient use of your *own* time, money, and energy is to invest in making your system and loads more energy efficient. This effort put in will be rewarded with increased functionality coming out, at lower cost in the long run.

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