Solar Vs. Hydro

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SOLAR OR HYDRO?

Everybody can access the sun for alternative energy. Hydro resources are far from universal, but not uncommon in rainy, mountainous Costa Rica. As far as agonizing choices go for a property owner, a dilemma between hydro and solar for alternative energy supply is an enviable position to be in.

Hydro Country: near San Ramón

Solar panels are at an all-time low price, and environmental costs, non-existent for solar, are on the rise for hydro. Up until 2008, hydro was once popularly considered an unbeatable resource if you had it present on your property. But with low solar panel prices, this is not true anymore. And with grid-tie law expecting to be formalized this year in Costa Rica, this introduces yet another variable to the relative favorability of the two quite different alternative energy technologies. In fact, with the forthcoming grid-tie law expected to rule out the sale of excess power to the grid, grid-tie designs must be scaled to demand and not oversized. Where confirmed hydro would intuitively seem to be favorable over solar, that's often not the case. For residential installations with modest power demands and a hydro option, the distinction is particularly relevant and not at all intuitive.

11.2 Kilowatt pedestal-mount solar near Dominical

THREE OPERATIONAL PARADIGMS IN COSTA RICA

There are three power-generation paradigms in Costa Rica: independent power supply, grid-tie, and cogeneration. Briefly:

1) **Independent** power systems depend on a charging source (hydro or solar), charge controller, battery bank and inverter. Each component must be sized to provide full facility demands. This is the style of alternative energy that is widely employed on the Osa Peninsula, where the electrical grid does not extend much beyond the town of Puerto Jimenez. It is <u>always</u> more-capital intensive than grid-tie and <u>never</u> as environmentally friendly since excess power is burned off as heat.

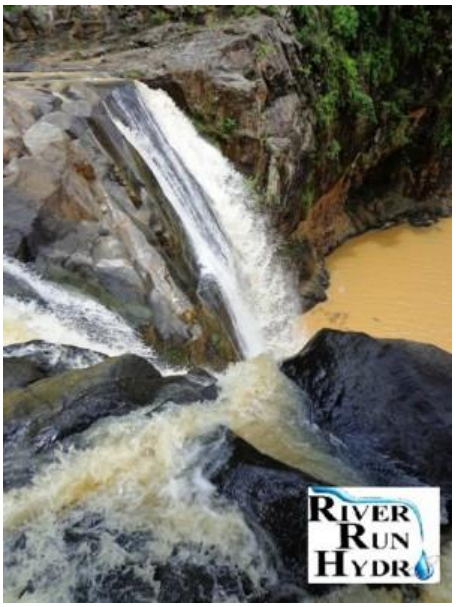
1.6 Kilowatt Grid-tie hydro, near Grecia

2) **Grid-Tie** applications require a charging source, a grid connection, and an inverter that exchanges power with the grid. It does not require batteries or charge controller and is less costly than independent systems. It is more efficient because excess generation goes into the

grid, so power is never burned off as heat. A grid-tie law is expected in 2016 to codify terms based on findings from a 4-year pilot program that ended in February 2015 when the nation hit its target 10 megawatts of grid-tie power, most of it solar. Though the pilot program was restricted to ICE, the new law will require all domestic power distributors to conform to the same standards. The new law will be based on simple net metering and will allow power trading at near parity rates for up to facility demand. Any power produced in excess of demand is banked for up to one year against future net demands in a use-or-lose framework. The new law will not allow for excess power sales to the grid.

600-watt grid-tie hydro near Puriscal

3) **Cogeneration** is a private-sector commercial/industrial activity to generate power for sale to the grid. It is governed by Law 7200 and subsequent amendments and is beyond the scope of this article. Notably, in the new grid-tie law coming out, grid-tie is capped to consumer demand, since excess production and sales to the grid has been interpreted as a public service rather than a private good and thereby already codified under Law 7200.



Hydro Country: near Pejibaye

4-Kilowatt grid-tie hydro, Lagunas Highlands near Dominical

Hydro, for all its bareback economic upsides north of 2- to 3-kilowatt capacity, has a major downside: permitting. It takes two to three years to nurture a hydro concession through its permitting process. Solar doesn't carry any such needs. And a concession in hand is a *requirement* for grid-tie hydro. While there is an ample record of institutional negotiations to streamline this process, it remains the single biggest logistical barrier to routine hydro grid-tie. Independent hydro generators have historically not bothered much with permits, so far without widespread regulatory recoil.

Setting aside permitting considerations, confirmed hydro tends to outcompete solar usually only for installations larger than an average home. For single homes, solar can be modularly calibrated and dialed in. Hydro has up-front one-time pipeline to install, and it's a larger commitment, both in upfront costs and in maintenance and upkeep, than a roof-mount solar system. But for large energy demands, hydro outcompetes solar by margins that grow in geometric proportion to generation capacity.

Kiddie-school rules apply for hydro and solar, two dramatically different alternative energy technologies:

Hydro

You need flowing water and an elevation drop (head) for hydro.

For sole-source independent hydro, your maximum generation capacity is limited by the extractable flow during the driest month of the year, April, in Costa Rica.

Hydro potential (watts) = Head (feet of elevation) x Flow (gallons per minute) x 0.18 x e (efficiency of turbine: use 50% if you don't have better information).

Lagunas 4-Kilowatt hydroelectric grid tie control panel circuitry and load diversion protection, turbine in near right foreground.

Solar

In Costa Rica you can expect a year-round average of three to four hours of fully rated, 100 percent production of your panel array, assuming optimal orientation and inclination.

The ideal orientation is due south. The rule of thumb is an inclination in degrees equivalent to latitude. But dust does not slide dry off glass well beneath 12 degrees, so 12 degrees is the best inclination to use for an installation you don't plan to tinker with. Roof-mount is the traditional configuration. Pedestal and ground arrays are alternatives.

10.6 Kilowatt solar grid tie, Hatillo.

Grid-Tie

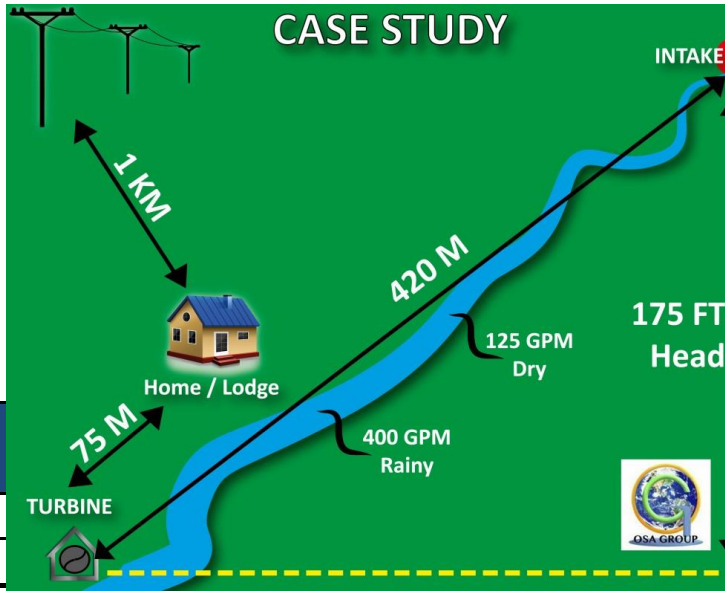
- Simple net metering means grid-tie clients are not compensated for power produced in excess of demand. This means that grid-tie production should be engineered to approximate facility demands and not exceed them, since there is no economic benefit in so doing.

- Grid-tie is applicable to individual service connections only. For facilities with multiple service connections, only one of these can be grid-tie. Large facilities have historically split consumption across multiple meters to offset peak billing scales. So, it may be necessary to rewire internal circuitry to be targeted by a grid-tie generation source into a single service connection.

- Excess generation is banked for up to a year to offset excess consumption at periods of net demand. So a large-output seasonal hydro can fully offset year-round power demands, despite standing dormant for dry-season months.

Case study: An economic analysis

We have a 35-hectare property with confirmed hydro close to an optimal build site. Either a conventional U.S.-style home or a small-scale commercial ecolodge will be built. The grid is one kilometer away. The property owners need to know what their power supply will cost for each alternative in order to decide how to develop the property.



Case	Demand Kw-hrs	Solar Kw	Hydro Kw
Home	20	5	0.83
Lodge	75	18.8	3.1

For roof-mount solar, the estimate is based on normalized costs from recent projects of $5.10 for independent and $3 for grid-tie systems on average, per installed watt. Hydroelectric costing varies as a function of pipe size, distance and other factors, every single case unique. Cost estimation for a 4" pipeline hydro for this case study is shown below on the left. On the right, the modeling of capital and economics on all pipe sizes and potential operating capacity is reported according to the same estimation model.

Item	Units	Qty	Unit Cost	Subtotal
Intake	job	1	$ 3,000	$ 3,000
4" SDR 26 PVC	pieces	70	$ 85	$ 5,950
Valves and fittings	lot	1	$ 750	$ 750
4000 watt turbine	set	1	$ 5,000	$ 5,000
3500 watt inverter	unit	1	$ 2,800	$ 2,800
S-550 rolls batteries	unit	4	$ 625	$ 2,500
Outback Flexmax-80	unit	1	$ 900	$ 900
Outback Mate control	unit	1	$ 100	$ 100
AWG #8 cable	meters	225	$ 1	$ 305
1.25" PVC conduit	pieces	12.5	$ 15	$ 188
Turbine Housing	job	1	$ 4,000	$ 4,000
Labor and Oversight	job	1	$ 15,000	$ 15,000
TOTAL				**$ 40,493**

Pipe D inches	Output Watts	Cost $	Per Watt $/Watt	Solar Equiv $/Watt
1.5	717	$ 24,013	$ 33.51	$ 5.58
2	1023	$ 29,958	$ 29.28	$ 4.88
3	2000	$ 35,153	$ 17.58	$ 2.93
4	4000	$ 40,493	$ 10.12	$ 1.69
6	8000	$ 70,263	$ 8.78	$ 1.46

These data now allow for a full-throated analysis of the two energy paradigms available: 1) independent and 2) grid-tie.

Independent

Home demand can be met with a 2" diameter hydro pipeline for $30,000. To offset the demand with solar requires a 5,000-watt charging source for a capital sink of $25,000. Solar is $5000 less, for a savings of 25%.

For the lodge, the dry-season maximum hydro is through a 3" pipe with a 2,000-watt output. But lodge demands require 3,325 watts, so hydro is inadequate for sole-source independent supply. The hydro deficit of 1,125 watts is equal to a 6.75 Kw solar equivalent, costing $34,425. Adding the cost of a 3" pipeline hydro and 6.75 Kw solar and stripping out equipment duplicates yields a cost of $64,000. A solar equivalent of 18.75 Kw costs $95,625. So, a hybrid independent system is 49% less costly than a solar-only independent power supply.

INDEPENDENT	Home	Lodge
Solar Only	$ 19,125	$ 99,625
Hydro Only	$ 25,000	NA
Hybrid	NA	$ 64,000

Grid-Tie

For the home, the 1 km distance from the grid imposes a capital sink of $50,000 just to extend the primary grid in order to connect. Implicitly a grid-tie connection in this case is wildly non-viable, with payback periods for either solar or hydro measured in decades.

3.2 Kilowatt independent roof-mount solar power: Ojochal

2.4 Kilowatt independent roof-mount solar power: Ojochal

For the lodge, however, its 75 Kw-hr daily demand can be offset in eight months of hydro production by a flow rate of 228 gallons per minute, the upper flow limit in 4" pipe and well within the stipulated resources. The capital costs of $90,000 incur yearly power bill offsets of $9,811, giving this option a payback period of 9.2 years and a return on investment 11 percent.

Solar costs to achieve the same hydro capacity include the same $50K grid extension plus $56,250 for the required solar charging source, a $106,250 capital sink for solar, $16,000 more than hydro.

GRID-TIE	Home	Lodge
Solar	NA	$106,250
Hydro	NA	$ 90,000

Conclusion

In this case, it is most economically prudent to discard grid-tie because of the distance from the grid and the relatively modest power demands. For the home, the best solution is solar-independent. For the lodge the best solution is independent hybrid hydro/solar. Had the grid been at the building site and not a kilometer away, then solar grid-tie would have been best for the home and hydro grid-tie for the lodge. If the head and flow are different, or facility demands, the costing matrix turns out different as well. But these variables are either known or easy to measure and calculate, and once hydro is defined in all its hypothetical ranges for any given site, economic comparison with its solar equivalent is straightforward and against facility demand an intuitive analysis.

Conclusions

Every property's case is unique, but here are a few rules I have found hold up pretty well in Costa Rica, plus some comments about biomass and wind.

1) If your power needs are large, proven year-round hydro usually out-competes solar.

2) If your power needs are large, grid-tie usually out-competes independent even if a sizable investment is required to extend the primary grid.

3) If your power needs are modest, solar usually out-competes hydro in both independent and grid-tie applications.

4) While colorful and evocative, hybrid systems are rarely competitive against sole-source solar or hydro.

5) Biomass is an agricultural grid-tie thermal application. It allows for timed power-generation to offset peak power demands in agro-industrial processing applications with abundant biomass resource and high power bills—think sugar cane.

6) In the doldrums wind is an inconstant and fickle resource. Orographic effects along ridgelines make it competitive in places, and the summer blow in Guanacaste makes it a reliable dry-season resource there. But by and large, most of Costa Rica can write wind off for home-power generation in any capacity.

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