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Photovoltaic Applications in Aquaculture: A Primer

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This publication examines the use of solar photovoltaic (PV) technology in aquaculture — the cultivation of fish and aquatic animals and plants. This publication outlines key questions to keep in mind if you are considering solar arrays for a closed aquaculture system. It also includes an example of a fish farm currently using PV power.

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Market-size catfish under harvest. Photo: Peggy Greb, courtesy of USDA/ARS

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Introduction

Closed aquaculture systems need pumps and aerators to provide oxygen, to move water into and through the system, and to purify the water. Solar-generated electric power, known as photovoltaics (PV), can be used to meet the power needs of an aquaculture operation.

Background

The basic elements of aquaculture production systems are (Gegner and Rinehart, 2009):

Extensive aquaculture is conducted in ponds that are stocked at a low density and yield small crops, but require little management. *Intensive aquaculture* is practiced in artificial systems such as constructed ponds, cages, raceways, and tanks that are stocked at a high density and have high yields, but require a lot of management.

Open systems allow water to flow through without reuse. Generally, the more intensive an aquaculture system, the more water that must flow through. In open systems, discharged water is lost from the system. Closed systems recirculate and recondition virtually all of the water used, largely freeing aquaculturists from water supply constraints. Closed systems have the potential to allow the production of almost any species anywhere, provided the market price can pay for the capital and energy requirements of the system.

Pond aquaculture is the most commonly practiced form of aquaculture. Most large-scale aquaculture farmers construct levee-type ponds, but these require large amounts of relatively level land.

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Many small-scale and a few large-scale aquaculture farms use watershed ponds.

Raceways, which are long, narrow canals with large flows, are the most widely used production system for the intensive culture of salmon, trout, and char.

Tank culture, in both open and closed systems, can be adapted to a wide range of species and situations. Tanks made of steel, fiberglass, or plastic can be dismantled and reassembled for transportation or relocation. The advantages of tank culture include minimal land requirements, portability, and ease of expansion. Tanks can be located indoors to reduce climate limitations. High equipment cost, especially in closed systems, is the main disadvantage of tank culture.

Closed aquaculture systems require moving water to:

- Aerate the water to keep dissolved oxygen levels high enough for fish to survive and thrive
- Pump water to and through the raceways and tanks
- Replace water lost to evaporation, seepage, and leaks

As a rule, the minimum recommended water quantity for a commercial operation using a pond is 13 gallons per minute per acre of pond surface area. The minimum recommended water quantity for a commercial operation using a raceway is 500 gallons per minute. You can anticipate that a commercial-scale tank system operation could have water exchanges of as much as 10% per day of the total tank volume. (Cooperative Extension Service, no date)

Solar energy can provide the power to drive closed-system aerators and pumps. The basic components of a PV system for aquaculture are not unlike any other system used for pumping water continuously:

- Solar array – a sufficient number of modules to meet electrical demand, described in more detail below.
- Battery bank – while marine and golf-cart batteries can be used in small PV systems, industrial-grade storage batteries are far better suited when electrical demand is constant.
- Charge controller – keeps the batteries from overcharging or becoming completely discharged.
- Pump controller – the current booster that interfaces between the PV array and the water pump (and aerators). It provides optimum power to the pump and can start the pump in low light conditions.
- Inverter – transforms the direct-current (DC) power from the solar panels to alternating current (AC) power. Avoid an inverter if at all possible since it adds cost and complexity to the system. Many very good DC pumps are available; only choose an AC pump if no DC pump that will meet the system's head and flow requirements is available.

Note that this PV array and hardware combination is based on the assumption that using additional stored water on cloudy days or at night is NOT an option.

Getting It Right – The Solar Array, Batteries, and Pumps

Properly locating the array can be difficult. For starters, locate the array in full sun with no shade. If the array is north of the equator, it should face true south (not magnetic south). If the array is south of the equator, it should face true north.

For year-round use in areas below latitude 25 degrees, multiply the latitude by .87 to get the optimum tilt angle for a fixed array—an array that is not adjusted between winter and summer.

For year-round use, a fixed array will likely be more economical and simpler than a tracking array that follows the sun across the sky. For the cost of the tracker, more panels could be added to the array. The array could be pole-mounted, so that it also provides shade over the fish tanks, or roof-mounted. Keep in mind that the roof must be structurally capable of handling the added weight of the array, and the roofing material must not be compromised to ensure that leaks do not occur.

The solar array will power the water pump or pump(s) and, if needed, an air pump for aeration.

The size of the array is based on the system's pressure and flow requirements and whether batteries are needed. You must account for friction in pipes and fittings, filters, and other system hardware that pumped water passes through. The pump must be sized to overcome this friction loss. The total pressure requirement that includes lift (how high water needs to be pumped) and friction loss is called *total dynamic head* (TDH). Once you know flow and head, consult with a vendor to help you determine the exact pump type/size, solar array size, and battery bank requirements.

PV costs have dropped dramatically and are currently less than $1.00/watt for the panels (excluding shipping, installation, or other components of the system). Installed system costs vary widely. In the contiguous United States, an installed residential PV system ranges from $3 to $8 a watt, plus the cost of batteries.

Since the aquaculture system operates constantly, batteries and a charge controller will be necessary. Flooded, gel, and absorbed glass mat sealed batteries are superior for solar-powered systems. They have thicker plates and can withstand many more deep discharge cycles than marine-grade or golf-cart batteries. (Zipp, 2013 and Sun Power Company, 2014)

Flooded lead-acid batteries require that water be added to them periodically. All flooded batteries release gas when charged and should not be used indoors, or they must be vented in enclosures to avoid explosive gas build-up.

Sealed gel batteries are not vented and will not release gas during the charging process. Because they can easily and safely be used indoors, these batteries maintain a more constant temperature and perform better.

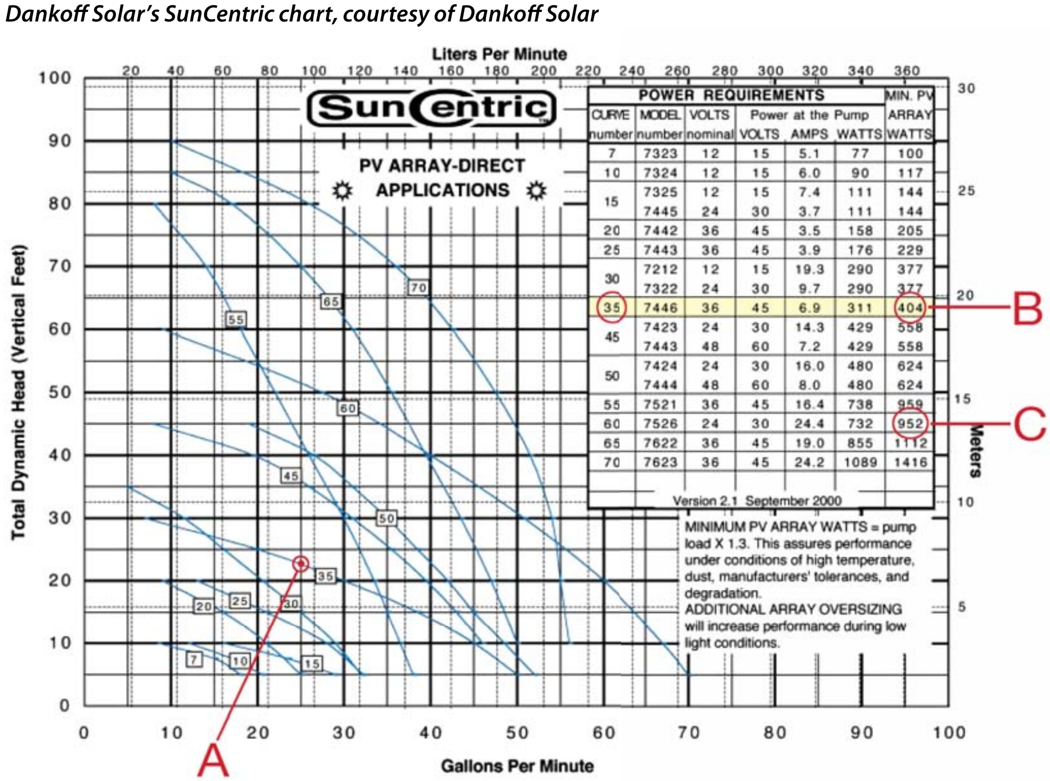
Absorbed glass mat batteries have a woven glass mat between the battery plates to hold the electrolyte. They do not leak or spill and do not release gas when charging. They maintain voltage better, discharge slower, and last longer (Sun Power Company, 2014). You must protect the batteries from direct sun, high heat, and freezing.

The pump controller provides optimum power to the pump and can start the pump in low light conditions. However, if the pump is a centrifugal pump, a pump controller is likely unnecessary as the pump will not start under low light conditions, and if the pump is running constantly, it won't need to start. However, the controller may be necessary for other controls (e.g., over/under voltage, motor overload, float switch, or on/off switch). The pump controller and charge controller can be included in the same unit.

Dankoff Solar* has created pump curve charts that can help an aquaculturalist who is considering solar power make more informed decisions before engaging a vendor. For example, if you had a pond that required 25 gpm and had 23 feet of head, here is how you would determine the pump size and minimum solar requirements, using Dankoff Solar's SunCentric chart below:

1) Find 25 gpm on the horizontal axis and 23 TDH on the vertical axis. Note the pump curve number where the lines cross, which, in this case, is 35 (A).

Dankoff Solar's SunCentric chart, courtesy of Dankoff Solar



2) Look for the number in the inset Power Requirements Table in the upper-right-hand corner. Follow the row across to the far right column to (B). Using a DC surface centrifugal pump that will pump 25 gpm at 23 TDH, you would need at least a 404-watt array, not including the aerator load and battery charging. Since there is no 404-watt solar array, your solar vendor will help you choose the next larger size array capable of driving the pump.

Fish Farming the Solar Way

Lashto Fish Farm in Haiti is not the only solar-powered fish farm in the world, but it certainly is one of the better known. And it provides an example of a large solar-powered tank system.

This fish farm has six 12,000-gallon tanks used to raise at least 90,000 tilapia fingerlings per year. Fingerlings spend two months at the fish farm growing to two to three inches in length. The talipia are then distributed to local farmers, who raise them to about 1 to 1.5 pounds for market.

The PV system that powers this tank system is BIG—a 63 Trinasolar* PV panel solar array generating up to 14,490 watts. The PV array is connected to 24 flooded lead-acid batteries with storage capacity of 3,232 amp-hours.

To reduce water evaporation loss and algae growth in the tanks, the solar arrays are located above the fish tanks and shade cloth is added between the panels for more complete shading. (NRG Solar, no date)

To see how the solar arrays shade the fish tanks, visit www.nrgenergy.com/haiti/pdfs/fish-and-solar.pdf.

You could use this same chart to determine the PV needs for a raceway system. To pump 500 gpm for a raceway system, you will need some number of pumps in parallel. On the chart, you'll see that a single DC surface centrifugal pump capable of delivering 60 gpm at 20 TDH would require about a 1,000-watt PV system (C), not including the aerator load and battery charging. Achieving 500 gpm would require nine pumps and at least nine PV arrays. During the day when the pump/aerators operate using solar power, the PV system also needs to charge the batteries for night-time use, so still more solar panels are needed.

Conclusion

Solar power can and is being used in aquaculture. Properly sizing the solar array, batteries, and all other necessary hardware for a closed aquaculture system's power demands is critical. The resources listed below, in addition to a credible PV vendor, can serve as great starting points for creating a functional, sustainable system.

** ATTRA makes no endorsements of specific commercial products. Any cited in this publication are for purposes of example.*

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Further Resources

Center for Tropical and Subtropical Aquaculture. www.ctsa.org

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