December 15, 2015

Gregorio Cruz-CIG
1400 Independence Avenue, SW
Room-5233-S
Washington, DC 20250

Dear Mr. Cruz,

Enclosed is a copy of the final report for NRCS CIG Agreement number 69-3A75-11-191, "Using Solar as an Alternative energy Source Needed to Power Small Off Grid Farm Applications". It is my opinion as project director that we completed a successful project. Through presentations, field days, workshops and the actual installation of solar projects we distributed information about the use of solar power in those locations where electricity is needed, but there in not a ready supply of AC electricity. This project also lends itself to be used as a continual demonstration and training tool as the solar systems put in place will be used in the future to conduct additional demonstrations and research on the effectiveness of solar in remote locations. We also foresee many additional presentations and articles which will disseminate information about this project and solar in general to interested persons at various local, state, national and international meetings. We have also had many impromptu meetings where persons have seen the system from a nearby road and stopped to ask about what the system was, how it works and how the solar power is used.

The grant has been completed, but plans are for future installations of similar systems in Georgia as well as additional presentations and publications to disseminate more information about the use of solar power for small scale irrigation needs. If you have any questions or need additional information feel free to contact me at 706-310-3526 or ghawkins@uga.edu.

Sincerely,

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Final Report

NRCS Agreement Number
69-3A75-11-191

Grant Title:
"Using Solar as an Alternative Energy Source Needed to Power Small Off-grid Farm Applications"

Submitted to:
Ed Biggers-CIG
1400 Independence Avenue, SW
Room-5233-S
Washington, DC 20250

Date Submitted:
15 December 2015

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NRCS CIG Agreement Number 69-3A75-11-191
Final Report Submitted to USDA NRCS CIG Program on Behalf of The University of Georgia

The following materials are submitted as the final report for the original grant agreement number NRCS 69-3A75-11-191 which was granted to The University of Georgia.

Summary:

Photovoltaics (solar panels) are being looked at more and more as means to providing power to off-grid and on-grid locations. Solar panels have been used to produce electricity for many years, but recently the interest has begun to climb. Systems installed are still small (kilowatt size), but occasionally you can find large systems (megawatt size) being installed for the production of electricity. This idea of using small solar systems was further explored in this project to demonstrate that small solar systems (1-8 kW) could be used to provide electricity to some off-grid sites in unique ways. The systems installed ranged from the typical small solar powered pumping system for livestock watering with a high head requirement to an 8.0 kW system to provide irrigation water to a pecan orchard with high flow requirements. The systems installed provided and continues to provide information on how the use of solar can be used in situations off-grid where a high pressure head has to be overcome as well as converting the DC electricity from the panels into AC power for pumping water or just having an AC source of power in remote locations. Overall, the system works great for small off-grid needs and based on the cost of running electricity lines to the various locations, the installed systems will pay for themselves in less than one year if not at the time of installation.

Introduction:

The use of alternative energy sources has been of increasing importance over the past 5-10 years. One of these minor alternative energy sources is the use of solar photovoltaics for the production of electricity. Solar only provide 0.1 percent of the BTUs of energy in 2008 (Figure 1) and has increased to 0.4% in the 2014 data as reported by the U.S. Energy Information Administration.

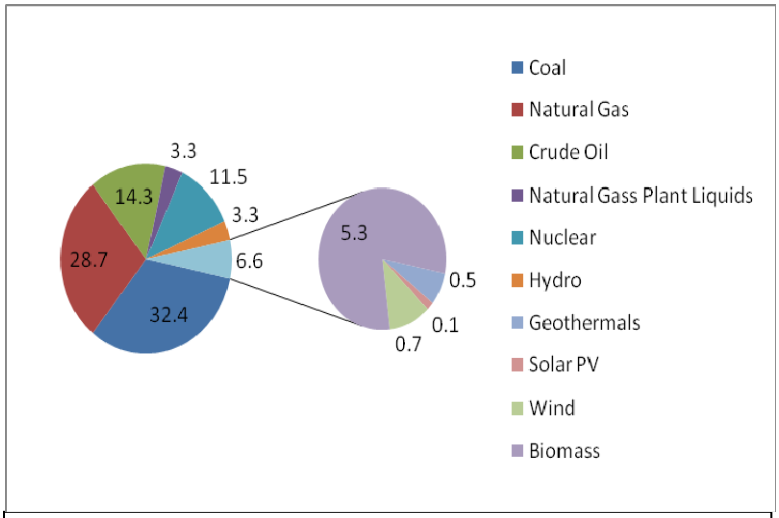


Figure 1. Energy produced in 2008 by type. Graph produced from data reported by Dept of Energy.

As the use of solar increases, there is still room for the use of solar in agriculture. This project was not designed to make solar apart of every farm ,but rather was designed to demonstrate the use of

solar in those places where it would be best used and would provide an economical return for the farmer. For example, in Georgia, NRCS will cost-share solar powered pumping if the cost is less than that of traditional electricity sources. Therefore, this project was used to demonstrate and provide information on how solar could be used in typically not thought of off-grid applications.

Reason for Project and Objectives:

Solar has a place in small applications where power is not readily available. The agricultural community has many different opportunities to use solar power in this situation. This project was designed to demonstrate how that might be done for different situations. These were; 1) how to cool livestock in remote paddocks, 2) how to produce AC electricity in remote locations from solar for multiple uses, 3) pumping water with high pressure heads and 4) pumping high volumes of water in drip irrigation systems. To do this the following objectives were set forth for the project:

1. Demonstrate the use of solar power for at least four different farming operations where traditionally AC power is currently used and
2. Disseminate information through trainings, workshops and presentations to farmers and farming groups interested in using solar power.

Project Location and Size:

The overall objective of the project did not allow for there to be a single farm used for the demonstration. Therefore, there were multiple locations used for the project. The location of the projects will be described in the individual project descriptions below.

What was done to meet project objectives:

Livestock cooling

The livestock cooling portion of the project was designed to provide a demonstration of how solar power could be used to power DC fans that would be used to provide a constant stream of wind over cows in paddocks. To accomplish this, two standard Schaefer (NOTE: The specific use of a product does not in any way suggest that the University of Georgia or USDA NRCS endorses the product) 120 volt AC fans were used. The AC motor in each fan was replaced with a DC motor. One of the DC motors was rated at 96 volt and 8 amps. The second motor was rated at 24 volts and 5 amps. As a result of the two different motors, the solar panel configuration was the only thing that had to change. The solar panels were either placed in series or parallel to meet the need of the motors. The fans were tested in a closed environment and the wind output was measured with the assistance of an anemometer placed at a distance 8 feet from the fans cage. The fan speed was measured and stored along with the solar radiation. The overall result of the testing indicated that as the sun's radiation increased in the fan speed increased. The fan and solar panels were demonstrated at many different locations including field days on the Tifton campus of UGA including US Legislative staffer visits, 3rd grade field days, and at the Sunbelt Agricultural expo in Moultrie Georgia. A picture of the set-up can be seen in Figure 2(a) and 2(b).

Figures 2(a) and 2(b). These are images of the solar fan on display. A can be seen the fan is run directly from the solar panels.

Producing AC power from DC source

This portion of the project was basically using an inverter to provide AC power to items needing AC power. The flow of power in this project was from the solar panel into a charge controller into a deep cycle battery and the through and inverter to AC power. Then any appliance needing AC power could be plugged into the inverter. This is the basic inversion system, but as the CIGs are set-up, it is using off the shelf technology to use in agricultural settings. When using with pond aeration, it should be noted that the maximum need for aeration is pre-dawn. Therefore, a battery system should be used with a basic timer than can turn the pump system on prior to dawn when the oxygen level is the lowest. As a result of the solar panel prices dropping over the time period of the grant, we were able to also purchase items to convert a 48 volt center pivot irrigation system currently operating on gasoline to a solar powered irrigation system. Test

comparing the cost savings of solar verses gasoline will be conducted in the 2016 growing season. A picture of the system for converting solar to AC power is shown in Figure 3 below:

Figure 3. Set-up of the typical system used to convert solar power to AC power. This includes a solar panel, disconnect box, charge controller, fuse, battery and inverter.

Pumping water with high pressure heads or elevations:

This is the basic solar pumping, but in the case of this project, the pressure head we were pushing water against was over 280 feet. The water elevation in the well was 150 feet and we had a pressurized tank set at 50 psi. The water in the tank was then distributed to multiple watering troughs across a set of pastures. The different pastures were used for rotational grazing. A picture of the installed system is shown in Figure 4 below.

Figure 4. Livestock watering system where solar was used to lift water with a high total dynamic head. This system includes a pressurized tank and pushes water to multiple pastures on the farm.

Pumping water at high volumes for a drip system:

This system was designed to pump water at over 250 gallons per minute through a drip irrigation system using a modified bubbler system. The water will be pumped from a pond through modified bubblers to provide an overland flow system to water pecan trees. This system in total is approximately 8 kW and as mentioned will pump over 250 gallons a minute across 19 acres. The design allows for 25 feet of head to overcome total dynamic head while providing the high flow rates required to adequately water the trees. The overland flow idea will allow the water to be used by both the trees as well as the grasses, clover and other vegetation on the ground. This ground vegetation will then provide food for cattle grazing after pecan harvest. This grazing method using the cattle to help loosen the soil while also redistributing the nutrients across the landscape.

Education and Outreach:

The Conservation Innovation Grant (CIG) Program is designed to demonstrate innovative use of technology on farm. Part of the CIG is also designed to disseminate information to other farmers. To accomplish the dissemination of information, the projects have been demonstrated and many different field days, workshops, presentations, expositions and through general conversation. To further disseminate information,

various presentations have been conducted at local, state, national and international workshops and conferences.

Various Field Days, visits and conversations:

To show how solar can be used in agriculture, the different systems have been demonstrated at various locations. The following are a few of the places where the projects components were demonstrated:

1. US Legislative staffers visited the UGA Tifton campus and the solar powered fan system was displayed and an informal presentation of how USDA NRCS EQIP dollars were used to develop the system.
2. The fan was displayed and operated at the Sunbelt Expo in Moultrie Georgia. The Expo annually draws over 200,000 persons from across the Southeast. The fan and solar panels were placed at the University of Georgia tent and was used to cool calves at the tent. This use of the fan lead to many different conversations on how the fan could be used and where it could be used.
3. A demonstration model of the solar pump has been used at the Sunbelt Expo in Moultrie Georgia for 5 years. This demonstration pump and panel is used in the NRCS tent at the Expo to demonstrate some of the programs available through NRCS EQIP funds. There are many interested questions and the conversation concerning placement, requirements, potential and other similar questions occur around the demonstration pump. The interested farmers are then directed to their local NRCS office for assistance.
4. The fan has been used at many different Agricultural and Environmental Awareness days on the UGA Tifton campus. The fan is used to keep the kids, teachers and parents cool, but it is also a way to teach the kids (and parents) about renewable energy. It also provides a way to visually show them the conversion of solar power to usable energy.
5. Presented to the 4^{th} and 5^{th} graders at the Tift County JT Reddick School as part of their Earth Day Activities.

Presentations:

Presentations were presented at the following locations to disseminate information on the solar powered irrigation system:

1. 2010 East Technology Workshop – Southeast, Tifton GA. *Energy as a Resource Concern: Opportunities and Challenges Practical Uses of Solar Energy on the Farm*
2. 2010 Georgia Association of Agricultural Agents Annual Meeting. *Solar Power Educational Workshop*
3. 2010 Growing Power Conference *Innovative Tools and Best Practices for Regenerating Small Scale "On The Farm Energy" Projects -- Solar And Anaerobic Digestion for On-Farm Energy*
4. 2010 Matt Wilson Middle School. *Electricity and Circuits*
5. 2010 Georgia Farm Bureau. *Solar Powered Livestock Watering Systems*
6. 2011 Solar Workshop *Solar Power 101 – The Basics of Solar Power*
    a. Augusta Georgia
    b. Camden County Solar Workshop

    c. NRCS Engineer training
7. 2011 GA/SC SWCS Annual Meeting *Solar Pumps and Alternative Energy*
8. 2012 Camden County Solar Workshop *Solar Power 101 – The Basics of Solar Power*
9. 2012 UGA Extension Agent training *Solar Power 101 – The Basics of Solar Power*
10. 2013 *Solar Power for Small Water Pumping Needs*
    a. Seven Rivers RC&D Council Meeting
    b. Georgia RC&D Council Meeting
11. 2014 South Georgia Solar Company Meeting Solar Power Basics 101
    a. Ben Hill County Young Farmer Meeting
    b. Berrien County Young Farmer Meeting
12. 2014 Georgia Multicultural Sustainable Agricultural Conference *Solar Powered Irrigation Systems*
13. 2014 Crop Consultant Training *On-Farm Energy Production: Now and in the Future*
14. 2014 Upson County Cattleman Meeting Workshop *Solar Power 101 – The Basics of Solar Power*
15. 2015 Georgia Poultry Conference *Solar Power 101 – The Basics of Solar Power*
16. 2015 Waste-to-Worth Conference *Using Solar Power to Provide Animals with Water While Protecting Water Quality*

Some of the presentation covers are shown in Appendix A.

Newsletters and Popular Press:

The issue of solar power for livestock watering, irrigation and other uses has been used as the base for many different newsletter articles, popular press articles and local county extension newsletter articles. A few of these are shown in Appendix B..

Benefits and Drawbacks:

The different parts of the project proved to be beneficial and have its drawbacks as would be expected. Some of these include:

Benefits:

1. Providing a water supply for the cattle helps the farmer better manage the pastures,
2. Using pond water to irrigate a pecan orchard along with the modified bubbler allows for watering of both trees and grasses and clover to provide a natural fertilizer and forage for cattle,
3. Showing that pumps can be used to overcome high head pressures makes the use in some places a possibility,
4. Being able to have a power source in a remote location is valuable and cost effective, and
5. The use of a solar system will provide “free’ electricity for 15 – 20 years.

Drawbacks:

1. A system, as installed, if placed within close proximity of an AC power source will not pay for itself within the useful life of the system unless you can get greater than 50% of the system paid,
2. Even with lighting protection, sometimes the solar control panels are damaged and the replacement parts cannot be purchased at the local hardware store, and
3. Education of how and where the systems are best suited is still an on-going need and opportunity.

Lessons Learned:

Some of the lessons learned from the installation of the solar systems are:

1. REMEMBER – Solar Panels are ACTIVE as soon as the sun hits the panel!!!!!!!!!!,
2. The weight and size of solar panels should be accounted for when designing the support structure,
3. Designing the pumping system based on future livestock needs is a necessity for proper amount of pump capacity,
4. Solar Pumps cannot be stored in water (storage is determined to be greater than 3 months of non-use)
5. When making connections, the proper amperage and voltage should be made available to the pump so as to not cause undue wear and tear,
6. The maximum power from the solar panels will occur in the middle to early afternoon. The sun will be shinning in the early morning and late afternoon, but the maximum solar radiation will occur around noon, and
7. Check with insurance company to determine if system will be covered in case there is a lighting strike or other reasons that the system may get damaged.

I expect there are others, but these are the main lessons that we learned from working on this project.

Other Locations and Conditions of Technology Application:

This technology should have very few places where it would not be appropriate to use. By that I mean, if there is a clear area from early morning to late afternoon then the solar system will produce power. However, some of the things that needs to be accounted for in such a system is the angle of the panels to the sun, the potential of shadows crossing the panels and the amount of radiation in the area of interest for installation. In areas where the solar radiation is low, then the panels will produce power, but they may not provide the rated power. On that same line, the number of solar day light hours is important in the amount of power that can be produced. The lower the number of solar daylight hours the lower the daily output of power. In terms of limits on the pumping system would be the head and flow rates from the pump. The solar panel array can be designed to provide the need watts. The pump however has a limit on the pressure head it can produce and the flow at various pressure heads.

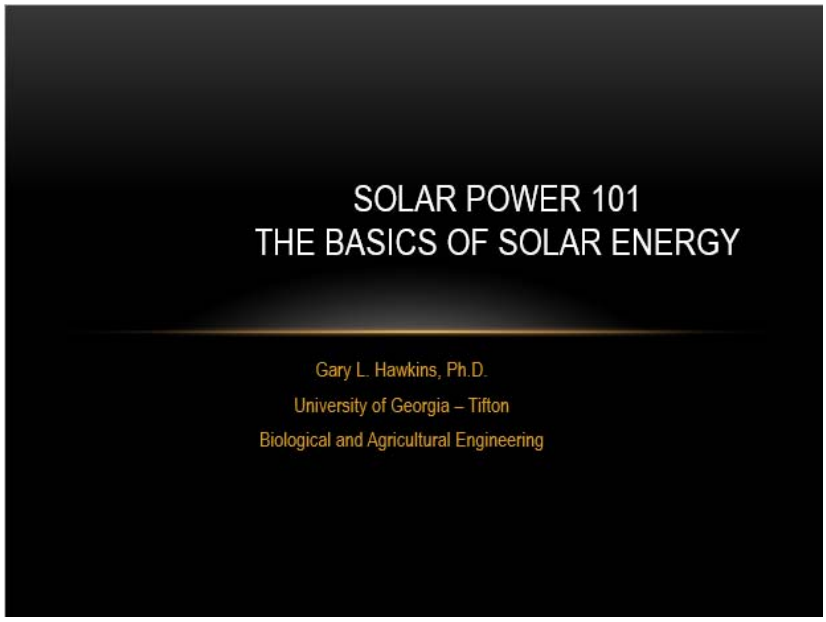
Using solar power to keep cows cool should be noted that as mentioned above, there is time period in the middle hours of the day that the fans would operate at maximum air flow. This is during the middle of the day (approximately 9 AM – 4 PM) before and after that the fans will still move air, but the rate will drop. However, outside this time, the temperatures will be slightly lower than mid-day.

Conclusions:

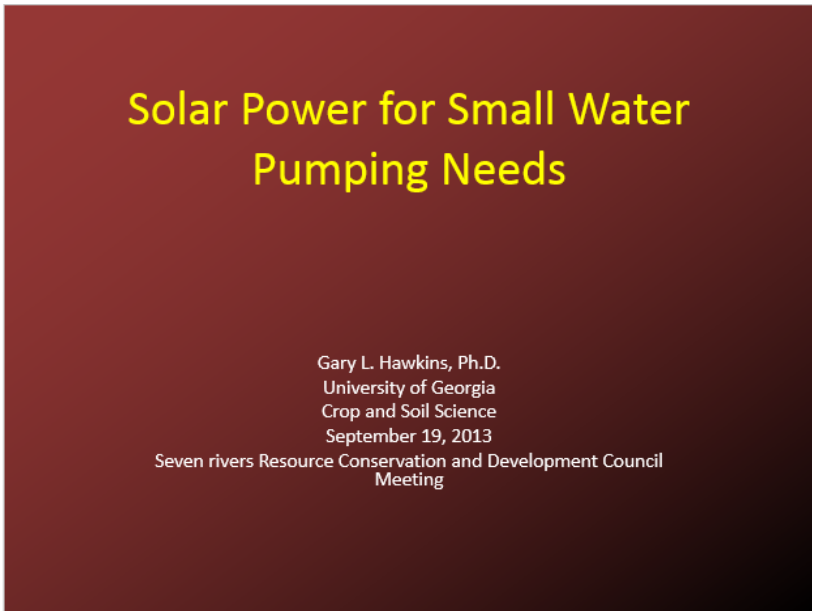
Overall the use of solar on a farm has it place. In situations where there is an electrical need and the cost of running electricity to the location is cost prohibitive, then solar can be used. In this project we demonstrated how solar can be used to pump water from a well requiring a need to overcome a high pressure head, power a fan for cattle cooling and converting power to AC power for off-grid applications. These demonstrations were shown to many different groups and people in many different settings. If information about installation of systems, the person was generally referred to their local NRCS office for some assistance, but basic information was provide at the point of contact which a basic discussion of what was needed in a system. Therefore, I feel this project was a success and through the many different presentations has provided information to farmers needing water for cattle to even providing basic information for farmers to work with solar companies and USDA Rural Development to install solar panels on chicken houses.

APPENDIX A

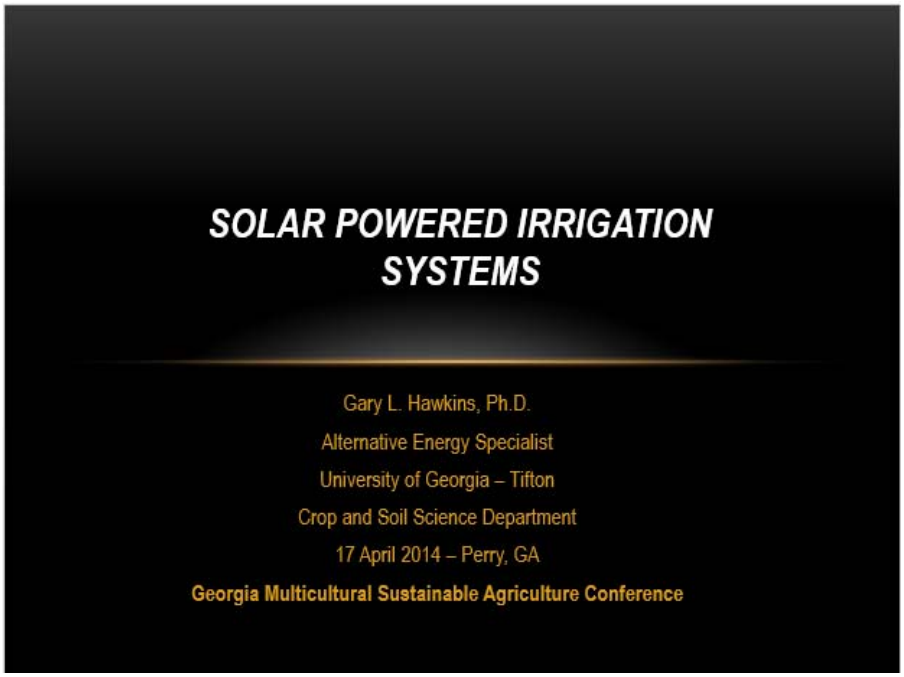
A few of the covers for Presentations presented as part of this project



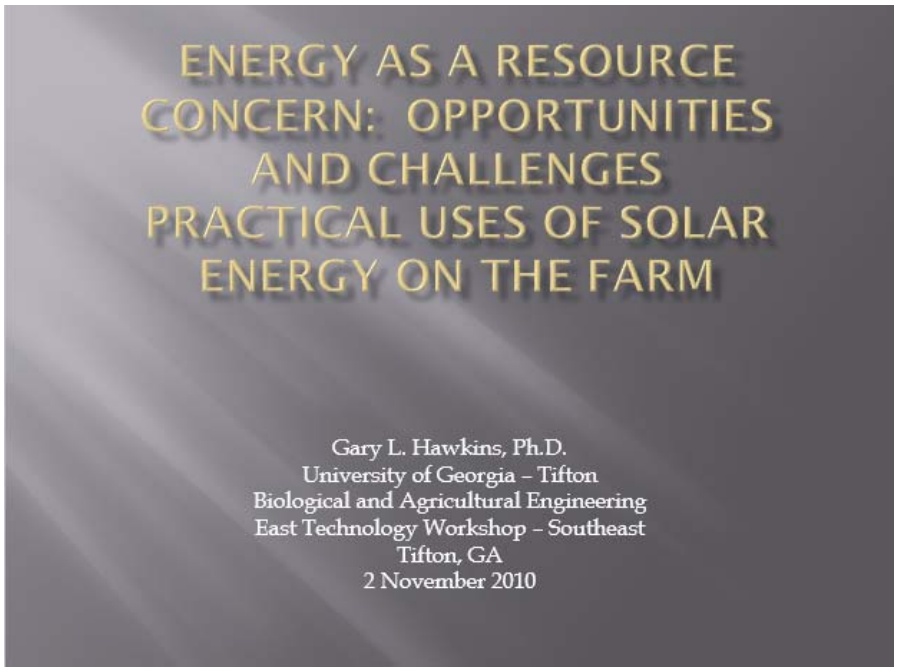
This presentationa nd a modification for audience was used as a basic introduction to solar power and its use. This was presented to groups ranging including Young Farmer groups, Extension Agenst, farmers interested in solar power and farmers looking to install on poultry houses.



This presentation was used to provide information on how solar power has been used to provide power to farmers needing power in remote locations. This was presented to the Georgia RC&D Council members.



This presentation was used to show farmers attending the Multicultural Sustainable Agriculture Conference how solar could be used on their farm.



This presentation was used to provide information to NRCSW personnel from the East Regional Technology Center.

APPENDIX B

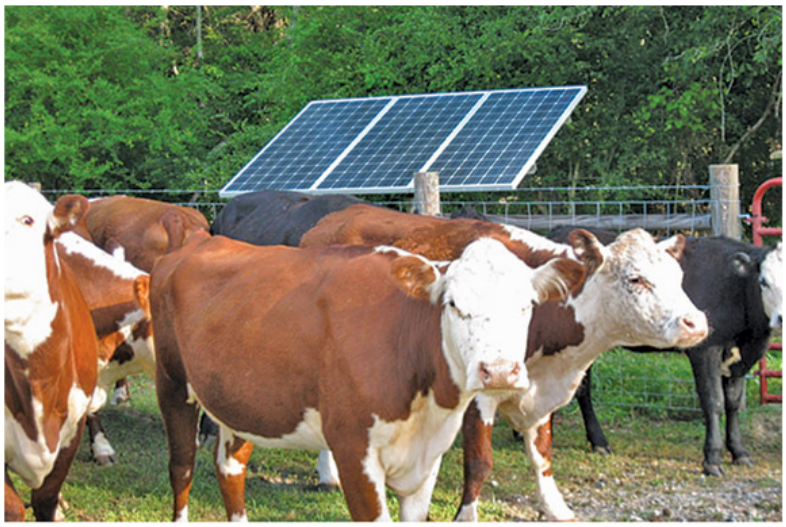
The following are a few of the articles written to introduce solar power to cattle farmers.

In *Progressive Cattleman* 24 June 2013 Issue

The sun can provide water for livestock

Written by Gary Hawkins Published on 24 June 2013

0 Comments



Related

- Ways to protect your land and facilities from wildfire
- Getting the most from bale processors
- Good squeeze chute essential for low-stress cattle handling

Water is one of those things we all need, including livestock.

So, when animals are isolated from a water source, what can a farmer do to get them water while implementing best management practices?

If there is no power line close to the needed area, you may consider using solar power.

In recent years, as an alternative energy specialist with the **University of Georgia Crop and Soil Science Department**, I have worked with farmers across the Southeast to install and demonstrate solar-powered pumping systems to provide water for livestock.

Installations have occurred in the central, southeast and northeast portions of Georgia as well as South Carolina. Other than these demonstration sites, many farmers have worked with solar companies to install solar-powered watering systems.

A solar-powered watering system is designed just like any other watering system. Differences include the power source and maybe the volume of water pumped.

Printed in the UGA Animal and dairy Science Department Newsletter.

Using the Sun to Protect Water Quality

By Gary L. Hawkins, Ph.D., Water Resource Management and Policy Specialist, Department of Crop and Soil Science, UGA

Just think about a warm to hot summer afternoon (or really anytime), the sun is beating down on your back, where would you like to be and what would you like to be doing? My suggestion would be that you would like to be under a shade tree with a cold glass of water in your hand or maybe even in a cool pool of water. Well livestock are like us, they would like to get a cool drink of water or be in a good pool of water or even be under a shade tree. But, sometimes the only water supply the livestock have is the creek that runs through the middle or along the edge of a pasture. So, the way we provide water for these animals is to let them in the water to cool off, drink and then deposit waste materials. The movement of livestock up and down banks, the lounging in the water and the depositing waste materials all potentially pollutes the water source they drink from or the water other animals and we use downstream. So, how do we remedy this potential problem? One way is through removing the animals from the water source and using the SUN.

By removing the animals, we can solve one problem but potentially form another. That being - how to get water to the animals. In remote locations, the SUN can be the reason for animals being in the water, but also can be a very valuable partner. By using the sun to operate solar powered pumps, water can be pumped from the water source to any location where you may have the livestock and even to multiple locations or pastures. Solar powered livestock watering systems can be pricy, but on a comparative basis (compared to running electric lines) solar can be very competitive and even be cheaper than running power. Typical solar powered livestock watering systems consist of a solar panel, a pump, a control panel and a tank. Solar powered livestock watering systems are designed for each specific situation based on distance from surface water source to tank or trough or depth of well and pumping height. The cost of the system also changes based on the size pump, number of panels and tank or trough used. Even with the various options for a solar powered system, the average cost of a system will be in the neighborhood of $6000. This could be lower with a shallow well and very little lifting of water required to a little higher for higher flows and a high pumping height.