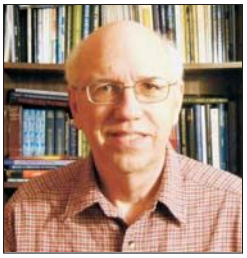

Paul Arveson

Article

Integrated Solar Cooking: An Underutilized Solution

Paul Arveson

Forty years ago, Francis Schaeffer challenged Christians to set an example of care for the environment. Now, as the earth has a population of more than seven billion, how well have we responded to this challenge? What have we done about global stewardship? This article describes a low-cost technology available to the poor of the world—not a "high tech" electrical device or a new energy source, but simply a technique to cook with the sun—using a fuel-free, labor-saving device, the solar cooker. The author's own experience and that of NGOs is reported. Solar cooking requires not only a radical shift in thinking about how we cook our food, but it also has many potential environmental, economic, and social benefits for billions of people.

In 1970, Francis Schaeffer published a paperback with the depressing title, *Pollution and the Death of Man*.[1] Although Schaeffer is widely known among evangelical Christians, this is not one of his more widely known books. It was one of the first books by an evangelical on the subject of "ecology" (actually, environmental ethics or what today is often called "creation care"). In it, Schaeffer recognized the serious problems of environmental damage in modern life, which cry out for solutions that can harness our Christian zeal in order to reduce pollution and rescue the environment. I was reminded of Schaeffer's book while reading Jack Swearengen's comprehensive book, *Beyond Paradise: Technology and the Kingdom of God*.[2] Schaeffer challenged the church to act as a "pilot plant," to set an example of environmental stewardship to the world. Stewardship should inspire Christians to practical action, both locally and globally,[3] and it should lead them away from eschatological fatalism.[4]

As an undergraduate, **Paul Arveson** *became a Christian in 1963. He received a BS in Physics from Virginia Tech and an MS in Computer Systems Management from the University of Maryland. He served as a civilian employee in the Navy, conducting research in acoustics and oceanography, and designed systems for signal processing and analysis. In 1998 Paul cofounded the Balanced Scorecard Institute, a management consulting firm. Paul has maintained a lifelong interest in issues of faith and science through his work with the ASA; he now serves as Secretary of the DC Metro Section. Paul facilitates a Sunday adult class at his church and was a cofounder of the C. S. Lewis Institute. Recently he has joined the Board of Solar Household Energy. He also currently serves on the Board of Managers of the Washington Academy of Sciences.*

The Challenge of Environmental Stewardship

It is not just about us. As Americans, our thinking about creation care naturally tends to focus on issues close at hand. We consider the fuel economy of cars and the cost of utilities for our homes. We worry about contamination of our food, excessive use of pesticides, and the reliability of electric power for our freezers and computers. These are the problems of a developed country. Meanwhile, there are billions of people around the world who live in comparative poverty. They are vulnerable to their environment in many ways, they suffer greatly, and we live alongside them on the same planet. This is an area in which scientists and technologists can intervene to offer innovative and appropriate solutions—especially when motivated by an ethic of *other-centered* Christian compassion.[5] But to be appropriate, interventions need to be carefully considered from the *bottom-up* viewpoint of the recipient. Thus, a first step in planning aid programs is to visualize in some detail the actual situation of the person in need. Constructing scenarios of people different from ourselves may lead to a better understanding of their needs. Such a scenario is provided in the example below, based on a compilation of field data.

A Day in the Life of Sarah

Sarah lives in a very sunny and warm part of the world. She lives with her husband in a stick-and-board house in a small village. It has a bedroom and a kitchen. They grow enough food to subsist, including beans, squash, and tomatoes, and Sarah trades some of these for corn and meat at the village marketplace. The family has to drink water from a muddy creek, because they often cannot afford to buy water from the tank truck that occasionally comes through the village. Sarah cooks in the traditional way. She moves three large stones together, then lights a fire in a pile of sticks and sets a pot over it. Sarah and her children are always coughing due to cooking smoke from burning sticks and dried dung. One of her children died of a lung disease last year.

Sarah's husband works in a field all day. For this, Sarah is grateful; many men have either left their wives or spend the day drinking and hanging out. They have four children. The older children stay around home and play; they cannot afford to buy the uniforms required to go to school.

Sarah gets up about 5:00 a.m. and lights a fire of sticks. She boils some water and makes hot cereal for breakfast. Sarah also makes a lunch for her husband to bring to the fields. Next she feeds her children, and then herself. After cleaning up, Sarah gathers clothes that need cleaning and walks to the creek to wash them, with one child strapped to her back and escorting a toddler. She brings home the wash and hangs it up to dry in the hot sun.

Her children help in gathering sticks for firewood. They sometimes have to walk several miles to find sufficient wood, and then they must carry the load back on their heads. All the local wood has been gathered already, and nearby landowners are scaring away poor people from gathering on their land. Often children get injured by thorns and insect bites. And it is always dangerous for women and children to be out in the woods alone.

Sometimes Sarah runs out of wood for the fire, because her children could not walk far enough to find a sufficient quantity. At these times she has to trade food for firewood. In the hot afternoon, she prepares lunch for the children and herself, by once again cutting up some sticks and starting the three-stone fire. After lunch she has some time to gather vegetables from her garden; she shells some beans and puts them into a soaking pot.

By late afternoon her husband returns home, tired and hungry. Sarah has prepared a meal of vegetables and rice over the fire. She feeds the children, scrubs out the cooking pots, and goes to bed—exhausted, coughing, and hot.

Billions of Sarahs

It is estimated that 2.5 billion people depend on food cooked indoors over open fires with biofuels, much as humans have done for hundreds of thousands of years.[6] According to the World Health Organization, this practice leads to respiratory diseases, accounting for nearly two million deaths per year, mostly of women and children.[7]

In rural Peru, for instance, a typical household will burn 3.6 tons of wood per year for heating and cooking.[8] Such consumption of firewood has many ripple effects. This wood must be either gathered by hand or purchased—one of the major household expenses. Fuel and food preparation consume so much time that women cannot earn extra income. They cannot send their children to school because they do not have enough money for school uniforms, and they need the children to gather wood and do other chores.[9] So, in many areas, the education level is not improving. These are chronic lifestyle habits that are not affected much by short-term government or NGO interventions.

The cumulative effect of a billion cooking fires (as well as slash-and-burn agriculture and other fires) adds significantly to the amount of black carbon,[10] aerosols,[11] and carbon dioxide in the atmosphere. Pollution of air, water, and earth (soil erosion) are evident in many places. The constant gathering of living and dead wood leads to deforestation and habitat loss. For example, in Haiti, the contrast between its barren land and the forests of the Dominican Republic can be seen clearly on satellite maps.[12]

The Energy-Poverty-Climate Nexus

In the year 2000, the United Nations announced eight global goals that must be achieved to meet the needs of people like Sarah.

The Millennium Development Goals

Goal 1: Eradicate extreme poverty and hunger.

Goal 2: Achieve universal primary education.

Goal 3: Promote gender equality and empower women.

Goal 4: Reduce child mortality.

Goal 5: Improve maternal health.

Goal 6: Combat HIV/AIDS, malaria and other diseases.

Goal 7: Ensure environmental sustainability.

Goal 8: Develop a global partnership for development.[13]

In reaching these goals, we need not assume that development in the less developed nations will take the same path that Western civilization took—along with its excesses. It is not necessarily desirable that the solution for them is to have what we have. The ultimate consumer "dream" may not be to have a big home with a dishwasher, a freezer, and an electric stove (along with all the resource demands, infrastructure costs, and environmental impacts that these products entail). In the colonial era, the USA was powered by wood. In the twentieth century, petroleum and its plastic and chemical products dominated. But with the advent of technologies such as the Internet, cell phones, satellites, fiber optics, vaccines, and nanotechnology, it is becoming possible for developing countries to "leapfrog" over energy-intensive products and to develop by more efficient paths. In some cases, it only takes a small amount of technology transfer to achieve significant economic impacts. This article will describe one such technology.

Daniel Kammen, a climate expert at the World Bank, noted that there is a "nexus" between energy, poverty, and climate change.[14] All three challenges are complementary; they impact each other. For example, as the story of Sarah's lifestyle indicates, reducing the need for firewood can also have an impact on poverty and climate change. Cooking over a fire is a major part of daily life, primarily of women. Moreover, the cost of fuel, or the labor in collecting firewood, is often a significant fraction of total household costs.[15] Because biomass fire-based cooking takes so much time and labor every day, it robs women and children of other opportunities such as education and small business. Hence, inefficient, fire-based cooking is one of the main causes of many social, health, economic, and environmental problems.[16]

The Solar Cooker

For many regions of the world, one approach to address the "nexus" is solar cooking. A *solar cooker* is a device that uses concentrated sunlight to cook foods. It does not require photovoltaic (PV) or other complex technologies; the only innovation required is a polished metal surface such as aluminum foil or metalized plastic film. Although it is "high tech" in terms of manufacturing, metalized film is very inexpensive and is now widely used as food packaging.

There are three basic types of solar cookers (figure 1), with many variations available:

1. Parabolic cookers, which use curved reflectors to focus sunlight onto a small area where a pot or teapot is mounted. Some designs include a sun-tracking device.
2. Panel cookers, in which flat sheets of shiny metal are arranged to focus sunlight on a black pot.
3. Box cookers, in which an insulated box covered with a transparent window captures sunlight to heat a black pot in the box.

There is a continuum from devices that heat by concentrating sunlight (parabolics) to devices that cook simply by retaining heat. Thus fuel-free cooker designs may be arranged in this order:

1. True parabolics with a high light concentration factor;
2. Modified parabolics (e.g., troughs);
3. Panel cookers with a transparent enclosure to reduce convective heat loss (This also includes evacuated tubes and solar hot water collectors.);
4. Boxes with shiny reflectors internally and externally;

5. Boxes with shiny external reflectors and black internal surfaces;
6. Boxes with no reflectors and black internal surfaces; and
7. Retained-heat insulated containers (no light input).

Solar cookers can also be characterized by three physical parameters:

- food and container mass
- light concentration factor
- net heat loss factor

The time it takes to heat food or water can be obtained from Newton's law of heating and cooling. The cooking time is directly proportional to the mass of the food and the pot, and the mean specific heat of the food and the pot, and inversely proportional to the reflector area and light concentration factor. Typically, a solar cooker takes from 1.5 to 2.5 hours to cook a meal. It performs like the slow cooker or "crock pot" in many American kitchens.

The maximum temperature achieved by a solar cooker is also dependent on the rate of heat loss; at equilibrium, the losses will equal the solar input. To reduce cooking time, the cooking pots and container walls are usually painted black. But at equilibrium, radiation loss will equal incoming solar radiation energy (Kirchhoff's law). Convection is also an efficient cause of heat loss, so box cookers must use a tightly sealed box. Of course, for water-based foods such as rice, polenta, or stews, the maximum internal temperature is self-limited to around 100°C.

Thus the main cooking requirements—quantity of food and cooking time—lead to solar cooker design requirements. Each type and size of cooker has its appropriate uses. For frying foods, parabolic or other curved reflectors can attain very high temperatures by concentrating sunlight on a small spot where a pot or frying pan is placed. These devices cook food in a short time, although the reflector must be turned frequently to keep it aligned to the sun direction.

For emergencies, and in refugee situations, a low-cost cardboard-and-aluminum panel cooker called the CooKit has been developed by Solar Cookers International (SCI). Tens of thousands of these devices have been distributed in camps in Africa.[17] The CooKit design is simple and can be made locally with existing materials such as cardboard and any kind of shiny material, e.g., aluminum foil, or even potato chip bags, candy wrappers, or cigarette packs.[18] The reflective panel can be used with any black pot, as long as it is enclosed in a roaster bag to reduce convection. It can reach temperatures around 120°C.[19] In addition to cooking food, the CooKit is used for pasteurizing water and milk, because experiments have shown that to pasteurize water it is only necessary to achieve a temperature of 65°C; it is not necessary to boil the water.[20]

A more durable general-purpose panel cooker is the HotPot, which includes a polished aluminum reflector, a glass bowl and cover, and an inner black enameled steel pot. The glass bowl acts to prevent convective heat loss. This product is well made and will last for many years. The author has personally used a HotPot cooker for a couple of years to cook

Figure 1. Solar Cooker Types.

vegetables, rib roasts, hot dogs, hamburgers, and cakes. He is one of many people in Washington DC, and other places around the USA who cook frequently with a solar cooker (figure 2).

Figure 2. Solar cooking on a snow day in DC, Feb. 2010.

Box cookers can be made of plywood, cardboard, or molded polymers. A simple box cooker design tested in Guatemala achieved 120°C in 30 minutes.[21] One commercial product, the Sun Oven™, claims to achieve temperatures of over 180°C.[22] Panel and box cookers do not need to be turned or adjusted frequently, and the pot does not need to be tended during cooking. These realities free up time for other activities. The American Society of Agricultural Engineers has published a standard for performance measurements of box cookers; international standards for solar cookers are currently being developed.[23]

Integrated Solar—Biomass Cooking

What does a solar cook do on cloudy days, or after dark? To provide for this, a modern *fuel-efficient stove* is recommended. Many designs have recently been developed. They are small and lightweight, typically made of clay or steel with insulated walls. They are efficient because of carefully designed air flow and reduced thermal mass. They can cook a meal quickly with only a small handful of wood or other biomass. Within the past year, a major effort has been launched to scale up the introduction of fuel-efficient stoves, the Global Alliance for Clean Cookstoves (GACC). Funded by hundreds of partners, the GACC seeks to distribute 10 million efficient stoves (including LPG stoves).[24] With widespread recognition, celebrity endorsements, and numerous meetings, the GACC has rapidly succeeded in focusing government and NGO efforts, primarily aimed at improving indoor air quality.

If food is cooked on a sunny afternoon in the solar cooker, how is it kept warm for the evening meal after sunset? For this purpose, a third component is required: a *large insulated basket or box*, which is lined with a thick insulating material such as straw or wool to reduce the heat loss factor. If a pot of hot food is stored in such a container, it will continue to cook and stay warm for hours.

The combination of these three simple devices—a solar cooker, a fuel-efficient stove, and a heat storage container—provides a complete "*integrated cooking solution*" for people in sunny regions all over the world, particularly in northern Africa and the Middle East, Central America, India and central Asia, Australia, and western South America. Haiti, for example, is dry for at least half the year—an excellent candidate for solar cooking.[25]

Fuel-efficient stoves reduce firewood requirements significantly. But solar cookers use *no fuel at all*. Thus, solar cookers can serve to drive down fuel costs for the poor, as well as reduce the environmental and health impacts from burning fuels.

Ongoing Solar Cooking Projects

Solar cooking devices are in widespread use in India, and production of solar cookers is growing rapidly in China.[26] For instance, there is an institution that feeds 30,000 people each day from a large solar cooker installation in India.[27] Solar Cookers International (SCI) has distributed tens of thousands of CooKits and other cooker products to African countries and Haiti.[28]

Solar Household Energy (SHE) is a nonprofit organization located in the Washington DC area to build awareness and support for solar cooking. (The author joined the board of this organization recently.) SHE has conducted field projects in El Salvador, Mexico, the Dominican Republic, Bolivia, Haiti, Senegal, and Chad. These projects are being evaluated to assess long-term acceptance by cooks in these countries. SHE also conducts research on cooker designs and is partnering with other US non-profit organizations to collect detailed measurements to improve cooker performance.

This year SHE established or advanced several important relationships, and provided technical assistance to these new partners. The United Nations High Commissioner for Refugees (UNHCR) contracted with SHE to train 48 women in the Gaga refugee camp in Chad to solar cook, and to distribute HotPot solar ovens for them to use (figure 3). UNHCR was interested in this project as a pilot to determine if a larger-scale program of solar ovens is warranted in the camps. The preliminary results are positive. The following description of the project is excerpted from SHE's final report to UNHCR:

> The preliminary results indicate that introducing solar cooking has caused them [the participants] to reduce their wood use by an average of 25–40% after only two months. These savings are likely to grow over time and could be further increased by additional measures. The users are extremely enthusiastic about their new HotPots and have adapted their cooking to use them every midday meal.[29]

Figure 3. Women solar cooking in refugee camp in Chad.

These results indicate that cultural acceptance and lifestyle changes are feasible. However, the scale of the projects so far has been small. SHE and SCI hope to scale up the size and duration of these projects, and many plans need to be prepared in order to be ready for this. SHE is currently working on ways to develop and test microfinancing practices, so that in-country entrepreneurs can enable solar cooking practices to grow organically within a country. This is a challenging, multidisciplinary long-term effort.

Challenges to the Introduction of Solar Cooking

It is gratifying to see the beginning of a large-scale introduction of more fuel-efficient biomass and LPG stoves around the world. However, fuel-efficient stoves of any kind still use fuels, they still generate CO_2, they reduce but do not eliminate deforestation, and they still require users to pay fuel costs and fuel distribution costs. In sunny regions, solar cooking can drive down costs, labor, pollution, and deforestation still further. But scaling up of solar cooker use faces several serious challenges. As Steve Jobs has said, "A lot of times, people do not know what they want until you show it to them."[30]

Many people in developing countries do not recognize solar cooking as a potential solution because it is such a paradigm shift in their thinking about how food is cooked. This is certainly understandable, and it implies that adequate training and careful adaptation to the local cooking practices is necessary for effective acceptance. However, based on recent pilot field projects, there is ample evidence that many users do accept solar cookers, especially as they begin to realize the economic, labor, and health benefits.

Despite the great potential benefits, currently there is little recognition of solar cooking in the USA. Field projects are small, because there are few significant sources of funding, either from nonprofit organizations or government agencies. Many people in developed countries, accustomed as we are to gas, electric, and microwave cooking, are unfamiliar with the *concept* of solar cooking. This is indicated in some common objections or misconceptions, such as the following.

"Two hours is too long to cook a meal." This objection is based on a misconception. Although solar cooking takes more "wall clock time," it takes much less actual labor time because food does not have to be stirred, as it does over a fire. Panel or box cookers work like an oven or slow cooker in a developed-world kitchen. You put the food in, then go away and do some other productive work. Moreover, solar

cooking significantly reduces the labor and time for wood gathering, cutting, preparing the fire, and other tasks. By visualizing "a day in the life" of the solar cook, one can begin to recognize more benefits that follow from this labor-saving use of the sun.

"Solar cookers don't get hot enough." Of course they do; people cook with them all over the world. But like any technological product, a solar cooker must be "the right tool for the job." Selection of the product must begin from the end user's requirements (including food types, latitude, climate, etc.) to derive design parameters such as those suggested above. Users need to know how to orient the cooker to the sun angle, anchor it properly, and so forth. Some well-intentioned interventions have reported poor performance because the products were not appropriate for the conditions, or because users were not properly trained in their use.[31]

"Solar cookers cost too much for the poor." It is true that the initial product cost may be prohibitive—for clean cookstoves as well as for solar cookers—but microfinancing methods are being implemented to reduce initial cost, and the reduction in fuel cost over time will decrease total cost of ownership. The economic rationale is parallel to that for fuel-efficient cookstoves. But more research is needed in order to design cookers that use lower-cost materials and reduced manufacturing labor, and to refine funding methods.

A key challenge is the lack of long-term evaluations of previous field projects. Often interventions begin with great enthusiasm, but follow-up reports are inadequate. Cooking is a daily routine that varies widely around the world; the appropriateness of a technological solution needs to be carefully matched to the "cooking facts" of a particular region or village. This requires anthropological data (e.g., "a day in the life of Sarah") as well as feedback from users, in order to optimize the fit for maximum usage. Video ethnography is a new technique that could be very helpful in this regard.[32]

There are numerous challenges of solar cooking that can be discouraging—until we are reminded of the large potential benefits of this technology for many people, as well as for the global environment. In fact, solar cooking has benefits that directly or indirectly cover *every one* of the eight Millennium Development Goals.

The Role of Christians in Meeting the Challenges

Christian organizations are playing a key role in achieving the Millennium Development Goals. Faith-based NGO's have advantages over government-sponsored programs in ensuring environmental sustainability. In a recent white paper, Amy Gambrill, a USAID official quoted advice from the findings of the African Biodiversity Collaborative Group as follows:

> Reach out to faith communities for dialogue and collaboration. The global urgency for a sustainable world demands multidimensional approaches and a persistent push for ideals based on innovative and pragmatic strategies. Faith-based communities comprise the largest social organizations in Africa, representing a repository of opportunities to spread the cause for sustainability in the continent. Conservation leaders should reach out to religious communities to collaborate in implementing these recommendations, with a view to enhancing the capacity for value-based sustainability decisions that link nature and human well-being.[33]

Gambrill notes that a purely technical approach to environmental challenges may overlook human values and motivations in the local culture, which frame the worldview of the people we intend to reach with interventions. Government-based aid programs typically have a short lifespan and cannot sustain long-term efforts. But mission organizations are often more trusted than governmental agencies, and they are going to be around for the long term to encourage adoption of new methods and products. Hence, some mission organizations are learning to partner and "piggyback" each other's programs to provide better care for the whole person's physical and spiritual needs.

Summary: The Sun Is Manna from Heaven

During the Exodus in the wilderness, the Israelites became hungry, and they suffered and grumbled to Moses (Exodus 16). God gave them manna. In the dryer areas of the earth, the sun is energy "manna" from heaven. It is distributed freely each day and almost every day. Like manna, each one can gather as much as she needs. Like manna, it cannot be stored but must be used on a daily basis. But until recently, it has not been possible to gather this "manna." One bit of new technology has changed that: metallized film and aluminum foil—materials that are now available cheaply everywhere, and are often considered trash. With this shiny material and other low-cost materials, the Sarahs of this world can obtain appropriately designed solar cookers and start gathering the "manna," cease gathering so much firewood, and immediately begin to enjoy the many benefits of solar cooking. ✦

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