Examining Sustainable Solar Cooking Options

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Introduction

Cooking food is an aspect of life in industrialized nations that a majority of the populace takes for granted, since access to appliances and cheap energy sources are commonplace. Energy is required to cook food. The earliest meals were cooked by burning wood and using the heat released from the fire. Modern technology has allowed humanity to cook using either fossil fuel directly, or electricity which is usually derived from burning fossil fuels. Fossil fuels are a non-renewable resource, since they are used up and cannot be readily created again. Burning wood is slightly more renewable, but it depends largely on where the wood was taken from and at what rate. Whenever a fuel source is burned, it is consumed in the process and carbon is released into the atmosphere. Atmospheric carbon is the most abundant greenhouse gas, and will continue to increase as more fossil fuels and biomass is burned. In many developing nations, families spend considerable amounts of time, effort, and money acquiring wood to be used as fuel for cooking. Often this fuel source can be so expensive relative to yearly income that it impacts food security. Aside from the social impacts of fuel wood reliance, this widespread use of wood for fuel in developing nations has contributed to both biodiversity loss and increasing concentrations of greenhouse gasses in the Earth's atmosphere (Abbaspour & Ghazi 2013). An alternative to burning a fuel source is to harness the energy of the sun in order to cook food, in a device called a solar cooker. A switch from fuel wood to a solar cooker can result not only in time and energy savings, but also increases in food and energy security (Pouris & Wentzel 2007). The prevalence of wood burning for cooking and space heating in developing nations is leading to what is known as the fuel wood crisis (FAO 2000). The objective of my research is to create and test two cheap and easy to construct solar cookers against each other and decide which one, if either, would be a viable option for cooking using solar energy in developing nations

The first documented experiments with solar cookers were done in the early eighteenth century. For the next hundred years, various methods were used, and levels of success experienced by the people attempting them also varied. By 1877, the French mathematician Mouchot created portable solar cookers for French soldiers by fashioning a shiny metal cone out of a 105° section of a circle. This is the first documentation of widely used solar cookers (Saxena et al). Mouchot later wrote the first book on solar energy and its industrial applications. In 1891 an American plumbing manufacturer invented the first commercial water heater that used solar energy. In 1984, a merchant in China was using solar energy to roast ducks (Saxena et al). Since then there have been an extensive amount of studies done on the effectiveness of solar cooking involving different methods, materials, and climates. Despite the improvement of solar cooking methods over the past century, mainstream usage of solar options still has yet to become popular, even as global warming increasingly impacts Earth's climate.

A major issue in the developing world is what is known as the fuel wood crisis. In addition to the greenhouse gases released from burning wood, harvesting wood for fuel has led to a reduction in the size of the Earth's forests, and has also contributed to species loss. In the United States, is it quite rare for people to cook using wood as the fuel source, but at the end of the 20th century, there was still around 50% of the Earth's population using fuel wood daily (Population Action International, 1999). It is estimated that 75% of all wood harvested in developing nations is used for fuel wood. More than 50% of all wood harvested globally is used to produce energy as opposed to producing goods such as lumber or paper (FAO 2000). These estimates are almost 15 years old, but a 2012 study published in Population and Environment describes how global household size has been in decline since the 1970s, and that global population growth over the same period of time has caused a great increase in the number of households (Knight & Rosa, 2012). The shift towards nuclear families in developing nations has made fuel wood consumption per capita increase. Per capita fuel wood consumption increase along with overall population increases has caused the fuel wood crisis to become even more of an issue in recent years. (Knight & Rosa, 2012).

Purchasing and burning fuel wood has impacts on local economies and food security in developing nations as well. Domestic use, such as space heating and cooking, accounts for the greatest fuel usage in most developing nations (FAO, 2000). In some developing nations, the percentage of fuel used for cooking relative to total fuel consumption can be as high as 90% (Nandwani 1996) Rural inhabitants are usually able to secure their own fuel wood from the surrounding forests, but urban families rely on fuel wood that is trucked in and has to be purchased. Especially among impoverished people in these nations, fuel wood is a major yearly expense that is necessary for survival. Often it can be so expensive relative to yearly income that it impacts food security, because families can afford either the food or the fuel to cook it, but not always both (Population Action International, 1999). Other types of fuel such as kerosene or natural gas are simply too expensive or too scarce to be a realistic option to millions of people.

This continuous reliance on fuel wood in the third world is an unsustainable practice. The prevailing dilemma of how to cook food in developing nations is too often solved by the burning of fuel wood. Cooking using solar power is both environmentally friendly and does not require a fuel source that needs to be purchased. Solar ovens can be bought from commercial vendors for a few hundred U.S. dollars, but in developing nations, that can be equal to a little less than half of a family's yearly income. (Vietta et al, 2006). One of the solutions to this problem may lie in solar cooking technology that was discovered hundreds of years ago. The objective of this research is focused on solar ovens that can be constructed with cheap or recycled materials and with a very basic understanding of construction. The idea behind this is that people in developing nations will be able to replicate the methods used in this paper to construct their own low-cost, energy independent means of cooking to both save themselves money and reduce their impact on the atmosphere and forests from which their fuel source currently originates. I constructed and then tested two different styles of solar ovens: the box method and the car windshield shade method. (Solarcooking.wikia.com) Criterion that will be compared includes cost of materials, long-term durability, ease of construction, and highest temperature achieved. Based on the results of these tests, I conclude whether or not these cheap, easy, and sustainable methods of cooking would be realistic in very poor developing nations where the fuel wood crisis is a real issue.

Methods

Solar oven selection and construction

Since one of the main goals of my research was to determine which methods of solar cooking could be done the cheapest and easiest, I searched for models that could be constructed quickly, easily, and with materials that are common and low cost. I also tried to limit my search to models that required materials which are readily available in developing nations. After looking through many different books and websites, I finally decided on two models which I decided to be the easiest to construct with respect to cost. The two models I decided on were the minimum box model and the car windshield shade model. Instructions for the construction of each can be found on Solarcooking.wikia.com by following the links labeled with each of their respective names. Once I settled on the two models which I would compare, I decided that I would purchase all of the required materials so I would get an idea of the total cost of each. Following the instructions found on Solarcooking.wikia.com, I constructed both models in less than 1 hour, and made a couple of alterations by the time I had finished.

Construction of the Box Model

Since I believed it would take the most time of the two, I constructed the box model first. The total construction time required for the box model was approximately 30 minutes. My materials were two cardboard boxes (18"x16" and 16" by 15"), a black metal roasting pot, some old newspapers, an oven bag, tin foil, a can of matte black spray paint, duct tape, and a bottle of nontoxic glue. To construct the base, I placed the roasting pot inside the larger box (18"x16") and cut the height of the box down so there was 6" from the top of the pot to the top of the box edges. I was careful to make precise cuts on this box so that I could use the scraps to create a lid. I then used old newspaper wads in each of the four corners and middle of the larger box to create an approximate 1" platform. On top of this platform I set my smaller box (16" by 15") so that there was a 1" gap between the bottoms of the two boxes and at least a 1" gap in between the sides of each box. I then added more old newspapers to the gaps between the sides of both for added stability, and trimmed the top of the smaller box (16" by 15") so that it was the same height as the top of the outer, larger box (18"x16"). I used the duct tape to seal the gap between the two boxes, and used the top of the larger box (18"x16"that I had cut earlier to create a lid with a reflection flap. To do this I cut 2" inside three of the sides of the cover, and then glued the oven bag on the underside of the opening left behind after the flap was created. I put a strip of duct tape on each of the corners of the lid and then stretched the lid so that it would slip over the top of the base. I then put a layer of tinfoil on every side of the inside box (16" by 15") as well as the reflection flap on the lid using the glue as an adhesive. After letting the glue dry overnight, the box model was ready for operation. After briefly testing the model the next day, I painted the entire exterior of the box model with the matte black spray paint in an attempt to absorb more heat from the sun while also reducing its susceptibility to water damage. The finished product can be seen below. (Figure 1)

Figure 1: Completed Box Model with painted exterior

Construction of the Windshield Shade Model

Shortly after I had completed the box model and had set it in a safe place to dry, I started constructing the windshield shade model. My materials were a standard car windshield shade, a black roasting pot and oven bag identical to the ones used in the box model, some strips of Velcro, a cake rack, and a bucket. The bucket is the base of this model. Next I cut three 2" strips of both types of Velcro, and put three strips at equal intervals on each side of the bottom of the windshield shade, ensuring that I had all female Velcro on one side, and all male Velcro on the reverse side. (Figure 2)

Figure 2: Windshield shade with Velcro. When flipped over, the other side looks identical.

I then took ahold of both outside edges of the windshield shade and created a funnel shape out of it, ensuring to attach all of the Velcro so the shape would remain after I let go. The next step is to place the funnel inside the bucket, and place the cake rack inside the funnel so that it rests on the side of the bucket. Next, I put the black roasting pot inside the oven bag, set the pot and bag on the cake rack, and the model was complete. I later used a stick spanned across the outer edge of the top of the windshield shade to both improve stability and increase the amount of sunlight reflected onto the pot. The finished product can be seen below. (Figure 3)

Figure 3: Completed Windshield Shade Model with stick in place

Upon completion of the two models, I commenced to test them at the same time in three separate trials, with each trial taking place during different weather conditions. Variables included outdoor temperature, amount of cloud cover, and wind speed. The first trial, which I labeled “Windy”, took place on a day that was slightly overcast, around 55°F, and had wind speeds around 22 mph. The second trial, which I labeled “Cold”, took place on a day that was sunny, exhibited winds under 8 mph, and temperature around 29°F. The third trial, which I labeled “Greenhouse”, took place in the USD greenhouse to control for wind and attempt to closer mimic temperatures near the equator. The temperature inside the greenhouse was around 80°F and it was a sunny day. The first testing period was the only time food was actually cooked, and I chose black beans since they do not pose a risk of illness when undercooked. During each of next two trails, I added about 4 inches of water to the pots and used a meat thermometer in each to measure the temperature of the water. I also looked up prices, durability reviews, and estimated maximum temperatures of two popular commercially available solar cooking options on Amazon.com so that I could compare my cheap low-tech models to more expensive and more efficient models.

Results

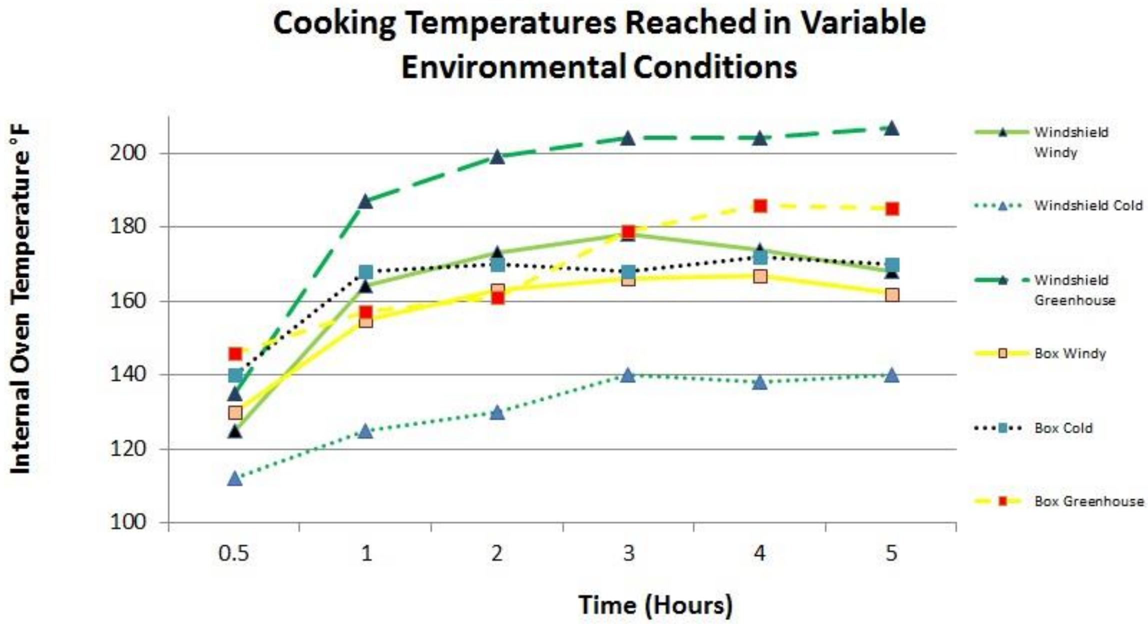

Figure 4: Internal cooking temperatures over a 5 hour period by windshield shade model and box shade model over a range of environmental conditions including cold, windy, and greenhouse conditions.

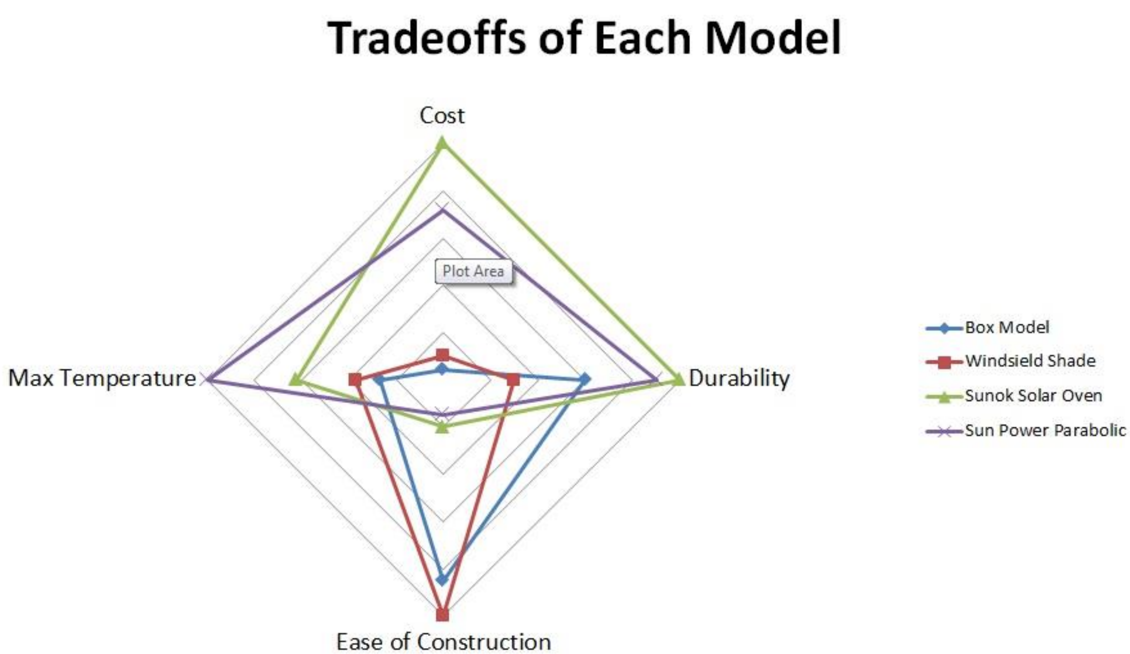

Figure 5: Tradeoffs in performance characteristics among the box, windshield shade, Sunok Solar Oven, and Sun Power Parabolic models. All values shown have been scaled from 0 to 1 with 1 indicating the model with the highest value for each performance indicator. Durability and ease of construction values were estimated qualitatively.

Using all newly bought materials, the Box Model cost around $20.00 and the Windshield Shade Model cost was around $25.00. The major expense for both was a flat black cooking pot and a meat thermometer which was necessary for taking temperature readings. Costs could be even lower if repurposed materials had been used. During the first trial, labeled "windy", the box model reached a maximum temperature of 164˚F and successfully cooked black beans over the 5 hour period tested (Figure 4). The windshield shade model reached a maximum temperature of 178˚F during the same conditions and over-cooked the black beans (Figure 4). During the second trial, labeled "cold", the box model reached a maximum temperature of 166˚F, while the windshield shade model only reached 139˚F (Figure 4). During the third and final trial, labeled "greenhouse", the box model reached a maximum temperature of 183˚F and the windshield shade model reached a maximum temperature of 207˚F (Figure 4). Water was not able to be boiled at any point. When compared to the commercially available models, the two easily constructed models I chose to create did not come close to the maximum temperatures or durability of the more expensive models.

Discussion

The minimum recommended cooking temperature for most kinds of meat is 165 degrees (Foodsafety.gov). Both solar cookers examined were able to reach and sustain this temperature even when operating during environmental temperatures far below what are seen day to day in most developing nations. For this reason, I conclude that both options are a realistic means of cooking at least some percentage of the meals prepared in developing nations.

How the two compare to each other are as follows:

- Cost – Draw. *A difference of $5.00 is negligible (Figure 5)*
- Durability – Box method. *The Windshield Shade model had considerable difficulty under windy conditions. (Figure 5)*

- Ease of Construction – Windshield Shade. *Total construction time is about 2 minutes, Box Method requires at least 30 minutes (Figure 5)*

- Maximum Temperature: Windshield Shade Method. *Peak temperature reached was 207 °F compared with only 185 °F for the Box cooker (Figure 4)*

Compared to commercially available options for solar cooking, these two DIY methods are far cheaper and easier to construct (figure 5). Both DIY models are lightweight, cheap, and easy to create. Most of the materials needed can be easily purchased or found whereas the two commercially available options utilize steel and glass in their designs and are far too expensive for the people they would benefit most. . Both models are capable of cooking food to safe temperatures, and could be used on a daily basis. Under ideal conditions, the Windshield Shade Model is superior. In colder or windier areas, the Box Model is more feasible. Almost 300 years after the discovery of this method of cooking, the benefits of these methods are easy to realize. Adoption of these methods by even a small percentage of people in developing nations could save time, money, and environmental impact. Based on the results of this research, I think a strong case could be made for using more solar cooking methods in tropical climates especially.

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