Focus: An Efficient Solar Cooking System

Sampada Peshwe

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A Thesis Submitted to the Faculty of
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In candidacy for the degree of
Master of Fine Arts in Industrial Design

FOCUS: AN EFFICIENT SOLAR COOKING SYSTEM

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PREFACE

My first brush with solar cooking was as a teenager while staying a summer with an aunt. I had never heard of or seen a solar cooker before. It would be very interesting to see her fill those black vessels with food, place the vessels inside the box cooker and carry the cooker outside into the sun. It was fascinating how food would get cooked simply sitting in the sun.

The next time I thought of a solar cooker was after I got married five years ago. I was working with environment friendly and low cost technologies at that time and I thought of bringing the technology home. But try as I did, I was unable to find a solar cooker in my city or nearby cities. I was told they had stopped selling solar cookers a long time back because they did not have much commercial success.

By that time I had got to know a rare few people other than my aunt who had solar cookers. I got talking to them regarding why the box solar cookers did not seem to be popular and I learnt that they were highly inconvenient to use. A few of the deterrent factors were that you could cook only a limited range of food, their heavy bulk had to be carried outside every time and they needed to be reoriented towards the sun every once in a while by dragging them on the ground. I got thinking that it was time someone designed a solar cooker that was convenient to use.

I was not able to take up the project at that time but when time came for
my master’s thesis project, it came back to me. For my thesis I had wanted to
do a project related to environment friendly issues and this seemed a good
idea to take up.

Sampada Peshwe

January 2005
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CHAPTER 1
INTRODUCTION

Project Background

Most of the world’s energy, including electricity, comes from oil, coal and natural gas. These non renewable energy sources are fast depleting and although new reserves are being found, we know they will not last forever. A more serious side of this depletion of resources is its irreversible impact on the environment. The jump in carbon dioxide and other greenhouse gases released into the atmosphere because of this relentless burning of fossil fuels will have serious consequences for our Earth by boosting smog, ozone depletion and global warming. The need to design products that utilize sustainable or renewable energy only increases with each passing day.

Cooking is one of the major energy uses worldwide. This is especially pronounced in developing nations where the primary cooking fuels are fossil fuels (liquid petroleum gas, coal, etc.) and firewood. Hence in these countries the activity of cooking contributes heavily to the utilization of fossil fuel reserves and its dangerous side effects.

In the search for an alternative cooking fuel, solar energy undoubtedly
qualifies as the best choice. It is an energy source that is not only sustainable but endless for all practical purposes. Sunlight is heat energy and it can be used directly to cook food, there is no need to convert it to any other form of energy. It is almost universally available and does not need any supply infrastructure. And the most importantly advantage of sunlight is that it is free!

The reason I call solar energy alternative cooking fuel is because of a few obvious shortcomings of this energy source. This energy is not available during the night or when the sky is overcast. Therefore even when you have a solar cooker you still need a backup way of cooking. Yet there is no disputing the fact that using solar cookers can result in a tremendous saving of fossil fuels, as we shall see in the study I will present in the next chapter.

A lot of research is being done on solar cookers by dedicated individuals, but these efforts are largely targeted towards the economically challenged people of third world. The aim of these endeavors is to provide an extremely economical alternative means of cooking to people who cannot afford cooking fuel or who face extreme difficulty procuring it. To keep the cost of these cookers within the reach of these people, these cookers are very basic in nature.

These solar cookers have failed to capture the interest of the average market savvy consumer in developing and developed nations due to the
fact that they do not suit the requirements of this market. As a product designer I feel there is great potential for a solar cooker designed for this niche. For my thesis project I decided I would design a solar cooker for this target user.

My target consumer is going to be the average urban Indian. India is a good choice for a variety of reasons. The first reason is that India is a subtropical country with plenty of sunshine. It receives daily solar energy in the region of 5 - 7 KWH/M² for 300 to 365 days a year, which is more than sufficient for cooking. To better understand this quantity of available solar energy, it is roughly 200 times the total energy requirement of the country. Secondly, it is a developing country that has a rapidly growing urban population and therefore an expanding potential consumer base. Lastly, being a native of India I would be able to identify and understand the user needs very well.

Definition of ‘Rural’ and ‘Urban’ in Indian Context

I would like to loosely define the terms ‘rural’ and ‘urban’ in reference to India as I will be using them very frequently in my project.

Rural population is the population living in villages (figs. 1 – 2). Their houses are mud walled and thatch (or tile) roofed. They have very little or no electricity supply and use fuels like kerosene (a petroleum product) for lighting. Water supply and sewage disposal infrastructure is very poor in
rural areas and does not reach every home. Usually rural people have to get water from community taps. Rural people are less educated and lead an underprivileged lifestyle sustaining themselves primarily on agriculture. Their fuel sources for cooking are kerosene, coal or firewood.

The urban population lives in towns or cities, in brick and concrete houses which are usually multistoried (figs. 3 - 4). They have regular electricity supply for lighting and for other electric appliances. Water supply and sewage disposal infrastructure reaches every home. The urban population is well educated and leads a modern, fast paced lifestyle. Their main cooking fuel is Liquid Petroleum Gas (LPG).

India, being a rapidly developing country, means these boundaries many times are not so black and white, and some population falls in the grey areas in between these two groups. But nevertheless these definitions help understand the general classification.
Solar Cooking Scenario in India

Today the box type solar cooker is the most widely available solar cooker in India (fig. 5). These solar cookers were first promoted on mass scale in India in the early 1980’s by the Ministry of Non-conventional Energy Sources. They became more popular in rural areas than urban areas. As of yet roughly 550,000 box type solar cookers have been sold in India, mostly in rural areas. This figure is but a tiny fraction of India’s total of approximately 187 million households.

These box type solar cookers are more popular in rural areas since they are more suited to the rural lifestyle. Staple food for people living in villages is simple food like cooked rice, lentil soup and cooked vegetables. This cooker is able to cook these types of dishes well. The cooking time in this cooker is long and needs to be spread over the day. But this is not that inconvenient for rural people since the lady of the house mostly works either at home or near her home. Cooking in rural homes is still done at
floor level and so these women do not mind using this cooker at floor level (figs. 5 - 6). Their regular cooking fuel produces a lot of smoke that fills up the room. The solar cooker is smoke free.

Fig. 5. Typical rural kitchen in India

Fig. 6. Box type solar cooker

Cooking needs of the urban population are more complex and cosmopolitan in nature. Their cooking comprises, in addition to cooked rice, lentil soup and cooked vegetables, shallow frying, grilling, toasting, etc. which the box type solar cooker cannot offer. The long cooking time does not suit the urban lifestyle as they need to cook food quicker in pace with their fast lifestyle. Also, cooking in urban homes is done on kitchen platforms and hence a solar cooker placed on the floor will be highly inconvenient (figs. 7 – 8). And the deterrent factor from the point of view of salability is that these cookers compete with LPG cooking systems. The box type solar cookers are aimed at achieving a low cost and hence lack aesthetic appeal, while the LPG cooking systems are much more attractive.
Fig. 7. LPG cooking system

Fig. 8. Kitchen in urban India

Having sketched out the general lifestyle of the urban population, a solar cooker for this target consumer group would have to address these basic issues –

1. Urban lifestyle compatibility in terms of fast cooking time and the range of cooking types offered by the cooker.

2. Ergonomic compatibility with their current cooking habits, for example, cooking being done at platform level.

3. Ease of storage and mobility.

CHAPTER 2
RESEARCH

LPG Statistics for India

LPG (liquid petroleum gas), commonly called cooking gas, is the primary cooking fuel for urban India. We shall now see why the need for an alternative source of cooking fuel for this sector is truly serious.

Currently there are around 63.5 million households or customers for LPG, serving a population of 317 million. This number has nearly doubled in only seven years, with the LPG consumption consequently going up from 3.849 MMT (Million Metric Ton) in 1995 – 96 to 7.310 MMT in 2001 – 02. LPG is one of the many petroleum products, but its share in the total petroleum consumption has been steadily increasing. Today it has the fastest growth rate amongst petroleum products beating even transportation oil (high speed diesel) and kerosene, the products with currently the highest stake amongst all petroleum products.

The reason why LPG consumption becomes such a grave issue is because of the precarious situation of petroleum reserves. In India petroleum remains the primary source of energy. The consumption of petroleum products has multiplied by 35 times in the past 50 years from a
mere 3.5 MMT in 1951 – 52 to 130 MMT in 2001 – 02.

Current indigenous production is less than half the requirement. The present and expected rates of consumption imply that the known Indian reserves may not last even 10 years.

This grave situation has compelled the government of India to take steps towards conservation of petroleum by promoting non conventional sources of energy. India has amongst the world’s largest programs for renewable energy and development of solar energy applications is one of the most important constituents of this program. The attempt by the Ministry of Non-Conventional Energy Sources at popularizing solar cookers is a part of this program.

Solar Energy and Cooking

When it comes to design of consumer products using sustainable sources of energy, cooking is one area that remains underestimated and completely unexplored.

Box type solar cookers can save roughly in between a third to fourth of a household’s annual LPG consumption. If every Indian household were to use a solar cooker it could potentially save around 200,000 tons of petroleum per year (2.0% to 2.6%) of the country’s total petroleum consumption! Using a more efficient solar cooking system would result in more LPG saving and hence more petroleum conservation.
Cost wise, how much does a user save? With the box-type cooker, a user would recover the cost of the cooker in 1 - 2 years. With a more efficient cooker, the user will save more fuel. But a more efficient cooker will also cost a little more, hence it will take about the same time to recover its cost. But, after that, all solar cooking will be free!

Types of Solar Cookers

Currently existing solar cookers can be classified into two major types:

a. Reflective type cookers: Sunlight is reflected off a single panel or multiple panels onto the cooking vessel. In case of box type, the cooking vessel sits in a box that has a glass cover to trap the heat inside. Its subtypes are -

- Box type solar cookers (fig. 6)
- Panel type solar cookers (figs. 9 - 10)

Advantages of this type of cooker are that food can be left to cook in the cooker without the fear of it getting burned up. And these cookers are usually portable since the panels can easily be folded up.

But these cookers have a longer cooking time, usually ranging between an hour to an hour and a half. And they do not reach temperatures beyond 110 deg. F.

b. Concentrating type cookers: Sunlight is reflected off surfaces that concentrate sunlight (figs. 11 – 12).
Concentrating type cookers can easily reach temperatures up to 350 deg. F. and higher, and therefore require a shorter cooking time of only half an hour to an hour and a half.

But they require careful handling because the reflective surfaces are metallic and hence become extremely hot. Another major disadvantage is that these surfaces focus sunlight upwards from ground level and pose a danger to the eyes. These dish type cookers also tend to be bulky and are usually not portable.
CHAPTER 3

IDEATION AND DESIGN DEVELOPMENT

Fresnel Lens Technology

After studying the available types of solar cookers and the subsequent technologies, none of them seemed suitable for my project. I was looking for a solar cooking technology that would give me concentrated sunlight for more efficient cooking. Yet I did not want to employ any of the currently available solar concentrating technologies because of their glaring disadvantages. At the suggestion of my advisors I started looking outside of the realm of solar cookers for a solution.

During my research I came across Fresnel lenses that are being used in NASA space satellites to concentrate sunlight on to their solar panels to increase their efficiency (fig. 13). Another major solar application of these lenses is in production of electricity at power plant capacity levels (fig. 14). A more common use of fresnel lenses can be seen in traffic signals, overhead projectors, large television screens, etc.

A Fresnel lens works by the principle of refraction of light. A cross section of the lens reveals thousands of tiny spiral microgrooves which
refract the incident light, bending it to the requisite emergence angle (fig. 15). Depending upon the desired result the fresnel lens section can be designed to get emergent light rays that are convergent, parallel or divergent.

![Fig. 13. Solar panels of a NASA space satellite](image1.png)

![Fig. 14. Array of fresnel lenses used to produce electricity in a power plant](image2.png)

![Fig. 15. Cross section of a fresnel lens](image3.png)

A comparative study between concentrating dishes and fresnel lenses reveals that fresnel lenses are more advantageous. Fresnel lenses are safer for eyes since the lens casts its focus downwards, unlike concentrating dishes which focus upwards. Unlike concentrating dishes which have a metallic reflective surface, there is no reflection off the lens surface since the
lens is made of translucent material. Fresnel lenses offer freedom with shape and material. For example, they can be dome shaped, vault shaped, flat or even be out of collapsible material (figs. 16 - 17). Since there is this freedom to design the shape of the lens, they can be made very portable and easy to store.

I decided that I was going to use the fresnel lens as the sunlight focusing mechanism in my cooker design.

Initial Brainstorming

After finalizing the mechanism I would be employing, I started brainstorming for concepts on how this focused sunlight would ultimately reach the cooking vessel and the food. A few initial concepts to arise out of this ideation were –
- The cooking vessel itself receives the focused sunlight at a designated hotspot and the heat is distributed all over the vessel through high heat conducting veins (fig. 18 A).
- The focused sunlight falls on strip of high heat conducting metal and this heat is then conducted to branching strips which will act as hotplates for the cooking vessels (fig. 18 B).
- The food inside a cooking vessel directly receives the focused sunlight (fig. 19 C).
- The focused sunlight heats up a mesh of high heat conducting metal within a container and this mesh conducts the heat to the cooking vessel (fig. 19 D).

Fig. 18. Concept brainstorming
This initial ideation phase also saw me searching for a form for the fresnel lens.

Solar cookers have to be reoriented in two axes every once in a while to align with the sun’s changing position in the sky. Azimuth is the movement of the sun along the horizon and altitude is the angle of the sun in the sky with the ground. I wanted to see if I could eliminate this problem with the shape of the lens.
A few concepts for the shape of the lens were –

- Vault shaped lens will eliminate the need to realign the lens along the sun’s altitude (fig. 20).
- Dome shape will eliminate the need to reorient the lens along either axes (fig. 21 A).
- A faceted dome shape would fold up nicely and be very portable (fig. 21 B).

At first I was considering the possibility of having the solar cooking unit inside the kitchen which would have made cooking very convenient. I looked at possible positions of the cooker in the kitchen that would be best suited to accommodate the sun’s changing position in the sky (fig. 22). But the need to accommodate the sun’s varying positions presented too many restrictions concerning the location and direction of the kitchen. Finally I decided it would be most advantageous and practical to have the cooker outdoors.
Fig. 20. Ideation for lens shape
Fig. 21. Ideation for lens shape (continued)
Experimentation using Fresnel Lens

During my research I found no documentation for a solar cooker using a fresnel lens. This fact was reinforced in my communication with Ralph Leutz, author of the book *Nonimaging Fresnel Lenses: Design and Performance of Solar Concentrators*, who is working with Tokyo University in developing fresnel lenses for non imaging applications. He conveyed that he did not know of a solar cooker design using a fresnel lens. Since I had no precedent to follow regarding the cooking capabilities of a fresnel...
lens I decided to get a fresnel lens and do some experimentation to gather some basic information.

I had a discussion with Prof. Jodoin, Head of the Physics dept. at R.I.T., regarding the size of the fresnel lens needed to achieve temperatures of 400 to 500 deg. F, which is the temperature range offered by LPG and electric cooking systems. According to him the resultant temperature would be dependent, besides the capability of the lens, on a lot of factors like the receiving material, the ambient temperature, etc. But for practical purposes a lens of approximately 1 sq.m. would collect adequate sunlight to achieve these temperatures.

I was able to procure a huge 3 feet by 4 feet fresnel lens from a television repair shop, which was just about the size I required. My early experimentation was all done in my front yard, using pots and pans from my kitchen.

These were my observations from those experiments –

- Heating foods or liquids directly under the sunlight focus is not sufficient as the surrounding air keeps cooling it. The food and the cooking vessel need to be inside another enclosure to help isolate them from surrounding air (figs. 23 – 25). Water in the pot kept directly under the focus took 15 – 20 minutes to just become warm (fig. 24) while water in the pot kept inside a glass covered enclosure reached boiling temperature in the same time (fig. 25).
- Liquids heat up well when directly under the sunlight focus since convectional current within them help spread the intense heat. But if food is kept directly under the focus, the portion in the focus gets overdone or burnt. Soaked lentils kept under the focus (fig. 26) took 45 minutes to get cooked but were overdone in the portion directly
under the focus. Therefore to cook food evenly, it is better to have the focus fall on the cooking vessel or a lid which will in turn conduct the heat to the food (fig. 27).

- In trying to grill or toast a food item, it is better if the food item has a metal mesh on the top. This metal mesh, when under the sunlight focus, heats up quickly and in turn grills or toasts the food item well. A piece of bread kept directly under the focus does not get toasted
even after 10 minutes, while bread sandwiched between the metal grill and kept under the focus toasts in a matter of minutes.

- It was possible to obtain temperatures of up to 400 deg. F. inside the pot enclosure using these regular pots and pans. When the appropriate materials are used I believe the results will be even better.

![Fig. 28. Toast directly under focus](image1)

![Fig. 29. Toast in between flanges of grill](image2)

Concept Development

By now I had decided that I would use a flat lens that I could orient to the sun rather than a vault or dome shaped lens. The reason was that although vault shaped and dome shaped lenses would require less reorienting with the sun, due to their very shape only a portion of the lens would be aligned with the sun. Hence the lens would not be functioning at full capacity. Though a flat lens would require more realigning, the whole of the lens would be facing the sun and thus would be utilized fully, providing more energy for cooking.
I now started ideation on the relationship between the lens and the actual cooking unit and on the lens aligning mechanism (figs. 30 - 35).

Alternative 1:

Lens rotates along one edge fixed to a raised base platform. Cooker is fixed to the platform.

The problem is that as the lens is moved to align with sun, the focus shifts away from cooker.

![Fig. 30. Alternative 1](image)

Alternative 2:

Lens and cooker fixed to each other with the cooker at the focal point of lens. Lens moves around its central axis to align with the sun.

The problem is that cooker will move in a pendulum fashion along with the lens, which is not good when you have food cooking inside it.
Alternative 3:

Cooker remains fixed to platform and lens moves around center of cooker. That way cooker stays in focus of lens and there is no movement of food.

Fig. 31. Alternative 2

Fig. 32. Alternative 3

I chose to go ahead with alternative 3 because it seemed the most practical amongst the three alternatives. At this juncture I was contemplating taking the design in the direction of having the whole cooking system assembled out of reused material. This would have definitely added to its eco friendliness value. But the major drawback of this direction was standardization of design which a mass produced product needs. It would be very difficult to find the same discarded materials in different cities and adapting the design to these changes would be completely unpractical. So I decided not to go along this path.
Fig. 33. Alternative 1 expanded

Fig. 34. Alternative 2 expanded

Fig. 35. Alternative 3 expanded
Design Development

When I started developing the concept further, I decided to expand on the portability function of the cooker to make it more usable and hence increase its consumer value.

Design Stage 1:

The cooking system is divided into two main parts – a folding base with cooker attached to it and a detachable lens unit that folds away (figs 36 – 38). The base is table-like with four legs that fold and tuck under the cooker and the cooker is ready to go.

Fig. 36. Cooking system: Stage 1
Design Stage 2:

This was the stage after I did some more design work focused on aesthetics to eliminate the cooking system's mechanical look (figs 39 - 41).
Fig. 40. Design development sketches: Stage 2 (continued)

Fig. 41. Leg folding mechanism model: Stage 2

Design Stage 3:

The folding mechanism of the legs seemed too heavy visually and seemed to overpower the cooker itself. I worked on trying to make it look less dominant (fig. 42).
Design Stage 4:

At this stage I decided to have a base with a center member and radiating legs as this would be easier for orientation of the lens (fig. 43).

Fig. 42. Leg folding mechanism changed

Fig. 43. Base changed to center support with radiating legs.
CHAPTER 4

FINAL DESIGN: FOCUS - AN EFFICIENT SOLAR COOKING SYSTEM

Focus is an efficient solar cooking system. It provides cooking temperatures up to 550 deg. F., which means cooking times comparable to conventional cooking systems. A whole range of cooking types like boiling, baking, roasting, grilling and shallow frying is possible with Focus. Its most important feature is its portability. In a dismantled and folded form, Focus can easily fit into the trunk of a compact car.

Focus has three main parts – a folding lens unit and a folding base unit that attach to the cooker unit (figs. 44 - 45). The lens unit detaches from the cooker and folds into half, converting into a very manageable size. The radiating legs of the base unit also detach from the cooker and fold in umbrella style to make the unit compact. The cooker unit has a rigidly fixed shelf that acts like its base and makes it into a standalone unit.

Lens Unit

The fresnel lens concentrates sunrays into the cooker unit, delivering the energy source for the cooking system. The lens is most efficient when
Detachable and folding lens unit

Cooking unit with fixed shelf

Detachable and folding base unit

Fig. 44. Features of Focus

Lens unit attaches to the cooker on top

Base unit attaches to the cooker on the

Fig. 45. Three main parts of the cooking system
perpendicular to the direction of sunlight and hence it needs to be reoriented to the changing position of the sun. The aligning mechanism is described in detail later in this chapter.

The lens is 36 inches by 36 inches in size, divided into two parts. The lens unit attaches to the cooker unit by its set of arms. A pair of spring loaded struts holds the lens in its unfolded usable position. These struts collapse at their joints to allow folding of the unit (fig. 46). The folded unit can be lifted by the struts that now act as handles.

Fig. 46. Folding mechanism of lens unit
Base Unit

The base unit has five legs radiating from a central support. The top part of the central rod fits into a corresponding shaped receiving aperture on the bottom of the cooker unit.

The legs are so arranged that there is more spacing between the front two legs to give room for user foot movement. The advantage in a five leg system is that there is always one leg on the backside of every pair of legs, arresting the toppling motion that may result because of the large top lens unit.

The lens unit collapses in an umbrella-like fashion to form a compact unit (fig. 47). The user grips the handle attached to the joint between the five legs to fold and unfold the base unit. A screw mechanism holds the legs in open or collapsed positions and needs to be loosened to make the change. The central member has two corresponding threaded holes on the top and bottom portion to allow the screw to fit in.

In order to make moving the whole cooking system easy, the legs have wheels at their ends. The leg tip extends beyond the wheels to prevent any toppling motion of the system over the wheel.
Cooker Unit

The cooker unit is where the cooking activity takes place and therefore it is the most important part of this cooking system.

It has a cavity inside that receives sunlight focused by the lens through a window in its lid. Food to be cooked is put in cooking vessels, which are placed inside the cooker by opening its lid (figs. 49 – 50). The light focus falls on the vessel and heats it up, cooking the food (fig. 48). Whatever portion of light that does not on fall on a vessel is reflected by the inside surface of the cooker and gets trapped inside, like a greenhouse,
increasing the inside temperature. The cooker is insulated on the outside to prevent heat being conducted to the surrounding air.

I have designed four types of cooking vessels for different types of cooking (fig. 51). The pot is for boiling and baking items. It is donut shaped, which helps the heat reach more surface area and thus heat the vessel more. The central core helps the heat in reaching the middle portion of food, cooking it more evenly and efficiently. The pan permits shallow frying of food items. The grill is designed to hold food items in between its two flanges so that it can be grilled from both sides. The divided flat pan is also designed for cooking from both sides. It is best for items like pancakes.

The outer portion of the handle on all vessels sticks outside the cooker, through an aperture specially provided for this purpose, thus preventing it from getting hot under the focus and making it possible to lift the heated vessel. This portion of the handle is made out of heat resistant material to resist heat conduction from the hot parts.

The shelf provides a handy place for cooking paraphernalia like the ingredients, spoons for stirring, etc. (figs. 49 – 50). This shelf is rigidly fixed to the cooker and rotates along with the cooker, ensuring that the items on the shelf do not get knocked down by the cooker movement.
Sunlight focused by fresnel lens

Cooker enclosure

Cooking vessel handle sticking out of cooker

Fig. 48. Cross section through the cooker

Fig. 49. Cooker with lid open

Fig. 50. Cooker with cooking vessel inside and lid closed
The cooker unit has protrusions on both sides, with rotatable ends where the arms of the lens unit come and attach. The cooker is the center pivot around which the lens unit rotates in the vertical direction.

Lens Alignment

As I have mentioned previously, the position of sun in the sky changes through the duration of the day and the time of the year. Position of the sun is mapped along two coordinate systems – the azimuth and the altitude.
Azimuth is the sun’s position along the horizon or in the horizontal plane. Altitude is the angle the sun makes in the vertical plane, with the horizontal.

The lens unit has the ability to align with the sun along both azimuth and altitude. Alignment along the altitude is achieved by the lens unit’s rotation around the cooker. It is possible to align the lens along the azimuth by turning the cooker unit on the base unit. Complete alignment is achieved by a combination of both these movements (fig. 52).

Focus offers a simple mechanism to find out if the lens is perpendicular to the direction of sunlight, which is the position in which it is at its best focusing capability. This small simple mechanism consists of a pin that is fixed perpendicular on a circular plane. This plane is parallel to the lens surface, which means when the sun is perpendicular to the small plane it is perpendicular to the lens surface. This plane stays parallel to the lens when the lens is being moved for alignment. The only situation in which the pin will not cast a shadow on the plane is when the sun is directly over the pin, that is, the sunrays are parallel to the pin and perpendicular to the plane.

When the lens is being aligned, the user can keep on referring to this mechanism and judge the direction in which the lens needs to be moved for perfect alignment (figs. 53 – 54).
Fig. 52. Lens alignment mechanism

Lens movement to align it along the sun’s azimuth or angle along horizon

Pin with its shadow

Fig. 53. Pin shadow visible, lens not aligned

Pin with no shadow

Fig. 54. No pin shadow, lens is aligned
User profile

The two primary uses of Focus are cooking at home (fig. 55) and cooking at campings or outings. Although the project targets the Indian urban user, this design is easily universally applicable with minimal adjustments for height, cooking types, etc. Focus can also be used in a variety of other situations like open to sky food stalls, restaurant kitchens and workplaces (to heat food and beverages).

Fig. 55. Typical use of Focus in the front yard or backyard of an urban house in India
Human factors

Effective height of the cooker, that is the height at which the cooking vessels will sit, is 36 inches from the ground (fig. 58). This is equivalent to height at which cooking is done in urban Indian homes, which is a 30 inch high cooking platform plus 6 inches for the LPG cooking system on top of that. The bottom of the lens, when unfolded and in use is just higher than the average Indian adult height of 63.5 inches to prevent the user’s head hitting the lens when the lens is in perfectly horizontal position. The angle of lens varies with the change in the sun’s position and therefore it will be in a perfectly horizontal position only at noon. The rest of the day it will be at an angle, giving the user sufficient headroom.

The lens folding mechanism is within arms reach of the user, requiring only minimal bending of back (fig. 58). There is more spacing between the front two legs of the base, as compared to the spacing between other legs, to provide more room for the user’s foot movement.
Focus has a system of ‘safe touch points’ which are color coded. These areas of heat resistant material are strategically placed at points where the user would need to grip a part of the cooker to operate it. Since the cooker will be outdoors in the sun, its body is bound to heat up. It would be not only highly impractical but unnecessary to cover the whole body in heat resistant material since there are only a few areas on the cooking system that the user would need to touch in order to operate it. All the safe touch points are red in color, so that whenever the user sees a red area on the cooker, s/he would know it is a safe area to grip.

Fig. 57. Life size mockup of Focus
Fig. 58. Human Factors
One day using a solar cooker

What does a day of a solar cooker user look like? A solar cooker is usually used from one hour after sunrise till one hour before sunset, which is roughly from 8.00 am till 5.00 pm for India. A user who is at home the whole day can potentially cook anytime in this time window. For a person who works outside of the home during the day, they can utilize this time period by using Focus as a slow cooker.

![Fig. 59. One day using a solar cooker](image-url)
Focus as a slow cooker

Along with the efficiency of Focus comes the need for cooking to be supervised regularly for fear of it getting burnt if left too long in the cooker. The only advantage of a slow cooker over a concentrating cooker is that unattended cooking is possible. Food items like jams, jellies, roasted nuts, etc. can be easily left in a slow cooker to be done over a longer duration. Focus can be used as a slow cooker by affixing a set of reflective panels on the cooker unit which reflect sunlight into of the cooker (fig. 60). Thus the user is able to utilize that part of the day when s/he cannot actively supervise cooking with the fresnel lens.

Fig. 60. Focus as a slow cooker
Materials and finishes

The body of Focus is constructed out of aluminum extrusions with an anodized finish. This finish is satin textured to minimize reflectivity and for ease of maintenance. The safe touch points are made of a silicone based material for heat resistance.

The outer surface of cooker is insulated to prevent escape of heat to the surrounding air. The inside surface of the cooker is coated with a finish low in absorption and high in reflectivity so that the light not falling on the utensils is reflected back efficiently without being absorbed into the walls. Good choices for the outside finish of the cooking utensils are Solec Solkote selective surface paint or Solkchrome. These finishes that have high absorption (0.84 – 0.98) and low emissivity (0.1 – 0.49) properties. These are optical coatings specially formulated for solar thermal applications. Utensil handles are in a silicone based material for heat resistance, similar to the safe touch points.

The fresnel lens will be made of architectural acrylic, which has excellent long-term UV stability and very little loss of clarity, around 2% in 20 years.

Conclusion

In conclusion, the Focus achieves the overall aim that I set out with, which was to design a solar cooker that would be commercially viable in the urban Indian user market. At the end of the first chapter I outlined four
major considerations that are the basis of my design:

- User lifestyle compatibility
- Ergonomic considerations
- Storage/portability and
- Product aesthetics.

Focus successfully addresses all of these issues in its design evolution. However there is still scope for further exploration and development in the design in order to make it yet more effective. Feedback offered on the final design by my thesis committee and others attending my thesis project presentation was as follows -

- Size of the cooker is overwhelming: The size of the cooker is a result of the dimensions of the lens and the size of the mechanism needed to support this lens. The lens size for Focus is derived from the lens area required to collect and focus enough sunlight to produce the requisite cooking temperatures. It would be possible to reduce the size of the lens, and consequently the size of the cooking system, with a fresnel lens designed to be more efficient.

- Possibility of users tripping over the radiating legs of the cooking system base: Portability of the cooking system was a major consideration in my design and the radiating legs configuration offered the most efficient solution for folding of
the base. This configuration also allows easy alignment of the lens. It is a valid observation that users may trip over the legs. Looking at this possibility there is definitely a need to further research the tradeoff between the portability of the unit and a safer base configuration and explore further possibilities in the design of the cooking system base. Studying why the users would trip over the legs and working to eliminate these reasons would also contribute to resolving this issue to some extent.

- Effect of wind on the lens: During windy conditions the lens might catch the wind and get blown around, rendering the cooking system unstable. Possible solutions might be to create perforations in the lens and/or break up the total lens surface and create gaps in between to release the wind pressure.

- Choice of the color red for the 'safe touch points' signifies 'danger': It was brought to my attention that in the United States the color red is used to signify danger or unsafe and therefore may not be the best choice of color for the safe touch points. But this is not true in India. The considerations I had in mind when deciding a color for the safe touch areas were colors that would stand out outdoors and be seen well in
the bright sunlight. The suggestion of thinking of the
connotation of the color red is very valid, especially taking into
consideration the possible future global application of Focus.

Future of Focus

Focus is only the beginning of products that use solar energy for
cooking. This concept is only going to grow as the need for alternative
means of energy increases day by day. I can see Focus proliferating into a
whole line of consumer products not limited to –

- Small solar cookers for specific cooking needs like heating
  beverages, rice cookers, etc.
- Larger solar cookers for mass scale cooking like camps, resort
  restaurants, etc.
- A range of cooking vessels specifically to be used in the solar
  cooker.

Even though Focus has been designed for the Indian urban market, it
can easily be used anywhere in the world where there is requisite sunlight.
Focus could be the precursor to a new movement of bringing the use of
alternative sources of energy into our homes.
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