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Use of Parabolic Reflectors to Generate Clean Energy in Rural Areas

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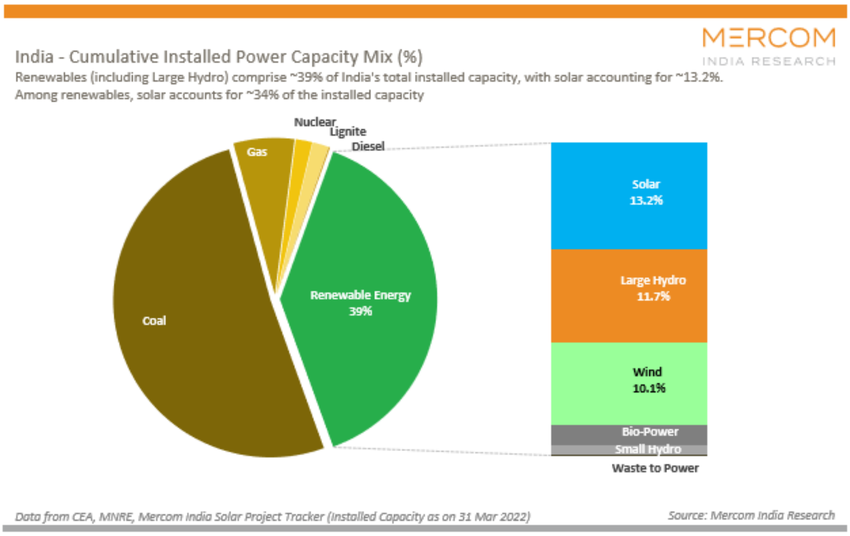
Abstract: ***If no new resources of energy are discovered and effectively used, reserves can run out sooner. This will render the world to fend on its own, in a time where everything depends on energy; scarcity would result in people being unable to even cook their food. This research paper explores the feasibility and effectiveness of using parabolic reflectors as an alternative, clean energy source for cooking and domestic applications, particularly in remote areas with limited access to conventional energy resources. The paper provides an overview of the growing importance of energy efficiency and the need for sustainable solutions to reduce reliance on fossil fuels. It examines the historical development of parabolic reflectors and their ability to concentrate energy at a focal point. The study introduces a model utilizing dish antennas coated with aluminum foil as parabolic reflectors and optical fibers for transferring the concentrated light to the cooking area. Data analysis reveals that larger diameter concentrators result in higher concentration ratios, enhancing the system's efficiency. Safety precautions are highlighted due to the high temperatures produced by the focused light. The research concludes that parabolic reflectors offer a promising avenue for harnessing abundant sunlight to meet cooking and domestic needs in regions where conventional energy sources are limited. The use of this renewable and cost - effective technology has the potential to make a positive impact on energy conservation and environmental sustainability.***

Keywords: Parabolic Reflector, Clean Energy

1. Introduction

"Energy efficiency is a national concern" because of the crucial role it plays in the operation of our everyday lives. Electrical energy powers everything from our cars, to our refrigerators and light bulbs and is largely provided by fossil fuels.

According to the data shown by a 2022 report on the website - the Ministry of Coal, India, coal amounts for about 55% of the country's energy needs.



According to the world population review, this is the coal consumption by India in 2022 -

India	Coal Consumption - MMcf:	966.3B	Coal Consumption per Capita - MMcf:	729	Coal Consumption - Exajoules 2020:	17.54	Coal Production - Exajoules 2020:	12.68	Coal Reserves - Million tons 2020:	111,052

All these data showcase that due to the diminishing reserves of these resources, the world has to be motivated to find ways to conserve energy and discover new ways to power their appliances to order to reduce the consumption of non - renewable sources like fossil fuels, solar energy, and hydroelectric power have to be explored more.

In recent years, these renewable sources of energy have become more prominent and are used increasingly because they do not harm the environment as much as these fossil fuels. As the rate of consumption exceeds the rate of production, it will inevitably lead to a shortage of fossil fuels available to us. Moreover, in the production of electricity at coal power plants and village areas where coal and wood are being used for cooking foods, the use of coal does more harm to the environment while it is burning as it contributes to problems such as global warming and acid rain. Thus, there is a need to find energy sources that have zero net emissions of carbon dioxide and are more cost - effective. This has motivated us to look for "clean methods to cook and for other domestic uses".

In some village areas, there is no access to electricity and no way of transportation for gas cylinders. Hence, the people there often cut trees and burn the wood to heat and cook food. This results in deforestation and further releases emissions of carbon dioxide which damages the environment. However, the one thing that is present in large quantities is sunlight. If used in the right way, this sunlight can be used to cook food in the villages. One solution to this could be to use solar cookers. Unfortunately, its use is limited. The other solution can be to use the reflectors to concentrate this sunlight on one point, which will have enough heat to boil water and cook food. Our research showed that the best and most effective kind of reflector is a parabolic reflector.

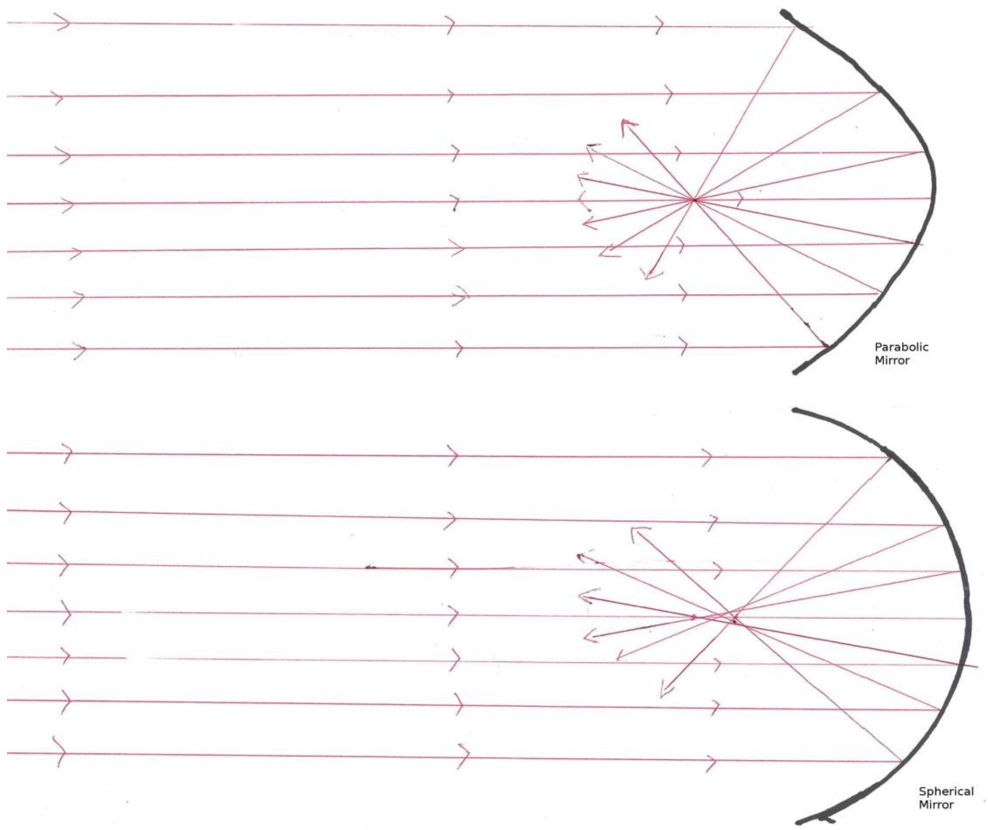
These are the following reasons a parabolic reflector attracts attention -

- It uses heat energy from direct sunlight which is one of the most abundant energy sources present and is renewable.
- It is comparatively cost - effective.
- It has a constant focal point.
- Decreases spherical aberration.

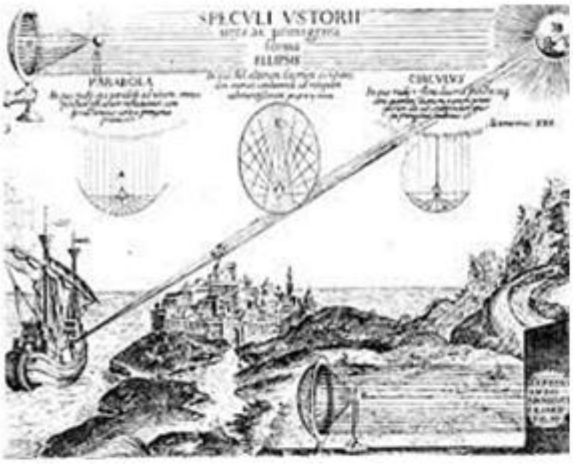
Producing a parabolic reflector all on its own may prove to be an endeavor. So we need to look for cost - effective ways to produce it. After researching, we found out that dish antennas have parabolic shapes. Also due to the rise of smart televisions and Ousehich uses the internet, their uses are limited, and hence they are wasted. This is why we plan on using a dish antenna as our parabolic reflector as it will reduce the wastage making the device in price. Although our main source of energy - sunlight, is not available during the night, the benefits greatly outweigh the limitation and will prove to be extremely useful.

2. Background Information

It is a theoretically known fact that concave objects, upon receiving various waves, reflect them with all of the waves getting concentrated at a point called 'focus'. However, practically, there are minor lobes, and there is no particular point where all of the waves can be concentrated. To fix this issue, parabolic reflectors can be employed because this is the focal point to which all waves are reflected and is the distance from the vertex on the parabolic shape's axis of symmetry.



The parabolic reflector is certainly not a new invention. Past research has shown us that in 212 B. C., the Greek scientist and mathematician Archimedes created a massive mirror that used the sun to ignite Roman warships during combat. He used the principle of reflections to focus sunlight onto a large number of mirrors onto Roman ships that were attempting to invade Greece.



The first parabolic reflector was invented with an antenna feed at the focal point by Heinrich Hertz, a German physicist who proved the existence of radio waves in 1887. While developing the parabolic antenna, Hertz used a curved surface with a cross - sectional area that is mounted at the mouth of the parabola as the parabolic reflector to direct the radio waves to the receiver in its focal point. Further, it will reflect energy from the reflector in the form of parallel rays that can be focused. The Encyclopedia of Physical Science and Technology (Third Edition) clearly states that the parallel rays will concentrate the energy at the focal point as they enter the receiving antenna. Only a small amount of energy will be received by the reflector from the backward direction. In the transmitting antenna, a beam of rays is formed which is directed towards a distant tangent right after it is concentrated and no energy will be transmitted back from the reflector. Moreover, making the structure mobile improves its quality since the mirror can be moved in accordance with how the energy source is moving. For instance, solar parabolic receptors can be adjusted to match the position of the sun, enabling it to harness maximum solar power.

Further classifying parabolic reflectors into two forms - one being parabolic troughs and the other being parabolic dishes. A cylindrical, two - dimensional parabola is shown in a parabolic trough. The visual representation of such a structure can be a cylinder cut in half lengthwise; viewed from the ends. For solar panels, parabolic troughs are utilized. These panels have a tracking system that adjusts the vertical angle of the trough in accordance with where the sun is in the sky. Some troughs also have water in the center tube that heats up from the sun's rays' focus. Whereas, a parabolic dish is a three - dimensional parabola that is similar to a curved, circular - shaped dish. The incident rays in this case are focused at one central point because of which they are used as antennae. Some examples include satellites and TV antennae. Additionally, the dish is compatible enough to move horizontally and vertically to track the movement of the energy source which aids to maintain a stable focus of energy and can receive the incident rays more precisely and best fit the result.

Modelling

Our model is based on two key parts; the concentrator which is a parabolic reflector and the receiver which is a utensil.

Concentrator Design

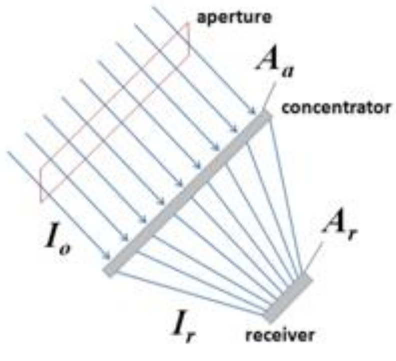
In the design of the concentrator we will be using dish antennas as parabolic reflectors, with a coating of aluminum foil over it, the dish will reflect all of the light rays at a point at a particular distance. While designing the concentrator, we took dish antennae and coated them with aluminum foil because it reflects all of the light due to the shiny surface. We then measured the diameter and depth of the parabolic dish. After that, we placed it on a stand with wheels. We took the stand to a dark room and lit laser lights from different angles. All the light rays incident on the surface of the reflector and reflect to one common point which is known as the ‘focal point’, due to the parabolic depth in the dish. This procedure conforms to the law of reflection principle, which establishes that the angle of incidence equals the angle of reflection. We then measured the distance from the dish where all of the lits were concentrated. As the ray is concentrated on one point, it maximizes the number of light rays meeting at one particular point which then leads to the maximization of heat energy being produced and the temperature reached. The geometric qualities of the paraboloidal shape allow the parabolic reflector to function: any entering ray that is parallel to the axis of the dish will be reflected on the focus. Because many different types of energy can be reflected in this manner, parabolic reflectors can be used to collect and concentrate energy that enters the reflector at a specific angle.

The following quantities that are important and affect the heat energy collected and its efficiency are

1) Focal length
2) The aperture of the parabolic reflector
3) Depth of the parabolic reflector
4) Concentration ratio

Concentration ratio

The concentration is how by which the incident energy flux is optically enhanced on the receiving surface. If we restrict the opening through which the light can enter so that it is more focused, then it is possible to increase the flux.



In our model, the opening is not restricted, which will reduce the amount of flux, and makes sure that all the beams are at the focal point and are concentrated. This will result in a greater concentration reaching the utensil we want to heat, increasing efficiency.

Receiver and transmitter

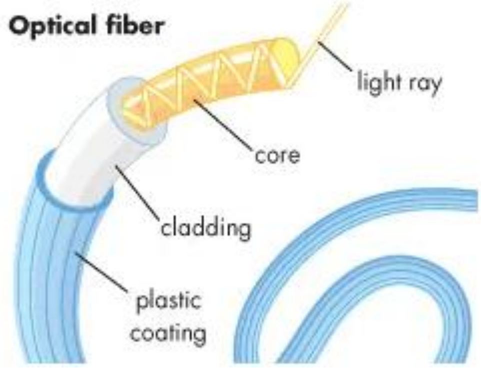
All energy was concentrated at one point but transferring that energy to the kitchen of the house was a difficult task. We first thought of using metal bars but after researching more about it, using metal bars was not efficient, as it radiated a lot of energy which was eventually wasted. This failed the objective of building an effective efficient energy source. Then we came up with the idea of using multiple mirrors to reflect the light on the utensil and eventually heat it. But, the problem with this idea is the danger to the rest of the house which could catch fire if the light is reflected in the wrong direction. This problem would be present throughout as the mirrors will have been tilted and adjusted to match the direction of the sun.

Eventually, we thought of using optical fiber, which would transfer the concentrated light to the cooking top and heat it. This will increase efficiency and safety and make it easier to use for people in rural areas.

At the concentrated point, the optical fiber will be attached which will continue until it reaches the receiver.

Optical fiber

An optical fiber is a thin rod made of a glass core and another glass layer known as cladding and can carry light from one point to the other. Light is transmitted through its properties of total internal reflection. The glass core and the cladding, both have a dissimilar refractive index, causing the light to bend at a certain angle. When light enters through one point, following the law of reflection, it will reflect off of the surfaces of the glass core and the cladding. Since the angle of incidence is greater than the critical angle, no refraction takes place, resulting in total internal reflection, resulting in the light reaching the other point with the same intensity as when it entered. The end of the optical fiber is aimed below the heating plate to cook food, and the light will then heat it. This will then help in the cooking of food through conduction.



3. Data Collection, Data Analysis & Optical Efficiency Testing

Efficiency plays an important role when collecting energy from any source. Parabolic reflectors are devices with one of the efficiency rates. The total efficiency depends on the efficiency of the parabolic dish (we call it a concentrator) and the heat - receiving device (utensil in this particular case).

The table below shows the effect of the diameter of a parabolic concentrator on the concentration ratio -

Diameter of optical fiber - 0.05 cm

S. no.	Diameter of parabolic concentrator (cm)	Depth of the concentrator (cm)	Focal length (cm)	Concentration ratio
1	82	6	70	2690000
2	100	3	208	4000000
3	150	12	100	9000000

This shows how as the diameter and focal length increase, the amount of light concentrated at the focal point also increases, making it more effective and easier to heat an object to cooking food.

Tata sky parabolic reflector	Diameter (m)	Depth (m)	Focal length (m)	Receiver (optical fiber) diameter (m)	Area of aperture (m^2)	Area of the receiver (m^2)	Concentration ratio
	0.6	0.6	0.0375	0.0005	0.2827	1.963E-07	1440000

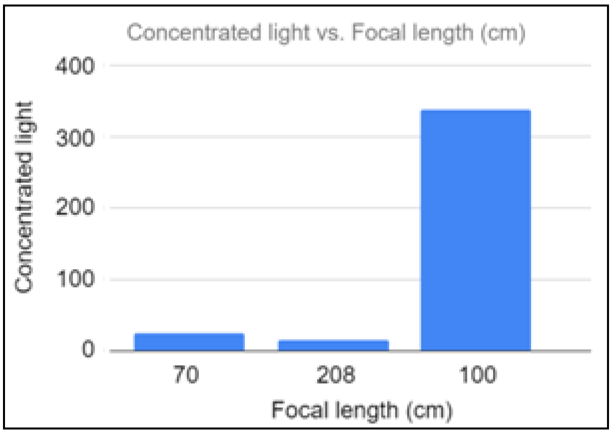
Measurements of a tata sky tv parabolic reflector
Diameter - 60 cm
Depth - 60 cm
Focal length - radius^2/ 4* depth
Focal length = 3.75 cm
Concentration ratio -

$$C_{geo} = \frac{\text{area of the aperture}}{\text{area of the receiver}} = \frac{A_a}{A_r}$$

Receiver - optical fiber
Optical fiber radius - 0.025cm
Concentration ratio=1440000

As the diameter of the parabolic concentrator increases, the concentration ratio also increases. Using a normal tata sky tv parabolic reflector, the concentration ratio is 1440000. A research study posted by the University of Babylon for Engineering used parabolic concentrators with a greater diameter and so the concentration ratio also increases.

A report *by Umer Jamil and Wajahat Ali, dated 31 May 2016*, stated that parabolic reflectors have an efficiency of 78 to 89% which is comparatively higher than other sources of energy. According to a more recent investigation, a cavity - type receiver with a 500 mm diameter aperture received 95% of the insolation reflected from a 500 m2 dish (mirror reflectivity of 93.5%). The aperture size of a cavity - type receiver is directly impacted by improved optics with high concentration ratios. Thermal losses would be reduced by 21% with a 540 mm aperture size reduction. Based on test findings utilizing a 500 m2 dish, direct steam generation with a parabolic dish and cavity - type receiver has been reported to achieve 90% thermal efficiency at 535 °C.



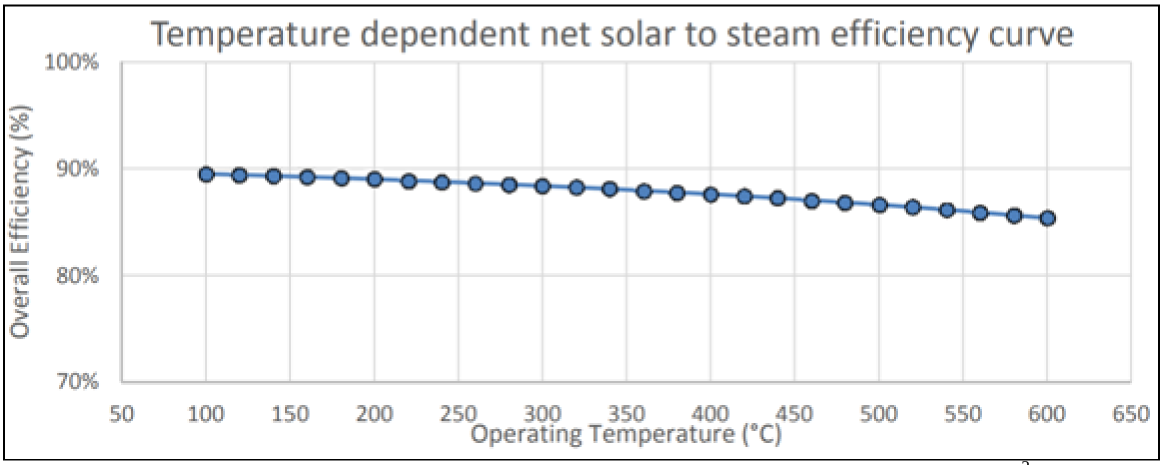


Figure 7: Net sun to steam efficiency of Solar Invictus established at DNI 850W/m^2

Parabolic Reflector Advantages and Disadvantages

The use of a parabolic reflector reduces minor lobes i. e. the minor part of the reflected field which in turn reduces the amount of power wastage, making it more effective than other antennas.

Advantages

- Minor lobes are reduced when parabolic reflectors are utilized
- It has a high gain and a high degree of directivity
- The amount of power wasted is comparatively less than that of other antennas.
- It permits greater flexibility in positioning the feed element.
- The use of parabolic reflectors facilitates beam adjustment.
- Can reach very temperatures in a very small amount of time.
- Affordable as it has a one - time cost to set up.

Disadvantages

- The orientation is large.
- A small element of paraboloid causes a minimal amount of power obstruction.
- The waves coming out from the parabola towards the primary antenna causes interaction and mismatching.
- The presence of a primary element in the path of radiation causes blockage in the central part of the aperture, thus supporting more minor lobes.

Limitations

- Energy can only be generated when there is sunlight.
- There should be a place to set up where there is no obstruction for the light rays to fall on the reflector.

Safety Precautions

- Light rays getting concentrated at one point cause a lot of heat energy, so everyone should maintain a distance from the model and should come close only if they have an adequate costume.
- Make sure to keep the optical fiber at accurate angles to reflect the concentration of heat accurately and not move the optical fiber from the focal point as it may cause a fire in the surroundings.

4. Future Improvements

Currently, we are making use of an aluminum coating over the glass parabolic reflector

The experiment is most efficient and cost - effective when the parabolic reflector is covered by strips of nickel sheet metal and the receiver object is made of the radiator heat exchanger.

5. Conclusion

Using parabolic reflectors will help us collect energy and use it for cooking purposes etc in rural areas where other forms of energy and LPG cylinders are unable to reach. This will lead to low one - time costs and close to no maintenance costs with high efficiency with only about 10 - 15% of energy getting wasted. From the data we have collected, it is observed that the bigger the concentrator is, the more energy can be generated as more light rays are concentrated at the point of optical fiber. With the concentrator - the dish antennas, we can generate more than enough energy used to cook food as temperatures like 300 degrees Celcius can be reached within a few seconds. This helps heat the cooking top quickly and will help achieve efficiency in the process.

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