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# The Impact of Solar Azimuth Angle Variations on Flux Distribution Across the Receiver Area

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## Abstract

Obviously, a huge portion of the most significant challenges facing the world today is reducing dependence on fossil fuels and advancing the development of new and renewable energy sources that can supplement and, where applicable, replace the dwindling fossil fuel reserves. Solar energy stands out as a particularly promising solution to these issues, as it is renewable, non-polluting, and universally available, albeit with varying levels of intensity. Ray tracing is a crucial tool for designing receiver systems in elliptical-hyperboloid concentrators (EHC). Information about flux distribution and ray tracing on the EHC receiver is crucial for determining the receiver's size using OptisTM Ray-trace software. This study examines the effects of changes in the sun azimuth angle on the EHC receiver's flux distribution. Obviously, the solar energy source is traveled via the primary axis of the aperture's x-y plane, ranging between 0° and 90° in 15° increments. A maximum optical efficiency is noted for every azimuth angle, which rises since the solar source is shifted between 0° to 90°. The findings also show how concentrated radiant energy is distributed throughout the receiver/absorber region that can supplement and, where applicable, replace the dwindling fossil fuel reserves. Solar energy stands out as a particularly promising solution to these issues, as it is renewable, non-polluting, and universally available, albeit with varying levels of intensity. Ray tracing is a crucial tool for designing receiver systems in elliptical-hyperboloid concentrators (EHC). Information about flux distribution and ray tracing on the EHC receiver is crucial for determining the receiver's size using OptisTM Ray-trace software. This study examines the effects of changes in the sun azimuth angle on the EHC receiver's flux distribution. Obviously, the solar energy source is traveled via the primary axis of the aperture's x-y plane, ranging between 0° and 90° in 15° increments. A maximum optical efficiency is noted for every azimuth angle, which rises since the solar source is shifted between 0° to 90°. The findings also show how concentrated radiant energy is distributed throughout the receiver/absorber region.

**Keywords:** *Azimuth angle, flux distribution., ray tracing, optical efficiency.*

# 1. Introduction

Numerous studies on optimizing tilt angles have examined various factors, including cloudiness [1], effects of wind speed cooling [2], make best use of radiation on flat-plate collectors [3], and the method of optimizing the clearness index [4]. Additionally, research has explored radiation transfer methods [5] and the maximization of sun radiation over different topographical regions [6, 7]. The mentioned approaches have been utilized to create relevant maps for determining the optimum azimuth angles and tilt for the photovoltaic (PV) installations, enhancing the yearly energy production of PV systems, and analyzing azimuth angles' effects on energy generation at two different PV sites. The analyses employed cumulative density function modeling techniques and normal distribution functions [8].Further research has demonstrated the performance of photovoltaic systems in achieving maximum power efficiency across various azimuth angles and tilt positions [9], illustrating how power generation is influenced by changes in azimuth angle and how solar irradiation varies over time. The impact of azimuth angle on building-integrated photovoltaic (BIPV) applications, particularly concerning temperature effects, has also been highlighted [10]. One critical parameter affecting the solar collector's performance is the angle and tilt of solar azimuth, which influences the distribution of flux on the receiving area. Variations in the solar azimuth angle affect the quantity of solar radiation reaches the surface of the receiver. Analysis was done on the flux distribution on the receiver area for various incidence angles using OptisTM ray tracing [11]. As the incidence angle rises, the area averaged flux and peak magnitude drop.

In this paper, we examine the distribution of flux on the Elliptical-Hyperboloid Concentrators (EHC) receiver area, focusing on how variations in solar azimuth affect the intensity of solar radiation reaching the receiver surface. The goal is to find out the optimal orientation and tilt angle (surface azimuth angle) for solar collectors at any latitude. To achieve this, we utilized the OptisTM ray-tracing software to assess maximum optical efficiency. This was analyzed via alterating the solar energy source through the aperture's major axis (x-y plane) between 0° and 90°. The results indicate that the maximum optical efficiency gradually inclines as the solar source is transitioned between 0° and 90°.

# 2. Optical Study of Elliptical Hyperboloid Concentrator

## 2.1. Ray Tracing of Elliptical-Hyperboloid Concentrators at Various Incidence Angles

The source of the rays was modeled to mimic the sun's path throughout a normal daily cycle. Utilizing the method of ray tracing outlined in [11], we obtained the following findings represent the 3-D EHC. As it is shown in figure 1, the diagram illustrates various incident angles of the ray tracing:

0°, 15°, 30°, and 60°. From these preliminary models, It is obvious that as the source of radiation is straightly overhead (θ = 0°), the greatest amount of rays that reach the receiver. As the incidence angle rises, the rays number presenting on the receiver drops, with no rays being absorbed while the angle of incident is ±60°.

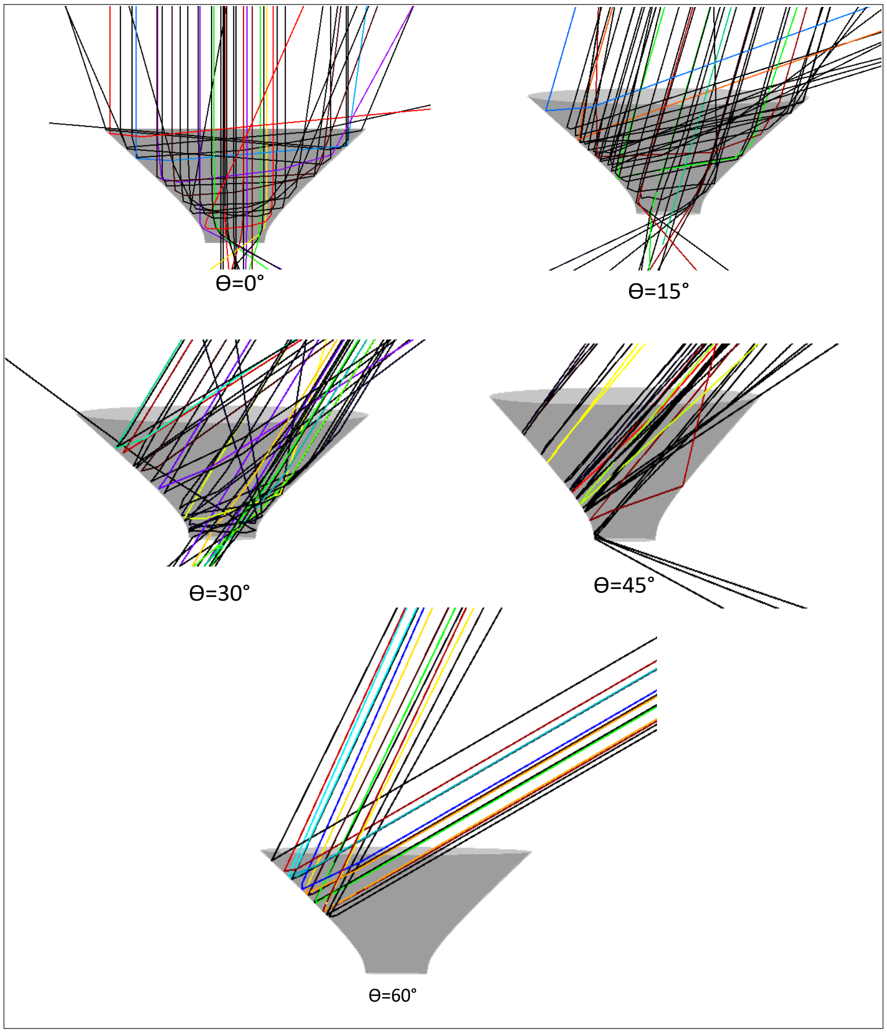


*Figure 1: Ray Tracing of Elliptical-Hyperboloid Concentrators at Various Incidence Angles (0°, 15°, 30°, 45°, and 60°)*

## 2.2. Impact of Changes in the Solar Azimuth Angle

Model of ray tracing using to examined how variations in the angle of solar azimuth (Ψ) affect the the EHC optical efficiency. The angle of solar azimuth represents the sun from true south angular deviation [6]. As solar source shifted through the the major axis aperture plane xy, varying the angle between 0° to 90° in 5° increments. For each interval, the angle of solar incidence was adjusted between 0° to 60°. Figure 2 illustrates the orientation used for this particular simulation work, which includes variations in the major axis aperture.

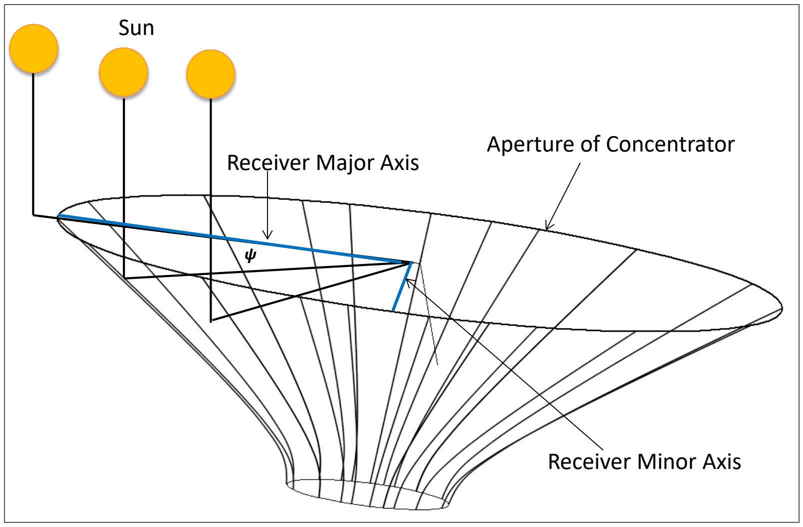


*Figure 2: Elliptical-Hyperboloid Concentrators with Changes in Major Axis Aperture.*

Then, we investigated the impact of varying the angle of solar azimuth on the efficiency of optical. Figure 3 illustrates the relationship between azimuth angle, incidence angle, and optical efficiency. As the angle of solar azimuth rised between 0° to 90° with the solar source moving between south and north—the accepted angle rised from around 30° in the south to lower than 5° when it approached the north. For each variation in azimuth angle, we observed a single peak in optical efficiency. However, this maximum efficiency diminished as the solar source was shifted from 0° to 90°.

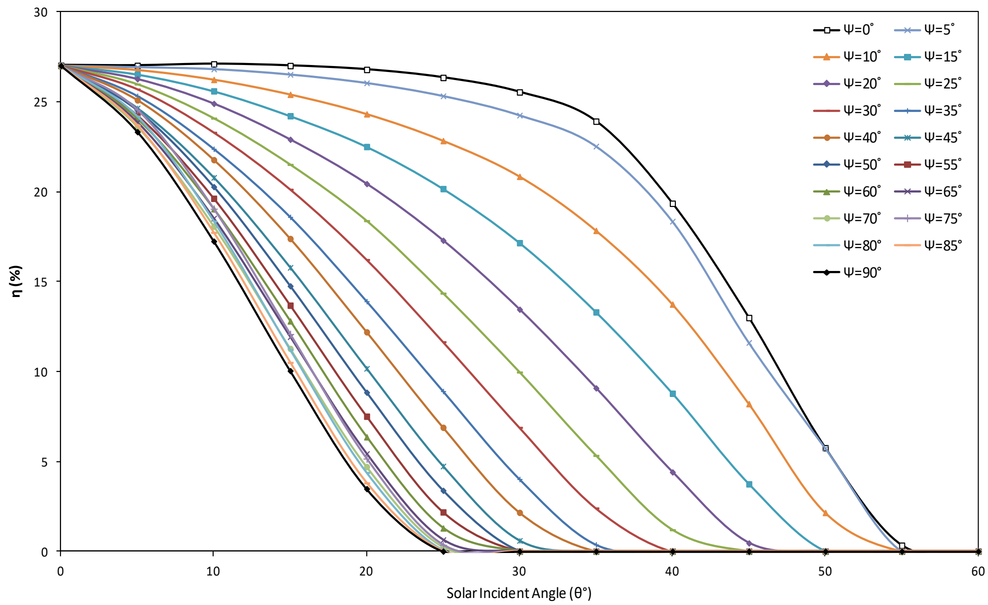


*Figure 3: Optical Efficiency Variation with Azimuth and Incidence Angles*

### 2.3. Flux Distribution on the Receiver Area for Various Azimuth Angles

Applying a 3-D ray tracing work simulation, we examined how variations in the angle of solar azimuth affect the distribution of flux on the receiving spot of the EHC. The source of solar was moved via the major axis aperture x-y plane between 0° and 90° in 15° increments. The results are presented in Figures 4 to 6. And from Figures 4 and 5, we observed that at solar azimuth angles 0° to 15°, this shows uniformly distribution of the flux across the receiver for angles of solar incidence ranging from 0° to 30°. However, at a 45° incidence angle, the flux distribution becomes non-uniform and is concentrated at one end of the receiver, resulting in higher flux values in that area. Similarly, Figures 6 and 7 show that at solar azimuth angles between 30° - 45°, the flux is evenly extent across the incidence angles receiver between 0° and 15°. However, at a 30° incidence angle, most of the measured flux is concentrated on one side of the receiver, with no radiation detected at angles above 30°. A similar pattern is observed for solar azimuth angles of 75° - 90°, as depicted in Figures 8 and 9. Additionally, the deviation in the distribution of the flux through both the minor and major axes of the receiver is illustrated in Figures 10 to 15.

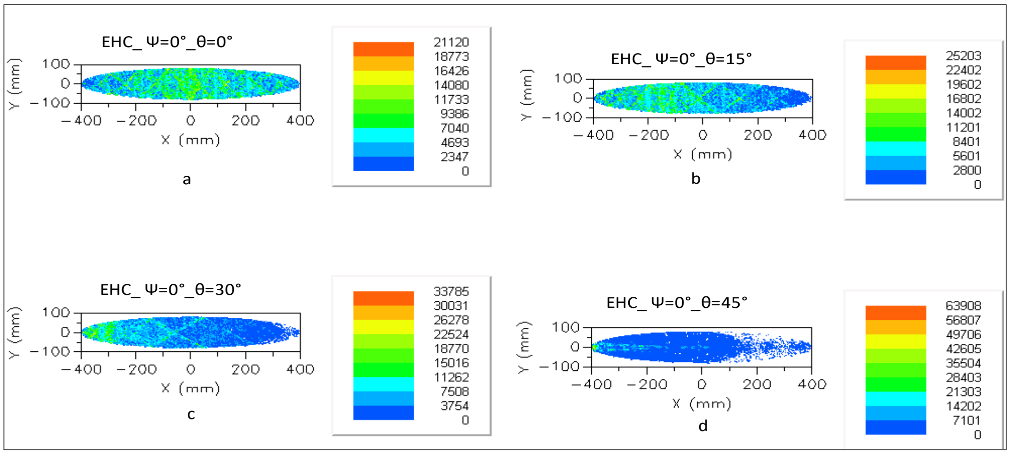


*Figure 4: Distributed Flux at a Solar Azimuth Angle of 0° with Incidence Variations from 0° to 45°*

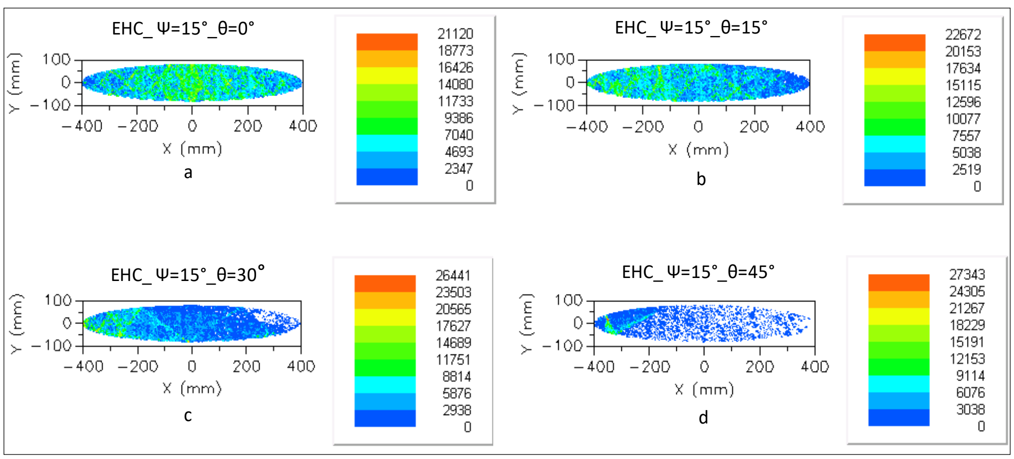


*Figure 5: Distributed Flux at a Plane Angle of 15° with Incidence Variation from 0° to 45*

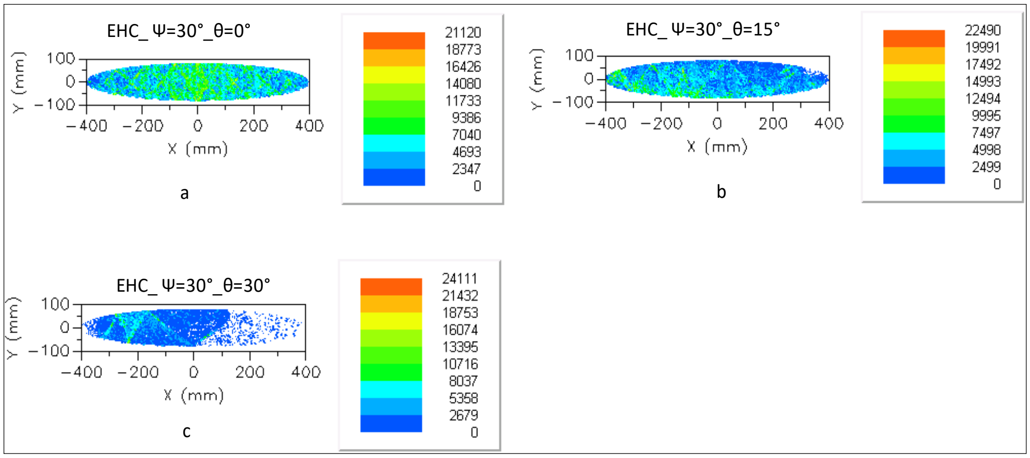


*Figure 6: Distributions of the Flux at a Solar Azimuth Angle of 30° with Incidence Variations from 0° to 30°*

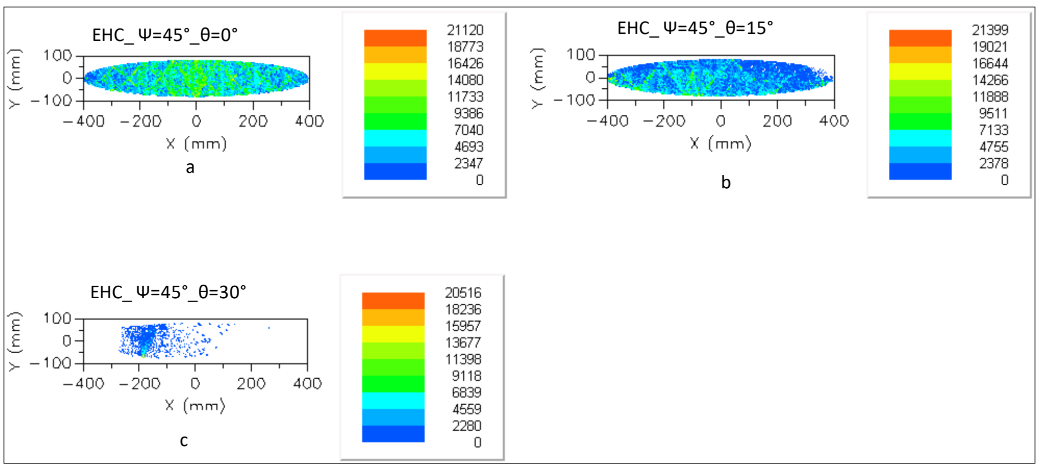


*Figure 7: Distribution of the Flux at a 45° Angle with Incidence Variations from 0° to 30°*

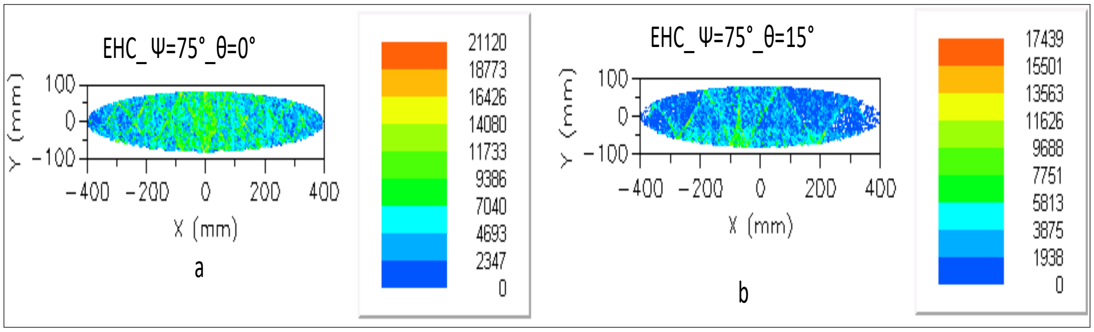


*Figure.8: Flux Distributions on Plane Angle is 75° and Incidence Variation for 0° -15°*

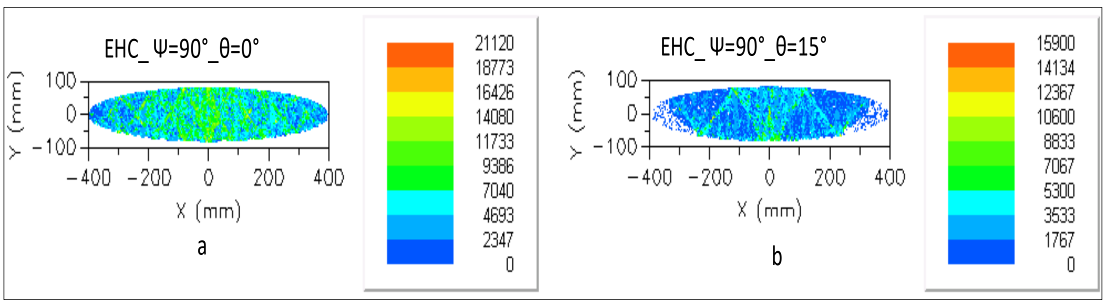


*Figure 9: Flux Distributions at a 90° Plane Angle with Incidence Variations from 0° to 15°*

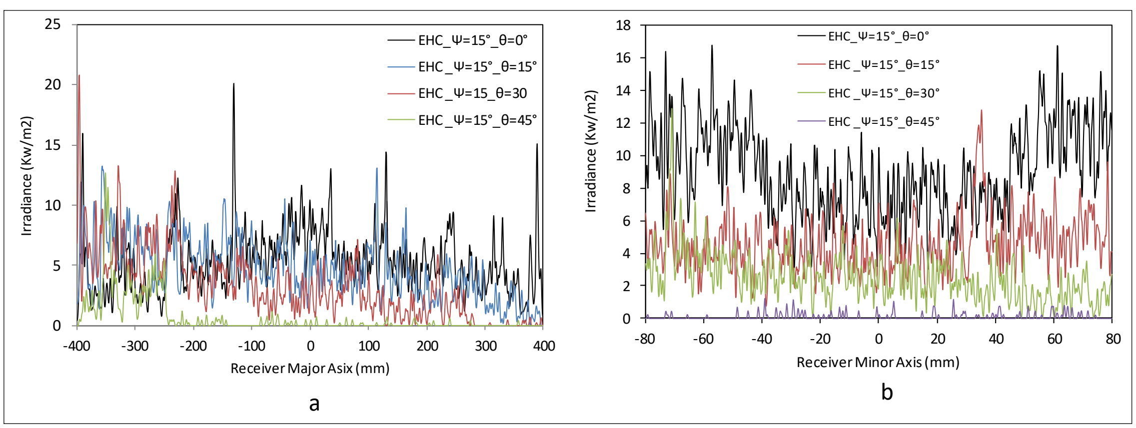


*Figure 10: Flux Distributions along the Center Line of (a) the Major Axis and (b) the Minor Axis for Various Plans (ψ = 15°) and Different Incidence Angles.*

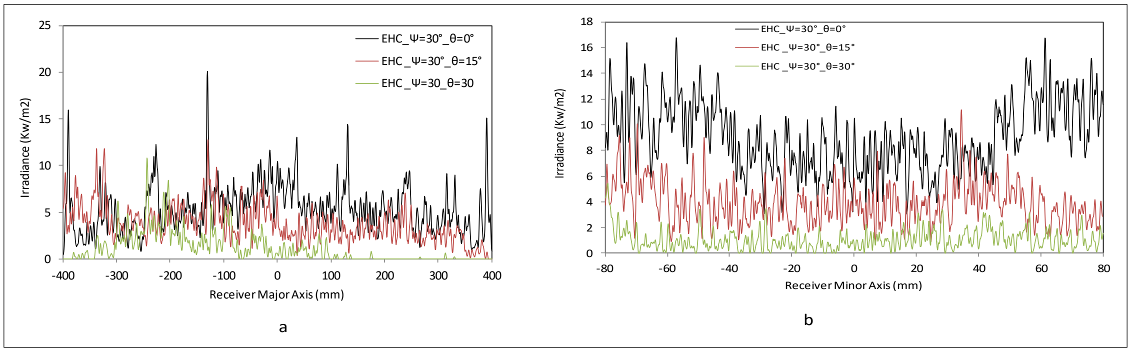


*Figure 11: Flux Distributions along the Center Line of (a) the Major Axis and (b) the Minor Axis for Various Plans (ψ = 30°) for Different Incidence Angles.*

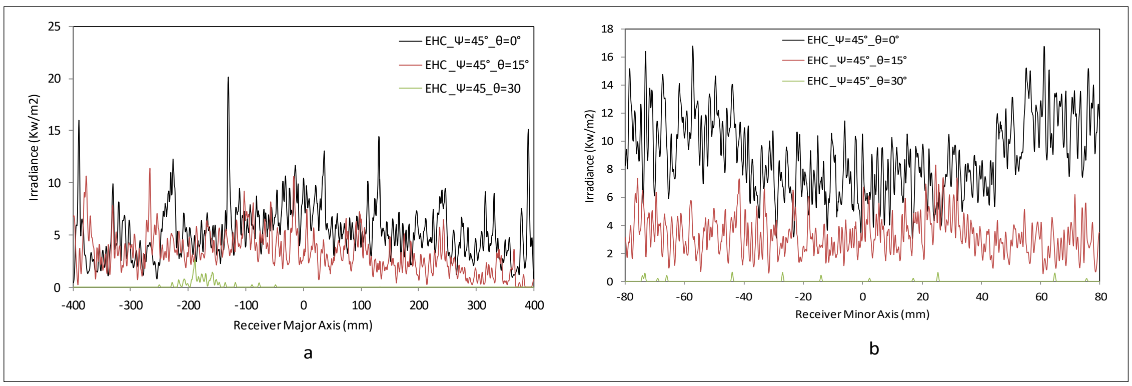


*Figure 12: Flux Distributions along the Center Line of (a) the Major Axis and (b) the Minor Axis for Various Plans (ψ = 45°) for Different Incidence Angles.*

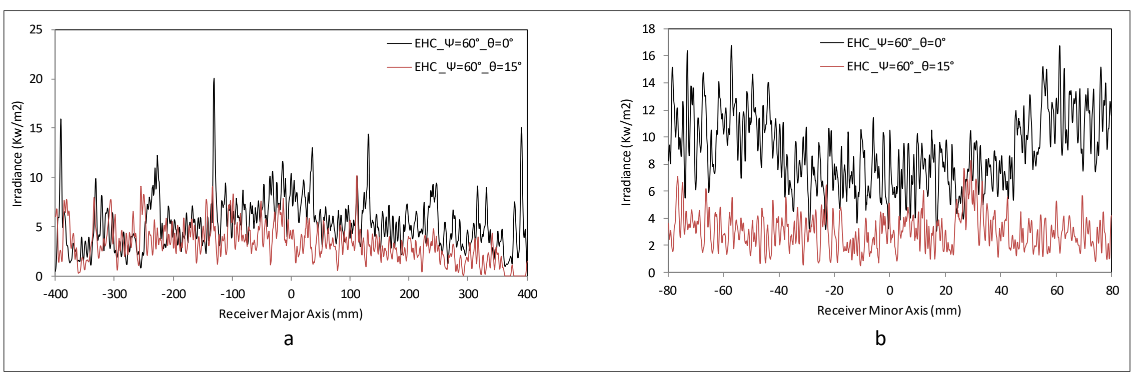


*Figure13: Flux Distributions along the Center Line of (a) the Major Axis and (b) the Minor Axis for Various Plans (ψ = 60°) for Different Incidence Angles.*

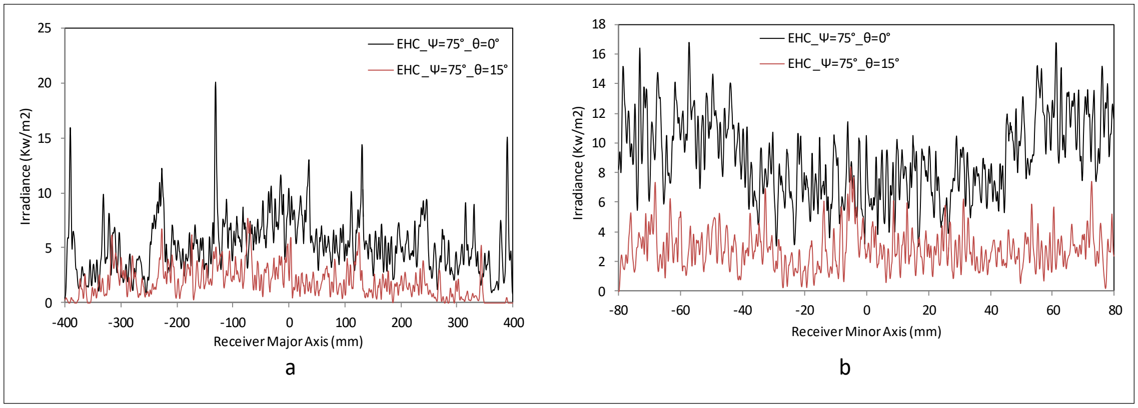


*Figure14 : Flux Distributions along the Center Line of (a) the Major Axis and (b) the Minor Axis for Various Plans ($\psi$ = 75°) for Different Incidence Angles.*

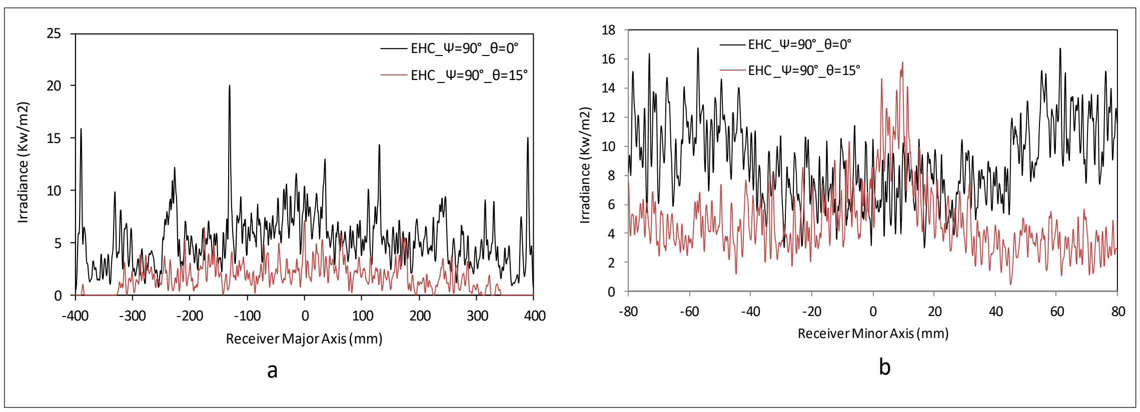


*Figure15: Flux Distributions along the Center Line of (a) the Major Axis and (b) the Minor Axis for Various Plans ($\psi$ = 90°) for Different Incidence Angles.*

## 3. Conclusion

*The present study provides clear and promising results regarding the Elliptical Hyperboloid Concentrator (EHC) optical performance through ray tracing analysis conducted at various incidence angles and orientations. Specifically, the investigation focused on the impact angle of solar azimuth variations on the distributed flux within the EHC's receiving area. This was accomplished by repositioning the solar energy source through the aperture's x-y plane of major axis between 0° - 90°, with increments at 15°. The findings indicate a reduction in the solar source's maximum optical efficiency at each angle is transitioned from 0° to 90°. Additionally, the 3-D tracing work simulations further elucidate the consequence of the angle variations of the basic solar azimuth follows the flux distribution within the receiver area of the EHC. Notably, at a 45° incidence angle,* *the flux distribution was observed to be non-uniform, exhibiting a scattered pattern across the receiver. However, concentrated flux values were recorded at one end of the receiver, where intensity was significantly higher.*

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