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# P2_6 The Power of Moonlight

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**Abstract**

In this paper we investigate the concept of using the Moon as an energy producing Mega-structure, by covering its surface in solar panels. We find that the energy yield, in 28 days, from using modern-day solar panels is 5.327x10$^{16}$ $J$ and that 815 identical structures would be required to meet the global energy usage of 2016 (5.656x 10$^{20}J$).

## Introduction

The Kardashev scale measures a civilizations technological advancement by how much energy it can harness. According to this scale, a Type I civilization is able to use and store all the solar energy, that reaches its planet from its parent star [1]. A civilization constructing a Mega-structure such as Dyson sphere to collect energy is a common trope in science fiction. In this paper we investigate the concept of converting the Moon into an energy producing Mega-structure, by covering its entire surface in modern-day solar panels. By estimating the total power reaching its surface due to incident solar flux over the period of one lunar orbit (28 days), we then calculate how much energy can be collected.

## Theory

The amount of power radiated from the Sun, $P_s$, is dependent on its surface temperature, $T_s$, such that:

$$P_s = 4\pi\sigma R_s^2 T_s^4, \tag{1}$$

where $\sigma$ is the Stefan-Boltzmann constant and $R_s$ is the Sun's radius. We assume that this power is radiated uniformly away from the Sun in all directions. The flux at the moon surface, $W_m$, can be found by dividing the Sun's output power, $P_s$, by the surface area of a hypothetical sphere at a radius equal to the Sun - Moon separation, $R_{SM}$.

$$W_m = \frac{P_s}{4\pi R_{SM}^2}, \tag{2}$$

Given the fact that the Moon is in an approximate 28 day orbit around the Earth which simultaneously orbits around the Sun with a period of around 365 days, the separation of the Sun and Moon and thus the insolation varies with time. For simplicity we model the orbits of the Moon around the Earth and the Earth around the Sun to have an eccentricity of 0 (circular orbit). This allows the Sun-Moon distance, $R_{SM}$, to be found using the cosine rule:

$$R_{SM}^2 = R_{SE}^2 + R_{EM}^2 - 2R_{SE}R_{EM}\cos\omega T, \tag{3}$$

Where $R_{SE}$ is the Sun-Earth separation, $R_{EM}$ is the Earth-Moon separation, $T$ is the orbital period of the moon and $\omega$ is the rate at which the angle extended by $R_{SE}$ and $R_{EM}$ changes during an orbit. As the Moon completes an entire circular orbit around the Earth it sweeps through an angle of $0^o$ to $360^o$ , in 28 days giving an angular frequency, $\omega$, of $12.857^o day^{-1}$ . Finally, the total power reaching the surface of the moon, $P_m$ is given by the product of the moons insolation and cross-sectional area;

$$P_m = W_m \pi R_m^2, \quad (4)$$

Where $R_m$ is the radius of the Moon.

## Results & Discussion

By combining the equations stated in the theory we were able to express the power reaching the Moons surface, $P_m$, in terms of the orbital period, $T$. We plotted the power receipt over a complete orbit and estimated that the total energy, using R to perform trapezium rule integration, which would be received to be $3.551\text{x}10^{17}$ $J$. The Sun has a surface temperature of 5772 $K$, a

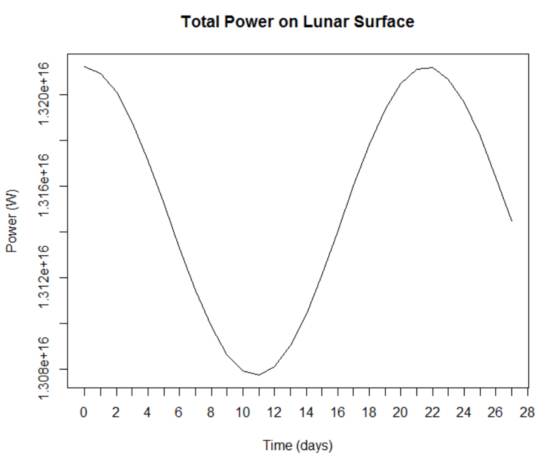


Figure 1: Plot showing the power receipt on the lunar surface over a full orbit

radius of 695700 $km$ and seperation of $1.496\text{x}10^{11}$ $m$ from Earth [2]. The Moon has a radius of 1737 $km$, and its average distance from the Earth was used; 384400 $km$ [3]. We considered the orbits of the Moon and Earth to be circular, as the Earth's eccentricity cycle and the nodal precession of the Moon would have deeply complicated the calculation of energy receipt on the Lunar surface. The ISS's solar panels, were industry leading standard when it was launched and have an efficiency of around 15% when used in space [4]. Assuming the same solar panels are used to cover the Moons surface then the total energy yield in a single orbit would be $5.327\text{x}10^{16}$ $J$. Giving an annual yield of $6.944\text{x}10^{17}J$, assuming the solar output was constant. The total global energy usage in 2016 was 5.656x $10^{20}J$ [5]. In order to achieve this, you would need around 815 Moon sized energy producing Mega-structures in orbit around the Earth which would prove disastrous for civilization for several reasons such as the gravitational effects on the ocean. A larger energy yield could be achieved by using more efficient solar panels.

## Conclusion

With the technology that would be required to create the energy platform, the solar panels used would probably be more advanced and thus yield more energy. Although the advanced technology and techniques required would most likely use more energy. It is unlikely that such a concept will ever become reality due restraints presented by our current technology for example there is currently no feasible way of transporting the generated energy back to Earth.

## References


[1] `https://en.wikipedia.org/wiki/Kardashev_scale` [Date Accessed 31st October 2017]

[2] `https://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html` [Date Accessed 31st October 2017]

[3] `https://en.wikipedia.org/wiki/Moon` [Date Accessed 31st October 2017]

[4] `https://blog.urthecast.com/company/international-space-stations-solar-panels-have-a-no-fail-mission/` [Date Accessed 31st October 2017]

[5] `https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html` [Date Accessed 31st October 2017]