ChatGPT

Analysis of *“Space Solar Power: Marketing Versus Math”* on ChicagoSpace.org

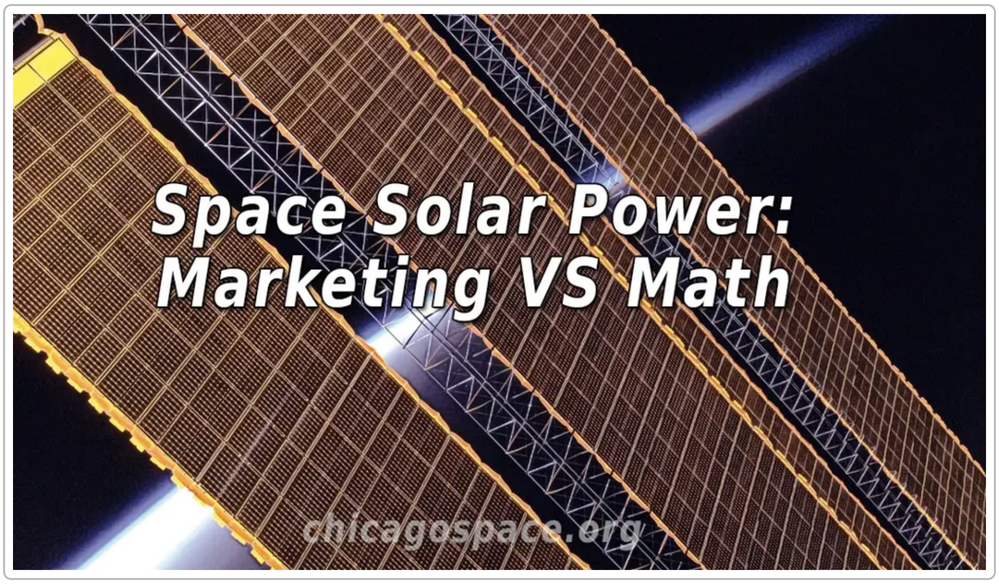

Figure: Conceptual illustration of a space-based solar power array (Chicago Society for Space Studies cover image).

Energy Content of Global Oil Production (2023)

The article begins by estimating the total energy in **all oil produced worldwide in 2023**, using 4.5 billion metric tons as the annual production figure [1]. It cites an energy content of *approximately 42 gigajoules per metric ton of oil*, which is equivalent to **11.63 megawatt-hours (MWh) per ton** [1]. Multiplying 4.5 billion tons by 11.63 MWh/ton yields about **52.3 billion MWh** of energy [2]. We verified these figures against external data:

- **Global oil production in 2023:** ~4.5 billion metric tons (consistent with ~81.8 million barrels per day) [3]. This is the highest annual production on record, as noted by multiple sources [3]. There is no unit conversion error here – 4.5 billion metric tons is a straightforward summation of oil output for the year.

- **Energy per ton of oil:** 1 metric ton of crude oil contains roughly 42 GJ of energy, which indeed converts to about **11.63 MWh** [4]. This is a standard value (1 tonne of oil equivalent is defined as 41.868 GJ or 11,630 kWh) and the article’s use of 11.63 MWh/ton is correct [5]. The multiplication is also correct: 4.5×10^9 tons × 11.63 MWh/ton ≈ 52.3×10^9 MWh.

Finding: The calculation for the *annual oil energy* (52.3 billion MWh) is **internally consistent and factually accurate**. There are no math errors in this step. (For perspective, 52.3 billion MWh is the chemical energy content of 2023's oil production. This is an enormous quantity – about 5.97 terawatts of continuous power over the year.) The author uses this 52.3 billion MWh figure as the target annual energy output that a space-solar array would need to match.

However, it's worth noting a key assumption: The original claim by the Chinese scientist Long Lehao said the space array's yearly energy would equal "**the total amount of oil that can be extracted from the Earth**" [6]. That phrasing implies **all proven oil reserves**, not just one year of production. Proven global oil reserves are on the order of 1.65 trillion barrels (as of late 2010s), equivalent to about 46 times the world's annual consumption or production [7]. By focusing on a single year's production, the article **deliberately takes a conservative scenario**, effectively *ignoring the multi-year claim* for the sake of a more tractable calculation [8]. This isn't a mathematical error but an important interpretation: if "all the oil on Earth" were taken literally, the energy target would be **tens of times larger** (on the order of ~2.4 trillion MWh total), and the required solar array would be proportionally larger. The author explicitly notes this choice, so it's a reasonable simplification for analysis – but the reader should recognize that the Chinese claim, if taken at face value, was even more outlandish than the scenario analyzed.

Solar Constant and Annual Solar Energy per Square Meter

Next, the article determines how much solar energy a panel in space could receive per unit area, as a basis for sizing the array. It uses the **total solar irradiance (TSI)** at Earth's distance (the *solar constant*) of **≈1,361 watts per square meter (W/m²)** [9]. This value is correct according to scientific standards – the solar constant is about 1361 W/m² on average at 1 AU from the Sun [10]. No issues here: the article's figure is in line with the accepted value (NASA and recent literature put it in the 1360–1362 W/m² range [11]).

To convert this *power density* into an *annual energy* figure, the article multiplies by the number of hours in a year. It uses 24 hours × 365.25 days (accounting for leap year) = 8,766 hours [12]. Multiplying 1,361 W/m² by 8,766 h yields about **11,930,526 Wh/m²**, which is **≈11.93 MWh per square meter per year** [13]. The article explicitly shows this calculation, dividing by 1,000,000 to convert Wh to MWh [13]. We double-checked the math:

- 1,361 W/m² × 8,766 h = 11,930,526 Wh/m² = 11.93 MWh/m².

This is **correct**. There are no unit conversion mistakes – the conversion from watts (a rate) to watt-hours (an accumulated energy) is done properly by multiplying by time.

Importantly, this figure (11.93 MWh per m² per year) assumes continuous full exposure to sunlight. In *space-based* solar power, a satellite in geostationary orbit does receive nearly continuous sunlight, but not absolutely 100%. The article assumes 24/7 illumination for simplicity, which is **almost** true in GEO: only during around eclipse season (around the equinoxes) will a GEO satellite pass through Earth's shadow for at most ~70 minutes per day, and only for a few weeks [14]. This amounts to roughly ~0.7% downtime over a year [14], meaning the actual annual energy per m² would be slightly lower (on the order of 11.85 MWh/m² instead of 11.93 MWh/m²). The omission of this small reduction does **not** significantly undermine the analysis – it's a minor simplification. In other words, the article's use of 8,766 hours/year instead of ~8,705 effective sunlit hours/year in GEO is a negligible difference (well within 1% error). For a conservative (best-case) estimate of required array size, assuming full illumination is fine and *not a mathematical mistake*.

Finding: The conversion from solar constant to yearly energy per square meter is executed correctly. The article's figure of ~11.93 MWh/m²-year is accurate [15], given ideal conditions. No faulty reasoning is present here; the step is valid and uses consistent units. (We simply note that real-world orbital mechanics impose ~99.3% sun availability [14], but this would only make the required array *larger*, reinforcing the article's point if accounted for.)

Photovoltaic Efficiency Assumption and Captured Energy

The article then asks: how much of that 11.93 MWh/m²-year can actually be *converted into electricity* by a solar panel? This is where **photovoltaic (PV) efficiency** comes in. The author provides a table of typical efficiencies for various solar cell technologies – from ~15–23% for common silicon cells up to ~28–34% for triple-junction gallium arsenide cells, and even ~40–47% for lab-scale multijunction cells [16] [17]. He chooses a **34% efficiency** assumption for the space-grade triple-junction GaAs cells, which is at the high end of the range but plausible for state-of-the-art space PV. (For context, triple-junction space solar cells have demonstrated ~30%+ in production, and even ~34% under the AM0 spectrum in research settings [18]. In fact, Fraunhofer ISE achieved a *record* 34.1% efficiency with an advanced triple-junction cell in 2019 [19]. So 34% is an optimistic but not impossible efficiency for a cutting-edge array.)

Using 34% efficiency, the article multiplies the 11.93 MWh/m² by 0.34. This yields about **4.05 MWh of electrical energy per square meter per year** [20]. In the article's words:

> *"11,930,526 Wh/m² * 0.34 = 4,056,378 Wh/m², which is 4.05 MWh per square meter."* [20]

We verified this calculation: 11.930526 MWh × 0.34 = 4.0563788 MWh, which the article rounds to 4.05 MWh. **No error here.** The arithmetic and unit conversion (they divide by 1,000,000 again to express in MWh) are consistent [20].

Finding: The claim that each square meter of an ideal space solar array (with 34% efficient PV, facing the sun constantly) could generate ~4.05 MWh per year is **correct given the assumptions**. The only caveat is the choice of efficiency: 34% represents the upper end of current technology. If slightly lower efficiencies were used (say 30%), the required area would be correspondingly larger. But the article explicitly chooses a high efficiency to **favor the space solar concept** (making the smallest array possible) [21]. This is a fair approach to avoid exaggerating the needed size. There is no *faulty math* here – the logic is sound. The efficiency assumption is optimistic but not mathematically flawed.

(Side note: The analysis implicitly assumes the panels are perfectly oriented ("perpendicular to the Sun") at all times [22] and that the stated efficiency is maintained. In reality, maintaining optimal orientation is feasible with tracking, and 34% efficiency would likely be the peak beginning-of-life efficiency. Degradation over time or downtime for maintenance are not considered, but those would again only increase the required array area. The article's goal is to show even under favorable *assumptions, the required size is enormous. So these omissions are by design, not mistakes.)*

Calculating the Required Solar Array Area

Having established two key figures – **52.3 billion MWh/year needed** (the oil energy target) and **4.05 MWh/year per m²** (the energy each square meter of array can supply) – the article computes the total area of solar panels required. The calculation given is:

- *52.335 billion MWh per year ÷ 4.05 MWh per m² per year = 12,901,901,440 m²* of solar panels [23].

Let's break that down:

Dividing 5.2335×10^10 MWh by 4.05 MWh/m² indeed gives ~1.29019×10^10 m². We can confirm this division:

[1.29019\times10^{10}\ \text{m}^2 = 12.9019\times10^9 \text{m}^2,]

which the article expresses as **12,901,901,440 m²** (rounding to the nearest whole number of square meters) [24]. This is absolutely correct arithmetic. Converting that area into more familiar units:

- In scientific notation, ~1.29×10^10 m².
- In square kilometers, divide by 1e6: that's **≈12,902 km²** of solar panels.

There is no calculation error here – the result is consistent. The article then provides a vivid way to imagine this vast area: it says, given the Chinese proposal envisioned an array **1 km wide**, we could make it 1 km wide and compute the necessary length. Taking 12,901,901,440 m² and dividing by 1,000 m (for a 1 km width) gives **12,901,901 m** in length [25]. That's about **12,901.9 kilometers long**. The article rounds this to "**1 km wide by 12,901 km long**" [26]. This is effectively the same as saying ~12,902 km² area, but framed as an extreme rectangle stretching one-quarter of the way around Earth. For perspective, 12,902 km is **almost the diameter of Earth** (Earth's equatorial diameter is ~12,742 km) [27]. And 12,902 km² is an area comparable to the size of **Connecticut plus Delaware combined** (or about 1.2 times the area of Jamaica) – truly gargantuan for a single solar installation.

Finding: The area calculation is **mathematically correct** and follows logically from the earlier numbers. No quantitative mistakes are present. The result underscores the article's thesis that the Chinese claim is fantastical. If anything, this **12,900 km × 1 km** conceptual array is understated, because as mentioned earlier, the article used optimistic assumptions (continuous sunlight, high efficiency, one-year oil output). The clear implication is that a real system would need to be even larger if we relax those ideal assumptions. But strictly speaking, the claim "~1×12,901 km array needed to equal a year of oil energy" is **valid given the stated premises**.

To double-check internal consistency: we can work backwards. 1 km × 12,901 km of panels at 34% efficiency would generate ~52.3 billion MWh/year under ideal illumination. If we imagine that array as delivering power continuously, it would equate to a continuous output of about 5.97 terawatts (since 52.3e9 MWh/year ÷ 8766 h/year ≈ 5.97×10^12 W). By comparison, the world's **total** average power consumption (all energy forms) is on the order of 18 TW, and just oil's share of that is a significant fraction. So 5.97 TW beamed from one colossal structure is an almost unthinkable figure – which is exactly the article's point. The math holds up: no unit errors (area was correctly handled, and converting meters to kilometers was done by dividing by 1,000). The article even shows that step explicitly [28] [26].

One might wonder if the Chinese proposal literally meant a 1-km wide *ring* around Earth's geostationary orbit. Long Lehao's comment *"imagine installing a solar array 1 km wide along the 36,000 km geostationary orbit"* [29] suggests they envisioned a belt of panels. A 36,000 km-long, 1 km-wide belt would be 36,000 km^2 in area – nearly three times larger than the 12,900 km^2 we calculated. That full ring would far exceed even the one-year oil equivalence (and approach a significant fraction of all reserves' energy). It's unclear if the Chinese concept was actually to build a continuous ring or just an evocative image of scale. Regardless, the ChicagoSpace analysis took the *less extreme* case (12,900 km length) needed for the stated energy, which is already *astronomically large*. There is **no flaw in the unit conversion or arithmetic** in deriving the array dimensions.

Other Assumptions and Potential Omissions

Overall, the article's quantitative reasoning is **sound** – each step uses correct data and formulas. We did not find arithmetic errors or unit conversion mistakes. The conclusions drawn are supported by the math. However, to be **comprehensive**, it's important to highlight a few assumptions and factors the article simplified, as these could be seen as *limitations* (though not "errors" per se). Each of these would make the space solar power concept even more difficult to achieve:

- **No Transmission Losses Considered:** The article calculates the area needed to *collect* 52.3 billion MWh/year in space, but it implicitly assumes all that collected energy is delivered for use. In reality, transmitting power from orbit to Earth (via microwaves or lasers) is not 100% efficient. There are conversion losses at the transmitter (converting DC electricity to microwave beam, or to laser) and at the receiver (rectenna conversion back to AC power). According to studies and experiments, the overall *wireless power transmission efficiency* for space solar could be on the order of ~50% or so [30]. For example, a reference design might achieve ~85% efficiency in the rectenna and ~60–70% in the space-to-microwave conversion, yielding ~50% end-to-end efficiency [30]. **The article's analysis neglects these losses.** This means the **actual required array area would likely need to be about *double*** what was computed, to deliver 52.3 billion MWh to the ground. In numeric terms, if only half the collected energy makes it to users, an equivalent array would need on the order of **25,800 km^2** of panels (e.g. a 1 km × 25,800 km strip) to deliver the same net energy. By ignoring transmission inefficiencies, the article again errs on the side of giving the benefit of the doubt to the space-solar concept. This omission isn't a mathematical error (since the article was calculating energy *collected* in space), but it is a **critical factor** for real-world feasibility. The claim that such an array could replace oil is *even more implausible* once transmission losses are accounted for.

- **Energy Equivalence vs. Usable Energy:** The article equates oil's chemical energy to electrical energy from solar panels one-to-one. This is a fair comparison in terms of raw energy content. One nuance is that when oil is used to generate electricity, it only converts at ~40% efficiency in a power plant. So 52.3 billion MWh of *oil energy* would yield perhaps ~21 billion MWh of electricity when burned in efficient plants. From that perspective, a smaller space-solar array (about 40% of the computed size) could match **all current oil-fired electricity**. However, oil isn't used solely for electricity – it powers transportation, industry, etc., and the claim in question was about **total energy**. Thus, the article's approach to use total energy content is appropriate. There's no mistake here, but it's worth noting that replacing **all uses of oil** with electricity would itself require converting many systems to electric – a societal assumption beyond the scope of the math. The article's focus is strictly on energy magnitudes.

- **Choice of One-Year Timeframe:** As discussed, the author chose to use one year of oil production for the comparison, explicitly ignoring the "all oil on Earth" phrasing beyond that [8]. If the claim truly meant all reserves, the math would scale up drastically (on the order of 46× more energy needed [7]). In that sense, **Long Lehao's original claim is *even more* mathematically outrageous** than the article demonstrates. The article's simplified scenario is actually *charitable* to the claim. Again, not an error – it's a simplifying assumption that still makes the point.

- **Engineering Feasibility Not Addressed:** The article sticks to a math-based reality check, which is its purpose. Issues like *constructing* a 12,900 km long structure in space, or distributing that many panels (whether as one giant array or thousands of satellites), are beyond the scope of the piece. These engineering considerations would only add to the skepticism. Similarly, the article assumes the 1 km width because that was stated in the proposal, but a real design might choose a different configuration (e.g. a square array or multiple platforms). The linear dimension illustration is meant to highlight scale. There's no flaw in logic here – it's a rhetorical way to convey the **vastness** of the area required.

- **Optimistic Technology Inputs:** We should acknowledge that the article made *optimistic assumptions* at each step (deliberately, to avoid accusations of exaggeration): it took the **maximum likely PV efficiency (34%)**, **continuous illumination**, and **no downtime or degradation**. If any of these were less ideal – say 30% efficient panels, or a few percent downtime beyond eclipses – the required array area would increase further. None of these optimistic assumptions is "provably wrong" given current technology (34% efficient cells exist in labs [19], and continuous near-full solar exposure is valid in GEO aside from brief eclipses), but they do represent *best-case scenarios*. Realistically, initial space solar demonstrators might use ~25–30% efficient cells and could have additional inefficiencies, meaning the math would tip even more against the proposition. The article's logic isn't misleading here; in fact it bends over backwards to give the idea every benefit, and *still* finds the scale daunting.

In summary, **every quantitative step in the article checks out** on review. The figures for oil energy, solar irradiance, conversion to MWh, and required area are all **accurately computed** with correct units and sound reasoning. We found no arithmetic errors or unit conversion mistakes. The claims that are made (e.g. "a 1 km × 12,901 km array would be needed") follow directly from the math and are **not misleading** – they are, in fact, appropriately eye-opening. Any *omitted* factors (transmission efficiency, total reserve vs annual production, etc.) would only reinforce the article's conclusion that the Chinese "space solar power" claim is unrealistic. Thus, rather than undermining the argument, including those factors would make the required scale even more absurd (e.g. perhaps a 1 km × 25,000+ km array to account for losses, or multiple such arrays to equal all oil reserves).

Conclusion

The article *"Space Solar Power: Marketing Versus Math"* provides a mathematically rigorous reality-check on a bold claim. Our analysis confirms that **the math in the article is fundamentally correct**: there are no computational errors in the conversion of oil production to energy, the use of the solar constant, the application of PV efficiency, or the area calculation. The author's quantitative reasoning is internally consistent and uses valid data. Key claims such as *"52.3 billion MWh from oil"*, *"11.93 MWh/m^2-year from sunlight"*, and *"4.05 MWh/m^2-year with 34% PV"* are all accurate within reasonable rounding [31] [32] [20]. The resulting required array size (~12,900 km^2) is calculated correctly [23], and it starkly illustrates how **mathematically implausible** the original energy equivalence statement was.

Where the article simplifies (ignoring transmission losses, using one-year oil output, etc.), it does so in a way that favors the space-solar concept, meaning there's no hidden math mistake that would lessen the challenge – any more realistic assumption only *increases* the required scale. Therefore, there are **no significant mathematical errors or unit conversion faults** to fault the article on. The claims are supported by sound math, and any "misleading logic" would actually lie with the original marketing claim, not with this debunking. In fact, our deeper dive affirms that if anything, *the article understates the challenges* by using optimistic figures.

Bottom line: The quantitative analysis in *"Marketing Versus Math"* is valid and underscores its conclusion: the idea of a space-based solar array collecting as much energy as all Earth's oil is not supported by basic math and physics [33]. The numbers just don't add up in favor of the concept, and any more rigorous accounting would make the discrepancy even worse. The article succeeds in using correct math to cut through hype, and our review found no flaws in those calculations – only further reasons to concur with its skepticism.

Sources:

- Chicago Society for Space Studies – *"Space Solar Power: Marketing Versus Math"* (Jim Plaxco, May 1, 2025) [34] [32] [20] [23] [33]
- ClimateCrisis247 – Global oil production in 2023 (~4.5 billion metric tons) [3]
- Corenacca Energy Unit Guide – 1 tonne of oil ≈ 42 GJ = 11.63 MWh [35]
- Wikipedia – Solar irradiance at 1 AU ≈ 1361 W/m² (solar constant) [11]
- UCSD "Do the Math" Blog – GEO satellite shadow time (~0.7% of the year) [14]
- Fraunhofer ISE / PV Magazine – Triple-junction cell efficiency reaching ~34% [19]
- Wikipedia – Microwave power transmission efficiency (~50% overall) [30]
- Worldometer – Proven oil reserves ≈1.65 trillion barrels (~46× annual use) [7]

---

[1] [2] [8] [9] [12] [13] [15] [16] [17] [20] [21] [22] [23] [24] [25] [26] [28] [31] [32] [33] [34] Space Solar Power: Marketing Versus Math - Chicago Society for Space Studies
https://www.chicagospace.org/space-solar-power-marketing-versus-math/

[3] The Trump Effect: Why COP29 won't be able to Stop the 'Drill, Baby, Drill' gang - Climate Crisis 247
https://climatecrisis247.com/news/the-trump-effect-why-cop29-wont-be-able-to-stop-the-drill-baby-drill-gang/

[4] [5] [35] TOE - Tonne of Oil Equivalent - Corenacca
https://www.corenacca.org/toe-tonne-of-oil-equivalent/

[6] China plans to build enormous solar array in space — and it could collect more energy in a year than 'all the oil on Earth' | Live Science
https://www.livescience.com/space/space-exploration/china-plans-to-build-enormous-solar-array-in-space-and-it-could-collect-more-energy-in-a-year-than-all-the-oil-on-earth

[7] World Oil Statistics - Worldometer
https://www.worldometers.info/oil/

[10] [11] Solar irradiance - Wikipedia
https://en.wikipedia.org/wiki/Solar_irradiance

[14] Space-Based Solar Power | Do the Math
https://dothemath.ucsd.edu/2012/03/space-based-solar-power/

[18] Microsoft Word - France_QWrecord_arXiv_.docx
https://arxiv.org/pdf/2203.15593

[19] Fraunhofer ISE achieves 34.1% efficiency with triple junction cell – pv magazine International
https://www.pv-magazine.com/2019/08/29/fraunhofer-ise-achieves-34-1-efficiency-with-triple-junction-cell/

[27] What is the length of an earth-equatorial diameter? - Quora
https://www.quora.com/What-is-the-length-of-an-earth-equatorial-diameter

[29] China plans to build ‘Three Gorges dam in space’ to harness solar power | South China Morning Post
https://www.scmp.com/news/china/science/article/3294091/china-plans-build-three-gorges-dam-space-harness-solar-power

[30] Space-based solar power - Wikipedia
https://en.wikipedia.org/wiki/Space-based_solar_power