Could space-based satellites power remote mines?

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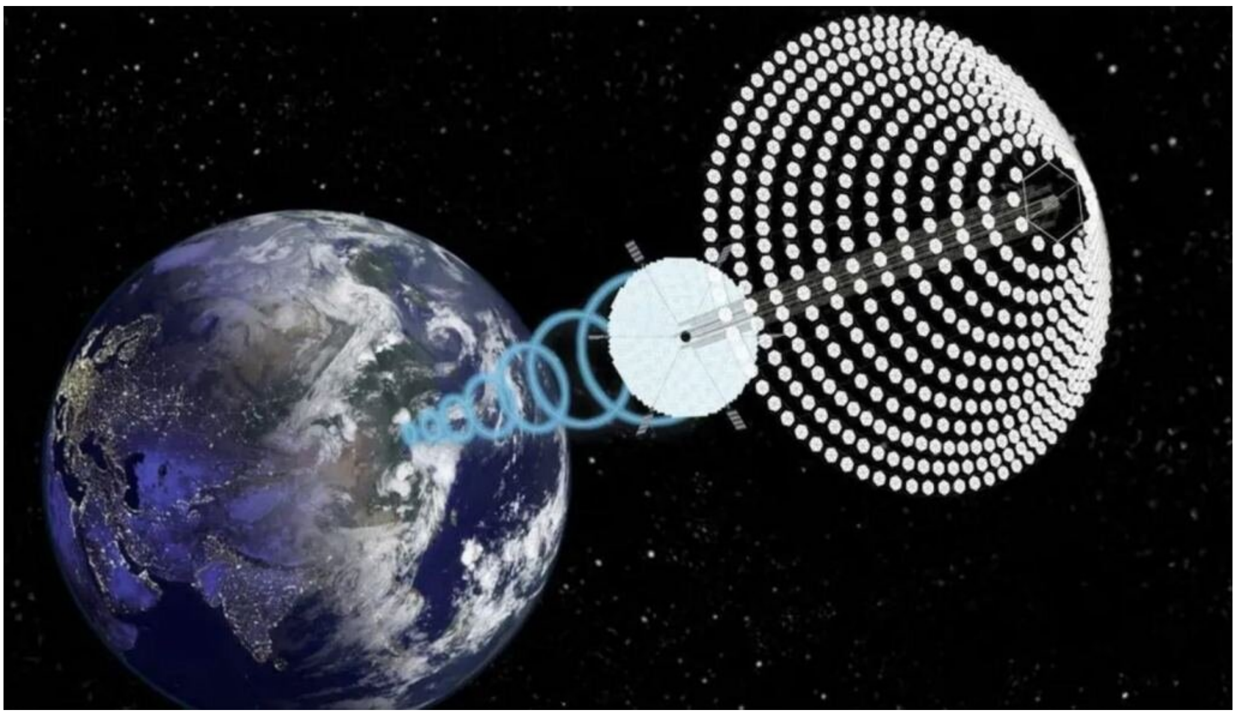

Artist's impression of an SPS-ALPHA satellite operating in space. Credit: John Mankins

Many space-based technologies are still looking for their "killer app"—the thing that they do better than anything else and makes them indispensable to whoever needs to have that app to solve a problem. At this point in the development of humanity, most of those killer apps will involve solving a problem back on Earth. Space-based solar power satellites are certainly one of those technologies.

They have the potential to fundamentally transform the energy industry here on Earth. But they need that one "killer app" to get people interested in investing in them. A study from a group of researchers at the Colorado School of Mines looked at one potential use case—powering remote mining sites that aren't connected to any electric grid. Unfortunately, even at those extremes, solar power satellites aren't yet economical enough to warrant the investment.

At first glance, remote mines would be an excellent candidate to be powered by a solar-power satellite. Many aren't anywhere near a power grid connection, and it would be too costly to run electric lines directly there. Typically, they truck diesel fuel in to run gigantic generators, which is expensive, costing up to ten times as much as the typical electricity of a mine connected to the grid. In part, that's because they are challenging to get to, especially in the more treacherous parts of the northern hemisphere, where the mines are sometimes only accessible by ice roads.

A typical mine uses about 20 MW of power to operate, and they typically pay a power purchase agreement (PPA) to a power provider that provides the generators or some other form of energy. Wind and solar are two possible alternatives, but they are too intermittent to provide steady power, especially at the latitudes most mines are located. As such, many mine operators would be open to an alternative.

But, as with so much technology, it comes down to cost. On average, a typical mine pays up $.30 per kWh of operation, so in a best-case scenario, that is the price that a power satellite would have to be at least close to. However, there could be some wiggle room, as a mine operator might want to look more "green" by not burning thousands of gallons of diesel fuel, so they might take a serious look at a power satellite that can provide energy at a slightly higher price.

So how much does energy from a power satellite cost? Since there isn't yet one in operation, it's hard to judge, but the researchers based their calculations on a proposal put forward by John Mankins called the SPS-ALPHA 18 system. As the name implies, it provides 18 MW of power, conveniently close to the average use case of a typical remote mine. It is also detailed in a paper Mankins wrote and an upcoming book that explains an updated version. Since that book wasn't released at the time of writing of the paper, their calculations are based on the (assumedly inferior) original satellite platform.

In the paper, published in *Acta Astronautica*, Mankin provides three different types of cost estimates that would help put a price on the electricity supplied by the power satellite system. The first of those is manufacturing—with an estimate of almost $800 million to build the various parts of the SPS-ALPHA 18 system. "Other" costs, including the R&D and building the ground station, come in at another $600 million. The final expense, launch cost, is the focal point of so much of the development of the commercial space flight industry and varies widely based on some assumptions. In a best-case scenario, a flight with what was then known as the BFR, now known as Starship, can launch the slightly over 1 million kg necessary to get a satellite into orbit for just over $600 million in total.

All told, that's around a $2 billion cost to get a complete functional power satellite into orbit. That's actually on the scale of some large-scale power plants, especially of the nuclear variety. However, those ground-based power plants are designed to be tied into a power grid and produce a few orders of magnitude more power than the SPS-ALPHA 18 would. So would that $2 billion investment look like a good one from the standpoint of a potential investor?

The simplest way to calculate the overall energy cost of a mine is to figure out how much they use per year and then multiply it by the life expectancy of the mine itself. At 18 MW per year, the SPS-ALPHA 18 could provide pretty much the mine's total energy consumption. Thirty cents per kilowatt hour spread out over 24 hours a day, and it comes to something like $47.3 million annually. Over a life span of a mine (about 25 years), that annual revenue totals around $1.1 billion.

So even in a best-case scenario, the proposition to power a remote mine with a satellite would still lose money. However, to an economist's eyes, it's even worse. They use a variable called the "discount rate," basically a way of calculating how much the money used to finance a project costs, which includes things like inflation and opportunity cost (i.e., how much they would make from investing elsewhere). Another big factor in determining the discount rate is the risk of failure of the project itself—given the novel nature of a space power satellite, this is pretty high for a project of this nature.

Dr. Ian Lange and his co-authors selected a 12% discount rate, which, he points out, is about average for the remote mining industry. But that means that each year, the revenue from the project is worth 12% less than the revenue from the previous year. Moreover, they expect a 5-year capital investment up front, where there wouldn't be any actual revenue for five years, which means that in 5 years, the $47.3 million in revenue from the first year would only be worth $26.84 million in today's money.

And it gets worse from there, with the total revenue at the end of the project only counting for about $2.78 million in today's money. All of these economic calculations end up with a number called the "net present value" or NPV. Investors look at that number and attempt to decide whether or not a project is investable.

In the case of using SPS-ALPHA 18, the most thought of space power platform designed at the time of writing the paper, the net present value of using SPS-ALPHA 18 to power a remote mine is, at best, -$1.8 billion. That's a stretch even for the most space-minded billionaire.

So the answer to whether a space-based power satellite could power remote mines is "yes," but there's not much of a business case for it. There's still a long way to go before beaming power from space becomes a profitable venture. But, as the authors note at the end of the paper, the whole calculation changes dramatically if some of the parts for the satellite are manufactured in space. So there is still a point in the future, with a much more fleshed-out space infrastructure, where the price might eventually become competitive. But there will be lots of necessary investment, at a very negative NPV, before humanity gets to that point.

More information: Nicholas Proctor et al, Feasibility of space solar power for remote mining operations, *Acta Astronautica* (2021). DOI: 10.1016/j.actaastro.2021.04.001

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