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Economic Feasibility of Space Solar Power in Remote Mining Applications

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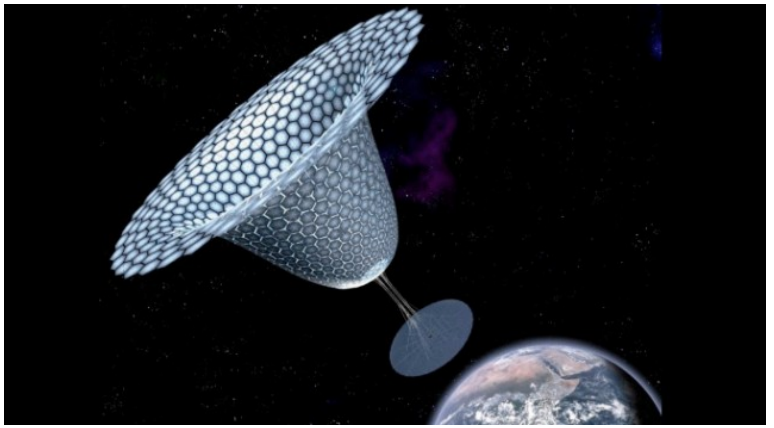
Ideal Market Conditions for Space Solar Power

While space solar power (SSP) is making strides in reducing its costs of providing electricity, it is not cost competitive with terrestrial power sources.

Criteria for a Nice SSP Customer

1. Not connected to the terrestrial power grid
2. Demands a substantial amount of power for most hours of the day
3. Able to sign a power purchase agreement (PPA) for multiple years



SPS Alpha

Credit: John Mankins, 2012

Remote Mining Operations

Remote mining operations fit all of these requirements

1. Located away from population centers and often powered by diesel trucked onsite
2. Mills and other machinery run constantly 24 hours per day, 7 days per week
3. 10-20 year demand for electricity means power prices hedged with a multi-year PPA

DeGrussa Mine, Sandfire Resources

Western Australia, 900 km NE of Perth

Copper & Gold

10 year mine life, 20 MW demand

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Discounted Cash Flow Analysis

- Common tool in investment decision making.
- Brings revenues and costs to the same metric.
- Takes into consideration the time-value of money and project risk.
- Cash flows (in and out) earlier in the project carry more weight than later cash flows.

Framework for our analysis

- Discount rate of 12%
- 25 year life of project
- 5 year development period
- 20 year revenue stream
- $4.5 B cost to first power
- $0.30 per kWh

Parameters	DRM 3 / Case 1 (SPS-ALPHA Pilot Plant, with Minimal Tech Advances)	DRM 4 / Case_1 (First Full-size SPS, with Minimal Tech Advances)	DRM 5 / Case_4B (Recurring SPS, with Aggressive Tech Advances)
Power Delivered to Earth	18 MW	500 MW	2,000 MW
WPT Transmission Freq.	2.45 GHz	2.45 GHz	2.45 GHz
Solar Power Gen. Efficiency	25% BOL	48% BOL	60% BOL
WPT Efficiency	70% (DC-to-RF)	70% (DC-to-RF)	80% (DC-to-RF)
ETO Cost ($/kg)	$1,500/kg	$500/kg	$500/kg
Cost to First Power (estimated at Earth)	~$ 4.5 B (~$250 per Watt)	~$ 12.2 B (~$24 per Watt)	~$ 31 B (~$16 per Watt)

The system we based our evaluation on is Mankins' DRM 3 / Case 1

Simple DCF Analysis

Project Year	Years	0	1	2	3	4	5	24	25
Discount Rate	12%								
Gross Revenue	M$	-	-	-	-	-	52.56	52.56	52.56
Capital costs	M$	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	-	-	-
Cash Flow	M$	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	52.56	52.56	52.56
Discounted Cash Flow	M$	(900.00)	(803.57)	(717.47)	(640.60)	(571.97)	29.82	3.46	3.89

Assumptions

- Mankins' SPS-ALPHA, 18 MW system from GEO
- No operating expense
- Capital costs evenly distributed across first 5 years
- Capitalized all costs associated with manufacturing, ETO and assembly
- No tax considerations (depreciation, federal, state, carry forward, etc.)

Investment Decision Metrics

Decision Metric	Unit	SSP	Generally Acceptable
Discounted Cash Flow ROR	%	**-9%**	> 10%
Net Present Value	(M$)	**$ (3,381)**	> 0.00
Maximum Cash Exposure	(M$)	**$ (3,634)**	-
Breakeven Investment**	(M$)	**$ 313**	-

* Costs need to decrease by 93% from $4.5 B

What May Improve Feasibility & Next Areas of Study

Economic

Decrease in launch costs to GEO

Increase in electricity cost/kWh, hence increase in revenues from SSP

Technologic breakthroughs (lighter materials, more efficient materials, etc.)

Government Policy

Carbon tax policies

Government subsidies

- Direct investment, Tax Credits

Corporate

Accelerated manufacturing, launch and assembly

Launching satellites to LEO rather than GEO

Smaller discount rate

Debt financing

Multiple clients (GEO - single sat, mining district; LEO - multi-sat, multi-client)

Appendix


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Breakeven Comparison

Breakeven

Project Year	Years	0	1	2	3	4	5	24	25
Discount Rate	12%								
Gross Revenue	M$	-	-	-	-	-	52.56	52.56	52.56
Capital costs	M$	(62.60)	(62.60)	(62.60)	(62.60)	(62.60)	-	-	-
Cash Flow	M$	(62.60)	(62.60)	(62.60)	(62.60)	(62.60)	52.56	52.56	52.56
Discounted Cash Flow	M$	(62.60)	(55.86)	(49.88)	(44.53)	(39.76)	29.82	3.46	3.09

ROR: 12% **Capital costs: $ 313 M**

NPV: $ 0.00 **Revenue stream remains unaltered**

Original

Project Year	Years	0	1	2	3	4	5	24	25
Discount Rate	12%								
Gross Revenue	M$	-	-	-	-	-	31.54	31.54	31.54
Capital costs	M$	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	-	-	-
Cash Flow	M$	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	31.54	31.54	31.54
Discounted Cash Flow	M$	(900.00)	(803.57)	(717.47)	(640.60)	(571.97)	17.89	2.08	1.86

ROR: -12% **Capital costs: $ 4.50 B**

NPV: $ -3.48 B

Revenue Assumption

Cost per kWh: $0.20

Cost per MWh: $200

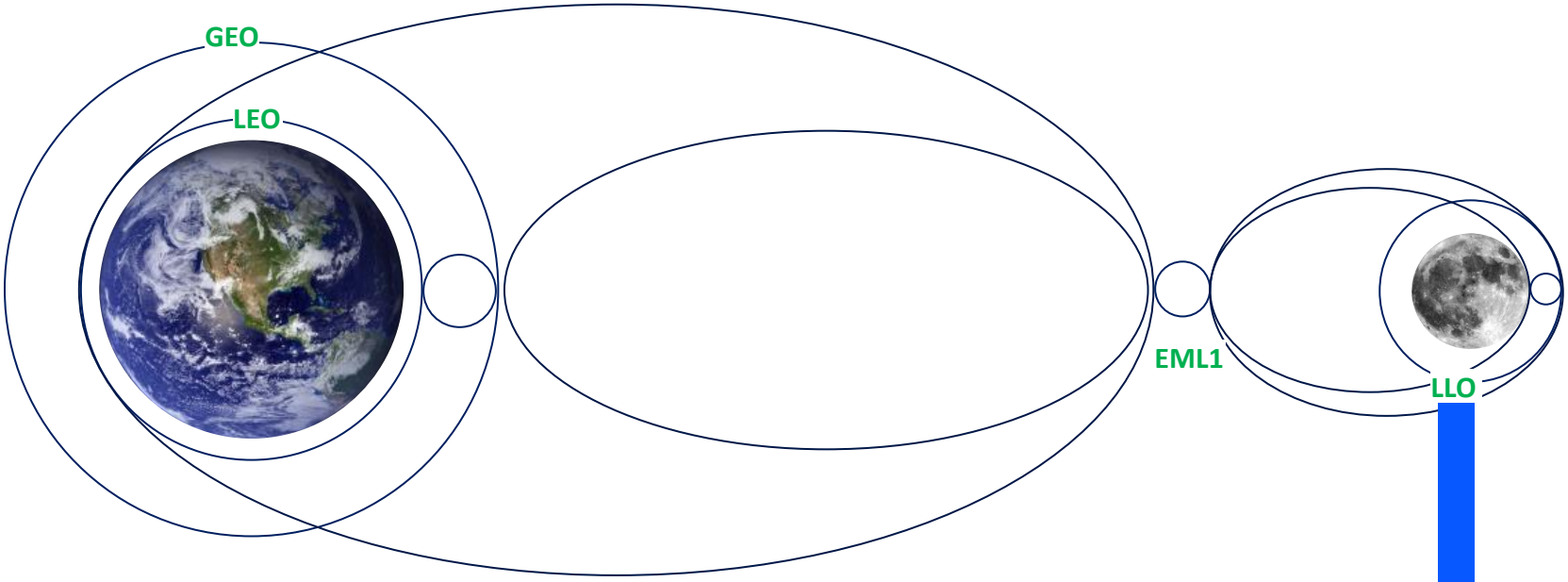
MW delivered to Earth: 18 MW

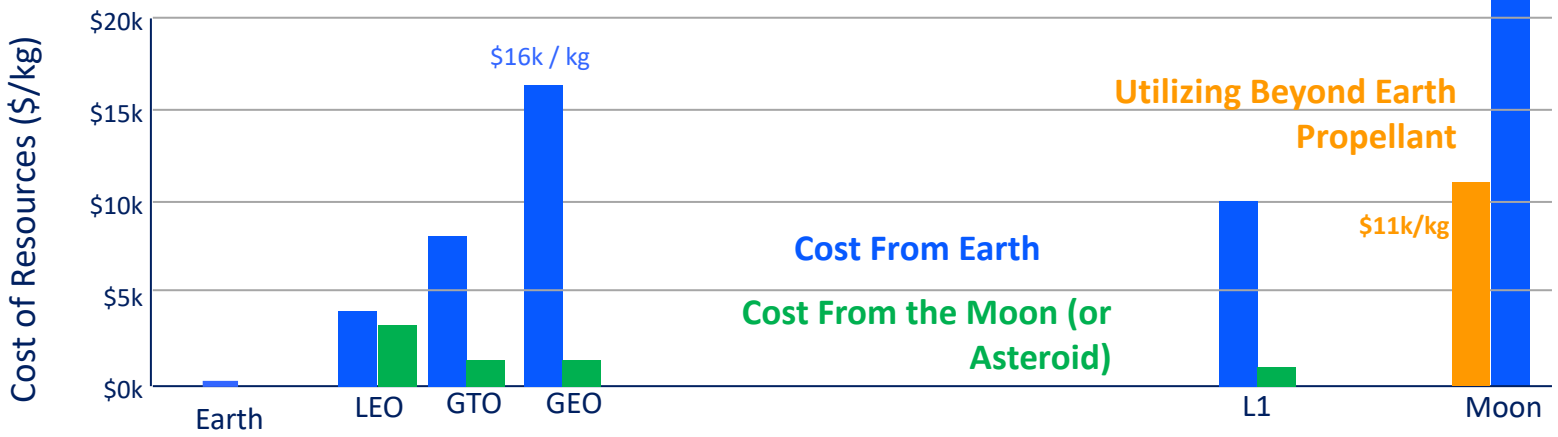
Annual hours of operation: 8,760

Capacity Factor: 100%

$200 * 18 MW * 8,760 hours * 100% Capacity Factor = $ 31.54 M / annum

Costs of Resource in Cislunar Space





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