

Lunar Solar Power (LSP) System: Practical Means to Power Sustainable Prosperity*

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Abstract

The world now consumes ~ 14 terawatts of commercial thermal power (14 TWt). The surface of our Moon independably intercepts 13,000 TWs of solar power. This Lunar Solar Power is converted on the Moon into to electric power and then to beams of ~2.5 GHz microwaves to which Earth's atmosphere is transparent. Beam receivers on Earth convert the low-intensity microwaves ($\leq 20\%$ of sunlight) to commercial electric power. A given receiver outputs ~200 W/m² of load following electric power to its regional electric grid. LSP facilities are made from the local lunar materials by small manufacturing units transported from Earth to the Moon (<http://www.tipmagazine.com/tip/INPHFA/vol-8/iss-2/p12.pdf> article and subsequent letters to the editor). The LSP System can quickly grow to provide ≥ 2 kWe/person to 10 billion people, ≥ 20 TWe, and enable GWP ≥ 800 T\$/y. For scale, at 33% efficiency for oil-to-electricity ~ 1,000 million barrels of oil per day must be burned to produce the 20 TWe.

LUNAR SOLAR POWER (LSP) SYSTEM: PRACTICAL MEANS TO POWER SUSTAINABLE PROSPERITY

Abstract #600724

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To the

**AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS**

**Session: Theme X - Energy Minerals in the
Solar System – Resources for the 21st Century**

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NEED: ADEQUATE GLOBAL POWER

- EXISTING GLOBAL POWER SYSTEM

- 1 billion “rich” people use electric equivalent of ≥ 2 kWe/person
- 5 billion “poor” people use ≤ 0.6 kWe/person
- GWP ~ 45 T\$
- Global power use is equivalent of
 - ~ 220 million barrels of oil/day, or
 - $\sim 4.8 \cdot 10^{12}$ Watts-electric = 4.8 TWe
- Not renewable, polluting, depends on politically sensitive regions, too expensive for most people, must move molecules

- NEEDED GLOBAL POWER SYSTEM

- Now (≥ 2 kWe/person \cdot 6 billion people) ≥ 12 TWe
- By 2050 10 billion prosperous people will need ≥ 20 TWe
- Power must be clean, safe, affordable, dependable, & sustainable
- Power from photons and electrons
- Can enable GWP > 800 T\$ by 2050 (Match W. Europe 42 T\$/TWe-Y)

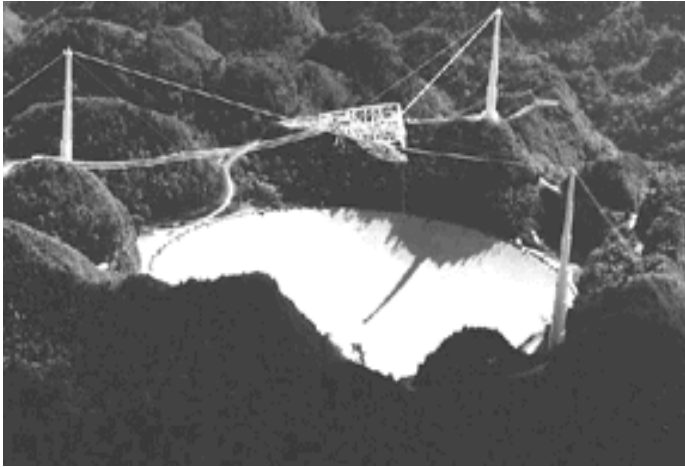
SOLUTION: LUNAR SOLAR POWER SYSTEM

- SUN SENDS 13,000 TW_s OF RELIABLE SOLAR POWER TO LUNAR SURFACE
- BASES ON MOON CONVERT SOLAR POWER TO MICROWAVE BEAMS



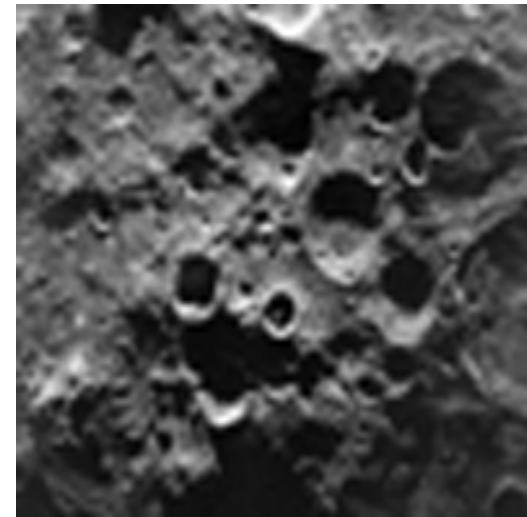
- BEAMS DELIVER POWER TO RECTENNAS
 - Safe (<20% of sunlight)
 - Reliable (through clouds, rain, smoke, etc.)
- RECTENNAS ON EARTH
 - Convert beams to electricity
 - Deliver electricity to power grid
 - $\geq 200 \text{ We/m}^2$ or 10*renewables

POWER BEAMING



- SPECIALIZED FORM OF RADAR
- EARTH-TO-MOON DEMONSTRATED BY ARECIBO

- MOON-TO-EARTH BEAMING IS REASONABLE EXTENSION OF EXISTING TECHNOLOGIES
 - Large phased arrays
 - Distributed arrays (ex. VLA)
- MASSLESS POWER LINES



PHASED ARRAY RADAR



- **SPACE GUARD**

- Eglin A.F.B., FL
- Segmented transmitter (left)
- Operated 24/7 since 1968
- Upgraded in 1999 while in full operation
- Largest of several dozen National Missile Defense units
- Meet EPA regulations

- **PROJECTED BEAM**

- Near-field peak $\sim 25,000 \text{ W/m}^2$ (5% duty-cycle)
- Near-field average $\sim 130 \text{ W/m}^2$
- Beamed to space equivalent of $\sim 100,000$ barrels of oil over 39 years (assume 35% conversion efficiency)

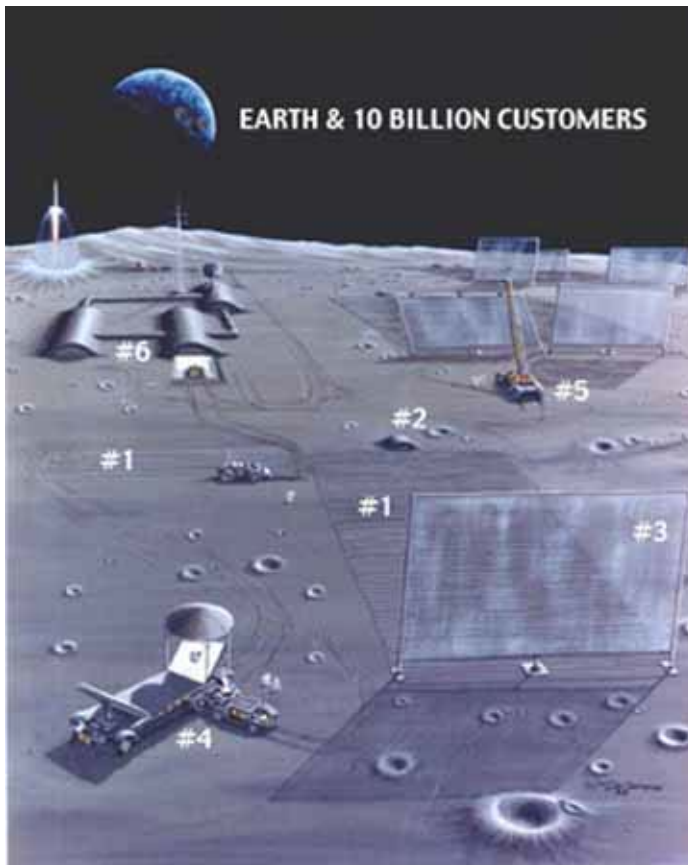
EARTH'S MOON & LSP POWER BASES



Harvested Moon

- MOON WITH BASES
 - Receives 13,000 TWs
 - Bases built using known lunar materials in known environment
- 10 POWER BASE PAIRS
 - Always face the Earth
 - Beam $\sim 20 - 30$ TWe to Earth

DEMONSTRATION LSP BASE

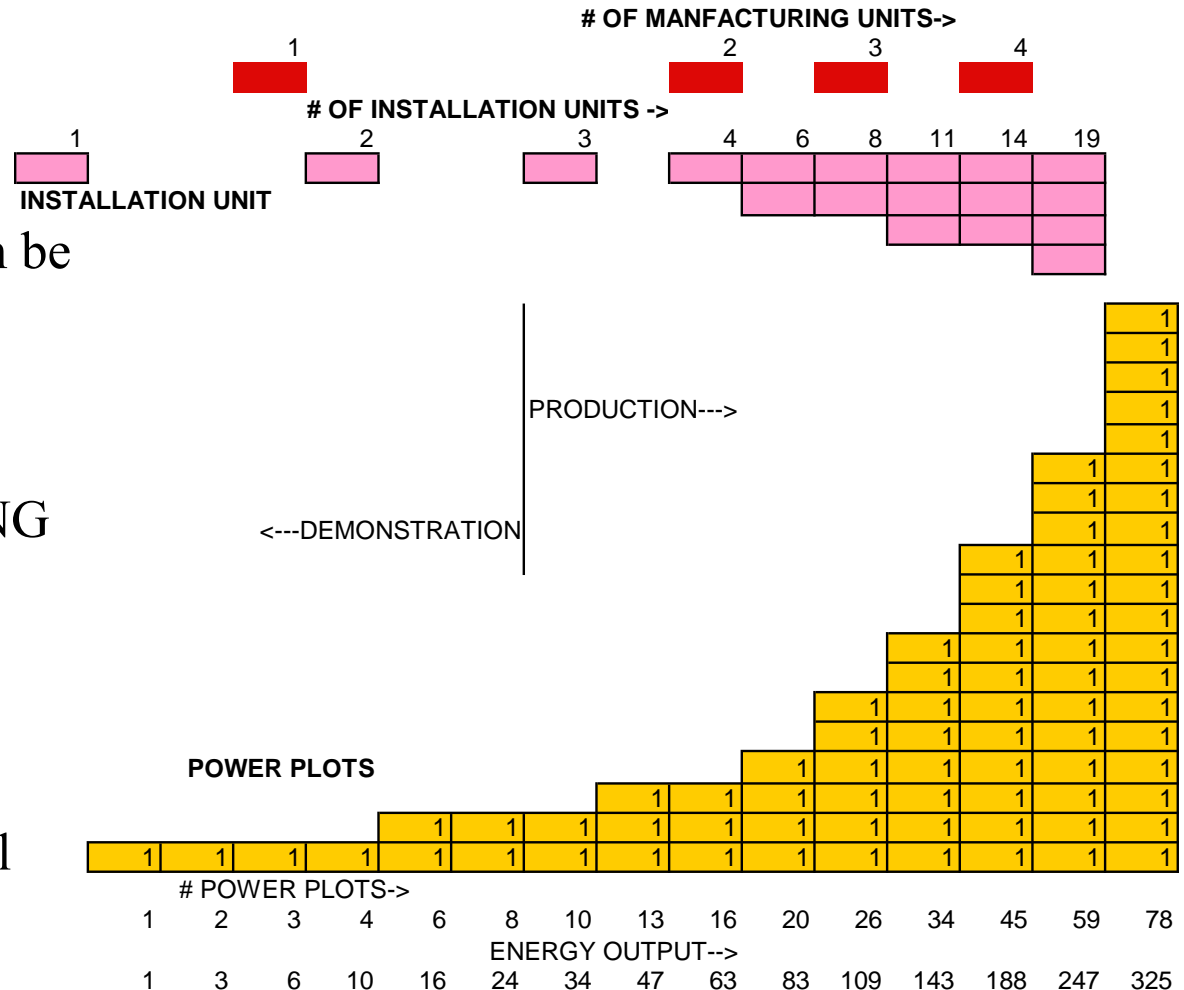


Harvesting the Moon

- EARTH IS FIXED IN SKY
- BASE IS COMPOSED OF POWER PLOTS
- POWER PLOT - BASIC UNIT
 - #1 Solar arrays, buried wiring
 - #2 Microwave transmitters
 - #3 Reflectors overlap to form the large power-base aperture as seen from Earth
- #1, 2, & 3 ARE MADE FROM LUNAR MATERIALS BY MOBIL (#4 & #5) & FIXED (#6) PRODUCTION EQUIPMENT

EXPONENTIAL GROWTH OF POWER PLOTS

- INSTALLATION UNITS (pink) designed so that ~90%, by mass, can be made of lunar materials
- Import additional MANUFACTURING UNITS (red) that make new INSTALLATION UNITS
- Enables exponential growth of POWER PLOTS (yellow)



MASS & COST PROJECTIONS

- 20 TWe BY 2050 & 1,000 TWe-y BY 2070 (WEC18th)
 - 90% local manufacturing on Moon & tele-operation from Earth
 - $1 \cdot 10^5$ km² of reflective rectennas on Earth (0.8 T\$)*

TOTAL MASS TO MOON (tonnes)	
Micro-manufacturing	24,361
Hot Forming	10,313
Beneficiation	3,212
Habitats, shops, mobile units	22,085
Chemical Refining	2,469
Gather & eject to orbit	438
Excavation	80
Cold Assembly	28
TOTAL	62,915
PEOPLE (6 month tours)	
Moon	436
Lunar Orbit	59
Earth Orbit	63
LUNAR & SPACE COST (2000\$)	0.8 T\$
*ENGINEERING COST (¢/kWe-h)	0.1

• COST DISTRIBUTION

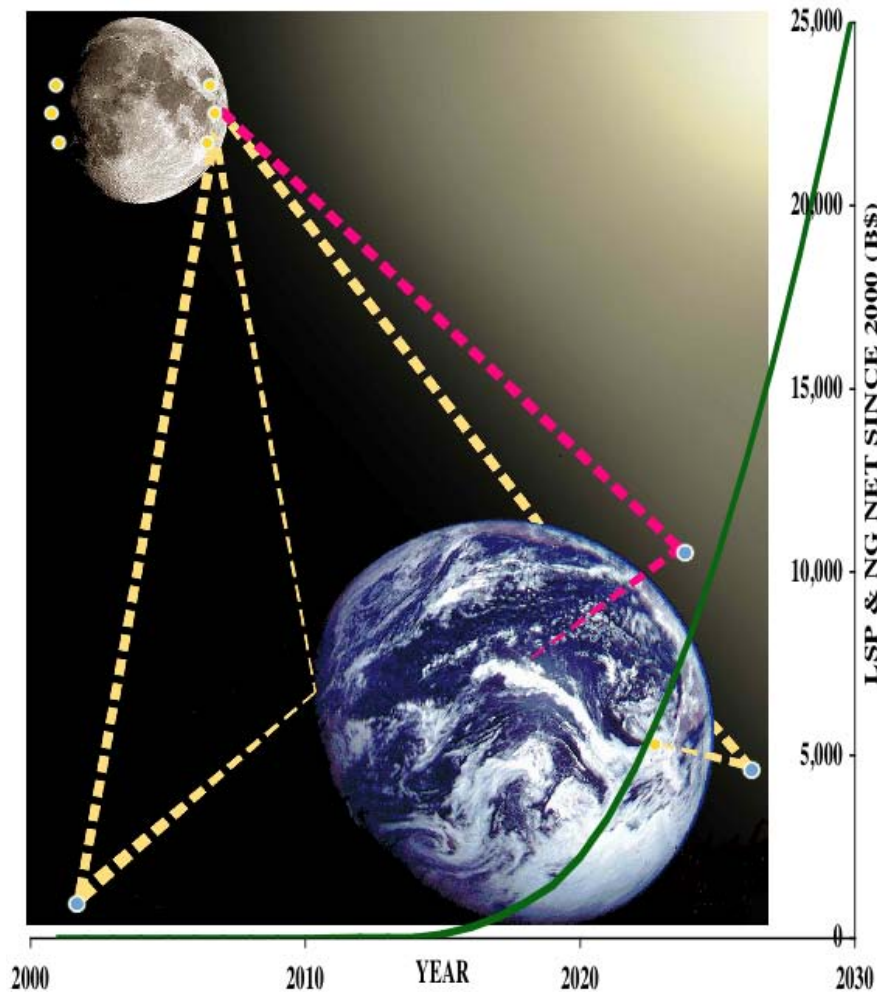
- ~75% first 30 years
- ~12 years breakeven

• TOTAL REVENUE ~80 T\$ @ 1 ¢/kWe-h

• REVENUE NOT INCLUDED

- Clean energy premium
- Rectenna area dual-use

SUN->MOON->EARTH GRID



- SOLAR POWER BASES ON MOON
 - Energize the Moon – > Earth electric grids
 - Powers rectennas worldwide (load following)
 - Sustainable net-new energy
 - Safe (< 20% of sunlight)
 - Reliable (through clouds, rain, smoke, etc.)
 - < 1/10th cost per kWe-h of alternatives
 - Exponential growth of sustainable prosperity
- LSP System
 - Based on >1B\$ of space power & lunar studies
 - Profitable with 1980s technology
 - Enables sustainable exploration & development of our solar system

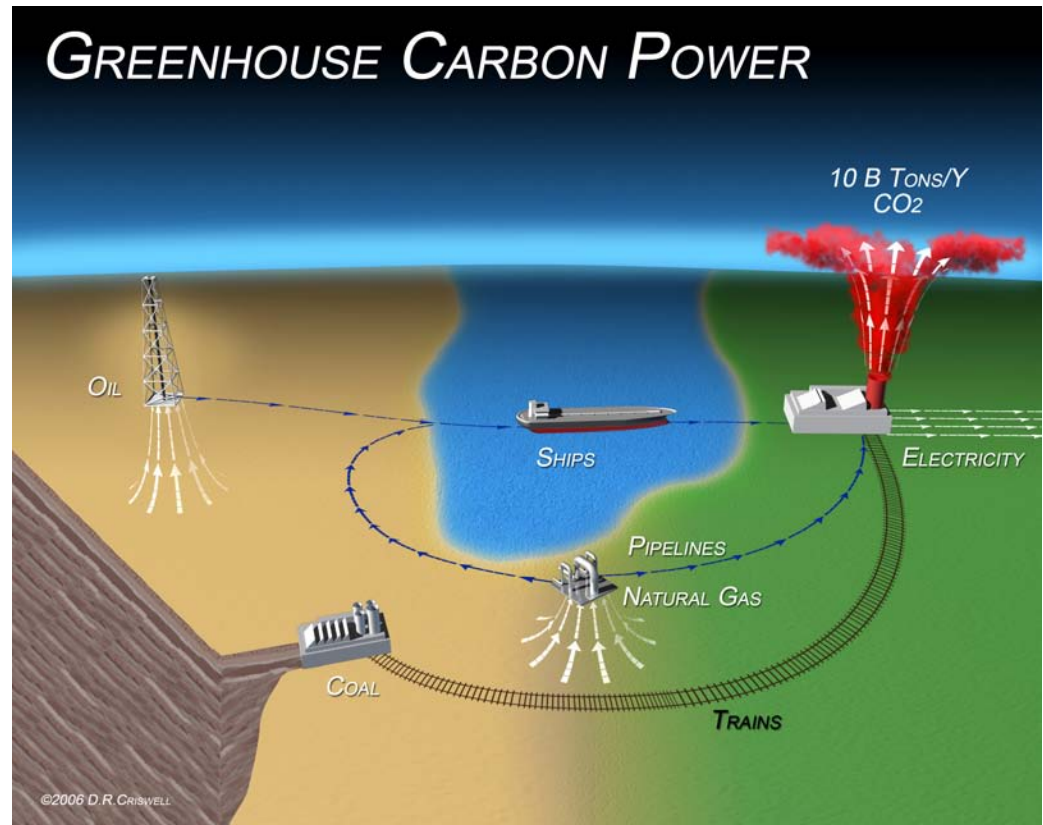
RECTENNA ELECTRICITY

- DOES NOT PRODUCE GREENHOUSE GASSES, FUEL SPILLS, NUCLIDES, DUST, INDUSTRIAL WASTES, ETC.
- ELIMINATES NEED FOR HAZARDOUS FACILITIES (OIL, NUCLEAR, DAMS, MINES, ETC.)
- ENABLES REMEDIATION OF ENVIRONMENTAL DAMAGE, REMOVAL OF INDUSTRIAL CO₂ FROM ATMOSPHERE, RECYCLING OF GOODS & SYNTHETIC FUELS, DESALINATED & RECYCLED WATER, AND NON-POLLUTING SERVICES AND TRANSPORT
- ALLOWS DUAL USE OF LAND UNDER RECTENNA
- ENABLES BIOSPHERE-INDEPENDENT POWER



20th CENTURY CARBON WEALTH

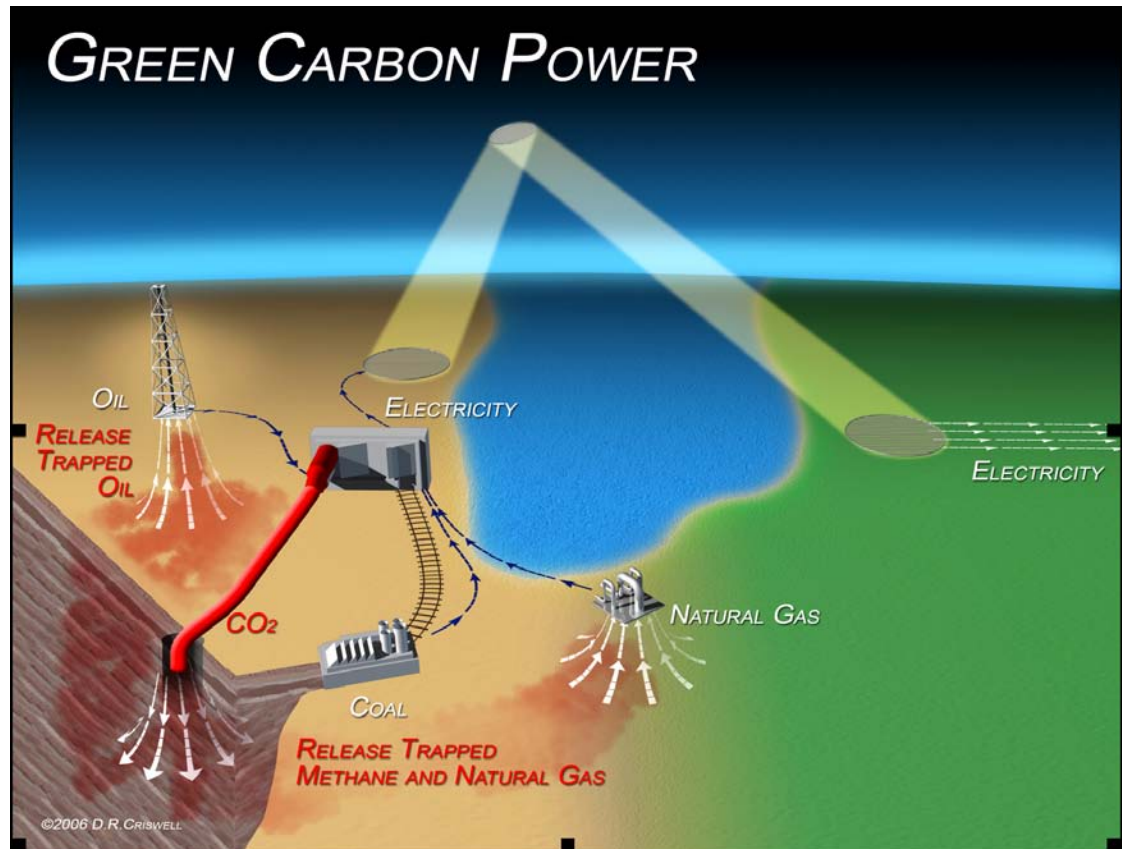
- 20th CENTURY WEALTH TOOLS
 - Mining & transport
 - O₂ & carbon-fired electric generators
 - Power lines
 - Electric “engines”
 - Electronics



- OUR AIR'S FREE O₂ & MINED FUEL-MOLECULES ARE MOVED & BURNED TO MAKE ELECTRICITY

GREEN CARBON TRANSITION

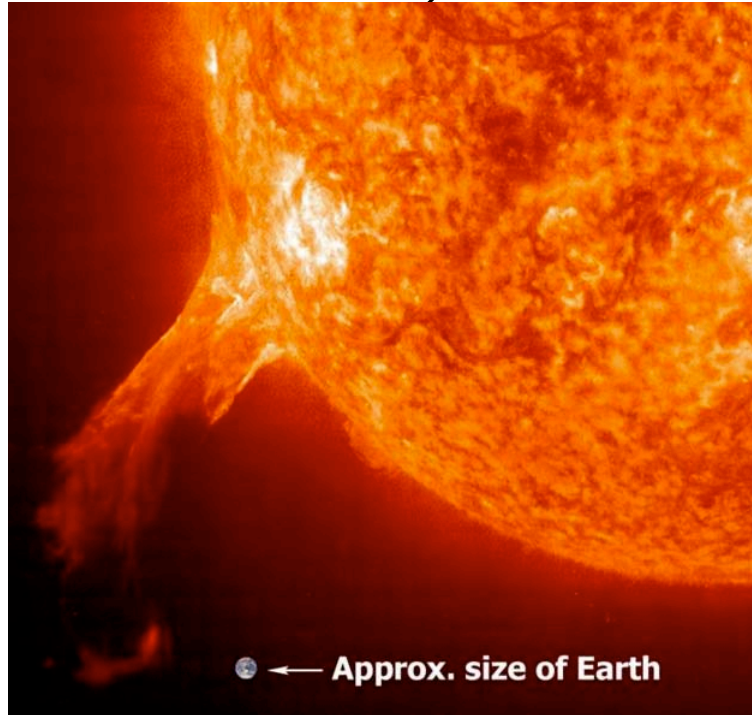
- ENERGY INDUSTRY GROWTH TO LSP SYSTEM
 - Power beaming
 - Redirectors (space)
 - Rectennas
- BENEFITS
 - Immediate CO₂ sequestration
 - Enhanced recovery of hydrocarbons
 - Secure distribution of electric power
 - Green Carbon Power to users



ENERGY POTENTIAL & ISSUES

- LSP CAN PROVIDE >1 TWe WITHIN 15 YEARS AND EXPONENTIAL GROWTH THEREAFTER
- NO TECHNICAL BARRIERS
 - Key operational technologies are understood (PVs, radar)
 - Key industrial steps can be demonstrated on Earth and then on Moon
 - Small-scale manufacturing can grow using lunar resources
- POLICY & COST ISSUES
 - Permanent legal & industrial system to enable lunar development
 - Joint U.S.-industry LSP demo to enable prudent private investment
 - Microwave spectrum re-allocations
- SUSTAINABILITY
 - > 1 billion years
 - Can use Lunar Solar Power to protect & nurture Earth's biosphere
 - Can enable humans to settle permanently beyond Earth

OUR SUN, EARTH, & LUNAR POWER



- OUR SUN
 - 26 trillion times our present commercial power
 - Paid for, no operating costs
- OUR POWER SYSTEMS
 - Move molecules globally
 - Push limits of biosphere
 - Limit economic growth

- LUNAR SOLAR POWER SYSTEM
 - Moon directly accesses 13,000 TWs of our sun's power
 - LSP System uses available & proven technologies
 - Outputs pure electricity at Earth with least infrastructure
 - Enables clean & sustainable exponential economic growth

RECENT LSP REFERENCES

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