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LEGAL FRAMEWORKS FOR THE SUSTAINABLE USE OF OUTER SPACE FOR ENERGY SECURITY, EQUITY AND PROSPERITY FOR ALL STATES

Yewande F. Oluwajobi*, Oreoluwa Omotayo Oduniyi**, Adetutu A. Adewole***, Akinjide O. Oluwajobi****

ABSTRACT

The world energy crisis is real and this has been caused, among many reasons, by overpopulation, international wars and natural disasters. The energy shortfall and the demand for more energy options have raised worries among active players in the energy sector. The current trend is to explore renewable energy resources; however, the energy class from outer space has yet to be explored and offers a wide range of alternatives. It is crucial to note that abundant energy can be extracted from the sun, and solar energy has previously been employed on the terrestrial earth to address some energy restrictions. However, weather fluctuations significantly reduce the usefulness of solar power. One significant disadvantage of exploring and using renewable energy from outer space is the necessity for an appropriate legal and administrative framework to regulate energy-tapping activities. This research examines the factors militating against the effective use of energy from outer space. It sheds light on environmental and health laws and human considerations. It also examined the Space Treaties and other relevant Laws regulating the activities carried out in outer space. The research makes recommendations on how to tap into the use of renewable energy from outer space.

Keywords: Legal Frameworks, Outer Space, Space Solar Power, Energy, Sustainable Use.

1. INTRODUCTION

Energy is everything; it drives individuals, industries and modern life.[1] Many aspects of our society depend on energy for convenience and smooth

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running. Yet, an energy crisis is a common problem every state faces, and it appears that there is not enough energy to go around the world today.[2] This accounts for the many conferences and seminars on renewable energy. Fossil fuel has been the main energy source worldwide, but there are fears that it will be depleted and exhausted.[3] Scientists and jurists are looking at sustainable alternative energy sources with little or no negative environmental impact.[4]

Outer space offers many opportunities for clean and renewable energy that can be used to address the energy crisis on Earth. The beauty of outer space is that "there is plenty of room for renewable energy in space. Development opportunities are growing from photovoltaic orbiting Earth to satellites that monitor energy supply, through the search for new high-tech solutions to improve the efficiency and reliability of terrestrial solar and wind systems".[5]

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1 E. D. Coyle and R. A. Simmons, Understanding the Global Energy Crisis (2014) Purdue University Press (Knowledge Unlatched Open Access Edition).

2 David Hunt, 'Space-Based Solar Power: A Disputes Minefield' (Global Legal Post, 06 May 2022) <https://www/globallegalpost.com/news/space-based-solar-power-a-disputes-minefield-1976730430>. accessed 29 June 2024.

3 S. Foster and D. Elzinga, 'The Role of Fossil Fuel in a Sustainable Energy System' (UN Chronicle, December 2015) No 3, Vol. LII, <https://www.un.org/en/chronicle/article/role-fossil-fuels-sustainable-energy-system> accessed 27 July 2024.

4 Business Gateways International LLC, 'Can Renewable Energy Truly Replace Fossil Fuels? Exploring the Prospects and Challenges' (January 31, 2024) <https://www.linkedin.com/pulse/can-renewable-energy-truly-replace-6yiof accessed 27/07/ 2024>; O. Obafemi et al, Electric Power Crisis in Nigeria: A Strategic Call for Change of Focus to Renewable Sources (2018) IOP Conf. Ser.: Mater. Sci. Eng. 413 012053.

5 "Energy from Renewable Sources, What Does Space Have to Offer", (18 December, 2023) <https://www.eni.com/en-IT/media/powdered-by-wired/renewables-space. html#:~text:=There%20is%20plenty%20of%20room,system%2C%20development%20opportunities%20are%20growing> accessed 29 June 2024.

State governments, private entities, and intergovernmental agencies are looking towards space to explore lunar resources and the atmosphere to create renewable energy. An example is using solar panels to reduce land use, "…guarantee the continuous production of clean energy without the consumption of land mass, consequently promoting social sustainability".[6]

In order to deal with the energy deficit in Europe, the European Space Agency began the 'Solaris Program'[7] in 2023. One of the areas of focus is solar-based power, which is seen as a solution to the sustainability of energy by collecting energy from space and transmitting it to the earth. The essence of space-based solar power (SBSP) is its ability to reach remote places on Earth[8] to provide the deficit of the power already being supplied by existing power grids. States and international entities are investing in research and developments (R&D) that encourage solar energy from outer space to get clean energy without the attendant greenhouse emissions from traditional fossil fuels. Incidentally, NASA is also looking at space-based solar energy possibilities.[9]

Advocates of space-based solar energy believe that space could provide enough energy for everyone on Earth.[10] Furthermore, this is without the adverse effects on the environment as already seen in the space sector, though

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6 Ibid.

7 See generally, SOLARIS, Sustainability Report 2023, <https://www.solarisbus.com/public/assets/contents/firma/esg/2023/Raport_Zrownowazonego_Rozwoju_2023_ENG.pdf>; ESA, Research Activities in Support of Space-Based Solar Power for Terrestrial Needs (26 February, 2023) <https://indico.esa.int/event/453/attachment/5098/8054/Request%20for%20Information%20-%20Research%20Activities%20for%Space-Based%20Solar%20Power.pdf> accessed 27 July 2024.

8 I. S. Zarma et al, 'Benefits of Solar Power in Nigerian Rural Communities' (2017) 35th National Solar Energy Forum, <https://www.researchgate.net/publication/321184680> accessed 27 July 2024.

9 New Study Updates NASA on Space-Based Solar Power, (NASA Communications, Jan 11, 2024) <https://www.nasa.gov/organizations/otps/space-based-solar-power-report/> accessed 23 July 2024.

10 NSS, 'Space Solar Power Info: Limitless Clean Energy From Space' <https://nss.org/space-solar-power-info/#:~text=Space%20solar%20power%20can%20provide, greater%20than%20we%20use%today> accessed 27 July 2024; S. Clark, 'Beam Me Down: Can Solar Power from Space Helps Solve Our Energy Needs?' The Guardian (9 October 2022) <https://amp.theguardian.com/science/2022/oct/09/ beam-me-down-can-solar-power-from-space-help-solve-our-energy-needs> accessed 27 July2024.

that enthusiasm is not without some reservations.[11] Recent wars[12] and domestic crises[13] have led to distrust and antagonism amongst states and caused states to realise that unmitigated reliance on fossil fuels is dangerous and foolhardy. Solutions are now being sought from different perspectives.[14]

Researches are ongoing in many regions on the possibilities of generating clean energy from outer space.[15] Space activities had moved from the exclusive preserve of the few space-faring states involved in space exploration at the early stage. More states have come to appreciate the importance and relevance of the use of outer space. On the other hand, private companies have pushed for more involvement in the exploitation and exploration of the space sector.[16] Many factors interplay and contribute to the world's energy crisis, so this study will examine a few of the factors below:

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[11] Phil Plait, 'NASA's Hopes for Solar Power Are Looking Dim' Sci Am (8 March 2024) <https://www.scientificamerican.com/article/nasas-hopes-for-space-solar-power -are-looking-dim/> accessed 23 July 2024.

[12] M. T. Klare, 'Twenty-First Century Energy Wars: How Oil and Gas are Fuelling Global Conflicts' Energy Post.eu (15 July 2014) https://energypost.eu/twenty-first-century-wars-oil-gas-fuelling-global-conflicts/ accessed 24 July 2024; D. Gaffen, 'How the Russia-Ukraine War Accelerate a Global Energy Crisis' Reuters (15 December 2022) <https://www.reuters.com/business/energy/year-russia-turbo charged-global-energy-crisis-2022-12-13/> accessed 24 July 2024.

[13] European Union, 'A Year of War and the Energy and Climate Crisis' EEAS (02 January, 2023) <https://www.eeas.europa.eu/eeas/year-war-and-energy-and-climate -crisis-en accessed 24/07/2024>; IEA 50, 'How the Energy Crisis Started, How Global Energy Markets are Impacting Our Daily Life, and What Governments are Doing About It' <https://www.iea.org/topics/global-energy-crisis> accessed 24 July 2024.

[14] M. Farghali et al, 'Strategies to Save Energy in the Context of the Energy Crisis: A Review' (2023) Environmental Chemistry Letters 21: 2003-2039; Coldwell Solar, 'Causes, Effects and Solutions to the Global Energy Crisis' <https://coldwell solar.com/commercial-solar-blog/causes-effects-and-solutions-to-the-global-energy-crisis/> accessed 27 July 2024.

[15] NASA Communications, 'New Study Updates NASA on Space Based Solar Power' NASA (11 January 2024) <https://www.nasa.gov/organizations/otps/space-based-solar-power-report/#:~:text=Creating%20a%20space%2Dbased%20solar,the%20 harvested%20energy%20to20Earth> accessed 27 July 2024.

[16] S. Goguichvili et al, 'The Global Legal Landscape of Space: Who Writes the Rules on the Final Frontier' The Wilson Center, (1 October, 2021) <https://www.wilsoncenter.org/article/global-legal-landscape-space-who-writes-rules-final-frontier> accessed 29 June 2024.

1.1 The Population Boom

As the world population increases daily,[17] pressure is being put on all available human and natural resources, including the energy sector, because a surge in the population leads to a surge in the energy demand.[18] It is believed that the planet is under immense pressure due to population growth, persistent dependence on traditional energy sources and migration crisis,[19] caused by conflicts all around the world. Humans always require energy, and its sustainability would be an issue of consideration for the governments of any society. Also, the population boom creates pressure on sustainability, with "…a greater urgency today than heretofore to identifying sustainable sources of energy, increasing the efficiency of energy usage, and finding new sources of energy due to expanding world population, depletion of energy sources, and growing environmental concerns."[20]

Global population growth and globalisation demand fiscal safeguards and living sustainably, a contrast that population and other factors make nearly impossible for most of the world. As the world population increases, the demand for more energy to meet human and industrial needs invariably increases. However, because supply is lower than demand, there is an energy deficit, as humans always require energy. Consequently, when demand exceeds supply, it creates higher commodity prices and economic problems.

1.2 The Environment

The environment is indispensable for the world as energy is mostly extracted from the earth, and its waste products are released into the environment.[21] The earth's natural resources are affected by burning fossil fuels, leading to environmental damages and climate change challenges that further upsurge the energy crisis.[22] It is like a vicious circle, and scientists believe that the climate change crisis is due to humanitarian actions causing increased levels of

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17 Worldometer, Current World Population, <https://www.worldometers.info/world-population/> accessed 27 July 2024.

18 H. Manchandani, 'Space Based Solar Power Versus Ground Based Solar Power' (2017) International Journal of Research and Engineering, 260-262.

19 A. Scott, L. Worral and S. Pickard, 'Energy Migration and the 2030 Agenda for Sustainable Development' (July 2018) Swiss Agency for Development and Coopera tion SDC <https://odi/org/documents/5818/12301.pdf> accessed 27 July 2024.

20 Coyle and Simmons (n 1) at 12.

21 Ibid.

22 Coyle and Simmons (n 1).

greenhouse gases. If the level of greenhouse gases is lowered, the impact on individuals, society, and the global economy will be felt worldwide.[23]

Unfortunately, energy infrastructure uses fossil fuels that are not sustainable energy sources because of the likelihood of their being exhausted. In addition, burning fossil fuels produces greenhouse gases, including carbon dioxide (CO2).[24] On the impact of humans on the environment, it must be noted that "Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system".[25]

1.3 The Energy Crunch

The Covid-19 crisis and its aftermath exacerbated the energy crisis already existing worldwide.[26] The aftermath resulted in high cost of prices, inflation and invariably, household poverty.[27] It pushed many households below the poverty threshold, especially in the developing countries[28]. The energy crisis adversely impacted individuals, states, and the commercial sectors, with gas, electricity, and coal prices going over the roof.[29] Several factors, including international politics, economic factors, and energy production costs, cause the economic crunch. However, most of the impacts have been felt by the

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23 Ibid.

24 Klaus Jager et al, Solar Energy, Fundamental Technology and Systems (2014) Delft University of Technology.

25 Thomas Stocker, et al, Climate Change 2013 - The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, United Kingdom, 2014)

26 A. Tuan Hoang, 'Impacts of COVID-19 Pandemic on the Global Energy System and the Shift Progress to Renewable Energy: Opportunities, Challenges and Policy Implications' (2021) PubMed Central <https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC8455103/> accessed 27 July 2024

27 Ibid.

28 O.J. Olujobi, E.S., Olarinde, T.E., Yebisi, U.E. Okorie, U.E., COVID-19 Pandemic: The Impacts of Crude Oil Price Shock on Nigeria's Economy, Legal and Policy Options, Sustainability (2022), 14(18), 11166, 6. >https://doi.org /10.3390/su 141811166> accessed September 8,2024.

29 Statista, 'Global Energy Crisis, Statista Trend Report on the Global Energy Crisis' <https://www.statista.com/study/123861/global-energy-crisis/> accessed 24 July 2024.

world's poorer nations.[30] The energy crunch continues to fuel the imbalance in the world's energy landscape,[31] with most states relying on the world's most significant fossil fuel suppliers.[32] The Russian-German Nord Stream 2 pipeline conflictand the Russian/Ukraine war are major factors in the energy crisis.[33]

2. SPACE-BASED SOLAR POWER

Space-based solar power (SBSP) takes energy from outer space and celestial bodies due to man's desire and quests to solve the energy crisis by prospecting for a new source of sustainable energy that is also cheap, achievable and environmentally friendly.[34] The demand for cleaner energy is growing because climate change and its challenges are linked to environmental devastations caused by the processing of fossil fuels.[35] Therefore, There are calls for clean energy, but affordability and sustainability are important factors to consider. The energy that is needed must have what is called net zero and have the following characteristics:

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30 I. Bremmer and C. Kupchan, 'Risk 6: Energy Crunch' (Eurasia group, 3 January 2023) <https://www.eurasiagroup.net/live-post/top-risk-2023-6-Energy-Crunch> accessed 24 July 2024.

31 International Energy Agency, 'World Energy Outlook 2023' (2023) <World EnergyOutlook2023.pdf> accessed 22 July 2023.

32 Ibid.

33 E. Thomson, '6 Ways Russia's Invasion of Ukraine Has Reshaped the Energy World' (World Economic Forum, 8 November 2022) <https://www.weforum.org/agenda/2022/11/russia-ukraine-invasion-global-energy-crisis/> accessed 27 July 2024; N. E. Kaya, 'A Year into Russia's War in Ukraine: Energy Crisis Deepens, But Renewables Emerge Stronger' (AA, 20 February, 2023) <https://www.aa.com.tr /en/economy/a-year-into-russias-war-in-ukraine-energy-crisis-deepens-but-renewa bles-emerge-stronger/2825355> accessed 27 July 2024.

34 Frazer-Nash Consultancy, 'Space Based Solar Power' (2021) <https://www.fnc.co .uk/media/e15ing0q/frazer-nash-sbsp-executive-summary-final.pdf > accessed 01 July 2024.

35 Standford University, 'Global Carbon Emissions from Fossil Fuels Reached Record High in 2023' (Standford Doeer, 5 December 2023) <https:// sustainability.edu/ news/global-carbon-emission-fossil-fuels-reached-high-2023 accessed 27/07/2024>; United Nations, 'Causes and Effects of Climate Change' <https://www.un.org/en/climatechange/science/causes-effects-climate-change#:~:text=fossil%20fuels%20%E2%80%93%20coal%2C%20oil%20and,they%20trap%20the%20sun's%20heat> accessed 27 July 2024.

> It has to be clean, with no CO_2 or other waste; it must provide baseload power and deliver affordable energy for homes and industry; it must be secure in terms of both reliability and UK sovereign control, and it should be resilient to natural disasters and terrorist attack; the fuel supply should be scalable, abundant and sustainable; it should not take up too much land area; it must be safe, it should integrate well into existing power distribution grid…[36]

An abundance of energy can be tapped from the sun, and solar energy has already been used on the terrestrial Earth to address some energy limitations. However, weather fluctuations greatly hinder the effectiveness of solar power. This limitation makes space-based solar energy attractive: "Space-Based Solar Power is the concept of collecting this abundant solar power in orbit and beaming it securely to a fixed point on the earth. Its main advantage over wind and terrestrial solar energy is the ability to deliver energy day and night throughout the year and in all weathers".[37] It is the process of harnessing sunlight energy from the orbit and transmitting it to the earth's surface using power stations on earth in order to generate alternative clean energy. It is the generation of electricity from solar energy through satellites.[38] This is achieved through solar power enabled by the sun and transmitted via satellites to the Earth station. Space-based solar power gathers solar radios that are then changed into radio frequencies and sent back to the receiving segment on the earth, a wireless transmission of electrical energy. This is achieved by two essential components: the space segment and the ground segment.[39]

Energy is abundant in the solar system in outer space that remains unhindered by the earthly weather fluctuations. Such energy can be harnessed as long as scientists can possibly place solar panels in geosynchronous orbit.[40] The essence of placing solar panels in the geosynchronous orbit is the possibility of tapping sunlight energy directly without needing a battery or storing power since energy can be transmitted

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[36] Ibid.

[37] Ibid

[38] K.R. Karduri, 'Exploring the Viability of Space-Based Solar Power' (2019) International Journal of Advanced Innovative Discoveries in Engineering and Application (IJARIDEA) Vol.4, Issue 2,16-24.

[39] J. P. Pagel, A Study of Space-Based Solar Power Systems (2022) Thesis Submitted to NAVAL POST-GRADUATE SCHOOL, Monterey California,

[40] F.J.T. Salazar and O.C. Winter, 'Solar Power Satellite in Formation on a Common Geostationary Orbit' (2017) IOP Conference Series: Journal of Physis 911.

directly to the earth using microwave beams called magnetrons.[41] While in the past, the possibility of space-based solar power was quickly discarded due to the exorbitant costs, the availability of modern technology has made it possible and cheaper. An observer noted that it is "…the most clean and direct energy resource without dangerous implications as in the case of nuclear energy".[42] Outer space remains one of the places scientists have been looking at for a solution to the energy crisis confounding the Earth as far back as the 1970s. The reason for the relentless search is encapsulated in the following observations.

> One of the possible sources of energy to which attention has been directed in recent years is solar energy. Scientists estimate that the total amount of energy reaching the Earth's surface environment from solar, geothermal, and tidal sources is about 173,000 × 10 watts. Solar radiation accounts for 99.98 percent of the total. The sun's contribution to the available energy supplies of the Earth is 5000 times greater than the energy input of all other sources combined.[43]

Solar energy can be converted into electricity through silicon or photovoltaic cells, and it has remained an area of interest for many years, though it is still not considered economical on a large scale.[44] The reason for the reservation is that compared to conventional fuel-generating mechanisms such as water, wind and hydrocarbon energy sources, and it is expensive now but likely to be more cost-effective as technology improves.[45] Jurists for many years have flaunted the possibilities in the exploration of outer space for energy solutions and have commented as follows:

> It might be technologically feasible sometime in the future to set up appropriate units in outer space for the purposes of collecting the sun's energy and relaying it back to the Earth. The advantages of such devices would include the avoidance of the day-night cycle and cloudy weather conditions with the result that solar energy would be available nearly 24 hours for everyday use. A satellite solar power station (SSPS) could be placed into a synchronous orbit above the Earth's Equator so that its

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41 H. Manchandani (n 18)

42 Ibid.

43 S Gorove, 'Solar Energy and Space Law' (1976) 10 INT'L L. 531 <https://scholar.smu.edu/til/vol10/iss3/13> accessed June 2024.

44 H. Barde, 'A Skeptic's Take on Beaming Power to Earth from Space' (IEEE Spectrum, 09 May 2024) <https:spectrum.ieee.org/amp/space-based-solar-power-2667878868-2667878868> accessed 27 July 2024.

45 Ibid, at 532.

> solar collectors would always face the sun its transmitting antenna would direct a microwave beam to a receiving antenna on Earth. The microwave beam would permit all-weather transmission, making full use of nearly 24-hour availability of solar energy.[46]

Solar power satellites (SPS) provide uninterrupted power by supplying "10 million kilowatts of power" to be accepted on earth through rectennas that can yield electricity for millions of people.[47] Improved technology would be needed to harness the energy from outer space. Though the costs might be higher now than conventional energy sources, in the long run, it would generate cheaper energy to solve energy problems on Earth. Space mining will make it possible by reducing the prices of materials transported to orbits.[48] There are many benefits of space solar-based energy, and NASA explained the following merits: in contrast to the traditional sources of energy, solar energy does not produce greenhouse gases; does not require land or water resources or precious materials that should be used for fertiliser in the bio-ethanol and bio-diesel industries. It does not generate harmful wastes which take years to eradicate. In addition, there is a constant supply of sunlight that is not hindered by the weather conditions and is an unlikely target for terrorist attacks, and it is not subject to mining restrictions. NASA also made the following observations

> Space solar power will provide true energy independence for the nations that develop it, eliminating a major source of national competition for limited Earth-based energy resources. Space solar power will not require dependence on unstable or hostile foreign oil providers to meet energy needs, enabling us to expend resources in other ways. Space solar power can be exported to virtually any place in the world, and its energy can be converted for local needs – such as manufacturing methanol in places like rural India without electric power grids. Space solar power can also be used for the desalination of seawater. Space solar power can use our current and historic investment in aerospace expertise to expand employment opportunities and solve the difficult problems of energy security and climate change. Space solar power can provide a market large enough to develop the low-cost space transportation system required for

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46 Gorove (n 42) at 533.

47 Ty. S. Twibell, 'Space Law: Legal Restraints on Commercialisation and Develop ment of Outer Space' (1997) 65 UMKC L. REV. 589, 634

48 Ibid at 634.

> its deployment. This, in turn, will also bring the solar system's resources within economic reach.[49]

Space-based solar systems have their demerits, but the most essential is the high cost of deploying the solar systems. However, it has been argued that the cost of not investing in the solar systems is small compared to the military deployments all over the world.[50] Space-based solar energy is attractive if the following are in place, as noted by NASA below:

> Low-cost, environmentally-friendly launch vehicles. Expendable launch vehicles have been too expensive and at high launch rates may pose atmospheric pollution problems of their own. Cheaper, reusable launch vehicles are under development by more than one private company. Large-scale in-orbit construction and operations. To gather massive quantities of energy, solar power satellites must be large, far larger than the International Space Station (ISS), the largest spacecraft built to date. Fortunately, solar power satellites will be simpler than the ISS as they will consist of many identical parts. Power transmission. A relatively small effort is also necessary to assess how to best transmit power from satellites to the Earth's surface with minimal environmental impact.

The technology for the above is still in the developmental stage, and though it has excellent prospects, yet more research and development studies are required for it to manifest. As technology upsurges, it might be possible to assemble solar satellites in orbit shortly instead of transporting them from the Earth. Moreover, since space mining is already in the pipeline, there is the possibility of manufacturing satellite materials in space with little likelihood of environmental damage to the Earth, as most of the activities are conducted in orbit. The only structure to be installed on the earth would be the ground receivers, solving the earth's greatest need.[51] Space-based solar power comprises important components that would be discussed below:

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[49] NASA, (n 15)

[50] NSS, 'Space Solar Power Info: Limitless clean energy from space' <https://nss.org/space-solar-power-info/> accessed 23 July 2024.

[51] Ibid.

2.1 The Solar Power Satellites[52]

In order to extract energy for outer space, satellites are essential and would have to be built in the Geostationary Earth Orbit (GEO). Huge solar panels that can generate massive gigawatts of electricity from the satellite are used and changed into radio waves and sent to the earth through microwave beams received on earth by rectennas.[53] Radio frequencies[54] are essential to returning to the earth unhindered by earthly weather conditions. An encryption system achieves security. The rectenna transforms the received 'radio waves'[55] into electricity that is turned into electricity stored in the power grid, and the power generated can be as much as that produced by nuclear power.[56]

2.2 Space Launch and Transportation to Orbit

Constructing solar satellites is distinct from traditional spacecraft construction; it is "highly modular" because it involves using sturdy modules that can be produced in large quantities to reduce costs. The modular system is believed to be a better option as it shields from damage and technical problems without the likelihood of failing. In addition, robots can be used in construction, reducing human intervention and the need to take expertise to outer space. The essence of all these is to keep operating costs low, which will transform into cheaper energy costs for consumers.[57]

2.3 Ground Antennae Including Beam and Interface

Ground antennas[58] are vital for receiving electricity being beamed from the orbiting satellite via microwave beams. The components of the ground infrastructure are the "power and satellite mission control" and the

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52 Frazer-Nash Consultancy, 'Space Based Solar Power, De-risking the Pathway to Net Zero' (September 2021) <space-based-solar-power-derisking-pathway-to-net-zero.pdf> accessed 22 July 2024.

53 See generally, D. Oberhaus, 'Space Solar Power: An Extraterrestrial Energy Resources' (2021) Innovation Frontier Project

54 J. F. Weaver, 'Beaming Radio Frequency Solar Power From Space' (PV Magazine, 22 February 2024) <https:pv-magazine-usa.com/2024/02/22/beaming-radio-frequen cy-solar-power-from-space/> accessed 27 July 2024.

55 I. S. Bisht, 'Northrop Demonstrates Solar to Radio Frequency Conversion' The Defence Post, (29 December 2021) <https://www.thedefencepost.com/2021/12/29/northrop-solar-radio-frequency/> accessed 27 July 2024.

56 Frazer-Nash (n 51)

57 Ibid

58 Staff Writer, 'Antennas: The Interface with Space' (Via Satellite, 10 September 1999) https://www.satellitetoday.com/uncategorized/1999/09/10/antennas-the-interface-with-space/ accessed 27/07/2024.

"rectenna".[59] The rectenna is large, though it is made up of small aerials used to collect the energy being transmitted and then transform it into electricity. At the middle of the rectenna is a limited ray intensity that does not exceed an area of the sun's force, making it safe for humans on Earth. It is possible to site the rectenna amongst current wind farms and link them with the previously in-place power grid.[60]

2.4 Power and Satellite Mission Control

One of the issues hindering the possibility of energy from outer space is the exorbitant costs of taking satellite hardware from Earth to orbit. However, the influx of private companies like Elon Musk's SpaceX,[61] Blue Origin,[62] and Virgin Galactic[63] has reduced space launch costs. In addition, the space satellites market had grown exponentially,[64] thereby plummeting prices of space launches. These aspects would also touch the space-based solar sector by making the launch of solar satellites economical. It is envisioned that the request for space-based solar power might intensify the demand for more reusable spacecraft. In addition, robots can assemble satellites in orbits in the Medium Earth Orbit (MEO), further decreasing manufacturing costs and the possibility of space debris. The finished satellite is then placed in the geostationary orbit by the propulsion system and driven by solar power.[65]

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59 C. Bergsrud et al, 'Space Solar Rectifying Antenna on Earth' (2021) Online Journal of Space Communication, Vol. 10, Iss. 17, Article 12, <https://ohioopen.library.ohio.edu/spacejournal/vol10/iss17/12> accessed 27 July 2024.

60 Frazer-Nash (n 51)

61 P. Lionnet, 'SpaceX and the Categorical Imperative to achieve Low Launch Cost' (SpaceNews, 7 June 2024) <https://spacenews.com/spacex-and-the-categorical-imperative-to-achieve-low-launch-cost/> accessed 27 July 2024; Denise Chow, 'To Cheaply Go: How Falling Launch Costs Fueled a Thriving Economy in Orbit' (NBC News, 8 April, 2022)< https://www.nbcnews.com/news/amp/rcna23488> accessed 28 July 2024.

62 D. Chakraborty and J. Wattles, 'Blue Origin Launches Six Tourists to the Edge of Space After Nearly Two-Year Hiatus' (CNN, 20 May, 2024) <https://amp.cnn.com/cnn/2024/05/19/world/blue-origin-rockets-ns-25-mission-scn> accessed 28 July 2024.

63 M. Wall, 'Virgin Galactic to Launch 7the Commercial Spaceflight on June 8' (Space.com, 3 May 2024) <https://www.space.com/virgin-galactic-seventh-commer cial-spaceflight-june-8> accessed 28 July 2024.

64 Precedence Research, 'Space Technology Market Size, Share, and Trend 2024 t0 2033' <https://www.precedenceresearch.com/space-technology-market>.

65 Ibid

3. SPACE MINING

One of the fears posed by outer space exploration had centred on the issue of nuclear weapon attack. To combat these fears, all states have designated outer space as a place for peaceful use, including outer space for sustainable earth development.[66] An offshoot of the international law regulating space is the freedom of mining outer space resources for scientific and peaceful uses. Article III of the Outer Space Treaty of 1967 means that international law, including the Charter of the United Nations, would regulate outer space "in the interest of maintaining international peace and security and promoting international cooperation and understanding".

There are ample resources in outer space,[67] and it appears that the only hindrance to its exploration is that posed by the space treaties' provisions. Some of the space resources are vital to the energy sector on the earth apart from their importance to solar energy. In expounding the importance of these rich space resources, Quinn noted the following important observations:

> The natural vacuum and absence of gravity in space aid in manufacturing semiconductors, microchips, pharmaceuticals, and aids crystals formation necessary in genetic engineering and molecular electronics. Although technology has advanced on earth, the natural vacuum of space is still many times superior to that of our best terrestrial efforts. Equally renewable is solar power which is approximately fifteen times more efficient when captured in space than on earth. The cost to launch satellites capable of beaming solar energy is prohibitive, but would not be if the satellites were created from materials mined in space.[68]

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[66] UNOOSA, 'Space Supporting Sustainable Development Goals' <https://www.unoosa.org/oosa/en/ourwork/space4sdgs/index.html>; UNCTAD, 'Exploring Space Technologies for Sustainable Development' (UNCTAD, 2021) <https://unctad.org/system/files/official-document/district2021d1_en.pdf> accessed 28 July 2024

[67] E. Demirer, 'What is Space Mining and Space Resources' (2023) Istanbul Bar Association, <https://www.researchgate.net/publication/372907391_WHAT_IS_SPACE_MINING_AND_SPACE_RESOURCES> accessed 28 July 2024.

[68] Twibell (n 46); Rashmi Mayur, 'Solar Power Satellite and Third World Energy Future in SPACE MANUFACTURING 7: SPACE RESOURCES TO IMPROVE LIFE ON EARTH 159 (Barbara Faughnan & Gregg Maryniak eds., Nov, 1991) cited by Quinn at 488.

3.1 Hydrocarbons in Outer Space

Hydrocarbons[69], similar to important petrochemicals used in the oil, coal and petroleum industries, are gradually depleted on Earth. States are grappling with finding alternatives, but hydrocarbon is said to have been found in abundant quantity in the solar system.[70] The prospect of mining hydrocarbons from celestial bodies is attainable because they are commonly found to come close to the earth and can be extracted easily.[71] The quantity of hydrocarbons makes its usage in the energy sector attractive.[72] Twibell argued that abundant supply and accessibility make hydrocarbons vital in solving Earth's energy scarcity problem, provided that a workable legal framework is implemented to ensure the workability. Only the prospects of huge financial gain would make investors commit to the huge investments needed in the sector.[73]

3.2 Helium-3

Helium-3[74] is an isotope[75] important for the energy sector, and it is scarce on the Earth but abundant on the moon. The essence of helium-3 is that it allows

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69 Discovery Files, 'Found in Space: Complex Carbon-Based Molecules' (US NSF, 31 March 2021) <https://new.nsf/gov/news/found-space-complex-carbon-based-molecules> accessed 28 July 2024.

70 Twibell, (n 46) at 635; A. Zuppero, Discovery of Abundant, Accessible Hydrocarbons Neary Everywhere in the Solar System in STEWART W. JOHNSON, 2 ENGINEERING, CONSTRUCTION, AND OPERATIONS IN: SPACE V 791 (American Society of Civil Engineers, 1996) in Twibell.

71 J. Dewulf and H. V. Langenhove, 'Hydrocarbons in the Atmosphere' Encyclopedia of Life Support Systems (EOLSS) Vol. II <https://www.eolss.net/sample-chap ters/c06/E6-13-02-07.pdf> accessed 28 July 2024.

72 NASA, 'Titan's Surface Organics Surpass Oil Reserves on Earth' (NASA, 13 February 2008) <https://science.nasa.gov/solar-system/planets/saturn/saturn-moons/ ztitans-surface-organics-surpass-oil-reserves-on-earth/> accessed 28 July 2024; J. Klokocnik et al, 'Hydrocarbons on Mars'(2023)International Journal of Astrobiology, Cambridge University Press, Vol.22, Iss.6. <https://www.cambridge.org/core/journals/international-journal-of-astrobiology/article/abs/hydrocarbons-on-mars/75C0D61774BC478A9CD9A6C07F7332CA#> accessed 28 July 2024.

73 Twibell (n 46) at 635.

74 European Space Agency, 'Helium-3 Mining on the Lunar Surface' <https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/Energy/Helium-3_mining_on_the_lunar_surface> accessed 28 July 2024.

75 F. Vidal, 'Helium-3 from the Lunar Surface for Nuclear Fusion?' (Polytechnique Insights, 17 May, 2022) <https://www.polytechnique-insights.com/en/braincamps/space/extraterrestrial-mining/helium-3-from-the-lunar-surface-for-nuclear-fusion/> accessed 28 July 2024.

the nuclear reactor to use the fusion process instead of the fission process, thereby reducing the risks of environmental pollution and damage.[76] This is because "fusion produces little or no radioactive waste and eliminates the possibility of runaway reactions because very small quantities of fuel are used".[77] Fusion energy is claimed to be a better alternative to traditional fossil fuels. When fossil fuels are combined with other solid materials, such as deuterium, they can lead to dangerous chemical reactions in the environment. In the alternative, it was argued that when deuterium is mixed with Helium-3, it produces no dangerous reactions such as neutrons.[78] Vidal noted the following

> Of these, helium-3 represents the most significant potential in the field of energy. The non-radioactive isotope is an ideal fuel for the operation of a fusion reactor; it consists of fusing helium-3with deuterium, with the advantage of not producing neutrons. Whilst it is still in its experimental stages, the ability to contain such energy in the reactor's containment chamber could make it a viable energy source.[79]

Essentially, helium-3 is significant in the energy sector as a major substance that does not produce harmful chemical reactions. However, its availability on earth is scanty because the formation process is quite cumbersome and would produce a small quantity at best. The moon has an abundant supply of Helium-3, and as Twibell observes

> The solar wind carries massive quantities of helium-3. The lack of atmosphere on the Moon allows Helium-3 to be planted there in huge quantities by the solar wind, enough to power the Earth for centuries. Thus, an established mining industry would aid in making helium-3 mining on the Moon a lucrative investment with perhaps a higher rate of return than other mining operations. For example, platinum has a price of approximately $20 million per metric ton, while helium-3 has a market value of $15 billion per ton.[80]

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[76] Twibell (n 46) at 636.

[77] Twibell, id; see also Department of Energy, Office of Fusion Energy Homepage, About Fusion Energy at 1, <http://wwofe.er.doe.gov.More_HTML/more_fusion.html> in Twibell.

[78] Ibid

[79] Vidal (n 74)

[80] Twibell (n 46) 636-637.

In understanding the essence of helium-3, an observer had to look at the rate at which the space faring states are racing to get to the moon to dominate the sector. China is already racing to dominate the new frontier.[81]

4. LEGAL FRAMEWORK FOR SPACE USE

A cocktail of international, regional and national laws governs space. At the international level, five major treaties regulate all space activities. However, at the national level, each state can have domestic laws regulating its space activities as long as they comply with international laws, including the Charter of the United Nations. As agreed by state parties, there are also regional bilateral and multilateral laws regarding their use of outer space. The space treaties started with the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of 1967 (hereafter called the Outer Space Treaty). They ended with the last treaty in 1979, the Agreement Governing the Activities on the Moon and Other Celestial Bodies (hereafter called the Moon Agreement).[82] The outer space is designed as common ground[83] for all states to explore and utilise without hindrance.

4.1 The Space Treaties

The Outer Space Treaty (OST) is considered the magna carta of space law, formed in 1967, and it contains provisions that subsequent treaties expatiated upon and have enjoyed wide acceptance, having been ratified by over ninety states. It established outer space as a place for all states to explore as long as it

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81 Vidal (n 74)

82 While the Outer Space Treaty of 1967 was the first and the most popular space treaty encompassing all the provisions in the other treaties, there were other treaties that soon followed addressing particular issues in relation to the activities in outer space. The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects into Space of 1968; the Convention on International Liability for Damage Caused by Space Objects of 1972; the Convention on Registration of Objects Launched into Outer Space of 1975 and the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies of 1975 all specifically dealt in greater details issues addressed by the Outer Space Treaty.

83 Z. Meyer, 'Private Commercialization of Space in An International Regime: A Proposal for a Space District' (2010) 30 Nw. J. Int'l L. % Bus. 41; J. I. Gabrynowicz, 'Space Law: Its Cold War Origins and Challenges in the Era of Globalisation' (2004) 37 Suffolk U.L. Rev 1041

is done in the interest of all mankind to further the exploration and use of outer space for peaceful purposes.[84] States interpret the wordings of the OST according to the level of their technological advancements and their involvement in space activities. While the developed and space-faring states such as the United States, Russia, Japan, Canada and the European Space Agency argue that the 'common heritage' connotes ample exploration of space without any form of hindrance, the non-space-faring states mostly comprising the developing states argue that outer space and the benefits (including energy for the solar systems) are to be[85] dispersed impartially amongst all states whether they partake in the exploration or not.[86]

Another bone of contention between the states is the non-appropriation doctrine enshrined in the OST.[87] The developing states argue against any form of appropriation of outer space's resources since outer space is considered a global common.[88] In contrast, the space-faring states maintain the absolute appropriation of the resources by states and not by the private sector. Private entities in outer space are free to explore without restrictions.[89]

The treaties that came years later just enlarged some of the provisions of the OST, each detailing specific areas in greater detail. These include the Rescue Agreement, which covers the rescue of astronauts in distress while encouraging international cooperation and humanity.[90] The Liability Treaty dealt with the liabilities of states for the actions of their citizens in space,[91] the issue of which State to bear the costs of rescue assistance offered to distressed astronauts.[92] The Registration Treaty detailed the registration of space objects in the National Registry of the launching state and internationally at the

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84 See generally, the Outer Space Treaty; see also Eric Husby, 'Sovereignty and Property Rights in Outer Space' (1994) 3 J. INT'L L. & PRAC 359, 362 cited by A. G. Quinn, 'The New Age of Space Law: The Outer Space Treaty and the Weaponisation of Space' (2008) 17 MINN. J. INT'L L. 475.

85 M. B. Hershkowitz, 'Deep Space (Treaty) Exploration: Reviving Today's Obsolete Space Treaties (2019) 28 Mich St Int'l L. Rev 1.

86 L. M. Fountain, 'Creating Momentum in Space: Ending the Paralysis Produced by the "Common Heritage of Mankind" Doctrine' (2003) 35 CONN. L. REV. 1753, 1761 cited by Quinn supra n 13.

87 See Article II of the Outer Space Treaty.

88 Hershkowitz (n 84) 22.

89 Quinn (n 83) at 481.

90 D. A. Porras, 'The Common Heritage of Outer Space: Equal Benefits for Most of Mankind' (2006) 37 Cal W Int'l LJ 143.

91 Ibid.

92 Article VI of the Liability Treaty.

United Nations registry.[93] The last space treaty came out in 1979, known as the Moon Treaty. It is the least to enjoy acceptance and ratifications from the space-faring states because space-faring states considered its terms too restrictive to the exploration of outer space.

Most space-faring states had rejected the moon treaty in its entirety and had refused to be bound by its provisions in their activities in outer space.[94] Property rights were denied by the treaty to states and private entities,[95] leading to most states' wide rejection of the treaty. It is on record that only the developing states have ratified its provisions to date. Other resolutions adopted over the years that are significant use of outer space are noted below:

1. The 1963 Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space (Resolution 1962 (XVIII));
2. The 1962 Principles Governing the Use by States of Artificial Earth Satellites for the International Direct Television Broadcasting (Resolution 37/92);
3. The 1986 Principles Relating to Remote Sensing of the Earth from Outer Space (Resolution 41/ 65);
4. The 1992 Principles Relevant to the Use of Nuclear Power Sources in Outer Space (Resolution 47/68);
5. The 1996 Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interests of All States Taking into Particular Account the Needs of Developing Countries (Resolution 52/122).

4.2 The Applicability of Space Treaties to Solar Power Energy

Article I of OST allows for the use and exploration of outer space for states, irrespective of the level of development, without discrimination. Stephen Gorove noted that the prohibition on the national appropriation principle may not be applicable since solar energy "…inasmuch as solar energy constitutes an inexhaustible source of energy and any prohibition of its use would be against reason and common sense".[96]Space law applies to all exploration and usage of outer space including exploration for solar energy that can be classified as scientific activities. Space law would apply to space

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93 See Article VIII of the Outer Space Treaty and the Registration Treaty.
94 Goldmann at 87.
95 Quinn (n 83) 483.
96 Gorove (n 42) 534.

solar energy at every stage of its exploration, from development to exploitation. This is enshrined in Article 1 of the Moon Agreement and its entire application for the lunar resources, including the Moon and the Sun.[97]

Since electricity is likely to be transmitted through the airspace, it is important to consider Article 1 of the 1944 Chicago Convention on the issue of violation of sovereign rights. However, it can be argued that space solar power is a space activity that is regulated by the freedom of use under the Outer Space Treaty. Another consideration is whether the space solar power would violate the non-appropriation principle enshrined in Article II of the OST and Article II para 2 and 3 of the Moon Agreement. It should be explained that specific lunar and orbital stationing is not allowed, but solar energy and lunar resources used for solar energy can be factored into the use of outer space, and it can be argued that

> The use of solar energy that appears to be unlimited and renewable source of energy cannot be considered as an appropriation since it does not conduct to destroy, to give or to sell sun resources themselves. Such use does not exclude the ability for other states to use solar energy as well…States are already using solar energy through other satellites equipped with solar panels. So, no claim has been registered on the basis of the non-appropriation principle…[98]

Making a distinction between the lunar resources and the use of the sun for energy is necessary because while the use of lunar resources may be regarded as an appropriation of space resources, there is no violation of space law when solar power is being used as the OST guarantees it to the effect that space is to be used for the betterment of humankind. States can also come together to jointly exploit the lunar resources as epitomised in the adoption of the Convention on the Regulation of Antarctic Minerals Resources Activities of 1988, which permits limited controlled exploitation of the Antarctic resources that hitherto had been banned by the provisions of the Washington Treaty on the Antarctic of 1st December 1959.

Article IV para 1 of the OST prohibits the placement of weapons of mass destruction on the earth's orbits, and the provision must be adhered to by all

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97 L. Crapart and E. Marescaux, 'Legal Aspects of Solar Power Satellite' (Final Report), Institut du Droit de l'Espace et des Telecommunications, <file:///C/Users/USER/Desktop/ACT-GSP-SPS-0310%20Legal%20Aspects%20of%20SPS%20%20FI NAL%20REPORT%20s.pdf> accessed 23 July 2024.

98 Ibid

states involved in space solar exploration. States might have to demonstrate that solar satellites cannot be reconverted into weapons of mass destruction in the orbits because solar energy cannot be used for non-peaceful or aggressive purposes in contravention of the OST.

4.3 The International Telecommunication Union (ITU)

Almost all space activities use radio services[99]. The efficiency of satellites relies on the capacity to send and collect data, which is made possible via radio frequencies[100]. This made provisions of the ITU relevant for space-based solar systems, and radio frequencies are used for communications from the ground station to the satellites and back; it is necessary to ensure that radio frequencies for space energy do not interfere with other radio use and all such activities comply with the ITU rules. Allocation of the orbital slots for SPSS is provided for under Article 44.2 as follows:

> Members shall bear in mind that radio frequencies and the geostationary satellite orbit are limited natural resources and that they must be used rationally, efficiently and economically in conformity with the provision of the Radio Regulations so that the countries or groups of countries may have equitable access to both taking into account the special needs of the developing countries and the geographical situation of particular countries.

4.4 Environmental, Health, and Humanitarian Laws

Larsen and Lyall believe that the general principles of environmental law relevant to the terrestrial also apply to all space activities[101]. The 1992 Declaration of the United Nations Conference on the Human Environment is to the effect that "states share […] the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or areas beyond the limits of national jurisdiction"[102] States have the obligation of protecting the environment as held in the Trail Smelter Arbitration[103] case and Corfu Channel case[104]. Principle 15 of the Rio Declaration also states that

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99 F. Lyall and P.B. Larsen, Space Law: A Treatise (2018) 2nd Edn, Taylor and Francis, Routeledge London.

100 Ibid.

101 Lyal and Larsen (n 98) 246

102 Principle 21 of the 1972 Declaration of the United Nations Conference on the Human Environment.

103 The Trail Smelter Arbitration (US v Canada) 1938/41 3 RIAA 1905; (1941) 35 AJIL 684.

104 The Corfu Channel Case (UK v Albania) 1949 ICJ Rep 1.

> In order to protect the environment, the precautionary approach should be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, a lack of full scientific certainty shall not be used to postpone cost-effective measures to prevent environmental degradation.

States are to ensure that their activities, including space-based solar power, do not cause damage to the environment as well as pose a danger to humans. Since space solar power energy is woven around the use of microwave beams to transmit energy back to the earth and in orbits, there must be strict adherence to the limits placed by international and national radiation regulations. As long as the SPSS concepts conduct power via laser in space to the earth or from the space mission, the laws on disarmament treaties dealing with lasers may be applicable. Space debris must be factored into all space activities. The Space Debris Mitigation Guidelines and the works of the Inter-Agency Space Debris Coordination Committee are germane. The 1995 Additional Protocol on Blinding Laser Weapons or Restrictions on the Use of Certain Conventional Weapons is relevant.

5. SPACE SOLAR POWER FOR ENERGY SECURITY, EQUITY AND PROSPERITY

Amongst the huge benefits of space solar energy is its ability to help in disaster relief; SBSP would help illuminate the disaster zone during the humanitarian efforts to save lives and property by powering the areas.[105] Electricity beamed from space through microwave beams can reach the remotest parts of the earth, thus creating energy equity for all states. Space solar energy offers a continuous, uninterrupted supply of energy that bridges the energy gap between the developed and least developed states.[106] Energy security is created through diversification because energy can be generated from space irrespective of terrestrial crisis.[107] Finally, "the development of SBSP infrastructure and technology could stimulate the growth of a space-based industry, creating jobs and economic opportunities".[108]

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[105] Kristin Brumley et al, 'Space Solar Power for Disaster Relief' (2014) Online Journal of Space Communication Vol. 10: Iss. 17 Article 5.

[106] R. L. R. Karduri et al, 'Exploring the Viability of Space-Based Solar Power' (2019) IJARIDEA Vol.4, Iss.2, 27, 16-24.

[107] Ibid

[108] Ibid.

6. CONCLUSION

Space-based solar power (SBSP) is an option for the energy crisis. Clean energy with zero emission rate can be employed to reach the farthest parts of the earth, thereby bridging the energy gap. Electricity generated by SBSP would be accessible to every household and reduce the energy poverty experienced by the least developed states. However, the issue of the costs of launching solar satellites has to be addressed, and legal protection should be given to the private companies already involved in space energy. The regulatory challenges have to be dealt with at the international level.

Africa has many prospects to get from SBSP, but the high costs of launches would create hindrances for most African states. African States must come together jointly by adopting partnership options such as the ESA Partnership to benefit from space. African States should be mindful that the space-faring states are not likely to hand over the benefits of outer space to them. The States must act before the space-faring states take all the orbital slots. Africa must look inward, cooperate, and solve its energy crisis; Africa must arise.