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Comparative analysis of emerging energy sources: Solar thermochemical vs. ocean thermal energy conversion.

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Introduction

As the world intensifies efforts to transition toward sustainable and renewable energy, emerging technologies like solar thermochemical energy and ocean thermal energy conversion (OTEC) are gaining attention for their potential to provide clean, reliable power. Both approaches harness natural temperature gradients—solar thermochemical systems use high-temperature solar heat to drive chemical reactions, while OTEC exploits the thermal differences between warm surface and cold deep ocean waters. This article presents a comparative analysis of these two promising energy sources, focusing on their principles, technological maturity, resource availability, efficiency, environmental impact, and economic viability [1].

Solar thermochemical energy systems utilize concentrated solar radiation to achieve very high temperatures (typically above 1000°C) needed to drive endothermic chemical reactions that produce fuels or energy carriers. A common application is the solar-driven splitting of water into hydrogen and oxygen via metal oxide redox cycles. The produced hydrogen serves as a clean fuel with high energy density, which can be stored or converted back to electricity when needed. Solar thermochemical processes offer a way to store solar energy chemically, addressing intermittency issues associated with photovoltaics [2].

OTEC systems capitalize on the relatively stable temperature gradient between warm surface seawater (around 25°C) and cold deep seawater (around 5°C) in tropical and subtropical oceans. This thermal difference drives a Rankine or closed-cycle thermodynamic process, where a working fluid with a low boiling point (like ammonia) is vaporized by warm surface water, powering turbines to generate electricity. OTEC can provide continuous base-load power as ocean temperatures vary minimally over daily cycles [3].

Solar thermochemical energy depends primarily on direct normal irradiance (DNI), requiring sunny regions with clear skies and high solar concentration potential, such as deserts. It is location-specific but more widely applicable across arid and semi-arid regions worldwide. In contrast, OTEC requires oceanic thermal gradients of at least 20°C, limiting deployment to tropical coastal regions within about 20 degrees' latitude of the equator. While this narrows geographic scope, coastal nations in tropical zones can benefit significantly [4].

OTEC technology dates back to the 1880s but has seen limited commercial deployment due to engineering challenges, especially relating to heat exchanger fouling, biofouling, and deep water pumping. Pilot plants exist in Hawaii and Japan, demonstrating proof-of-concept. Solar thermochemical systems, although newer, are rapidly advancing through laboratory-scale demonstrations and pilot reactors, particularly for hydrogen production. However, large-scale commercial adoption is still in early stages [5].

Conclusion

Solar thermochemical and ocean thermal energy conversion represent complementary approaches to harnessing natural thermal gradients for clean energy production. Solar thermochemical systems excel in high-energy-density fuel generation with potential for widespread deployment in sunny regions, while OTEC offers reliable base-load electricity for tropical coastal communities. Both face technological and economic hurdles but hold

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great promise within a diversified renewable energy portfolio. Continued research, pilot demonstrations, and policy support are essential to unlock their full potential and contribute meaningfully to a sustainable energy future.

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