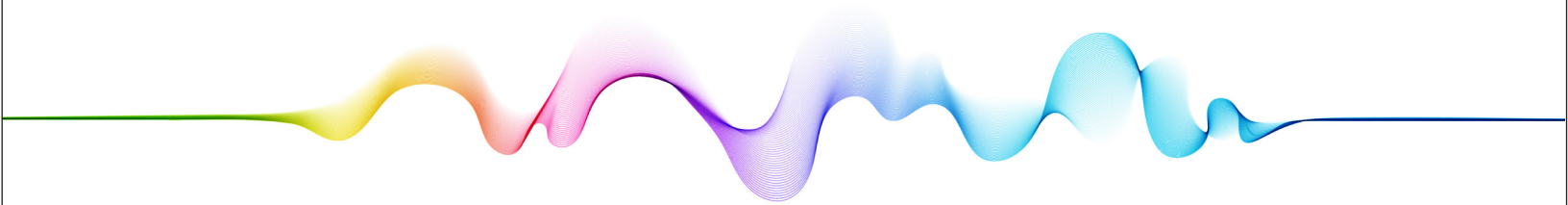


I N S I G H T R E P O R T

OVERVIEW OF RENEWABLE ENERGY COMMERCIAL MARKET



C L I M A T E S C I E N C E



TAG Insight Report: Overview of Renewable Energy Commercial Market

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Version 1.0

February 4, 2024

Introduction

This TAG Insights Report on *Renewable Energy for a Sustainable Future* is intended to help companies, managers, practitioners, researchers, investors, and commercial vendors better understand current trends, issues, and market opportunities in this area. A list of representative commercial vendors working in various areas of renewable energy is included. The five specific areas covered in this report include:

1. Solar and Wind Power Generation
2. Fission and Fusion
3. Hydropower Generation
4. Geothermal Energy Technologies
5. Bioenergy and Biomass Systems

This report is intended for general and unrestricted use, but interested readers are encouraged to connect with the TAG research and advisory team for more information on the private [TAG Research as a Service \(RaaS\)](#) community that covers, discusses, and shares information on these topics in more depth and includes a wider range of startups, vendors, and companies.

TAG Climate Taxonomy

We organize this TAG Insights Report as per our updated TAG Taxonomy which includes twenty categories of modern solution areas where stakeholders and buyers can find suitable commercial products and services for purchase and use. Each category has five subcategories

that correspond to the main areas in which practitioners can focus. These subcategories are discussed below.

TAG Climate Taxonomy V2.0 – 1Q2024

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Figure 1. TAG Climate Taxonomy

Overview of Renewable Energy

The following emerging global commercial opportunities for renewable energy solutions are covered in this report, including the listing of several viable commercial entities providing solutions on the market today:

- Nuclear fission utilizes the controlled splitting of uranium or plutonium atoms to release a significant amount of energy. While it is a low-carbon energy source, concerns about radioactive waste disposal and safety have limited its widespread adoption.
- Fusion energy, often regarded as the holy grail of clean energy, seeks to replicate the process that powers the sun—combining hydrogen atoms to release vast amounts of energy with minimal waste. Despite ongoing research, commercial fusion reactors remain elusive.
- Solar energy harnesses sunlight through photovoltaic cells, converting it directly into electricity. Solar panels are becoming more efficient and affordable, making them a promising option for decentralized power generation.
- Wind power relies on the kinetic energy of moving air to turn turbines and generate electricity. It has gained popularity due to its scalability and low emissions but requires suitable wind conditions.

- Hydropower harnesses the energy of flowing water by diverting it through turbines. It is a mature and reliable renewable source with significant environmental and ecosystem impacts.
- Geothermal energy taps into heat from the Earth's core to generate electricity or provide heating and cooling. It is consistent and low emission but is geographically limited.
- Bioenergy and biomass involve using organic materials like wood, crop residues, and animal waste for heat, electricity, or biofuels. While renewable, their sustainability depends on responsible sourcing and land management.

The transition to renewable energy sources is driven by commercial returns as well as environmental benefits. Such sources produce little to no greenhouse gas emissions, reduce air and water pollution, and decrease dependence on fossil fuels. Additionally, renewable energy technologies have the potential to create jobs, enhance energy security, and diversify energy sources. However, challenges such as intermittency, storage, and infrastructure development must be addressed to realize the full potential of renewables. Integrating renewable sources into a robust and flexible energy grid is essential for a sustainable and carbon-free future.

Renewable energy technologies offer a path towards a more sustainable and carbon-free future. While each source has advantages and limitations, they play a pivotal role in reducing carbon emissions, mitigating climate change, and securing a cleaner and more resilient energy landscape. Continued research, development, and investment – including the work we do at TAG – are essential to overcoming technical hurdles and maximizing the benefits of renewable energy sources. One can only hope that renewable energy reaches its full potential soon.

Focus Area: Solar and Wind Power Generation

Solar power, or photovoltaic (PV) power, exploits solar radiation as its primary energy source. It involves several sequential steps. First, Solar panels are constructed from semiconductor materials, predominantly silicon. These materials possess a property known as the photovoltaic effect, enabling them to convert sunlight into electricity. The photovoltaic effect initiates when photons, the elementary units of light, strike the semiconductor material. This event induces electron excitation, prompting movement of electrons and generation of an electric current.

The resultant electric current is in the form of direct current (DC). To make it suitable for most applications, an inverter transforms it into alternating current (AC), which is the prevalent form of electricity in most uses. The AC electricity is subsequently integrated into the electrical grid or directly employed for powering various devices. Any surplus electricity generated can be efficiently stored in batteries or sold back to the grid.

Wind power, in contrast, relies on the kinetic energy found in moving air masses. Its operation can be distilled into several stages: Wind turbines consist of rotor blades attached to a central hub. As wind flows over and under these blades, it creates a pressure disparity, resulting in lift.

This lift compels the rotor blades to rotate. The rotational motion is transmitted through a gearbox to a generator.

Within the generator, the mechanical energy derived from the spinning rotor undergoes a transformation into electrical energy. This energy is typically produced in the form of three-phase alternating current (AC). Similar to solar power, the AC electricity generated can be seamlessly integrated into the power grid, conveyed through an array of power lines to meet various energy demands. Any surplus electricity can be diverted to storage systems for future use or routed back to the grid.

Solar and wind power systems offer sustainable, carbon-neutral energy solutions. They contribute to mitigating climate change and decreasing reliance on finite fossil fuels. As technology advances, improving efficiency and cost-effectiveness, these energy sources will play an increasingly pivotal role in reshaping the global energy landscape. Engineers and scientists are working towards enhancing performance, reducing costs, and ensuring reliability, thus reinforcing solar and wind power as key to a sustainable energy future.

Focus Area: Fission and Fusion

Nuclear fission drives current nuclear power generation. It operates through a series of controlled reactions, governed by the principles of nuclear physics. In nuclear fission, specific isotopes of heavy elements, such as uranium-235 (U-235) or plutonium-239 (Pu-239), serve as the fuel. The process begins when a neutron collides with the nucleus of one of these isotopes, triggering a nuclear reaction. This collision initiates a nuclear fission reaction, causing the nucleus to split into smaller nuclei known as fission fragments. Simultaneously, several additional neutrons are released, along with a substantial amount of energy.

One of the crucial aspects of nuclear fission is the chain reaction it can create. The newly released neutrons have the potential to initiate further fission reactions in neighboring fuel nuclei. This self-sustaining chain reaction results in a continuous release of energy. The energy generated in the form of heat is harnessed for power generation. It is used to produce steam from water, which, in turn, drives a turbine connected to an electrical generator. This mechanical-to-electrical energy conversion is the fundamental principle underlying nuclear power generation.

To maintain safety and prevent overheating, nuclear reactors employ various safety measures. These include coolant systems to dissipate excess heat, control rods that can absorb neutrons and regulate the chain reaction, and other safety mechanisms that can rapidly shut down the reactor if necessary. However, one significant challenge associated with nuclear fission is the generation of radioactive waste. Proper disposal and long-term management of this waste are essential considerations to minimize environmental and health risks.

Nuclear fusion, in contrast, holds the potential to be a clean and virtually limitless energy source by replicating the process occurring in the sun and other stars. Fusion requires the

creation of extreme conditions, typically involving very high temperatures and pressures. The fuel used is usually isotopes of hydrogen, specifically deuterium and tritium. Under these extreme conditions, the gas transforms into plasma, a state of matter consisting of charged particles, including ions and electrons. Plasma confinement and control are achieved within magnetic or inertial confinement systems.

Within the plasma, hydrogen isotopes undergo fusion reactions, combining to form helium. These fusion reactions release a substantial amount of energy. The energy generated from fusion is carried away primarily by neutrons and other particles. This energy can be used to heat a surrounding fluid, often water or a lithium-based coolant. The heated fluid then produces steam, which drives a turbine connected to a generator for electricity generation.

While nuclear fission is an established technology with nuclear power plants in operation worldwide, nuclear fusion remains in the experimental phase. The goal is to achieve sustained, controlled fusion reactions for practical energy production. Numerous technical challenges, including maintaining plasma stability, managing the high-energy neutrons produced, and sustaining the extreme conditions required for fusion, must be overcome to harness fusion as a viable energy source.

Focus Area: Hydropower Innovations

Hydropower, also referred to as hydroelectric power, is a well-established method of generating electricity by harnessing the kinetic energy of flowing water. Its technical processes encompass several key components. The initial stage involves selecting a suitable water source, typically a river or a dammed reservoir, characterized by adequate water flow and elevation change (head) to yield substantial energy.

An intake structure is then constructed to facilitate the controlled transfer of water from the source to the power plant. To prevent damage to turbines and ensure uninterrupted water flow, this structure often incorporates screens or filters to remove debris. Subsequently, water is channeled into a penstock—a large pipe or conduit. The pressure within the penstock is determined by the head and serves as the potential energy that will be converted.

Turbines, designed to convert the kinetic energy of moving water into mechanical energy, play a pivotal role. The rotation of turbine blades is the core mechanism for this conversion, and various types of turbines, such as Francis, Pelton, and Kaplan, are selected based on the specific requirements of the project. The mechanical energy generated by the turbines is then connected to a generator. Within the generator, this mechanical energy undergoes electromagnetic induction, transforming it into electrical energy.

The electricity produced is typically in the form of three-phase alternating current (AC). It is then routed through transformers to adjust voltage levels and transmitted via power lines to supply electricity to homes, businesses, and industries. After passing through the turbines, the water is discharged into a tailrace or discharge channel, allowing it to return to the natural

water source. This ensures the preservation of ecological balance and the continuity of the watercourse.

Hydropower systems offer consistent and reliable energy generation with minimal greenhouse gas emissions. Their efficiency is influenced by variables like the head, flow rate, and turbine design. While large-scale hydroelectric dams have the capacity to generate substantial electricity, they often introduce environmental and ecosystem impacts, such as changes to river ecosystems and community displacement.

In recent times, interest has surged in small-scale or micro hydropower installations. These systems have reduced environmental footprints and can be integrated into existing water infrastructure, providing decentralized renewable energy sources in areas blessed with suitable water resources. Hydropower, as a mature technology, significantly contributes to reducing carbon emissions in electricity generation. Ongoing advancements in turbine technology, environmental impact mitigation strategies, and efficient energy storage solutions continue to shape its future as a sustainable energy option.

Focus Area: Geothermal Energy Technologies

Geothermal energy, a renewable energy source, taps into the Earth's internal heat reservoirs, primarily driven by the planet's molten core and natural radioactive decay processes. This energy source operates through a series of well-defined procedures. The initial phase involves the identification of suitable geothermal locations. These sites are typically characterized by geological features like tectonic plate boundaries, volcanoes, and hot springs, where heat from the Earth's interior is accessible.

Upon location selection, wells are drilled into the Earth's crust to access the geothermal reservoir. The drilling depth and well design are determined by specific geological conditions and temperature gradients. Once the wells are established, a comprehensive assessment of the reservoir follows. Parameters such as temperature, pressure, and the chemical composition of the geothermal fluids are analyzed to ascertain the reservoir's capacity and sustainability.

The next stage involves the extraction of geothermal fluids. These fluids, often a mix of water and dissolved minerals, are brought to the surface through production wells. Depending on the reservoir's temperature, the extracted fluids may range from hot water to steam. The thermal energy contained in the geothermal fluids is then transferred to a secondary fluid in a heat exchanger. This secondary fluid typically has a lower boiling point and vaporizes, subsequently driving a turbine connected to a generator, thereby producing electricity.

After energy extraction, the now-cooled geothermal fluids are returned to the reservoir through injection wells. This process, called reinjection or re-injection, is vital for sustaining the reservoir's pressure and heat, ensuring the long-term viability of the geothermal resource. From an environmental perspective, geothermal power generation is considered eco-friendly, given its minimal emissions of greenhouse gases and air pollutants. Nevertheless, responsible

management of minerals and fluids disposal from the reservoir, as well as addressing potential subsurface land impacts, is essential to minimize environmental consequences.

The electricity generated by geothermal power plants is typically in the form of three-phase alternating current (AC). Transformers are employed to adjust voltage levels, and power lines transmit the electricity to meet the energy demands of homes, businesses, and industries. Geothermal energy stands out as a dependable and consistent renewable energy source, providing a steady supply of electricity. Its efficiency and capacity factor are influenced by variables such as reservoir temperature, fluid flow rate, and well design.

Geothermal power plants are recognized for their extended operational life and minimal maintenance requirements, establishing them as a sustainable and cost-effective energy solution. Ongoing research and development endeavors aim to expand the utilization of geothermal resources and enhance their efficiency, further solidifying their role in the transition to a cleaner and more sustainable energy landscape.

Focus Area: Bioenergy and Biomass Systems

Bioenergy and biomass systems represent a significant category within the realm of renewable energy, harnessing the inherent energy stored in organic materials. These systems embrace a diverse range of processes and technologies, all revolving around the utilization of biological matter. It all begins with the careful selection of organic materials as feedstock. Biomass feedstock options encompass a wide spectrum, including wood, crop residues, dedicated energy crops, and organic waste like agricultural residues and municipal solid waste.

Once the feedstock is determined, it undergoes a transformation process to unlock its latent energy potential. This process is the heart of bioenergy and biomass systems and includes combustion, gasification, and pyrolysis as primary conversion methods.

In combustion, organic materials are ignited in the presence of oxygen, generating heat. This heat is then harnessed to produce steam, which, in turn, drives a turbine connected to an electrical generator. The concept is similar to conventional fossil fuel combustion, but with the advantage of lower emissions.

Gasification employs a distinct approach. Organic materials are heated in a low-oxygen environment, resulting in the formation of a synthetic gas (syngas), primarily composed of carbon monoxide (CO) and hydrogen (H₂). Syngas can serve multiple purposes, including heat and power generation or acting as a feedstock for biofuel production.

For thermochemical processes, pyrolysis involves heating biomass in the absence of oxygen, leading to the production of biochar, bio-oil, and syngas. Each of these products finds applications, from soil enhancement with biochar to biofuel production and energy generation. Furthermore, biomass can be processed into various biofuels, including bioethanol, biodiesel, and biogas. These biofuels find utility in transportation, heating, and electricity generation.

One key concept related to bioenergy is cofiring. In specific scenarios, biomass can be combined with fossil fuels in existing power plants. This approach not only reduces greenhouse gas emissions but also serves as a transitional step towards cleaner energy sources. Environmental considerations loom large in the world of bioenergy and biomass. These systems are generally regarded as carbon-neutral because the carbon dioxide (CO₂) emitted during combustion or conversion is offset by the CO₂ absorbed during the growth of the biomass feedstock.

However, the key to maintaining this equilibrium lies in sustainable feedstock sourcing and responsible land management. The electricity generated by bioenergy and biomass systems takes the form of three-phase alternating current (AC) and integrates seamlessly into the electrical grid. Similarly, biofuels can be distributed and utilized much like their fossil fuel counterparts.

Bioenergy and biomass systems capitalize on organic materials to produce heat, electricity, and biofuels. Their impact extends beyond energy production, encompassing waste management, land restoration, and rural development. Nevertheless, the sustainability and environmental integrity of these systems hinge on responsible feedstock sourcing, efficient conversion technologies, and sound land management practices. Onward, ongoing research and technological innovations will raise the efficiency and environmental performance of bioenergy and biomass systems, contributing to a more sustainable energy future.

Companies and Contributions

The companies listed below emerged as part of our research at TAG Climate. Our goal in listing these fine firms is to provide a starting point for buyers, advocates, stakeholders, and researchers trying to make sense of the commercial landscape for renewable energy as a means for driving toward a more sustainable energy future.

Solar and Wind Power Generation Vendors

1. [Canadian Solar](#): Canadian Solar is a global solar module and solutions provider for clients.
2. [Enphase Energy](#): Enphase Energy offers advanced microinverter-based solar power systems.
3. [First Solar](#): First Solar specializes in the development of thin-film solar module technology for solar panels.
4. [GE Renewable Energy](#): GE Renewable Energy offers wind turbines, hydroelectric, and solar power solutions.
5. [Nordex](#): Nordex focuses on manufacturing wind turbines for onshore and offshore applications.
6. [Siemens Gamesa](#): Siemens Gamesa is a leading wind turbine manufacturer and renewable energy solutions provider.
7. [SolarEdge](#): SolarEdge provides advanced solar power optimization and monitoring solutions.

8. [SunPower](#): SunPower designs and manufactures high-efficiency solar panels and solar systems.
9. [Trina Solar](#): Trina Solar is a leading manufacturer of solar modules and solar energy solutions.
10. [Vestas](#): Vestas is a global leader in the development of wind turbine manufacturing and wind energy solutions.

Fission and Fusion Vendors

1. [Flibe Energy](#): Flibe Energy is actively engaged in the development of thorium-based liquid fluoride thorium reactors (LFTRs).
2. [General Fusion](#): General Fusion is dedicated to pioneering nuclear fusion technologies, which can provide clean and virtually limitless energy.
3. [Helion Energy](#): Helion Energy develops fusion energy solutions that can address the world's growing energy demands while reducing environmental impact. energy future.
4. [Kairos Power](#): Kairos Power is actively developing a novel pebble bed advanced reactor (PB-AHR).
5. [NuScale Power](#): NuScale Power specializes in the design and development of small modular nuclear reactors (SMRs).
6. [Oklo](#): Oklo is dedicated to designing advanced fission reactors that offer a clean and sustainable energy solution.
7. [TAE Technologies](#): TAE Technologies is at the forefront of nuclear fusion research, striving to make nuclear fusion a practical and sustainable energy source.
8. [TerraPower](#): TerraPower works in the field of nuclear energy, specializing in the development of advanced nuclear reactor technologies that are safe and efficient.
9. [ThorCon](#): ThorCon is dedicated to the advancement of molten salt nuclear reactors, a promising technology with potential benefits in terms of safety and efficiency.
10. [Tokamak Energy](#): Tokamak Energy is a pioneering organization researching compact fusion reactors.

Hydropower Innovation Vendors

1. [Alstom Hydro](#): Alstom Hydro focuses on the business of hydroelectric power generation and services.
2. [Andritz Hydro](#): Andritz Hydro specializes in hydroelectric power generation technologies.
3. [Emrgy](#): develops and deploys distributed hydropower solutions for off-grid and remote communities.
4. [GE Renewable Energy Hydro](#): GE offers a wide range of hydropower solutions, including turbines and generators.
5. [Gilkes](#): Gilkes designs and manufactures hydroelectric turbines consistent with a renewable focus.
6. [Hydro-Québec](#): Hydro-Québec is a global leader in hydropower research and development.
7. [Natel Energy](#): develops innovative low-head (fish safe) hydropower solutions for a sustainable energy future.

8. [SMEC Hydro](#): SMEC Hydro provides engineering and consulting services for hydropower projects.
9. [Verdant Power](#): designs and builds horizontal-axis tidal turbines that harness the power of ocean currents to generate electricity.
10. [Voith Hydro](#): Voith Hydro provides hydropower equipment and services, including turbines and generators.

Geothermal Energy Technology Vendors

1. [Albioma](#): Albioma specializes in biomass, photovoltaics and geothermal.
2. [Calpine](#): Calpine is a major geothermal energy producer and operator contributing to a more sustainable future.
3. [Climeon](#): Climeon offers modular geothermal heat power systems that convert low-temperature heat into electricity.
4. [Cyrq Energy](#): Cyrq Energy is developing renewable energy technology with geothermal, solar, and storage facilities generating energy.
5. [Dandelion Energy](#): Dandelion is a home geothermal company offering geothermal installations to heat, cool and provide hot water to homes.
6. [Eavor](#): Eavor is a tech company that has invented a new geothermal power generation technology called Eavor-Loop.
7. [Elsa Energy](#): Elsa Energy is an integrated energy services & digital solution company
8. [Enel Green Power](#): Enel Green Power is involved in various renewable energy projects, including geothermal.
9. [Fervo Energy](#): Fervo Energy commercializes proprietary technology to develop, own, and operate geothermal assets.
10. [GEODynamics](#): GEODynamics specializes in geothermal drilling and energy production technology.
11. [Geothermal Engineering Ltd.](#): Geothermal Engineering specializes in geothermal heat and power solutions.
12. [Geothermal Rising](#): GR promotes geothermal energy development and technology.
13. [GreenFire Energy](#): GreenFire Energy specializes in closed-loop geothermal systems for enhanced geothermal power generation.
14. [Mannvit](#): Mannvit provides geothermal energy consulting and engineering services for clients.
15. [Office of Energy Efficiency and Renewable Energy](#): Office of Energy Efficiency and Renewable Energy is the United States department of Energy that offers information and guidance to clean and renewable energy.
16. [Ormat Technologies](#): Ormat Technologies develops and operates geothermal and recovered energy power plants.
17. [Reykjavik Geothermal](#): Reykjavik Geothermal focuses on geothermal project development.
18. [Sarulla Operations](#): SOL has built the world's largest Geothermal Power Plant in a single contract.
19. [Silixa](#): Silixa provides fiber optic sensing solutions for geothermal reservoir monitoring.

20. [SLB](#): SLB offers clients geothermal exploration and development expertise.
21. [Turboden](#): Turboden, a Mitsubishi Heavy Industries group company, is an Italian firm and a global leader in the design, manufacture and maintenance of Organic Rankine Cycle (ORC) system.

Bioenergy and Biomass System Vendors

1. [Aemetis](#): Aemetis produces advanced renewable fuels and biochemicals from biomass feedstock.
2. [Climeon](#): Climeon provides heat power systems for converting low-temperature heat into electricity.
3. [Chevron](#): Chevron is a leading producer of advanced biofuels for renewable energy.
4. [Cool Planet](#): Cool Planet is involved in sustainable agriculture and renewable energy, including bioenergy.
5. [Enerkem](#): Enerkem focuses on producing biofuels and chemicals from municipal solid waste.
6. [Fulcrum BioEnergy](#): Fulcrum BioEnergy converts waste into low-carbon transportation fuels.
7. [GranBio](#): GranBio is involved in the business of advanced biofuel and biochemical production.
8. [LanzaTech](#): LanzaTech develops advanced carbon capture and utilization technologies for biofuels.
9. [Novozymes](#): Novozymes is a biotechnology company focused on enzymes for bioenergy production.
10. [Velocys](#): Velocys specializes in sustainable fuels and chemicals production from waste materials.

About TAG

TAG is a trusted next generation research and advisory company that utilizes an AI-powered SaaS platform to deliver on-demand insights, guidance, and recommendations in cybersecurity, artificial intelligence, and sustainability to enterprise teams, government agencies, and commercial vendors.

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