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# Emerging energetics alternatives

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## *ABSTRACT*

Energetics is the key to addressing climate change at scale and profitably. The current at scale and profitable climate energetics approach is renewables plus storage. This report summarizes nascent/emerging at scale and profitable energetics approaches for generation, storage, efficiency/conservation, and mitigation, the frontiers of responsible climate-related energetics. There are two weak nuclear force batteries that could provide competition for renewables and storage going forward. There are biologic approaches that could provide ultra-low-cost massive capacity biofuels, sequester massive amounts of atmospheric $CO_2$, and increase the planet's albedo. Based on the learnings from renewables, profitability is the apparent key to rapid, at scale response to climate change.

**Contribution/Originality:** Descriptions of major new energetics sources including two new weak nuclear force batteries and halophytes that utilize saline water and wastelands to produce massive amounts of inexpensive biomass/biofuels. It highlights the critical nature of both scalability and profitability for the application of energetics for climate change mitigation.

## 1. INTRODUCTION

Energy has been a key enabler of society since the advent of fire. Currently power and energy are some 6% of gross domestic product. The dearth of a major energy component (electricity) due to solar storm effects would have dire societal consequences, according to a congressional Electro-Magnetic Pulse commission report (Task Force On National And Homeland Security, 2021). The fundamental energy industry metrics are cost/profit, capacity, sustainability and safety. The major historic energy sources over the last centuries have been fossil fuels—petroleum, coal and natural gas. Their combustion, involving the release of massive amounts of $CO_2$ into the atmosphere, has resulted in increasing climate alterations, producing temperature rises, floods, droughts, storms, disease, rising sea levels, species extinction, ocean acidification and reductions in ocean thermohaline circulation (Lindwall, 2022). These impacts of climate change have become serious enough that $CO_2$ emissions from energy production should cease as soon as possible and existing atmospheric $CO_2$ should be removed and sequestered. This requirement spawned a major industry involving the development and buildout of renewable energy over decades, along with storage as needed, approaches that do not produce $CO_2$. Initially, the renewable energy industry developed slowly. However, once the technology developed to where the costs of renewable energy were below energy produced by fossil fuels, the development and adoption of renewables greatly accelerated. Costs of renewables, and storage as needed, continue to drop due to applicable research and economies of scale, along with increases in efficiency and utility. Apparently, profits were a greater motivator than climate change. The previous electrical energy production approaches, coal, oil, nuclear energy and natural gas are being eclipsed by renewables due to the greater profits brought by renewables. The major current renewable energies are on and offshore, wind, solar photovoltaic, solar thermal, geothermal, hydro and biomass. Considering the major energy metrics, renewables have a truly massive capacity, generate profits with decreasing costs, are "green", emit far less $CO_2$, and thus far have a reasonable safety record. The forecast is that renewables could provide up to 90% of electrical energy generation by 2050 (United Nations, 2024). Of the renewables, solar and wind can require storage, although solar thermal incorporates integral onsite thermal energy storage. Geothermal, hydro and biomass are base load. Biomass/biofuels emit $CO_2$ when burned, but they take up the $CO_2$ when they grow. Use of biofuels can reduce net $CO_2$ production from transportation fuel by up to 80%. To increase the reduction rate of $CO_2$ emission, there are increasing efforts in energy efficiency and conservation, with projections of a 50% reduction in per capita energy use going forward (American Council for An Energy-Efficient Economy, 2020). Contributing to this conservation/efficiency effort is increasing electrification, especially for transportation.

The purpose of the present paper is to consider the emerging energy and energy-related technology landscape with respect to major emerging possibilities to accelerate both energy cost reduction and the shift to "green" via more efficient and lower cost generation and usage, along with mitigation of extant factors driving climate change.

## 2. METHODS

Utilizing an extensive background in frontier energetics research in the national power, energy and space application arenas, the requirements and approaches that appear to be at the scale of climate change for climate mitigation are collected, evaluated and summarized across the board. The current climate approaches are not at scale, not profitable, and are ineffective since the global climate continues to worsen.

## 3. RESULTS AND DISCUSSION

### *3.1. Emerging Energy Generation Alternatives*

Halophytes [Bushnell 2024] are salt plants (halo meaning salt in Greek). These plants grow in water, deserts and wastelands, utilizing saline and seawater. There are many thousands of halophytes, and many mimic freshwater plants. The capacity to grow halophytes is immense; drylands comprise over 40% of the land and saline, seawater is some 97% of the water, and both are inexpensive compared to conventional freshwater agriculture. Ocean fertilization with iron-rich dust greatly increase the growth rate of algae, which, along with protein and increased fish production, provides oils and fuels at rates greater than land halophytes create biomass/biofuels. Estimates indicate that ocean fertilization would also sequester over seven gigatons of $CO_2$ out of the atmosphere. Land halophytes could literally green the planet profitably, providing massive amounts of biomass/biofuels for SAF aircraft fuels, supply chemical feedstock and sequester some four gigatons of $CO_2$ in their deep desert roots. The food plant halophytes would also free up some-to-most of the 70% of the fresh water now used for agriculture. Overall, in major ways, halophytes could uniquely and profitably address issues related to land, water, food, energy and climate. Weak nuclear force batteries – There are two new weak nuclear force batteries under development, one invented at the National Aeronautics and Space Administration (NASA) (Bushnell, Choi, & Moses, 2022) and one utilizing scaled low-energy nuclear reactions (LENR) by a Japanese firm (Clean Planet, 2024). Both augur possibilities to provide competition to renewables/energy storage to "solve" climate change at less cost and with enhanced versatility. The NASA battery is a gamma battery utilizing isotopes and is designed to minimize requisite radiation protection. This battery generates electricity directly and its alpha, Kgs/Kw, is of order of, whereas the alpha of fission reactors is of order 30. Nuclear thermionic avalanche cell (NTAC) batteries are much smaller and lighter than a reactor. NTAC batteries last for years and have the weak energy force density of 10,000 times chemical energy density. NTAC batteries scale from watts to megawatts. The use of nuclear fission energy for energy generation and national defense over many decades has resulted in massive stockpiles of nuclear waste, which still contains 85% of the nuclear energy. NTAC designs include possibilities to literally shovel this nuclear waste into NTAC devices to power the grid. There is sufficient nuclear waste to power the grid for approximately 100 years. Efforts are underway to determine whether the cost of NTAC powering the grid would be lower than the cost of renewables and storage. The other new weak nuclear force battery is under development by the Japanese firm Clean Planet. Their developments were enabled by a decade of serious efforts (funding, talent, time) in Japan to understand and scale low-energy nuclear reactions. This approach has no radiation, scales well up or down in power, and lasts over a year thus far. It is suitable for distributed generation and generation at point of use, including for transportation, and scales from watts to megawatts. The firm thus far has 95 patents and a published initial commercialization plan. Their alpha, Kgs/Kw, is two, so again much lighter and smaller than a fission reactor. This device utilizes inexpensive materials and very small amounts of regular hydrogen. The nuclear waste discussed above contains some very radioactive material with a very long life, hundreds of thousands of years. LENR produces transmutations, and Clean Planet has a patent for using their version of LENR at lower cost than other approaches that transmutates long-life nuclear waste into innocuous materials. Overall, Clean Planet's LENR should be very versatile, including for transportation, and should be small, light and inexpensive with the possibility of being a serious contender that can address requisite climate energy issues going forward.

Nuclear fusion – There are three major and long ongoing issues with nuclear fusion energy generation. Firstly, fusion does not produce sizable net energy generation; secondly, compared to the renewables/storage approach, fusion is very expensive; and thirdly, there would be a latency problem as the issue of climate change is becoming dire very rapidly. The time required to produce sufficient fusion generation plants to make a sizable difference in warding off major climate impacts would be too long. There is a plethora of ways to produce fusion; the one requiring the lowest input energy is pyroelectric fusion. Fusion can be produced by various means over a broad range of conditions, but thus far without useful net energy generation. However, there is a fusion approach that has contentiously indicated net generation, which is cavitation or bubble fusion (Fomitchev-Zamilov, 2012). This fusion approach might be able to address, to a to-be-determined extent, the three major fusion issues. It appears to be worthwhile to conduct serious research and development to determine the efficacy of this type of fusion.

Drilled geothermal energy – Historically, geothermal energy extraction utilized readily available hot rock resources, usually on or near the surface. The western US, and many other parts of the planet, have major geothermal resources and the costs of underground extraction are reducing. There was a superb MIT report that dealt with drilled geothermal energy with positive results published in the early 2000s (Tester et al., 2006). In productive areas, drilling down 2 km can access 200 °C rock, and at 5 km, 300 °C rock is accessible. The available drilling capability is beyond 10 km. A relatively recent approach regarding geothermal energy is increasing the utilization of the millions of abandoned oil and gas wells, saving up to 50% of the investment cost (Department of Energy, 2021). The geothermal capacity is massive, is base load, no storage is needed, and costs are low.

High altitude wind (Frederick, 2010; Jones, 2022) – Wind speeds increase with altitude up to the tropopause, with speeds some order of magnitude greater than usual terrestrial values. Also, winds are more consistent at high altitude. Estimates of high-altitude wind energy generation potential off the US east coast is twice the US installed grid load. Projections indicate that high altitude wind would have far lower costs than terrestrial wind. Generators could be positioned either on the ground or at altitude, and there are various ways to transfer the energy to the surface. No-fly regions would be required in the vicinity of the access/positioning cables.

Hyper-efficient photovoltaic (PV) energy - There are many ways to improve PV efficiency, including targeting more of the solar spectrum. Some work on two electrons per photon (Chandler, 2019) and can regenerate the heat losses and add IR capability for nighttime. Concentrators have been used, as have multijunction cells, tracking, and different coatings and materials. Some estimates indicate that PV efficiency increases greater than a factor of two going forward. PV placement over water is being used to reduce evaporation, and PV placements over farmland is increasing. The study by Yun, Mühlenbein, Knoche, Lotnyk, and Bhatnagar (2021) is indicative of continuing robust research with respect to improving PV efficiency.

### *3.2. Emerging Energy Storage Approaches*

Green/white hydrogen – Hydrogen is a developing storage method, not a generation approach. Hydrogen is often cited as efficacious because the products of combustion are mainly water and NOx. For aviation, water emitted above the tropopause (28 K ft plus/minus) is climate forcing due to weak cirrus clouds reflecting the outgoing IR back to the planet. At lower altitudes, water forming dense clouds is cooling. Hydrogen will require new infrastructures for supply and transport. Due to its low volumetric density, hydrogen requires different, new storage approaches. Green hydrogen production has low energy generation efficiency, an order of half of most storage approaches. Most green hydrogen is produced from green, renewable energy. White, natural hydrogen is produced from gas wells. Safety-wise, hydrogen is far easier to ignite than jet fuel. Hydrogen is corrosive for many materials, which can be addressed by engineering. A major issue associated with hydrogen as an energy source is the cost of storage, infrastructure, and the energy to generate, along with safety issues (Gaster, 2024). Smith (2006) suggests that the best use of hydrogen would be long-term storage. Positron storage (Danielson, Weber, & Surko, 2009; Smith, 2006) – Antimatter has the highest known energy density, some nine orders of magnitude greater than chemical. The cheapest antimatter is positrons, or positive electrons. When a positron annihilates with an electron, the process produces two and a half MEV gamma radiation pulses. There is no residual radiation. This radiation can be used to heat for direct utilization or to charge a heat battery. The major issue with the utilization of positrons for energy, especially in space where they provide two orders of magnitude greater energy density than fission/fusion, is high-number density positron storage. Current positron storage approaches include creating positronium or storing in Penning traps. Theory indicates that order of a year storage may be possible. Storage for 1,000 minutes has apparently been demonstrated. (Very) Distributed pumped hydro storage – There is an excellent worldwide study by the Australian National University (2019) on potential pumped hydro energy storage sites that resulted in the identification of 530,000 sites worldwide capable of storing 22 million gigawatt hours. These sites would enable pumping water into nearby higher elevations. This is cited as 'hundreds of times more than needed to support a 100% renewable energy world-wide grid". As is the case concerning renewables capacity, the apparent potential capacity for storage is far in excess of that required. The issue concerning storage is the fundamental one of cost and profit. The most used approach will be the one that has lowest cost and produces the most profits. Molecular solar thermal storage – This rapidly developing storage arena is referred to as MOST. Initial optimization utilized photons to convert norbornadiene into quadricyclane, which is metastable and reversible, proffering long-term (48-day) thermal storage. Orrego-Hernández, Dreos, and Moth-Poulsen (2020) provide a relatively recent review of the progress in this chemical energy storage approach. Overall, energy storage, driven by the storage requirements of solar and wind, has become increasing less costly and broad-spectrum. An example is the ongoing application of iron/air batteries offering major cost reductions.

### *3.3. Emerging Conservation, Efficiency Approaches*

The potential impacts of increasing energy conservation and efficiency are massive. The projections are, by 2050, a 50% reduction in energy use (ACEE, 2019), which would both greatly mitigate climate issues and energy costs. Multi-phase space radiators – In space, the only effective method of offloading waste heat is via radiation. The result is sizable radiators. One approach to greatly increasing the effective radiation area and reducing radiator size is to use droplet, or multi-phase, space radiators (Mattick & Hertzberg, 1981). There has long been research on this approach involving studies of several instantiations and optimization approaches but not yet sizable applications.

Distributed energy generation (Bushnell, 2021) – The dominant mode of providing electrical energy has long been central generation plants and transmission lines. These transmission lines incur sizable losses and costs, the latter increasing even more as "smart grids" are instituted. These long lines are also highly susceptible to large solar storms, which can take down the large transformers and result in closing down society's 'life blood', electricity. Estimates of the effects of such solar storm impacts are huge. Renewable energy approaches have enabled increased utilization of energy generation and storage, if necessary, at point of use, termed distributed energy generation. Distributed generation is more efficient than central generation and is less costly, especially as the costs of renewables and storage continue to decrease rapidly due to economies of scale and ever improving technologies. Distributed energy generation, along with the ongoing development of affordable, safe VTOL personal air vehicles, enables living off roads and wires in the cities and suburbs required by the industrial age, as we rapidly move through the IT age into the virtual age. The scalable Japanese weak nuclear force battery, with no radiation, could also provide distributed energy generation. Direct radiation to space for cooling, including air conditioning – With the ongoing climate effects, air conditioning is an increasing portion of the energy generation requirement. Direct radiation to space, utilizing frequencies for which the atmosphere is highly transparent, requires no additional energy, a major energy conservation approach, e.g., (Chen, Zhu, Raman, & Fan, 2016).

Waste heat recuperation (Bushnell, 2021) – Thermodynamics dictates that energy use results in sizable waste heat, which by conduction, convention and radiation is dealt with somehow with attendant costs. Recuperation, utilization of this waste heat is a major approach for conservation and improving overall efficiency. To accomplish this, the heat must be collected and converted into usable energy if heat is not a useful form. Heat conversion to electricity can be accomplished via thermodynamic cycles coupled to generators, thermal electrics, thermal photovoltaics, and pyroelectrics. There is a relatively recent NASA invention of a highly efficient, up to 25%, thermal-electric approach. Thermal PV has a relatively high efficiency, upwards of 60%. The Sterling cycle approach is up to 40%. Each of these approaches has associated system components which effect their cost and applicability. Energy harvesting – This approach utilizes ambient energy sources and, depending on what sources are available and their suitability, can be an adjunct to overall conservation and efficiency efforts (Bushnell, 2021). Its devices in many cases have reduced energy requirements, sometimes low enough for consideration of usual available ambient energy harvesting levels. Ambient energy harvesting possibilities include solar, thermal, wind, acoustics, vibrations, fluid motions, EM/RF, phase change and gravity. Heel strike energy has been studied, as has vehicle passage energy, and the 100 V/vertical meter electrostatic atmospheric electric field. Hygroelectricity, also known as humidity electricity (Mitchell, 2022), is an ongoing focus of study involving static electricity generation from humidity in the atmosphere, termed "Air-Gen" or hydroelectricity, and involves interactions between nanomaterials and colliding water molecules. The relative ubiquity of atmospheric humidity proffers widespread applications. Energy efficiency (Bushnell, 2021) – Advances in computations have enabled increases in efficiency, including at the systems level, via improved materials and reduced drag, among other impacts. Building "efficiency" has improved to where building can now be an energy producer instead of an energy consumer. A major (50%) "consumer" of energy is electric motors, and their efficiency has increased by 30%. Electric motors are twice as efficient as thermodynamic cycles; the ongoing switch from combustion to electrics for transportation and much else provides major increases in efficiency. The long, ongoing societal switch to tele-everything through on-site/physical travel has reduced the latter. For insulation, nanophotonic crystals can be 50% better than a vacuum.

### *3.4. Climate Mitigation*

$CO_2$ sequestration – Climate change/forcing due to the effects of historical and continuing energy generation/usage has become so dire that it is no longer sufficient to just stop $CO_2$ and Methane emissions. It is now also necessary to remove and sequester large amounts of such from the atmosphere. There are several ways to accomplish $CO_2$ sequestration, including biologically geologically and mechanically/ "technically". In general, biologically approaches are historical/natural and scale well, while mechanical approaches are expensive to scale. There are two biologic $CO_2$ capture/sequestration approaches that both uniquely scale to what is required to significantly mitigate climate change and are profitable (Bushnell, 2024). These two are greening the planet via utilization of halophyte agriculture, planting desserts/wastelands employing saline/salt water and ocean fertilization to greatly increase ocean algae growth. The halophytes can sequester up to four gigatons of carbon, while ocean fertilization estimates are in excess of eight gigatons of carbon. Ocean fertilization employs iron rich dust from ships and blown off near shore deserts. This dust is then distributed by ocean and atmospheric currents. Ocean fertilization experiments have resulted in major increases in algae growth, with resultant increases in fish populations. Algae are an excellent source of biofuels, oils and protein. Halophytes mimic most freshwater plants, many being food plants. Halophytes could, using inexpensive land and water, release much of the 70% of the fresh water we are running and now used for food production, to direct human use. Halophytes would also provide vast amounts of biofuels for aviation and other uses. Another emerging $CO_2$ "sequestration" approach is to utilize the Japanese LENR approach to transmutate carbon into iron. Planetary albedo increase – There are two interesting ways to increase the reflectivity of the planet to reduce climate impacts, one biologic and one technical. It is possible via the technologies of the bio revolution to increase plant albedo (Zamft & Conrado, 2015). The technical approach utilizes the huge societal impacts on the countryside by employing white roofs and white roads.

## 4. CONCLUSIONS

As discussed herein, there are emerging technologies and systems approaches, most of which posit, uniquely, profitably and at scale, major-to-revolutionary approaches for an energetics future that is both green and less costly. Progress/approaches thus far with regard to climate mitigation has not been effective at scale, except for renewables and storage. Climate change is becoming worse, not better. The rapid progress of renewables and storage at scale is apparently a result of low costs/profits probably more than climate. Climate has progressed to where very different major-to-revolutionary energetics related approaches are needed across the board, and generation, storage, efficiency/conservation and climate mitigation which, per the learnings from the development of renewables, should be profitable. In many cases, employing the new technologies and systems described herein will adversely impact current practices and employment, including major elements of societal econometrics such as energy generation and freshwater agriculture. For that to happen, profitable approaches are required, both to enable the requisite scale and the increasingly nearer term requisite employment time frames to effectively address climate. Most extant energetics and climate mitigation efforts are either not at scale or are developing too slowly. Technologies to rapidly change energetics and mitigate climate at scale and profitably are extant. As climate impacts become ever more obvious, extensive-to-existential technologies will probably be developed and employed. It would be beneficial and save many lives if they were employed sooner.

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