Review Article

Survey of Frontier Technological Approaches To Mitigate Climate Change

Abstract

Climate change with its' increasingly serious and wide spectrum adverse impacts is the Issue of the Age. Climatechange impacts have advanced to where mitigation solutions are now required for CO_2removal from the atmosphere and increasing planetary albedo/ other safe geoengineering approaches in addition to ever lower cost green energy generation and energy storage/ conversion/ conservation/ efficiency.There are extensive ongoing efforts involving all of these climate mitigation approaches. This work is a survey of additionalfrontier technologies, concepts and alternatives not yet deployed or nascent, which could greatly augment the ongoing climate mitigation efforts across the spectrum.

Key Words: Climate Mitigation;Energetics Profitability; Frontiers of Energetics; Halophytes; Societal Change;Weak Force Batteries

1.0 **Introduction**

It is axiomatic that technology is the basis of society. Humans have invented, developed, and deployed a vast and increasing array of revolutionary and disruptive technologies which typically have had both favorable and unfavorable utilizations and impacts. The industrial Revolution was powered by utilization, exploitation of fossil fuels - petroleum, coal and natural gas. A major unfavorable impact of their utilization, due to CO_2 emissions is now, planet wide, becoming extremely apparent, Climate Change [1,2]. This impact is causing increasingly worrisome-to-majortemperature increases, floods, droughts, storms, disease, ocean level rise, species extinctions, ocean acidification and ocean circulation changes. As atmospheric CO_2 levels rise, many positive feedbacks are occurring including fossil CO_2 and methane releases from the tundra and the oceans, reduced ocean CO_2 uptake, planet albedo reductions as the ice melts and increased water in the atmosphere. The Ocean level rise if all the ice melts is some 70 meters. The increasing adverse financial impactsaccompanying climate change are massive [3]. In the Permian warming eventtermed the "Great Dying", caused byCO_2 emissions from Siberian volcanoes at a rate some 1% of the current human CO_2 emissions, the ocean thermo-halinecirculators slowed much, the oceans went anoxic.This allowed the overgrowth of algae that produced hydrogen sulfide which in the atmosphere at some 100 parts per million is a deadly poison, producing over 90% species extinction [4].The Ocean Circulators are slowing rapidly now with oxygen changes forecast to begin by 2030-2040 [5].The scale and putative impacts of climate change approach the unimaginable. Some 1/6th of the earths' population lives off rivers rising from the Himalayan glaciers, which are going away.Climate change mitigation is of obvious and increasing-to-existential importance to society.

The overarching climate mitigation approach on the part of the humans thus far is to reduce the emission of ever more CO_2 into the atmosphere. Much of the CO_2 emission is due to electricity generation, along with various "on-site" energy uses including transportation, industrial activities, residential/ buildings and agriculture. Once they were financially competitive with fossil carbon electricity generation shifted to renewables plus storage. The present approaches to producing electricity sans CO_2include solar photovoltaics [PV], wind, biomass [approximates a closed CO_2 cycle], hydro and fission nuclear, along with some geothermal and solar thermal.Most of these renewable sourceshave truly massive capacity, many orders of magnitude greater than projected societal energy needs. Many opine that renewables per se require storage. Solar PV and wind, also hydro can require storage, but solar thermal, solar hydrogen and hydrocarbons and biomass are self-storing and high-altitude wind and ocean currents and tides along with geothermal are base load [6].

There are issues wrtsome of the current approaches to mitigating climate change. Nuclear is a current major emission-less electricity generation source. Nuclear has three major issues going forward, radioactive waste that lasts hundreds of thousands of years which we currently do not have good solutions for, cost which is greater than the renewables and a construction time latency at scale not in accordance with climate mitigation time-line requirements [3]. Green hydrogen generation has some half of the electric-to-electric efficiency of almost all other approaches [3] is corrosive, difficult to store, is expensive and requires new infrastructures. Space solar power is costly, has far too much latency at scale for requisite climate mitigation, and radiation and launch vehicle pollution concerns generated by the huge number of space launches required. Wave and tidal energy are expensive and lack requisite capacity.
There are many benefits associated with energy storage [3]including load leveling/ peak shaving, frequency regulation, arbitrage, resiliency, reliability, distributed generation, reserve/ backup/ standby, and replacement for "peaker" generation capacity. An additional benefit of the renewables is several are scalable to local, on-site use, enabling distributed energy generation vice the grid. The grid is expensive and very vulnerable to expected serious solar storms producingseriously major societal mortality due to the almost total society dependence on electrons and electronics [7]. The climate mitigating renewables should, along with reducing costs, enable distributed generation and much reducing CO_2 emissions, enable the shift of the other CO_2 generation portions of the economy to green electrification, i.e. transportation, manufacturing, buildings, agriculture.Overall, thecurrent societal situation wrt climate change is now so dire that just stopping CO2 emission is not enough soon enough. Society will have to in addition reduce atmospheric CO2 and utilize less energy along with some geoengineering such as increasing planetary albedo. Climate mitigation approach requirements include being effective soon enough at the scale of the problem, and being profitable and safe.

The purpose of this article is to elucidate the multitudinous frontier technology approaches which could possiblyand significantly accelerate the speed and extent of climate change mitigation. Arenas addressed include the frontiers of generation, storage, conservation, carbon removal from the atmosphere and increasing planetary albedo. Overall, these concepts and technologies could conceptually result in society going forward becoming low-cost energy rich and climate mitigated, due to the availability of an abundance of low-cost green energy. The societal impacts of the availability of low-cost energy, in addition to climate mitigation include reduced costs of living, far less pollution, altered world-wide econometrics, more affordable desalinization and minerals from seawater, reduced water use for energy generation, reduced requirements for fossil fuels and energy resilience, including wrt solar storm EMP effects. Previous summaries of climate change mitigation efforts include references 8 and 9.

2.0 **Frontier Renewable Energy Sources**

2.1 **Osmotic Power**–This approach employs water moving from dilute to concentrated saline solutions across a semipermeable membrane to attempt to equilibrate saline concentration. This increases the pressure on the saline side which can be used to operate turbines which power electricity generators. Perhaps the cleanest form of renewable energy generation, this has no emissions, is continuous, base load generation and can be regenerated using solar by evaporating the saline water to obtain fresh water. Some 97% of the water is saline, there are extensive saline aquifers, saline lakes, concentrated saline output from desalinization plants, salt mining efflux and the worlds' oceans and seas. Suitable requisite fresh water sources include contaminated water, treated water and river water. Optimal siting is river efflux into salt water. The major issue with this renewable energy approach is cost, which is some order of magnitudegreater than frontier PV. The current developmental activity for this method is primarily at sites in Europe. There are optimization approaches, one not involving a membrane and one involving reversed electrodialysis. The output level with usual membranes is 4 to 6 watts per square meter of membrane with advanced membranes conceptually as high as 200 watts per square meter. Typically, the membranesare some 80% of the initial capital cost. The approach is scalable [10 – 13].

2.2 **High Altitude Wind**–The current wind machines are mostly terrestrial with increasing capacity off shore. Wind speeds increase and become more consistent with altitude up to some 10,000 meters, proffering up to some 10X wind speeds compared to terrestrial siting and some order of magnitude greater power density, all with minimal land footprint. One of the worlds' greatest capacity density regions for high altitude wind is off the U.S. east coast, estimated as equating to twice the installed U.S. grid load. Some estimates indicate high altitude wind capacity at some 100X the current planet electric requirements. This is much less than solar PV but still a massive green energy resource. High altitude wind is projected at 10X lower cost and 2X the capacity factor of terrestrial wind. Major issues for high altitude wind include storms, lightening and establishment of "no fly" areas due to the requisite connective cables to control the wind device and for designs where the generator is aloft, the cable electrical transmission option. There is a rich design space wrt high altitude wind generation, including electrical generators either on the surface or aloft, various means to transfer energy to the ground, including via cable motions and a variety of aero platforms. The usual terrestrial wind issues of acoustics and birds are obviated. Generator height and position adjustments are straightforward [14 – 17].

2.3 **Biomass/ Biofuels Sourced From Halophytes** - The renewable alternative to green H2 and hydrocarbons for fuels is biofuels. Conventional biofuels are produced by freshwater plants with attendant concerns regarding competition with agriculture/food production for fresh water and arable landand consequent overall concerns for capacity and cost [8]. The frontier here is salt plants or halophytes [18]. There are many thousands of natural halophytes—plants that are tolerant to saline agriculturalland and water. [19]. Many of these grow reasonably well using direct seawater (no desalinizationneeded), even before we introduce advanced genomics. These plants could produce nearly allof the product classes that glycophytes (freshwater plants) now produce. The immense advantages of switching tohalophytes include [3]:

- Saline-tolerant plant biomass utilizes what we have a surfeit of (and what could be our last major play regarding the ecosystem): wastelands, deserts (44% of the land area), and seawater (97% of the planet's water resources).
- Seawater contains 80% of the nutrients needed to grow plants, and researchers are developing new techniques to extract nitrogen from the air, thus requiring little fertilizer.
- Advanced technology is not required, and cultivation uses inexpensive land and water, hence the economics are reasonable-to-good. The shift to halophytes could be accomplished in relatively short order.
- Halophyte cultivation for food would free up 70% or more of the freshwater we use for conventional glycophyte agriculture, and which we are now running out of, for direct human use, thus solving both water and food problems.
- Cultvation of halophyte biomass would similarly obviate the use of arable land and freshwater for biofuels and provide petrochemical feedstocks for plastics and other industrial products, replacing petroleum for this purpose.Halophytes proffer massive food, “green energy” and chemicals independent of drought and at much less cost.
- Halophytes sequester up to 18% of their carbon dioxide uptake in their roots, removing much CO2 from the atmosphere.
- Seawater contains trace elements essential to healthy human physiology, which we have largely depleted from arable land due to overuse.

Seaweed, and algae represent another class of halophytes with potential for aquacultural development. Several of these produce excellent oils and protein and are far more productive than land-based plants. Through genetic engineering, aquacultural halophytes could have enormous productivity. The continent-sized nutrient stream that is the Mississippi River outflow into the Gulf of Mexico, which is now causing overly rich anoxic conditions, couldpossibly be used to foster aquaculture, thus reducing pumping costs, land taxes, and other financial issues associated with terrestrial operations. The worldwide capacity for aquaculture to replace freshwater use in producing food andbiofuels—and provide sustenance to a much larger future human population—is truly massive.Overall, halophyte cultivation and development could address our interrelated land, water, food,energy, and climate problems [21 – 25].

2.4 **“Horizontal”Ocean Thermal Energy** – The worlds’ oceans and seas contain various and substantial temperature gradients which could be used to generate electricity, power which is continuous, base load. Historically there has been considerable effort to research and develop the oceans vertical temperature gradients [26], but a particularly interesting green energy opportunity seeks to utilize the horizontal temperature gradients of the Gulf Stream off of the U.S. east coast [27]. One concept is to float a heat exchanger in the warm Gulf Stream off Virginia and utilize the last visages of the cold southbound Labrador current inshore to increase the temperature gradient. This approach obviates the need to operate at substantial depths and the associated expense associated with exploiting vertical temperature gradients.A study of such “horizontal” OTEC [Ocean Thermal Energy Conversion] indicated that the capacity could be some twice the U.S. installed grid load, once again a sizable source of renewable green energy. The major issues with exploiting the usually studied vertical ocean temperature gradients include very low efficiency due to the small temperature differences, the corrosive environment, requisite piping, especially cold-water piping, biofouling and, overall, high cost.

2.5 Geothermal From Oil, Gas Wells–The zeroth order instantiation of geothermal energy is ground heat pumps. Geothermal has huge capacity and is base load, always available [28]. For some 50% of the large land masses, including the western U.S. if drill down 2 Km get some 200 degree C rock, 5 Km produces some 300 degrees C. The drilling capability is some 10 Km. plus. The cost of geothermal is nominally less than fossil fuels but more than solar PV and terrestrial wind. As a source of base load geothermal is far less expensive than fission or fusion nuclear. Near surface geothermal sources such as in Iceland and the Geysers field in the U.S have long been utilized. As oil and gas wells crease producing or are closed due to competition from the developing renewables they become available for geothermal energy production [29,30].In the U.S. suchabandoned wells number in the millions. Even operating fossil fuel production wells produce hot water at useful amounts and temperature levels. There is research aimed at improving energy conversion approaches toproduce electricity from lower than usual temperature levels. The cost of well drilling is typically some 50% of the cost of geothermal energy infrastructure.Utilization of oil, gas wells, functional and the huge number nonfunctional, is a major geothermal energy cost reducer. Current efforts to utilize oil/gas wells for geothermal are underway in such as Pennsylvania and Illinois as well as the western states. Abandoned wells can also be used for long term heat storage as part of the renewables and storage combination for solar and wind, as well as "seasonal storage" in the summer. Some half of household energy is usedfor heating and cooling.Heated water, thermal heat storage can be directly utilized as heat vice used for electricity production. A detailed study by MIT indicated that Geothermal writ large in the U.S. could generate some 100 Gigawatts of base load.

2.6 **Hyper-efficient Solar PV** – There are several fundamental metrics for solar PV, along with hydro and wind the current most productive green renewable energy sources [31,32]. These metrics include initial and operational cost, longevity/durability, efficiency and reliability/ availability. Increased efficiency could result in both reduced cost and reduced requisite ground coverage for a given connected load.There are a plethora of approaches to increase PV efficiency, these include utilizing more of the solar spectrum, producing 2 electrons per photon vice one, regeneration/ producing electricity from the heat losses, adding capability for IR to generate electricity from the ground at night, solar concentrators [reduces cost and requisite coverage, enables use of tailored PV with higher efficiency], panel cleanliness, control of operational temperature, tandem/ multiple junction cells [some 2X efficiency], anti-reflection coatings, sun-tracking, ultrathin films and crystalline layers/ structure.Factors of 2X to 3X efficiency increases are evidently available. Land use optimization includes placement over water resources and over farmland.

2.7 **LENR**–Rediscovered in the late 1980's [6,33] and dubbed "cold fusion," what is now usuallytermed Low Energy Nuclear Reactions [LENR], was an experimental discovery with replication issues at the time and lacked an acceptable theory. Three decades of worldwide experiments [34] indicate something nuclear. However, averified theory does not yet exist. There are weak force weak neutron-based theories involving surface plasmons, electroweak interactions explicable via plasmons onsurfaces, collective effects, heavy electrons, and ultraweak neutrons [35]. There are now many patents and LENR is beginning to enter the marketplace, particularly by the Japanese [36]. They have apparently determined how to scale LENR. They have some 65 plus patents and plan to market a 2 Kw device with a 600 Kw device in development. LENR uses minor amounts of H2 and nickel islight weight, a heat battery lasting over a year with measured energy density 10,000 times chemical. LENR should be low cost and applicable to most energy requirements and applications, including distributed, point of use energy generation. Surface materials are required that adsorb large amounts ofhydrogen (H_2 or D_2) such as Ni, palladium. LENR "products" include heat and transmutations, with negligible radiation [37, 38]. May be capable of transmutating nuclear waste.

2.8 **Energy Harvesting** - Energy harvesting constitutes energy generation usingambient energy sources [6 and 39 to 41]. The usual applications involve powering miniaturized,reduced required operating power, sensors, and IT devices. As IT device and sensor operational power levelshave reduced, the interest in energy harvesting has grown. Additional applications include mobile phones,sensor networks, national security usage, medical and health care sensors, implants, andconsumer goods. The potential energy sources vary instrength from microwatts to milliwatts plus with many energy conversion approaches employed.Energy sources include: photons/solar, thermal, wind, chemical, salinity gradients, kinetic energy includingacoustics, vibrations, fluid motions, ambient electromagnetic /radio frequency [EM/RF], chemical"fuels," phase change and gravity. Sources can be human generated or machine,ambient, and located inside or outside. Ambient energy harvesting sourcesinclude: heel strike, body heat/motions, auto passage, PV on roads, raindrops, back yardstreams, micro wind, ambient RF, the 100V D.C./vertical meter electric field in the atmospherenear the surface, ground heat pumps, road heating, arm/hand movements, thermal sources,tree movements, furnaces, combustion engines, cooling towers, mouse button clicks, andhelicopter and trainvibration.

2.9 – **Nuclear Waste Regeneration –** Radioactive nuclear waste is a major safety issue and a tremendous energy source, still contains some 85% plus of the energy content. There is a great deal of such waste and there is now an approach that could possibly provide energy regeneration in the form of electricity. From estimates there is sufficient waste to power the grid for a century [42]. The regeneration approach is the new NASA NTAC nuclear battery, a solid-state weak force device that utilizes high energy radiation to break loose inner band electrons which are efficiently converted into electricity [43]. This battery has an alpha [Kgs/Kw] of order 1, is some 30 times lighter than a reactor and scales from watts to many megawatts. The design of the battery makes it largely self-shielding. This approach does not reduce the radioactivity of the waste, it utilizes it while it is decaying to generate electricity.

3.0 **Frontier Energy Storage**

Frontier energy storage is the key to greater use and utilization of wind, solar PV and hydro,rapidly shifting transportation to renewables and more efficient electric propulsion, anddependable distributed generation. For central generation storage enables load leveling/ peak shaving, arbitrage, resiliency/ reliability, reserve/ standby capability and replaces additional, "peaker" generation units. Energy can be stored as electric energy, gas pressure, heat, mechanical energy and nuclear energy. key metrics overall for storage are cost and dependability [6 and 44, 45].

3.1 **Weight-Sensitive [Transportation] Storage**–Energy system weight, volume and cost are key metrics for green transportation.Current weight sensitive batteries, also used for the grid, are Li-Ion. Development is underway on a number of light weight batteries, including Li/S, Solid state, metal air, and Li-air. The latter is projected to have some factor of 6 or more greater energy density than Li-ion. There is also research on structural batteries, providing an overall weight advantage/ reduction. The Japanese LENR device discussed previously and currently under development, a many months long nuclear weak force battery, light weight, inexpensive,with some 10,000 times chemical energy density and no detected radiation would revolutionize transportation writ large and much more.

3.2 **Weight-Insensitive [Grid, Fixed Site] Storage** -Heavier storage approaches suitable for grid but not transportation use subsume electrochemical, chemical, thermal and mechanical approaches.In addition to the current pumped hydro and Li-ion battery storage, iron-air batteries at some 10% the cost of usual grid batteries have been recently deployed. There are advanced materials which will increase the pressure and utilization of pressurized air storage including underground or undersea using water depth for pressurization.One Hydrogen storage approachusessolar energy to create elemental zinc which when add water generates hydrogen at point of use.Overall hydrogen storage has some half the electric-to-electric efficiency of most other storage methods. Flow/redox batteries are developing nicely. Gravity based systems, e.g. trains up and down hills, moving blocks up and down are under early deployment. There is a large number of electrochemical batteries under study including metal-air approaches. An Australian study identified some 530,000 pumped hydro energy storage sites worldwide, far more than required to provide storage for 100% renewable energy using wind, solar and hydro. [46]. Recent research indicates that requisite elevation differences for pumped storage can be reduced by utilizing fluids heavier than water. For heat batteries there is white hot molten silicon at some 50% the cost of pumped hydro, albeit with conversion losses.There are also chemicals and materials with order of 4X the heat storage density of water and efforts to institute seasonal energy storage, storing cold in winter and heat in summer. Abandoned oil and gas well could also be utilized for heat storage.

4.0 **Energy Conversion**

Utilization of power and energy often requires energy conversion from one form to another more useful form for the particular application. The most commonconversion is heat into electricity, employed in nuclear fission reactors.There are many conversion approaches suitable for various applications, a system and system of systems level optimization concerningcost, weight, size, efficiency, robustness, temperature levels, materials, and safety. Energy conversion options nominal peak efficiency levels include (6 and 47):Thermal electrics, spatial temperature gradients, 5% to 20% efficiency,Piezo-electrics,mechanical movements,to 80%, Thermal photovoltaics, to 60% efficiency,Pyro-electrics, to 90% of Carnot efficiency, thermodynamic cycles, to 40% efficiency,fuel cells, to 80% efficient, solar cells/photovoltaics, to some 50%. Higher system conversion efficiencies have been and can be operationally obtained by combining several conversion processes.Conversion approaches are utilized in energy regeneration and primary generation. All have disparate optimization conditions.
Then there is the recent Sang Choi invention of a new approach to T-Econversion, with efficiencies predicted to be above 20% [48].Applications of the regeneration of heat and other losses to increase efficiency including autobraking, trains, wind turbines, elevators, buses, cranes, robotics, power plants, fuel cells, etc. Regeneration can have major impacts on initial system design and optimization across many metrics.

5.0 **Energy Efficiency/Conservation**

Energy conservation, efficiency and regeneration are major approaches to mitigating climate [6]and [49] to [51]. These reduce the use of energy, either by using less or enabling similar results with less energy. Nominaleffects of energy conservation upon energy usage is 44%

reductions by2040, with 50% to 60% expected by 2050. There are four major sources of energy use - electricitygeneration, transportation, manufacturing, and buildings/agriculture.
Improved electricity generation via renewables includes increasein efficiencies of PV, other renewables, and the efficiencies of energy conversion andstorage. Energy utilization in buildings for heating, ventilation and air conditioning, lighting,appliances, and electronics. Current conservation approaches include insulation, smart meters,occupancy sensors, passive solar, heat pumps, shelter belts, and light-emitting diodes along with regeneration from waste heat including dryer venting and ventilation.Of great importance are the major improvements (over 30%) in the efficiency of electric motors. These are responsible for some 50% of all electricity use. The frontiers for building energy efficiency include room temperature superconducting materials to obviate much of the electrical losses. Buildings can now
generate instead of use energy, which will enable both a major increase in rate of the growth of renewables to produce distributed energy and a reduction in the overall capacity of requisite renewables and storage.
Transportation is now shifting from heavy transportation fuels to electrics, electric motors are twice as efficient as combustion engines. A major source of transportation energy use reduction is the societal shift to tele-everything including tele-work, travel, shopping (CO_2 emissions reduced by 15X compared to physical shopping), medical, education, commerce, socialization, etc. The switch to virtual travel, to digital reality, produces major energy savings. In addition, there areregenerative braking and drag reduction. Drag reduction for trucks caninclude small TV cameras/monitors vs. the large external mirrors, front/side air dams, flushwheel covers, smart tires to reduce rolling friction and turning vanes at the rear to fill in the base region. A general energy conservation approach for transportation is weight reduction via structural design and frontier materials. It is now possible to nano print materials with much better microstructure, resulting in large improvements in material properties including reduced weight. Another overalltransportation energy conservation approach is the development of home printingmanufacturing, for products which would reduce the amount of tonnagetransported. In water, parts per million of high molecular weight polymer can reduce turbulent skin friction drag,a high percentage of ship drag. A large drag reduction could be obtained if the phyto and zooplankton were sieved out of the cooling water and cultured into a polymer for injection over thehull. For aircraft, large drag reduction is available through use of externally truss-braced wingswhich enable large spans for drag due to lift reduction and wing designs for laminar flow.
Opportunities for energy conservation in manufacturing include: going to autonomous robotic “dark factories,” advanced low energy electric motors, regeneration of waste heat from manufacturing processes and co-generation of heat and electricity, replacement of process combustion heat requirements with electrics that are less expensive and provides energy conservation, low pressure loss membranes, and improved fluid flows/reduced pressure drop throughout. Air conditioning, an increasing % of grid load, is available via limited and targeted direct spectral radiation to deep space.

6.0 **Frontier Approaches To Remove Carbon From The Atmosphere**

There are 4 frontier approaches to removing CO2 from the atmosphere, three of which involve biologics. As stated, halophytes, salt plants that grow on deserts and wastelands [44% of land] using saline/ seawater [97% of water] could profitably and soon and at the scale of the climate problem, grow food, replace fresh water AG [70% of water use] with Salt water AG, produce massive amounts of biomass, green the planet and in the process sequester some 18% of their CO_2 uptake in their deep desert roots. Ocean fertilization, surface addition of iron dust, has been proven to promote major algae blooms which estimates indicate sequester a sizable percentage of their CO_2 uptake into the ocean depths. Bio research/genomics is increasing plant CO_2 uptake providing increased sequestration. Also, fungi sequester much CO_2. Addingcalcium and magnesium to the CO_2 in the oceans producescarbonates, providing sequestration.

7.0**Increasing the Planetary Albedo**

There is an increasing plethora of geo or mega engineering approaches to mitigate climate. These include adding atmospheric particulates/ aerosols, sun shades, adding sulfur to the atmosphere, spraying, seawater, many others. Most have unknown to potentially serious potential issues-to-downsides. Several apparently benign "geoengineering" approaches to climate mitigation involve altering the planets albedo, increasing reflectivity of incoming sunlight. The obvious such is white roofs and white roads. The huge imprint of the humans on the countryside enables this to have nontrivial effects. Also, bio changes can alter plant and algae albedo, reflectivity, with major impacts upon climate mitigation [52].

8.0 **Afterward**

The huge scale, massive wide spectrum,serious to existential impacts and now immediacy of climate change makes imperative utilization of the full range of approaches having major favorable impacts upon climate. We have waited perhaps too long to become serious about climate. For renewables, not much happened until they became profitable. Concerns regarding costs and impacts upon current industries slowed by decades effective societal climate response. The now all too wide spectrum climate adverse effects with their huge impacts and associated concerns wrt climate tipping points and many positive feedbacks is now changing the immediacy and scope of climate mitigation response planning. Given the scale, impacts of the climate issues somethings very different, at the requisite scale are required. The ever-reducing costs of renewables and storage is enabling a major shift in electrical generation. The Japanese apparent breakthrough in radiation-less nuclear weak force LENR posits a distributed, point of use, scalable battery energy approach at the profitability level of the renewables,which being self-storing requires no additional storage and lasts over a year. Renewables and LENR will drop the costs of energy, enable very wide spread electrification and, overall, possibly produce a green, energy rich societal state. Other major, at scale, profitable approaches include Halophytes, salt plants capable of seriously addressing land, water, food, energy and climate in major ways, literally "greening the planet". A shift to distributed generation will solve the huge vulnerability of a society totally dependent upon electrics to solar storms and EMP while reducing energy costs. Energy efficient frontier engineering is apparently able to reduce energy consumption by some 50% plus going forward.

Overall, if we have the courage to make serious, but profitable major shifts to developing alternatives we can even reverse climate, but climate is not an issue that can be addressed without making wide spectrum major and rapid changes. Per the experience with the development of renewables, approaches that constitute serious change are greatly expedited if found profitable. Along with climate mitigation, the ongoing revolution in energy generation and use along with much reduced costs will result in reduced costs of living, individual energy independence, mitigation of the impacts of severe solar storms due to distributed generation/ energy resilience, stranded fossil fuel assets and more affordable desalination and minerals from seawater,

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