EXECUTIVE SUMMARY of BEST ELECTRIC MACHINE:

- *Electric motors* consume at least 45% of the entire global supply of electricity, which has a compounded annual growth of 4%, *electric generators* produce virtually all of the entire global supply of electricity, which includes electricity generated from renewable energy, and likely, electric motors and generators (*i.e., electric machines*) will consume the entire 70% of additional expected growth in the global supply of electricity to provide electric propulsion as the primary means of transportation by circa 2035:
  - As the backbone of the electricity infrastructure, more efficient electric machines (*i.e., electric motors or generators*) would save considerable amounts of electricity, associated cost, and resulting environmentally harsh emissions, such as CO2. For instance, a reasonable 2% incremental improvement in electric motor system efficiency (e.g., 90% efficiency to 92%) could save nearly 1% (e.g., Δ2% x 45%) of today's entire global supply of electricity; or by reasonably assuming 45% of all electric vehicle (**EV**) loss is associated with the propulsion electric machine system, the 2% incremental improvement could increase the range of a *fully regenerative* EV by a healthy 9% (e.g., Δ2% x 45%).
  - Always included in decarbonization application, such as renewable energy (e.g., wind, hydro, tidal, hydrogen, etc.), electric transportation (e.g., ships, EV, electric airplanes, trains, etc.), and industry (e.g., fans, pumps, machinery, etc.), **the very competitive electric machine market (including electronic control) is well over $300B annually, *all of which use the same century old electric machine circuit and control architecture*** comprising the asymmetry of a "passive rotor assembly" of permanent magnets, slip-induction windings, reluctance saliencies, or DC field windings.
  - In response, professional articles are being published almost daily that effectively focus on optimizing the efficiency, cost, and size of the century old electric machine circuit and control architecture by strategically applying readily available and conveniently appliable performance material, winding, thermal, packaging, manufacturing, and control **techniques** with similar results but with the majority of articles blindly focused on the expensive Chinese Communist Party (**CCP**) controlled neodymium-dysprosium rare-earth permanent magnet (**RE-PM**) electric machine system, which are *notionally* considered to be the best performing.
  - While "innovating for our clean and sustainable energy future," Best Electric Machine (BEM) provides the only practical solution to the CCP RE-PM electric machine system with a *new electric machine circuit and control architecture* (comprising the symmetry of an "active rotor assembly"), called SYNCHRO-SYM, that immediately *magnifies* the performance of the century old electric machine circuit and control architecture while reducing its cost and improving its efficiency, by effectively eliminating the entire "passive rotor assembly" of the century old, me-too asymmetric electric machine system where reasonably half of the electric machine cost, size, and loss per unit of active power rating occurs but without contributing additional active power rating.
- All electric machine systems operate with the combination of two orthogonal vector components for producing moving force or rotating torque in accordance with Lorentz Law, which are magnetizing current windings (or permanent magnet coercivity) for "passively" establishing the flux density in the air-gap between the rotating and stationary bodies (*i.e., static energy*) and torque current windings for "actively" establishing force at speed (*i.e., kinetic energy or work*):
  - The DC magnetizing current component of electrical and core loss can be eliminated by replacing the electrical provisioning and proportionally related volume of current carrying

windings providing passive magnetizing magneto-motive-force (**MMF**) with a proportionally related volume of permanent magnets providing passive coercivity but only with the competitive performance of high BH energy product and practical persistent magnetizing life of expensive cartel-controlled **RE-PMs** (see "The Important Role of Dysprosium In Modern Permanent Magnets").

- Virtually all of today's high-performance electric machines are electronically controlled (*i.e., electric machine systems*) 1) for practical operation, such as for a *functional* RE-PM or reluctance electric machine system, 2) for optimum application control, such as by adjusting excitation frequency for variable speed, 3) for torque and active power control, such as by adjusting torque current, and 4) for higher operating speeds (*e.g., constant horsepower speed range*) and electronic reliability control, such as by adjusting magnetizing MMF, commonly known as *field weakening*.

- For comparison purposes, Best Electric Machine (BEM) classifies all electric machine systems into two categories: 1) the *century old, me-too, asymmetric electric machine system* circuit and control architecture that always comprises: a) an active stator assembly with a directly excited multiphase winding set (*i.e., active winding set*), which establishes the total torque and active power rating, b) a "passive rotor assembly" with the asymmetry (*and associated loss, cost, and size*) of slip-induction dependent windings (*i.e., asynchronous*), saliencies (*i.e., reluctance*), or RE-PMs, conventional, or superconducting DC field windings (*i.e., synchronous*), which establishes the static airgap magnetic field but without contributing active power (*i.e., work*) to the electromechanical conversion process, and c) a derivative of field oriented control (**FOC**) or 2) the *symmetric electric machine system* circuit and control architecture (*i.e., symmetric multiphase wound-rotor [synchronous] doubly-fed electric machine system*) that always comprises: a) an active stator assembly (*and associated loss, cost, and size*), which establishes the torque rating, b) an operationally ideal "active rotor assembly" with the symmetry of another active (*i.e., directly excited multiphase*) winding set, which establishes the air-gap magnetic field while contributing additional active power in *synchronous* combination with the active stator assembly, and c) a brushless real time emulation controller (**BRTEC**):
  - As always postulated during academic study, a practical symmetric electric machine system is only possible with the elusive invention of a brushless, sensor-less and automatic (*i.e., emulation*), instantaneous (*i.e., real-time*), and multiphase electric machine control process to essentially eliminate the elusive torque angle shift and the reliance on slip-induction, altogether, in order to provide continuously stable operation at any speed from sub-synchronous, including zero speed, to super-synchronous, including about synchronous speed where slip-induction ceases to exists.
  - In effect, a practical symmetric electric machine system eliminates the entire "passive rotor assembly" from the century old, me-too asymmetric electric machine system where reasonably half of the electric machine cost, size, and loss per unit of active power rating occurs but without contributing additional active power rating.
- The RE-PM was originally discovered (circa 1980) with USA subsidized or funded research and development (**R+D**) but with controlling ownership over the abundance of minable rare-earth deposits and without regard for human labor and environmental considerations, the global affiliates and shell companies of the CCP have become the de facto manufacturer and supplier of virtually all RE-PM electric machine systems, components, and materials with critical environmental, free enterprise innovation, and geopolitical consequences:

  - Because of anecdotal superior performance attribute of no magnetizing MMF provisioning and the prodigious amounts of inherited USA taxpayer funded or subsidized R+D, CCP RE-PM electric machine systems are again becoming universal for at least electric vehicles and large wind turbines, which again allows the CCP to easily hijack other original pioneering work and investment by the USA (or others), such as the prodigious amount of taxpayer subsidized R+D, manufacture, and installation investments in electric transportation and wind turbines.
- Without addressing the self-defeating consequences of consistently offshoring taxpayer funded R+D and manufacture without repatriation concern, USA is belatedly funding R+D into electric machine systems that decouples the CCP RE-PM influence: 1) by using proportionally less RE-PM material with the smaller footprint of a higher speed electric machine system and the additional compounding cost, size, loss, complexity, and reliability of a speed reduction gearbox and sophisticated high frequency electronic control, 2) by using RE-PM material more efficiently by the practical application of better electromagnetically performing material, winding, packaging, manufacturing, thermal, and high speed control techniques, and 3) by eliminating the coercivity of RE-PM materials, altogether, by optimizing magnetizing MMF electric machine systems to similar or better performance, such as slip-induction dependent, DC field wound, reluctance, or futuristic superconducting electric machine systems:
  - A dominant proportion of any electric machine system R+D always reverts back to the CCP RE-PM electric machine system by the inherited R+D investment momentum with blind disregard to the CCP geopolitical consequences and limited operating life expectancy of RE-PMs.
  - The consistent offshoring of USA taxpayer funded research and manufacture is self-defeating, particularly with the pockets of the CCP as the likely end recipient because of its stealthy penetrating influence into every aspect of the electric machine system industry and academic research, including superconductor electric machine systems, that originated from the inherited control of the RE-PM electric machine system material and manufacture.
  - Equally affected by the CCP RE-PM debacle, at least Japan has taken a more proactive and protective approach with the purchase of Metglas, which was the USA inventor of amorphous metal ribbon, to continue Japanese empirical research in nanocrystalline derivatives, such as Nanomet and Finomet, and its *practical, cost effective electric machine manufacturing method* that reduces the amount of RE-PM material in electric machines by increasing core permeability; but unlike the USA, Japan protects its intellectual property of taxpayer funded research by forbidding offshore manufacture.
- The superior performance fixation on RE-PM asymmetric electric machine systems is more anecdotal:
  - An "optimally" designed asymmetric "slip-induction dependent" electric machine may show up to 9% (e.g., 0.09) more electrical loss (and size) than an "optimally" designed RE-PM electric machine because of the orthogonal vector of passive magnetizing MMF. For instance, if a RE-PM electric machine shows 10 watts of electrical loss (e.g., 90% efficiency for a 100 watt rated motor), a magnetizing MMF electric machine with similar optimization, such as a slip-induction electric machine, would show a tolerable 10.9 watts of loss (e.g., 89.1% efficiency) but without the expense and geopolitical consequences of RE-PMs or including the additional effects of compounding loss, cost, and size of the necessary system gearbox and high speed electronic controller.

  - The relatively recent spawning of a RE-PM recycling industry obviously shows the finite operating life expectancy of RE-PMs but more importantly, shows the lack of enough global mineable RE-PM material to support the expected application growth in RE-PM electric machine systems, which is its major consumer.
  - Although the original reason for migrating to asymmetric RE-PM electric machine systems was the elimination of electrical loss, cost, and size associated with the magnetizing MMF of slip-induction, DC Field wound, or reluctance electric machine systems, RE-PM electric machine systems are ironically re-introducing magnetizing MMF back into their asymmetric circuit and control architecture to regain its coveted benefit of field weakening (with similar associated electrical loss, cost, and size).
  - Exemplifying the blind fixation on the notion that RE-PM persistent magnetism provides superior performance to similarly optimized magnetizing MMF electric machine systems, recent research is ironically trying to eliminate expensive RE-PMs by substituting inexpensive Ferrite PMs with the non-competitive performance of very low BH product and short persistent magnetizing life.
- With the anecdotal notion that asymmetric RE-PM electric machine systems have superior performance, original equipment manufacturers (OEMs) of EVs are acquiescing to the CCP geopolitical consequences by effectively branding the same optimized CCP RE-PM electric machine system with marketing suggesting the discernable performance differences:
  - In retrospect, all OEMs would be better served by dropping the marketing ploy to at least provide the "economy of scale" from the highest volume of manufacture of an industry generic RE-PM electric machine system without the nuances of branding, such as from a universal OEM component supplier.
- While "innovating for our clean and sustainable energy future," Best Electric Machine (BEM) provides the only practical solution to the CCP RE-PM electric machine system debacle by leveraging the patents of a *symmetric electric machine system circuit and control architecture*, called SYNCHRO-SYM, as only possible with the invention of brushless real time emulation control (**BRTEC**), and a new (and only) high speed method of 3D Printing axial-flux electric machines, called MOTORPRINTER. Together, BEM, SYNCHRO-SYM and MOTORPRINTER *uniquely* provide the following:
  - R+D by the tried and true old fashion way with private sweat equity and investment in innovative free enterprising solutions that did not acquiesce to government funding, which continually directs R+D and manufacturing towards me-too RE-PM electric machine systems with careless disregard to the geopolitical, free enterprise, and electric machine innovation consequences of CCP control.
  - Innovation that brings the very "best" electric machine system technology and manufacturing (i.e., SYNCHRO-SYM and MOTORPRINTER) to the free enterprise market with a better choice to the CCP cartel-controlled RE-PM electric machine system.
  - Simple direct selectable speed, torque magnitude, and leading, lagging, or unity phase process control but with stochastic perturbations, such as kinetic energy, excitation frequency, or multiphase excitation phase perturbations, automatically, instantaneously, and sensorlessly addressed, as only possible with BRTEC of a symmetric electric machine system, instead of addressed with the detrimental reaction delays and imprecisions of offline measurement, estimation, compensation calculation, and excitation synthesis processing as always suffered with state-of-art controllers of the century old me-too asymmetric electric machine systems, such as Field Oriented Control (FOC).

- By the additional power rating of the active rotor assembly, simple qualitative observation easily shows the century old me-too asymmetric electric machine system *performance is immediately twice magnified with cost and electrical loss halved per unit of active power* by effectively eliminating the entire "passive rotor assembly" of slip-induction windings, DC field windings, reluctance saliencies, or RE-PMs where reasonably half of the cost, size, and loss per unit of active power rating occurs but without contributing additional active power rating.
- Likewise, *immediately twice magnifies the performance improvement* expected from the strategic application of the same performance material, winding, packaging, thermal, manufacturing, and control techniques that all century old, me-too asymmetric circuit and control architectures are compelled to use for their performance enhancement or so-called invention.
- *At least octuple the peak torque* of the century old, me-too asymmetric electric machine system nominal frame size by uniquely holding airgap flux density and port voltage constant with increasing torque current, which for instance, is essential for eliminating the compounding size, loss, cost, maintenance, and reliability of an electric vehicle gearbox.
- Saves precious CCP RE-PM materials for more strategic applications by providing a higher performance, cost, and reliability alternative to its major consumer, the RE-PM electric machine system.
- Inherently provides adjustable leading, lagging, or unity power factor correction for dynamic VAR compensation at the field application to dramatically improve electric distribution resiliency and electricity cost.
- Democratize the manufacture of high performance amorphous or nanocrystalline axial-flux electric machines with portable, high-speed, universally programmable, additive manufacturing (i.e., 3D Printer) to at least provide distributed, non-smokestack manufacturing with similar "economy of scale" as the high-volume manufacture of a generic me-too product.
- Brings superconductor electric machine systems of today closer to practical reality by brushlessly relocating the winding cryogenics to the stator assembly for improved logistics while eliminating electronic control harmonic heating.
- When AC superconductors become available by aggressive on-going research, the performance of the fully electromagnetic superconductor slip-induction electric machine system will be far superior to the RE-PM electric machine system but more importantly, the fully electromagnetic superconductor SYNCHRO-SYM will be the electric machine system of choice by far surpassing the performance of the superconductor slip-induction electric machine system.