(Carwell, H., Grant, B., Kadoda, G., Tharakan, J., Trimble, J., Verharen, C. (editors), 2012, Proceedings of the 5th International Conference on Appropriate Technology, p.109-116.)

A Rapid Solar Transition is not only Possible, it is Imperative!

[1]David Schwartzman and [2]Peter Schwartzman

[1] Department of Biology, Howard University, Washington, D.C. 20059, United States, E-mail: dschwartzman@gmail.com

[2] Department of Environmental Studies, Knox College, Galesburg Illinois. 61401, United States.

Key words: solar power, catastrophic climate change, energy poverty, fossil fuels

Abstract

Catastrophic climate change (C3) is inevitable if carbon emissions to the atmosphere are not rapidly reduced and the now unsafe atmospheric level (395 ppm) CO_2 (and rising) is not brought down by sequestration technologies to below 350 ppm. C3 prevention is possible with the replacement of global fossils fuel supplies by wind, concentrated solar power and photovoltaics, with the main obstacle being the political economy of global capitalism, specifically the "Military Industrial (Fossil Fuel, Nuclear, State Terror) Complex". There are three critical requirements for the "other world that is possible": demilitarization, agro-ecologies replacing industrial/GMO agriculture, and solarization. Expanding democratic, bottom-up governance is necessary to achieve these objectives. Energy poverty in the global South must end, reaching a rough minimum of 3.5 kilowatt/person. Our simulations show this solar transition is achievable in no more than 30 years with the consumption of less than 40% of the proven reserves of conventional petroleum, while supplying sufficient energy to sequester CO_2 from the atmosphere using a combination of global agroecologies increasing soil carbon storage and solar-powered-industrial-burial of carbonate in the crust. This approach would maximize the possibility of reaching a safe atmospheric CO_2 level before the tipping points to C3 are reached.

Introduction

Humanity is faced with two technological threats to the continuance of human civilization and biodiversity as we know it. The first is the continuing threat of nuclear war, not inevitable but deadly even if localized by virtue of climatic impact on food supplies. The second, catastrophic climate change (C3) is very likely inevitable if carbon emissions to the atmosphere are not rapidly and radically reduced and the now unsafe atmospheric level of 395 ppm CO_2 (and rising) is not reduced by sequestration technologies to below 350 ppm.

An unprecedented path to the "other world that is possible" will be opened up if humanity succeeds in the near future to overcome the obstacles standing in the way of decarbonizing our global energy supplies coupled with rapid implementation of state-of-the-science solar technologies such as wind, concentrated solar power and photovoltaics. The obstacles are not technological, rather lie in the political economy of real existing 21st Century global Capitalism, starting with the Dinosaur sitting in the Room, the Moloch called the Military Industrial (Fossil Fuel, Nuclear, State Terror) Complex. Only a transnational movement for peace and justice can put this Dinosaur in the Museum of Prehistory where it belongs. We argue that there are three critical requirements for that other world that is possible: demilitarization of our global economy, agro-ecologies replacing industrial and GMO agriculture, and the creation of a high-efficiency solar power infrastructure replacing unsustainable fossil fuels and nuclear power. Further, expanding democratic, bottom-up control of the process of transformation of the global economy is necessary to achieve these goals. We may have only 5 years left to begin radical cuts in carbon emissions, according to the most recent assessments, given the continued rise in global carbon emissions [1].

Theoretical Framework

We modeled global solar transition with computed simulations that assumed values for the energy return over energy invested for state of the science of the science wind/solar technologies, "EROEI", i.e., how much energy does the technology such as a photovoltaic array or wind turbine generate in its usable lifetime divided by the energy needed to construct it and maintain it [2]. To our knowledge this was the first study which computed the necessary non-renewable energy (mainly fossil fuel) needed to create the renewable capacity in a solar transition scenario. The critical factor that leads to exponential growth of this renewable energy supply is the feedback of energy from the growing renewable capacity back into the physical economy to create more of itself.

The following equation was used in these simulations

$$d(P_{RE})/dt = [(M/L)(f)(P_{RE})] + [(M/L)(f_{FF})(P_{FF})]$$

RE is defined as the wind/solar technology
P_{FF} : Current power delivery (85% supplied by fossil fuels)
f : fraction of P_{RE} used to make more P_{RE}
f_{FF} : fraction of P_{FF} used to make more P_{RE}
L: lifespan of any RE source
M (= EROI or EROEI): Energy return over energy invested for RE
(M/L) x instantaneous energy invested = instantaneous RE created

Results and Discussion
Some of our results are shown in Figure 1 (go to [2] for more details).

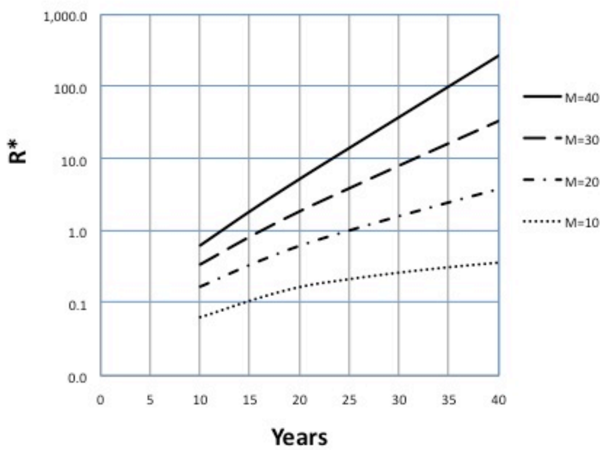

Figure 1. Future Renewable Energy Capacity with different assumed Energy Return Over Energy Invested values ("EROEI") = M for wind/solar technologies. R* is the ratio of future global renewable power delivery to existing energy generation per year, with 85% presently from fossil fuels. Assumed lifetime of installed wind/solar =20 yrs, with 10% of wind/solar energy produced being reinvested per year in making more of the same, and with 1% of the current annual consumption of energy being used per year to create wind/solar power. State of the science EROEI values of current technologies: Wind turbines: 20 to 75; Photovoltaics: 6 to >10; CSP: 7 to 40. Curves on graph descend from M = 40 (top) to M = 10 (bottom).

Mainly because of its lower carbon emission footprint compared to coal, the preferred fossil fuel to make a solar transition is petroleum (only conventional oil and natural gas, *excluding* the higher carbon footprint tar sands and fracked natural gas, as well as dangerous drilling on deep water continental shelves). We estimate that a robust solar transition can be completed in 20 to 30 years using no more than 40% of the proven conventional reserves of petroleum. The latter requirement will be reduced as higher EROEI wind/solar technologies are developed and put in place in this transition. At the culmination of this solar transition a global increase in energy would be delivered to the world, not a decrease, with many countries in the global North such as the U.S. decreasing their wasteful consumption, while most of humanity, living in the global South receiving a significant increase, reaching the rough minimum of 3.5 kilowatt/person required for state-of-the-science life expectancy levels (see Figure 2). We note that reaching the minimum 3.5 kilowatt/person is necessary but not sufficient for acquiring the highest life expectancy, noting that several petroleum-exporting countries in the Mid-East as well as Russia fall well below this value. Life expectancy for the United States is likewise below most industrial countries of the global North. Income inequality is robustly correlated with bad health and must be reduced to achieve the world

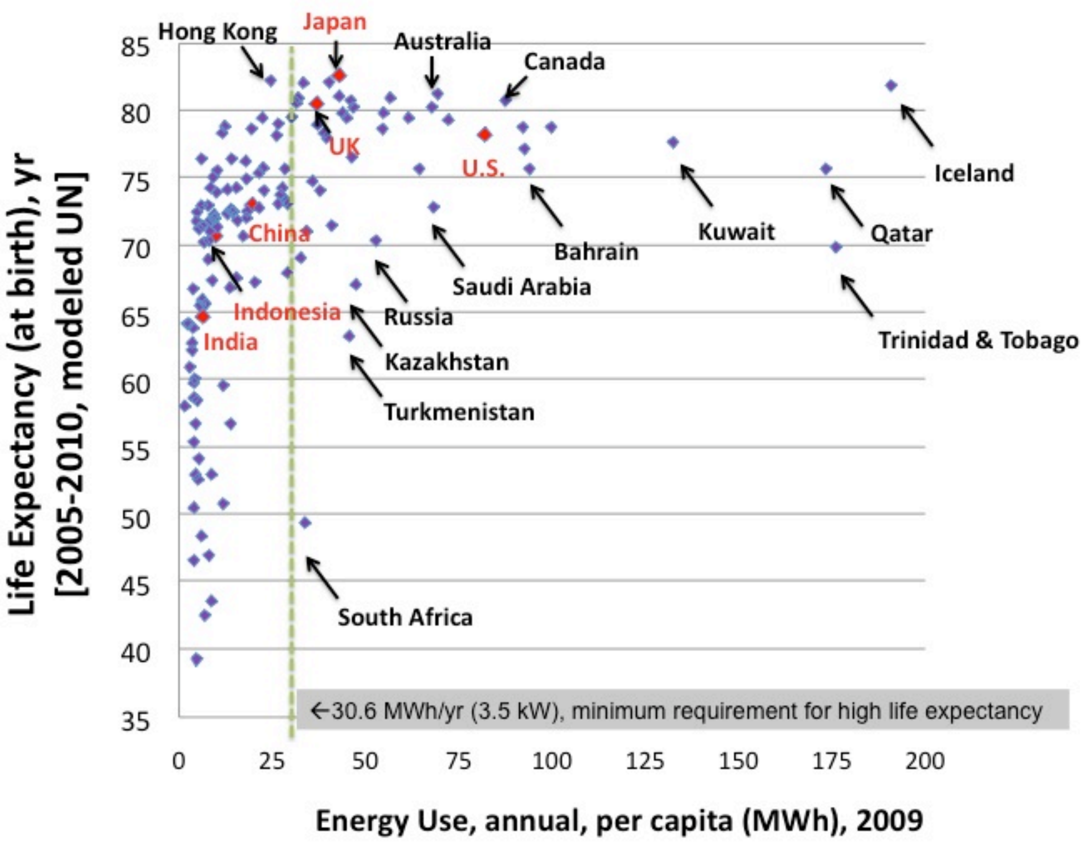

Figure 2. Life expectancy at birth (years) versus Energy use per capita. Source of data: [4].

standard life expectancy and quality of life [3]. Supplying the minimum 3.5 kilowatt/person for the present world population of 7 billion people requires a delivery equivalent to 25 Terawatts (TW), with the present delivery equal to 16 Terawatts (for further details go to www.solarutopia.org). Rapid phase-out of coal use as well as aggressive energy conservation in energy-wasteful countries such as the U.S. is imperative, and must start in the very near future to begin radical reduction in carbon emissions. Further, as the solar transition proceeds, energy conservation in the global North would free up petroleum needed for rapid solar development in the global South. Oil-rich countries in the Mid-East, South America (e.g., Venezuela) and Europe (e.g., Russia) will be valuable partners in this solar transition by providing the needed petroleum. There is little doubt that this transition will require global demilitarization as necessary condition for a global cooperative regime (for documentation go to [15]. If this transition is delayed then humanity will face the virtually inevitable onset of catastrophic climate change. Let's be clear that solar transition must be parasitic on existing energy supplies, just as the industrial fossil fuel revolution was parasitic on biomass energy, so-called plant power, until it replaced the former supply with sufficient capacity. The higher the EROEI value of the wind/solar technology used, the less unsustainable presently-used-energy is needed to effect the solar transition.

A likely maximum of 40% of the proven reserves of conventional petroleum is needed if a robust solar transition starts very soon.
The following provides the basis for our maximum 40% estimate of conventional petroleum needed in our preferred solar transition model to insure a steadily increasing global energy supply to a minimum 3.5 kilowatt/person globally, accompanied by an early phase out of coal, nuclear, big damaging hydropower and most biofuels. Assuming a conservative value of EROEI = 20 for wind/solar, two times the current global energy delivery or roughly 32 TW, corresponding to 9 billion people, is generated for a 20-30 year solar transition with the complete termination of fossil fuel/nuclear/biofuels. In order to ensure a steadily growing global supply of energy, conventional petroleum will provide the complementary supply to the growing wind/solar delivery, with a progressive decrease to zero at the end of the transition. We estimate that no more than 40% of the proven conventional reserves of petroleum (oil and natural gas, excluding tar sands and fracked gas reserves) is needed, roughly 7 ZJ.* The latter requirement will be reduced as higher EROEI wind and solar technologies are developed and put in place in this transition. In addition, coal, nuclear power, as well as hydropower and biofuels with significant carbon footprints, can contribute to RE creation before being phased out completely in the early phase of the transition, and thus this computed fraction of petroleum reserves needed as a backup is a likely maximum. The factors impacting on this estimate are discussed in [2].

* Here is the function used for progressive phase out of non-RE energy sources over the assumed 25 year transition period, with t being the time in years: $FF = 1 - 0.015\,t - 0.001\,t^2$;
$\int FF dt$ from t = 0 to 25, gives a total fossil fuel (“FF”) consumption equal to 15.1 times the present annual global energy consumption level (0.47 ZJ) or 7.1 ZJ, *which is 43% of the estimated global 16.7 ZJ remaining in conventional petroleum reserves* (oil and natural gas). Note: The “proven” reserves cited do not include tar sands, oil shale or fracked natural gas. In 2008, total worldwide energy consumption was 474 exajoules (474×1018 J=132,000 TWh [5]). Reference [6] cites [7] which estimates remaining natural gas reserves equal to 415 T cubic meters.

If a vigorous solar transition is delayed too long, then and only then will we likely face the gloom and doom scenario of Peak Oil and the virtually inevitable onset of catastrophic climate change, barring the implementation of near future revolutionary solar technologies with much higher EROEI values. Nevertheless, carbon sequestration powered by agroecologies and solar power is imperative, and must start as soon as possible to have any hope of preventing the onset of catastrophic climate change. The longer the excess carbon dioxide remains in the atmosphere the more likely the tipping points for C3 will be reached, therefore radical and early cuts in carbon emissions and carbon sequestration should go hand-in-hand.

Is the baseload supply of energy an obstacle for wind/solar?
Baseload is the backup supply of energy when a particular energy technology is not operating at full capacity. Commonly, supporters of continued reliance on fossil fuels and/or nuclear power raise the objection that wind/solar cannot meet the challenge of baseload. But this claim is misleading. Already available reliable and cheap storage technologies, along with tapping into geothermal energy, will facilitate the expansion of these renewables. However, a big enough array of turbines, especially offshore can likely can generate a baseload without the need to supplement it with separate storage systems [8]. Further, the progressive expansion of a combined system of wind, photovoltaics, and concentrated solar power in deserts will generate a baseload simply because the wind is blowing and the sun is shining somewhere in the system linked to one grid. Meanwhile baseload would be backed up by petroleum, with coal phasing out first, on the way to a completely wind/solar global energy infrastructure.

We have focused on the creation of wind and high efficiency solar technologies in our modeling since these have the greatest potential for not only rapidly replacing the present unsustainable energy supplies but also meeting the energy requirements of all of humanity. Nevertheless, other renewable sources will contribute to the new global infrastructure, notably geothermal (if its hot reservoirs are not depleted), tidal, wind and hydropower (especially small scale). Geothermal power can even become the dominant energy source in some locales (e.g., Iceland and potentially in East Africa). In contrast, most biofuels, such as ethanol derived from corn, are highly problematic, with low EROEI values and undesirable environmental and nutritional impacts.

Carbon-sequestration from the atmosphere must be a component of a solar transition
Carbon sequestration from the atmosphere is imperative, and must start in the near future since the longer the excess carbon dioxide remains in the atmosphere the more likely the tipping points for C3 will be reached. Only the thermal inertia of the oceans responding to the now unsafe and ever rising atmospheric level of CO_2 near 400 ppm gives us a short window of opportunity [9], [10]. Following the analysis provided in [9], a prevention program to have any chance of avoiding catastrophic climate change must include carbon-sequestration from the atmosphere to achieve an atmospheric CO_2 level at or below 350 ppm as soon as possible. A follow up study recommends a 6% cut/year in fossil fuel consumption starting now, with 100 Pg of carbon sequestered from the atmosphere by reforestation from 2031-2080 leaving 350 ppm CO_2 in the atmosphere by 2100 [10]. Lal estimates 2-4 Pg per year of carbon from the atmosphere could be sequestered globally as soil carbon from the atmosphere using agroecological approaches [11]. Assuming a rate of 2 Pg/year, in 50 years 100 Pg of carbon could be sequestered from the atmosphere. A likely complementary approach is solar-powered-industrial carbon sequestration from the atmosphere, burying carbon as carbonate in the crust. Assuming a minimum energy requirement of 442 KJ/mole CO_2 ([12], [13]) 100 Pg of carbon could be sequestered from the atmosphere requiring 3.7 ZJ, equivalent to 7.3 years of the present global energy delivery (16 TW). In a robust solar transition, assuming 7 ZJ of conventional petroleum are consumed in 25 years, with EROEI of wind/solar equal to 25 (same as their lifetime in years) then a total of 51 ZJ is generated, with industrial carbon sequestration energy being 7% of the total. This requirement would of course be reduced by the use of agriculturally-driven carbon sequestration into the soil.

Growth or Degrowth?
The degrowth movement is gaining support in Europe. Richard Heinberg is an influential champion of the Transition City movement. Here is a sample of his argument:

"there is no credible scenario in which alternative energy sources can entirely make up for fossil fuels as the latter deplete. The overwhelming likelihood is that, by 2100, global society will have less energy available for economic purposes, not more…A full replacement of energy currently derived from fossil fuels with energy from alternative sources is probably impossible over the short term; it may be unrealistic to expect it even over longer time frames. . . Fossil fuel supplies will almost surely decline faster than alternatives can be developed to replace them. ..we believe that the world has reached immediate, non-negotiable energy limits to growth." [14]

Au contraire, we show that a complete global transition to wind/solar energy is possible using current technology taking 20-30 years. Richard Heinberg's prescription would doom most of humanity to a future of living hell since *global* energy supplies must be increased to end energy poverty in the global South as well as create the capacity for carbon sequestration from the atmosphere and for the massive cleanup of the biosphere. Nevertheless, while degrowth is a very problematic recipe for global restructuring, it should not be dismissed as a useless response to the unsustainable reproduction of capital, with a reduction in certain kinds of consumption necessary especially in the global North and for elites in the global South. Thus arguments for degrowth should be taken seriously insofar as they address economic activities that increase consumption of fossil fuels, especially coal and tar sands, the two most intense carbon emitters.

The degrowth program is highly problematic because of its failure to analyze the qualitative aspects of economic growth and its emphasis on the local economy without recognizing the urgency to address global anthropogenic change from a transnational political perspective. This demands struggle on all spatial scales, from the neighborhood to the globe.

Global degrowth fails to come to terms with qualitative versus quantitative aspects of economic growth. Further, the energy base of the global physical economy is critical: global wind/solar power will pay its "entropic debt" to space as non-incremental waste heat, unlike its unsustainable alternatives. The concept of economic growth should be deconstructed, particularly with respect to ecological and health impacts. Growth of what are we speaking, weapons of mass destruction, unnecessary commodities, SUVs versus bicycles, culture, information, pollution, pornography, or simply more hot air? Instead, degrowthers commonly lump all growth into a homogenous outcome of the physical and political economy [15].

A Global Green New Deal (GGND) will deliver sustainable growth with huge benefits for both humans and nature, with clean air and water, organic food, meaningful employment and more free creative time for all on this planet [16]. Green sustainable growth will be a transition to a steady-state global solar economy in the 21st Century. Further, the GGND will create the social and material base for bottom-up democratic management of the political and physical economies while still having a chance to prevent C3.

Is the observed and projected market-driven growth of renewable energy capacity, notably of wind and photovoltaics, consistent with our goal? We wrote: "Nevertheless, despite recent developments, the transition to renewables currently underway still lacks the intensity that will allow it to drive the replacement of fossil fuels in a few decades." [2, p. 8]. We stand by this assessment, especially since global fossil fuel use continues to climb at the same time. We estimate that roughly an order of magnitude increase in investment into new wind/solar energy capacity is required. Implementing a GGND would meet this objective.

Conclusion

- A robust solar transition is possible in a few decades, with the potential of avoiding tipping points leading to irreversible catastrophic climate change.

- This transition would simultaneously end energy poverty in the global South, thereby meeting a necessary condition for the state of the science quality of life for all of humanity.

- The biggest obstacle blocking this transition is the Military Industrial (Fossil Fuel, Nuclear, State Terror) Complex. We cannot expect the capitalist market by itself to bypass this obstacle in time to prevent climate catastrophe.

- Only a powerful transnational of peace and justice, organized from the neighborhood to the globe, can overcome this obstacle, insuring this goal is achieved, by forcing rapid reduction in carbon emissions to the atmosphere and the robust creation of wind/solar energy capacity.

- The convergence of the economic, social and ecological/climate crises makes a rapid transition to wind/solar power imperative, hence a Global Green New Deal must be on the agenda for implementation in the very near future.

References

[1] Harvey F (November 9, 2011) World headed for irreversible climate change in five years, IEA warns If fossil fuel infrastructure is not rapidly changed, the world will 'lose for ever' the chance to avoid dangerous climate change. http://www.guardian.co.uk/environment/2011/ nov/09/fossil-fuel-infrastructure-climate-change.

[2] Schwartzman P & Schwartzman D (2011) *A Solar Transition is Possible.* http://iprd.org.uk and http://www.solarutopia.org.

[3] Wilkinson R & Pickett K (2009) *The Spirit Level Why Equality is Better for Everyone*. Penguin Books. London. Kawachi I & Kennedy BP (2006) *The Health of Nations: Why Inequality Is Harmful to Your Health.* The New Press. New York.

[4] http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE, http://en.wikipedia.org/wiki/List_of_countries_by_life_expectancy.

[5] http://en.wikipedia.org/wiki/World_energy_consumption.

[6] Smil V (2008) *Energy in Nature and Society.* MIT Press. Cambridge.

[7] Ahlbrandt TS, Charpentier RR, Klett TR, Schmoker JW, Schenk CJ, & Ulmishek GF   (2005) *Global Resource Estimates from Total Petroleum Systems*. Tulsa, Okla. AAPG.

[8] Archer CL & Jacobson MZ (2007) Supplying baseload power and reducing transmission requirements by interconnecting wind farms, *J. Applied Meteorol. and Climatology* **46**, 1701-1717, www.stanford.edu/group/efmh/winds/. Kempton W, Pimenta FM, Veron DE & Colle BA (2010) Electric power from offshore wind via synoptic-scale interconnection. *PNAS* **107**: 7240-7245.

[9] Hansen J, Sato M, Kharecha P, Beerling D, Berner R, Masson-Delmotte V, Pagani M, Raymo M, Royer DL & Zachos JC (2008) Target atmospheric CO_2: where should humanity aim? *Open Atmos. Sci. J.,* **2**, 217-231.

[10] Hansen J, Kharecha P, Sato M, Epstein P, Hearty PJ, Hoegh-Guldberg O, Parmesan C, Rahmstorf S, Rockstrom J, Rohling EJ, Sachs J, Smith P, Steffen K, von Schuckmann K & Zachos JC (2011) The Case for Young People and Nature: A Path to a Healthy, Natural, Prosperous Future. http://www.columbia.edu/~jeh1/mailings/.

[11] Lal R (2010) Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. *BioScience* **60**, 708-721.

[12] House KZ, Baclig AC, Ranjan M, van Nierop EA, Wilcox J & Herzog HJ (2011) Economic and energetic analysis of capturing CO_2 from ambient air. *PNAS* **108**, No. 51: 20428-20433.

[13] Zeman F (2007) Energy and material balance of CO_2 capture from ambient air. *Environ. Sci. Technol.* **41**, 7558-7563.

[14] Quotation posted from Heinberg R (2009) *Searching for a Miracle: Net Energy Limits and the Fate of Industrial Societies*. International Forum on Globalization and Post Carbon Institute. http://www.postcarbon.org/article/254838-earth-s-limits-why-growth-won-t-return. Also see: Heinberg R (2011) *The End of Growth.* New Society Publishers. British Columbia, Canada.

[15] Schwartzman D (2012) A Critique of Degrowth and its Politics. *Capitalism Nature Socialism* **23**, (1) 119-125. Schwartzman D (2009) Ecosocialism or Ecocatastrophe? *Capitalism Nature Socialism* **20**, (1) 6-33.

[16] Schwartzman D (2011) Green New Deal: An Ecosocialist Perspective. *Capitalism Nature Socialism* **22**, (3) 49-56.