A Fundamental Look At Supply Side Energy Reserves For The Planet

This is an update of the April 2009 Solar Update article. The objective of the 2009 article was to put in perspective the potential of often-cited nuclear and renewable alternatives to Greenhouse Gas (GHG) emitting fossil energy sources. Its main conclusion was that although a mix of alternatives, including hydropower, biomass/biofuels, geothermal, ocean thermal energy conversion, waves, tides, wind and solar, appeared like a sound approach to bringing about the desired economically and environmentally sustainable energy future (akin to putting future energy eggs in different baskets), a review of their potential clearly showed that the solar resource dwarfed all other renewables (and fossil/nuclear alike) by orders of magnitude. And therefore, the desired economically and environmentally sustainable energy mix of the future should be essentially solar-based.

The three-dimensional rendering appearing in the April 2009 Solar Update and reproduced here in Figure 1 compared the annual energy consumption of the world at the time to (1) the known economically exploitable reserves of the finite fossil and nuclear resources and (2) the yearly potential of the renewable alternatives. The volume of each sphere in the figure represents the total amount of energy recoverable from the finite reserves and the energy recoverable per annum from renewable sources.

Conditions have evolved since 2009, thus the rationale for this update. The energy consumption of the world has increased nearly 12% to 18.3TW-yr per annum in 2014 [26]. We estimate it will reach 27TWyr per annum in 2050. The economically exploitable fossil fuel energy reserves have increased appreciably thanks to the development of hydraulic fracturing technologies along with exploitation of the Canadian tar sands and Venezuela's Orinoco basin – although many question the correspondingly increased CHG and other environmental impacts of these technologies.

▼ Figure 1: 2009 estimate of finite and renewable planetary energy reserves (Terawatt-years). Total recoverable reserves are shown for the finite resources. Yearly potential is shown for the renewables.

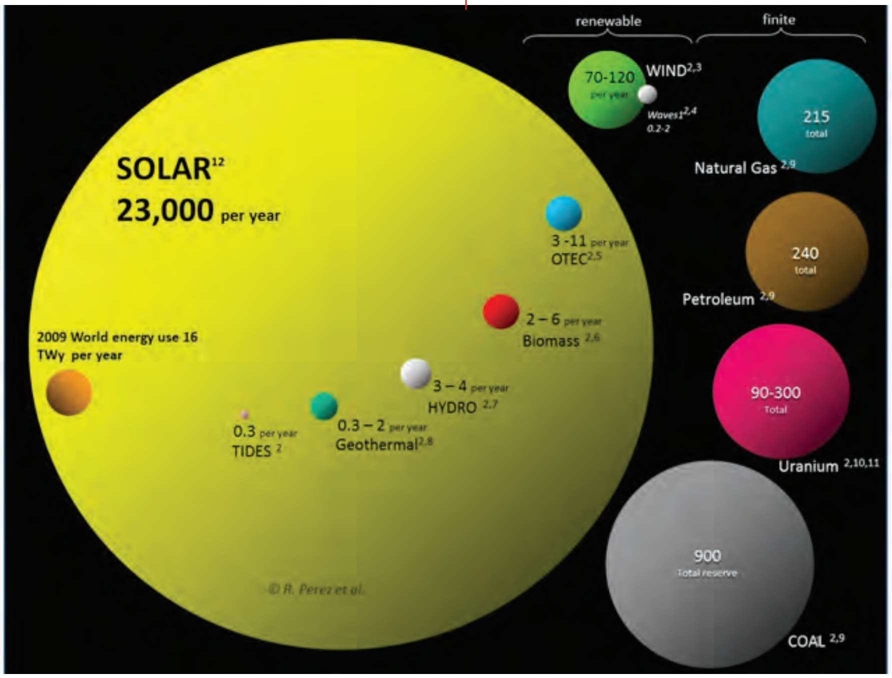

Figure 2 illustrates the current conditions. Overall, the conclusions remain the same – solar remains the largest resource by far. Even when pushing economically acceptable fossil sources to their current limit, the global picture is basically unchanged. Especially if one considers that the threshold for economic viability will be lowered by environmental pressure and, more effectively perhaps, by the fact that solar is rapidly becoming the lowest cost resource on a straight energy production basis, further lowering the economic viability threshold of other sources.

Figure 2 Notes:

1. The uranium sphere [13-20] assumes direct fission of all known exploitable sources of uranium on the planet including reasonably assured and inferred reserves, as well as prognosticated and speculated reserves, and uranium extractable from phosphates.

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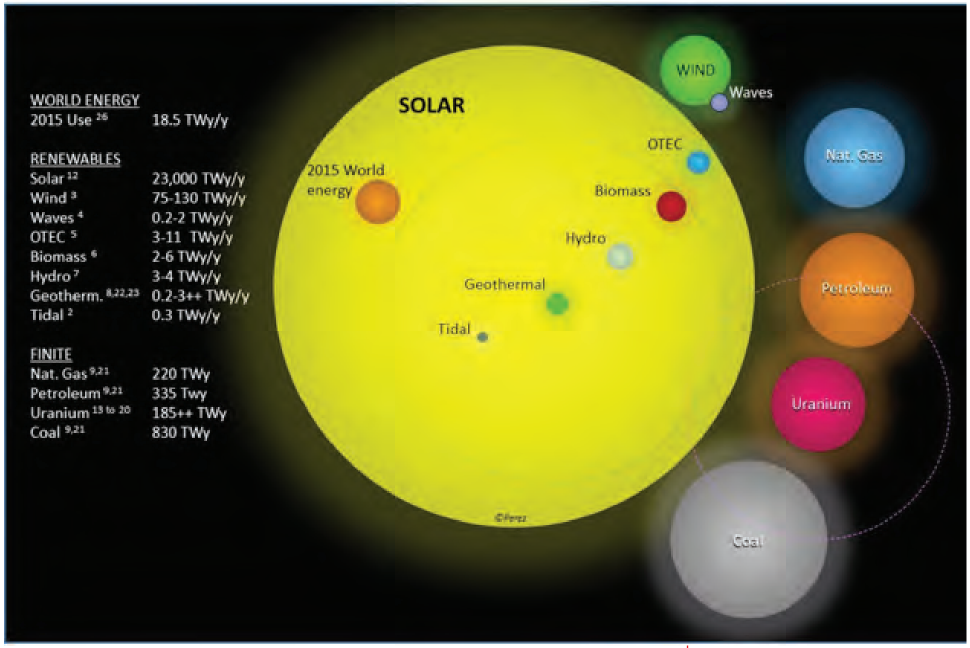

▲ **Figure 2: 2015 estimated finite and renewable planetary energy reserves (Terawatt-years). Total recoverable reserves are shown for the finite resources. Yearly potential is shown for the renewables.**

However it does not include uranium that could be extracted from seawater (a technology that does not yet exists). The dotted outline represents the nuclear potential that would be achievable if 100% of all fission byproducts were ideally reprocessed.

2. The yearly geothermal potential illustrated is based on the IEA cumulative recoverable estimate of 85 GW-yr to the year 2050 using conventional technologies [22]. Future, yet highly environmentally questionable, deep hydro-fracking-based technologies known as enhanced geothermal systems (EGS [23]) could enhance geothermal recovery well over a 100-fold (dotted line). These technologies do not exist today.

3. 2015 global primary energy use is extrapolated from the 2014 reference [26] by linear forecasting.

Another point that many have questioned in the 2009 article is that the solar resource potential represented is that of the entire planet (excluding oceans), accounting for weather, but assuming perfect conversion efficiency. However, even if one only assumes optimal solar deployment in urban/suburban areas of the world [23, 24] plus transportation and other networks and small amount of central plants deployment – a total amounting to <4% of land area, and a conversion efficiency of as little as 20% (achievable today and a very conservative estimate for the years to come) solar remains the essential part of the energy mix of the future. In addition, while with such efficiency and deployable land limits, the one-year solar potential would "only" be of the order of the planetary reserves of coal, a multiple-year outlook unquestionably shows that solar is the overwhelming energy solution for the future of the planet.

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12. Solar energy received by emerged continents only, assuming 65% losses by atmosphere and clouds

13. Number includes existing global stockpiles of U3O8 ore, Highly Enriched Uranium (HEU), Low Enriched Uranium (LEU), Plutonium stockpiles, Identified Resources (Reasonably Assured Recoverable + Inferred), Waste Resources (Stockpiles of Reprocessed Uranium, Depleted Uranium, Mill Tailings and Spent Nuclear Fuel), Undiscovered Resources (Prognosticated resources, and speculative resources) and super speculative resources including the assessed uranium resource in global marine and organic phosphates. All stockpiles and resources are converted to their N.U. equivalents available at a price point <=$450/kgU. For waste resources and resources with a low concentration of U235, the costs of reprocessing or enriching are taken into account as are the costs of downblending for already enriched resources like HEU and LEU. More information available upon request.

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* Note that 85 GWyr is the forecast for 2050 for cumulative Geothermal capacity outlay by the IEA. The potential of EGS (Enhanced Geothermal System) is nearly infinite. 8800 TWyr conservatively (accessing 2% of the resource). However, accessing this resource is fraught with environmental issues. [see 23]

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