Sustainability and Electrical Energy Production

Victor Goldschmidt, creating2@earthlink.net

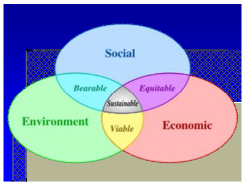
March 2012 ASHRAE St. Louis Chapter meeting

The industry at large has been challenged with the concept of sustainability. While some consider this to mean "leaving our environment to exactly the way we found it", it is quite more subtle than that. The formal definition appears to be by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development: "meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations. 1987."Report of the World Commission on Environment and Development." General Assembly Resolution 42/187, 11 December 1987. ).

This does not imply identical conditions remaining, but rather the same opportunity to maintain the current quality of life. In reality, a casual glimpse back into history prior to the advent of electricity, and even during its richest growth during the start of the industrial revolution, exhibits that in the average the quality of life has been improved steadily. It could be stated that we have been exceeding sustainability!

Two observations are in order. Our current ability to meet our needs is highly dependent on the availability of energy – and one essential form has been electrical energy. Secondly, there is an unquestionable correlation of different indicators such as life expectancy and the access to electrical power. It is suitable then to related electrical generation to sustainability.

There is an additional component of sustainability that must be considered. Like a three-legged stool, it reaches its "stability" via three sectors: environment, social, and economic.

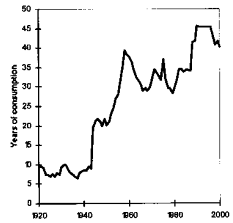



To simply meet the social and economic needs might be bearable; satisfying just the environment and economic, viable; and just social and economic, equitable. It is when all three sectors overlap that sustainability is met.

With this perspective, a cap-and-trade program is not sustainable as it fails to account for the social aspects calling for affordable power in nations currently with a shortage or even without electricity serving some of their citizens. On the other hand, removing dams with working hydroelectric plants is not sensitive to economic concerns as it excludes from service what is one of the most cost-effective sources for electrical power. It might also be said that focusing on renewable energy to the sacrifice of fossil fueled power plants is meeting only the environment concerns as driven by assumed impacts of carbon footprints without addressing the economic as well as the social concerns. Any consideration of this type must also have in sight the recognition that there is a notable shortage of electricity in many developing nations and a progressive desire for more in all other nations. And this is not necessarily bad, as we extrapolate from our past growth.

One major concern when addressing fossil fuels as sources of thermal energy to drive generators is their availability. Researching for this kind of data first of all shows a notable lack of well documented data. Secondly it exhibits surprisingly growing estimates for resources. One interesting index is the ratio of resources (in units of energy) to production (in units of energy per year). The ratio tends to suggest an approximate value for the least number of years for which that particular fuel might be available.

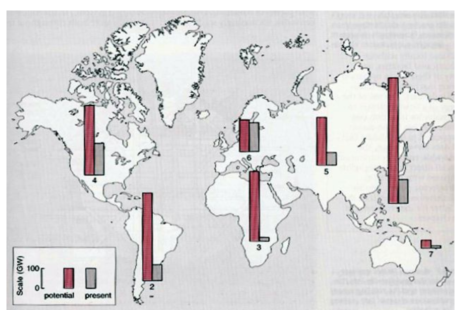
The R/P ratio for fuel oil, for example gives surprising results; it has been progressively exhibiting a trend of increasing over the years, as shown by Lomborg in the curve below. The current value is around 40 years.




The most common fossil fuel used in power plants is coal, with a slight decrease during recent years, while natural gas has been gaining more acceptance. The use of oil (for generation of electricity) has been almost insignificant. The corresponding “years of consumption” (i.e. R/P ratio) for coal is now 171 years, and for natural gas 60 years. These values are world averages, but they do reflect that world-wide there are considerable resources available. (Geo-political issues ignored.)

Nuclear power plants have been in steady increase up to the last few years – where a decline has been noted. One of the reasons for the decline has been more political than technical. In spite of that, nuclear power plants have an important contribution towards the world energy. Estimates for the R/P value for nuclear are fantastic – ranging from 360 to over 9000 years depending on differing assumptions.

Hydroelectric and geothermal sources are region dependent. Of these, hydroelectric is the most notable, and exhibits strong cost advantages over other sources. The Itaipu power plant is a case study showing the dramatic benefits it has had in Brazil, one of the sharing countries. There remain considerable opportunities for exploiting hydro power in quite a few regions of the world, as noted below.

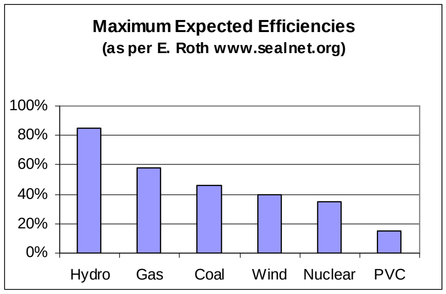



Small bars indicate installed capacities; taller bars indicate potentials

Fossil fuel, nuclear, geothermal and hydroelectric all exhibit the same desirable characteristics: non-intermittent service hence high capacity factors (the ratio of the yearly delivery compared to the maximum possible); relatively high efficiencies and long life performance. The threat to nuclear is the concern with treatment of the wastes, while that for fossil fuel plants-it is the suggested impact on climate. And it is this last concern that is driving the current interest in renewable energy sources such as photovoltaic cells and wind turbine generators. (Biomass is also considered, but based on a simplistic and short sighted assumption that it can’t be culpable as what is burned was from nature which at one time had taken in CO2 and is now releasing it. Hard to understand how that differs from fossil fuels except for the time difference.)

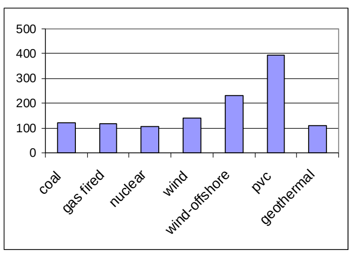
The growth in wind turbine generation has been dramatic, while the actual contribution to the overall energy production remains close to insignificant. The growth in PVC plants is also notable but there are cost factors that are still limiting their growth – at least when compared with wind farms. Both of these sources of energy have one major limitation. They are intermittent, and back up power must be available in short call to make up for the loss; and that power usually comes from fossil fueled plants. Diversity alone will not solve this problem – it might be that in time cost-effective storage systems might assist in providing a solution.

The “efficiencies” in a like manner are hard to compare as their basis for comparison generally exclude the capacity factors. When those are accounted for the results show a lower benefit for wind than for the non-intermittent thermal plants.




Energy pay-back and cost comparisons of various alternatives differ considerably according as to the background of the ones preparing the analyses. But there is general agreement that (in the absence of tax incentives) PVC is the most expensive alternative, while wind might be next, and the others differing slightly from each other

The bar chart below shows the “levelized costs” (based on a common 20 year base) for various alternatives (http://www.instituteforenergyresearch.org/2009/05/12/levelized-cost-of-new-generating-technologies). The table to the right shows comparable results with a recent EPRI study.




| | capacity | $/MWh |
|---|---|---|
| Geothermal | 85 - 90% | 55 - 87 |
| Photovoltaic | 25% | 526 - 481 |
| Biomass | 85% | 105 -107 |
| Wind | 32 - 42% | 75 - 96 |

It is interesting to compare the performance of a coal fired plant, wind turbines, and PVC arrays. The comparisons are based on the TVA Bull Run Coal plant, on a wind turbine in Traverse City Michigan (Vestas V44 with a 144 ft blade) and a PVC array tested also in Traverse City Michigan (with BP160 cells; 48 panels with 72 cells in each). The coal fired plant occupied 1.5 square miles, and generated 6.5 billion kWh per year. To reach a similar capacity would require 8000 wind turbines or alternatively 700,000 arrays occupying orders in magnitude more space than the coal plant

The one main reason to move from fossil fuels to either wind or solar (both of which would also require some back-up power) is the belief of its $CO_2$ emissions causing global warming. Otherwise there is little justification for the replacement, whether based on environmental, social or economic constraints. Raising concerns with complying with the requirements for sustainability .

A postscript is necessary. The justification for placing culpability on $CO_2$ is the tracking of concentration increases with temperature and in the results from computer models. Unfortunately more and more data are indicating that anthropogenic $CO_2$ has an insignificant impact, whereas solar variations and earth orbital variations are recognized as the main climate drivers. It is interesting that while there are some data indicating that temperature changes precede $CO_2$ changes, there are none convincingly showing the opposite. This places serious doubt on the culpability of $CO_2$, and hence on the sustainable conclusion that fossil fuel plants should be replaced primarily by solar and wind generation.

Acknowledgements: This paper was originally published as background information for a keynote lecture presented at CIAR X (Ibero-American Congress of Air Conditioning and Refrigeration)– Guayaquil, June 3, 2009. It is a challenge for serious thought by the reader; the author was not funded or influenced by a financial incentive.