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Toward Partial Redirection of Energy Policy for Responsible Development

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Abstract: This paper addresses the surprising lack of quality control on the analysis and selection on energy policies observable in the last decades. As an example, we discuss the delusional idea that it is possible to replace fossil energy with large scale ethanol production from agricultural crops. But if large scale ethanol production is not practical in energetic terms, why huge amount of money has been invested in it and is it still being invested? In order to answer this question we introduce two concepts useful to frame, in general terms, the predicament of quality control in science: (i) the concept of “granfalloon” proposed by K. Vonnegut (1963) flagging the danger of the formation of “crusades to save the world” void of real meaning. These granfalloon are often used by powerful lobbies to distort policy decisions; and (ii) the concept of Post-Normal science by S. Funtowicz and J. Ravetz (1990) indicating a standard predicament faced by science when producing information for governance. When mixing together uncertainty, multiple-scale and legitimate but contrasting views it becomes impossible to deal with complex issue using the conventional scientific approach based on reductionism. We finally discuss the implications of a different approach to the assessment of alternative energy sources by introducing the concept of Promethean technology.

Keywords: energy policy, biofuel, ethanol, Post-Normal science, Promethean technology, responsible development

JEL codes: O11, P48, Q43, Q57

1. Introduction

Developing countries in Asia are projected to have an average annual economic growth rate of 5.4% from 2004 to 2030 (Ito, 2007). Assuming this growth rate Ito provides a projection that Asia will reach a level of primary energy demand of 6.2 billion toe twice as much as the year 2004 level (3.1 billion toe). This projected energy demand from Asia would be almost 40% of the total energy demand in the world in 2030. Luft (2007) argued that 58% of China's oil imports came from the Middle East in 2007 and this share would reach 70% soon. China's concern for its growing dependence on oil imports has led to its active involvement in exploration and production in places like Kazakhstan, Russia, Venezuela, Sudan, West Africa, Iran, Saudi Arabia and Canada. However, China is not the only actor thirsty for oil in Asia. Other countries, including India, are projected to be major contributors to the world's energy demand. In fact, China and India are estimated to account for approximately 70% of the energy consumption in Asia over this 26 year time period (Ito, 2007). When facing this growing demand for primary energy sources, what about the supply side? To date, fossil energy (and oil in particular) is the main source of energy carriers (ECs) required to produce and consume all the products and services of modern economies. If the twilight of oil, vividly described by M. Simmons (2005) and described as "peak oil" in technical jargon (see the site of ASPO International) is really approaching, then oil producers in the Middle East will no longer be able to supply as much as the world will need. In this situation we should start considering an alternative energy scenario to the conventional petroleum-based scenario. As shown by the analysis of Colin J. Campbell, shown in Figure 1, the future of oil and natural gas production profile is not promising at all compared with the projected demand increase in energy. The projected gap between energy demand and supply should be a serious concern for many people. One of the two founders of the Quantum Group of Funds, Jim Rogers, states in his endorsement for Simmons' book: "everyone must understand the thesis, whether you agree or not, since it may change life as we know". We share this concern and wonder whether or not the strategy of perpetual economic growth (right now sold under the name of Sustainable Development) should be used to discuss policy options. For this reason we propose in the title of the paper the unfamiliar term of "Responsible Development" as an alternative to the most familiar term "sustainable development".

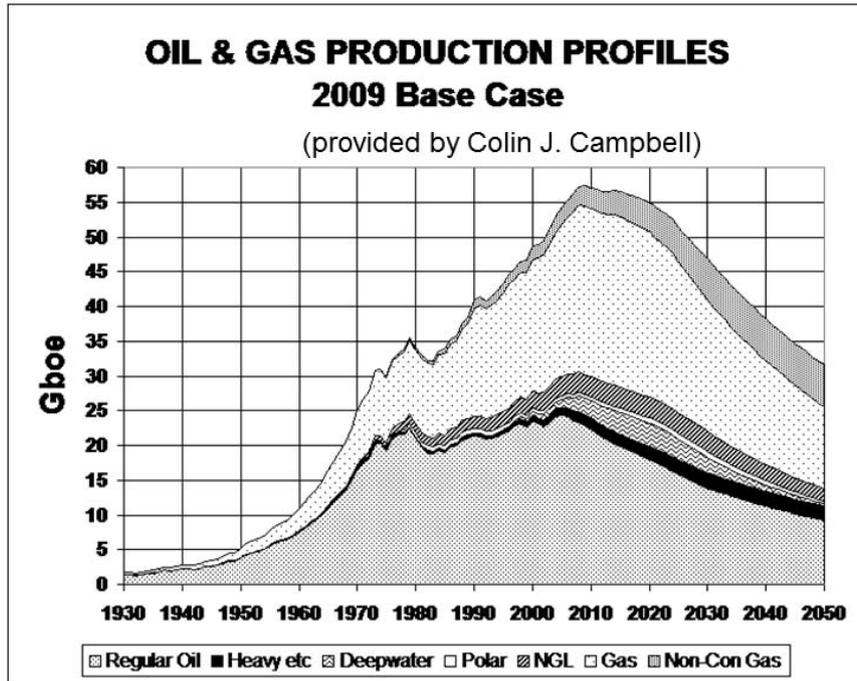


Figure 1. Peak Oil and Natural Gas

The first author of this paper knew about the label “Responsible Development” by Hideo Shingu, the President of Kyoto Energy-Environmental Research Association (Shingu, 2013). According to him Nitin Desai, the Deputy Secretary-General of the United Nations Conference on Environment and Development (Rio Earth Summit in 1992) wanted to propose the term, Responsible Development, rather than Sustainable Development at the Rio Earth Summit. However, since he was coordinating the work of the Secretariat related to *the development of Agenda 21* he could not propose his original idea of Responsible Development to that summit. In our interpretation because of his institutional duty he had to accept the combination of two quite contradictory words (Sustainable and Development) dropping the label “responsible development” pointing at an unavoidable sustainability predicament to be dealt with, when dealing with development. Akira Kurosawa states, “in a mad world, only the mad are sane”. Kurosawa’s insight forces us to look at ourselves as embedded in society and to reconsider our own values in order to ascertain whether or not we are sane. Georgescu-Roegen once stigmatized the people endorsing sustainable development as snake oil sellers (Georgescu-Roegen, 1992b). Snake oil sellers are probably much more dangerous for society than insane people!

Before closing this general introduction we want to mention another relevant concept for the discussion of this paper, the concept of scientific paradigm. According to Allen, “a paradigm is a tacit agreement not to ask certain questions” (Allen, 2008). This definition is illuminating since it implies that researchers working in well defined scientific fields are ‘supposed’ to ignore disturbing opinions or alternative points of view. The given paradigm protects them with an intellectual wall filtering unpleasant information and legitimate contrasting perspectives. This paper wants to provide a discussion carried outside these walls in relation to energy policy and economic beliefs. Put in another way, this paper wants to break the paradigms preventing us from reaching a better understanding of the sustainability predicament. The rest of the paper is organized as follows: Section 2 provides a practical example of the poor quality of the technical assessment of the performance of energy systems using the example of agro-biofuels. In spite of the huge investments in agro-biofuels (that have been justified by scientific analysis indicating the convenience of such an option) large scale ethanol production did not fulfill the original expectations (Giampietro and Mayumi, 2008). To explain the problematic aspects of the production of ethanol we use three indicators: (i) the metabolic pace of ethanol production per hour of labor; (ii) the metabolic density of ethanol production per hectare; and (iii) the ratio between the gross supply of energy carriers in the form of ethanol and the internal consumption of energy carriers in the process. When analyzing these three indicators it is easy to show that the production of ethanol (as done by USA and Brazil) does not represent a valid alternative to fossil energy. Section 3 addresses two thoughtful ideas useful to discuss the difficulties in guarantee a quality control in the production and use of science for governance: (i) the concept of granfalloon proposed by K. Vonnegut (1963); and (ii) the concept of Post-Normal science by S. Funtowicz and J. Ravetz (1990). Section 4 concludes the paper and introduces the concept of Promethean technology as a useful principle for assessing the feasibility and viability of alternative energy sources.

2. Delusion of large scale ethanol production from corn and sugar cane: USA and Brazil

In this section we provide an assessment of the two large scale experiments of ethanol productions developed by USA and Brazil. In order to better understand the logic of our analysis, we indicate eight important changes within socioeconomic systems that occurred after the industrial revolution: (i) the use of fossil fuels has dramatically

increased the “metabolic pace” of the consumption of energy carriers per hour of human activity (the exosomatic metabolism of human activity carried out in the house and on the work-place) and the “metabolic density” per unit of land use. This increase is due to the metabolism of machines and capital equipment (“exosomatic energy converters”); (ii) the establishment of a global transportation network that is a basis of the motive power of civilization; (iii) the dramatic increase in population size (the “endosomatic metabolism of human activity”); (iv) structural changes in population and industries toward “inverted triangle” (with ageing a larger share of the population becomes dependent); (v) land use pattern change (with a larger demand of land uses per person); (vi) human time allocation change; (vii) growth oriented behavior and attitude leading to income distribution problems (maximization of profit tend to generate inequity); (viii) institutional changes that have being reinforcing the seven changes described above.

In order to adequately address the effects of these eight changes we have developed a general scheme of accounting - Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM for short) that is a theoretical development based on a combination of the three pioneering fields of works: (i) Georgescu-Roegen's flow-fund production theory in economics (Georgescu-Roegen 1969; 1971); (ii) hierarchy theory in ecology (Allen and Starr, 1982; O'Neill et al., 1986; Salthe, 1985) and (iii) hypercycle theory developed first in relation to chemical reaction cycles (Eigen, 1971) and then extended to theoretical ecology by Ulanowicz (1986). MuSIASEM has been shown to be a useful tool that can study human time and land use pattern changes in relation to energy and monetary flows by using a set of intensive and extensive variables and parameters (Giampietro and Mayumi, 1997; 2000a; 200b; Giampietro et al. 2011; 2012; 2014). One of the theoretical pillars of MuSIASEM is that the technological development of a society can be described in terms of an acceleration of energy and material consumption of the whole society (when looking at the phenomenon using the society as a black box) coupled the dramatic reallocation of distribution of age classes, human time profile of activities and land use patterns in various sectors of modern economy (when looking at changes in the characteristics and the relative size of the internal compartments of the society, inside the black box). Therefore economic growth translates into a dramatic reduction of the number of hours of human activity (labor) to be invested in the energy sector and the agricultural sector. This change is possible because of the dramatic increase in the density of flows (fossil energy and industrial agriculture) handled by humans in these two sectors.

Using the MuSIASEM we can carry out a critical evaluation of large-scale agro-biofuel production using three key characteristic indicators:

(1) *the metabolic pace* (productivity of labor) achieved by the energy sector measured in terms of amount of energy carriers per labor hour; and

(2) *the metabolic density* (productivity of land) achieved by the energy sector measured in terms of the amount of net supply of energy carriers per area of managed land (e.g. per hectare);

(3) *(the Gross Output)/(Gross Output-Net Output) ratio* associated with the exploitation of a primary energy source to generate a net supply of energy carriers. The “Gross Output” is the amount of energy carriers generated by the exploitation process. Whereas the “Gross Output minus Net Output” is the amount of energy carriers internally used in the exploitation (the input whose availability depends on the output). The bigger this ratio (*ceteris paribus*), the better is the quality of the primary energy source in relation to the task of producing a net output of energy carrier at low biophysical and economic costs. To explain this point, it is important to recall that if in the process of exploitation used to produce energy carriers there is a significant internal consumption of energy carriers, it will generate an increase in the requirement of production factors (labor, technical capital and land in production). This will translate into an increase of the biophysical and economic costs (reducing the viability in relation to internal constraints) and a reduction in the metabolic density of the net supply of energy carriers and a consequent increase in the demand of land area (reducing the feasibility in relation to external constraints). Whenever the ratio “Gross Output”/“Gross Output minus Net Output” is small enough to generate non linear amplifications of the requirement of production actors, it would make more sense to directly burn the biomass – for heating or electricity – rather than converting it into a liquid fuel (a type of energy carrier).

It is possible to calculate for developed society benchmark values for the three indicators described so far as described in the left part of Figure 2: (i) the metabolic pace is of about 20,000MJ/hour - 47,000MJ/hour; (ii) the metabolic density is 10W/m²-100W/m² and (iii) (the Gross Output)/(Gross Output-Net Output) ratio 13/1-20/1 (Smil, 2003; Giampietro and Mayumi, 2009).

Using this set of indicators and the benchmarks described in Fig. 2, it becomes possible to check whether or not agro-biofuels can cover a significant fraction of the liquid fuels consumed in modern society.

Requirement by Developed Country	Actual Supply by Ethanol
1. Metabolic Speed 20,000MJ/hour—47,000MJ/hour	1. Metabolic Speed Corn-ethanol 224MJ/hour Sugarcane-ethanol (H) 150MJ/hour Sugarcane-ethanol (L) 395MJ/h
2. Metabolic Density 10W/m ² -100W/m ²	2. Metabolic Density Corn-ethanol 0.02W/m ² Sugarcane-ethanol (H) 0.1/m ² Sugarcane-ethanol (L) 0.4W/m ²
3. $\frac{\text{Gross Output}}{\text{Gross Output} - \text{Net Output}}$ 13/1 - 20/1	3. $\frac{\text{Gross Output}}{\text{Gross Output} - \text{Net Output}}$ Corn-ethanol 1.1/1 Sugarcane-ethanol (H) 1.5/1 Sugarcane-ethanol (L) 7/1

Figure 2. Performance of Ethanol Production by USA and Brazil Assessed in 2008

As reported by World Bank (2008), in that year the ethanol production of the USA and Brazil combined covered almost 90 per cent of the world production of biofuels. In 2006, the US produced 18.4 billion litres (46 per cent of the world's total) and Brazil 16 billion litres of ethanol (42 per cent of the world's total). Even though, in 2005 the combined quantity of ethanol was only 1.2 per cent of the world's liquid fuel supply, it represented a scale of operations large enough to allow an assessment of the technological coefficients starting from the analysis of aggregated values referring to the whole sector.

The following assessment is based on data provided by the ethanol industry for the whole sector. In this assessment we use the output/input ratio [for our terminology as the Gross Output/(Gross Output-Net Output)] calculated by Farrell et al (2006) for ethanol from corn in the US, but corrected by eliminating the energy credits for by-products [detailed explanations in Giampietro and Mayumi, 2009]. The calculated three indicators are shown in the right part of Figure 2 (compiled from Giampietro and Mayumi, 2009):

(i) the metabolic pace 224MJ/hour; (ii) the metabolic density 0.02W/m²; (iii) (the Gross Output)/(Gross Output-Net Output) ratio 1.1/1.

For the Brazilian assessment we used official data and technical coefficients provided by a very detailed and informative study published by the Sugar Cane Agroindustry Union (UNICA) in Brazil (De Carvalho Macedo, 2005). These data have been checked against the assessment of ethanol production from sugarcane in Brazil provided by Patzek and Pimentel (2005) and Pimentel et al. (2007), who were reporting a much worse performance. From this data set we obtain two sets of benchmarks.

* **Using high input (H) estimates** - from Pimentel et al (2007), the calculated values for the three indicators are shown in the right part of Figure 2: (i) metabolic pace: 150MJ/hour; (ii) metabolic density: 0.1W/m²; (iii) (the Gross Output)/(Gross Output-Net Output) ratio: 1.5/1 (Giampietro and Mayumi, 2009).

* **Using low input (L) estimates** - from De Carvalho Macedo (2005), the calculated values for the three indicators are shown in the right part of Figure 2: (i) metabolic pace: 395MJ/hour; (ii) metabolic density: 0.4W/m²; (iii) (the Gross Output)/(Gross Output-Net Output) ratio: 7/1 (Giampietro and Mayumi, 2009).

Figure 2 clearly indicates that both in USA and Brazil cases the production of ethanol is far from reaching the expected energetic performance of primary energy sources used by developed societies. To see the incredibly poor performance of USA case in terms of labor hours and land requirement, we conduct a “Gedanken experiment”: how much labor time and cultivated land would be required, when using these benchmark values, to cover just 10% of the liquid fuels used in transportation in the USA, if this quantity should be produced in terms of US corn-ethanol? The answer to this question is given in our book (Giampietro and Mayumi, 2009), based on the following assessments: 10% of fuels roughly corresponds to 3EJ (3 x 10¹⁸J) that is equivalent to 140 billion litres of ethanol. Because of the very low output/input ratio [(the Gross Output)/(Gross Output-Net Output)] for USA case, a value around 1.1/1, the total gross production of corn based ethanol must be 33EJ (1,540 billion litres). To produce a gross supply of 33 EJ, it is necessary to use 148Ghours of labor in biofuels production. This labor time would represent almost 48% of the labor hours that could be provided by USA work force even after absorbing all the unemployed. Please note that 117Ghours is the total labor hours for Japan in 1999. Obviously, this option is not feasible. It is impossible to transfer 148Ghours right now used in other sectors of US economy to the agro-biofuel

production. What about land requirement? The production of 1,540 billion litres of ethanol would require 5,500 million hectares of arable land. This land area corresponds to an area 31 times larger than the total arable land of USA (175 million hectares) in 2005.

3. Science and Technology in the era of Post-Normal Science

In the previous section, we illustrated a biophysical analysis of the performance of agro-biofuel production showing that especially for the USA the implementation of a large scale agro-biofuel production was not a particularly good idea. How is it possible that scientific analysis could not detect the systemic problems of this type of energy system? To better understand the critical situation of our modern society we want to introduce to conceptual ideas.

Let's start with the concept of "granfalloon". The term "granfalloon" was first introduced in *Cat's Cradle* by Kurt Vonnegut (1963). The concept of granfalloon is useful to explain the agro-biofuel folly. In this connection it is very instructive to introduce Pratkanis' explanation of granfalloons given in his paper "How to sell a pseudoscience" (1995): "granfalloons are powerful propaganda devices because they are easy to create and, once established, the granfalloon defines social reality and maintains social identities. *Information is dependent on the granfalloon*" (italics added, p. 22).

Incredible but true, there was a serious agro-biofuel granfalloon case also in Japan a country importing both food and energy because of shortage of arable land per capita. Nippon Chuyu Corporation Scandal that was financially supported by the Japanese government subsidy (*The Japan Times*, Thursday, Sept. 23, 2010) led to the suicide of Mr. Shibano in 2011. The fact that someone can believe that in a densely populated country as Japan that uses massive quantity of oil to reduce the demand of land, one should use massive quantities of land to reduce the demand of oil generates another question: why people are easily convinced or become believers in granfalloons based on unfounded scientific information?

To answer this question we can recall the work of C. S. Peirce, a great contributor to semiotics and well known as the father of pragmatism. He identified four methods to *fix our own beliefs* (1877): (i) *method of tenacity*. An individual sticks to her or his own opinions like an ostrich that buries its head in the sand without consulting other people's views; (ii) *method of authority*. A given authority or institution forces the

upholding of 'correct' theological and political doctrines. Therefore, this method required a priesthood or a centralized regime; (iii) *method of A Priori*. Whenever fundamental propositions seem to be "agreeable to reason", we find ourselves inclined to believe without referring to any observed facts. This method is exemplified in the history of metaphysical philosophy; (iv) *method of science*. According to Peirce, whenever our beliefs are determined by experience about some external permanency, which Peirce calls "Reality" we can talk of a scientific method. However, when making this statement he does not address the issue of whether or not for humans it is possible to perceive the "reality" in the first place. Many philosophers and philosophical traditions in fact have warned in the past that we cannot know the reality but only our perception of the reality. The bias introduced by human perception can never be eliminated also when dealing with scientific analysis (e.g., Chu, 2012; Foucault, 1989; Lyotard, 1984).

While Peirce seems to support the method of science as the best possible way of fixing our beliefs an enormous amount of evidence is accumulating to show that when dealing with complex problems and technology, science cannot eliminate uncertainty from its analytical outputs. In relation to this point, Fukushima nuclear accident in 2011 revealed many fragile aspects of nuclear power generation systems, unwavering confidence in the scientific method, that has been shaken as result of this fact. The following story, provided by H. Ino (2011), about Ductile Brittle Transition Temperatures (DBTT) is revealing, since the general public was instructed the safety of nuclear power generation systems for a long time despite the false and unreliable information coming from the scientists themselves.

The story is this. Japan started nuclear power generation in 1970. The reactors were designed to last about 30 years for Pressurized Water Reactor (PWR) and 40 years for Boiling Water Reactor (BWR). Therefore, the reactors now in operation have exceeded their life expectancies. Since neutrons are used as a moderator for these reactors, once the quantity of neutron radiation within the reactor vessel exceeds a certain threshold the reactor becomes extremely fragile. According to Ino's study (2011), Japan has seven nuclear power units that have considerably high Ductile Brittle Transition Temperatures (DBTT). The initial DBTT of high-strength steel is about minus 20°C. The Genkai Unit 1 in Saga Prefecture, Kyushu is reported to have reached a DBTT of 95°C. If the temperature of the reactor vessel is cooled below the DBTT, then there can be a high probability that the reactor will shatter on impact like glass,

especially in the case of a cold shutdown operation, without bending or deforming increases.

In addition to these major problems, the aging of nuclear power plants is a serious threat for the Japanese people. Ino's study revealed that the so-called scientific evidence that had been presented to the general public before the Fukushima accidents were not necessarily scientifically founded. In these examples, the role of scientists, envisioned by Peirce, had been unfortunately and drastically transformed. There are situations in which scientists have been transformed into a new type of priest endorsing the method of authority, without providing any sound scientific evidence. In this situation scientists are used to back-up the generation of dangerous granfalloon. This type of danger is not confined to nuclear power generation systems. There are many other important decisions to make in relation to sustainability challenges (besides looking for alternative energy, how to deal with climate change, how to control technological innovation, etc.).

Here we can introduce the second concept, that of Post-Normal Science, that is required because sustainability issues imply a new role for scientists in relation to human progress. In this situation issue-driven research takes precedence over curiosity-driven research and this requires the adoption of a much more integrated approach for describing the interplay between economic systems, social systems and their environment. The objective of scientific endeavour in this new context may well be to enhance the process of the social resolution of the problem, including participation and mutual learning among the stakeholders, rather than a definite once for all "solution" or technological fix. This is an important change in the relation between the problem identification and the prospects of science-based solutions. The new epistemological framework developed by Funtowicz and Ravetz (1990) called "Post-Normal Science" acknowledges that uncertainty, stakeholders and their value conflicts play a central role in process of decision-making. "Post-Normal" indicates a departure from curiosity-driven or puzzle-solving exercises of normal science, in the Kuhnian sense (Kuhn 1962). The chosen name wants to indicate the need of an important paradigm change in the conceptualization of scientific activity: Normal science, so successfully extended from the laboratory of core science to the conquest of nature through applied science, is no longer appropriate for the solution of sustainability problems. The social, technical and ecological dimensions of sustainability problems are so deeply connected that it is simply impossible to consider these dimensions as separated into conventional disciplinary fields. In relation to this point, we can recall

Sin-Itiro Tomonaga, Nobel Prize Winner in Physics, who shared the prize with R. Feynman and J. Schwinger. He warns us of unfounded optimism associated with scientific and technological implementations in the societal problems in his *Promethean Fire* (2012).

4. Conclusion: Promethean Technology and Malthusian instability

At the beginning of the famous 1999 film *The Matrix*, the protagonist is asked whether he is willing to take the “red pill”, capable of showing him the painful truth of reality, or the “blue pill”, allowing him to remain within the blissful simulation of reality that the establishment wants him to see. Since then, the “red pill” concept symbolizes the possibility of getting a fresh view of something that previously was perceived in a different way from within a well consolidated framework. In colloquial terms, taking the red pill means accepting the need of thinking outside the box and to challenge the existing perception of the external world. This is what we offer to the reader with this paper.

In relation to the sustainability of the energetic metabolism of socio-economic systems Georgescu-Roegen introduced an interesting concept to define a typology of technology that can lead to Malthusian instability: the concept of “Promethean technology” (or the viable energy technology). A Promethean technology is viable, just like a viable biological species, if - and only if - it can reproduce itself with a surplus of energy, after being set up by the technology that is now in use (Georgescu-Roegen, 1978). According to this definition the feasibility of a technology (the compatibility with boundary conditions) is not sufficient for defining its viability. To sustain a metabolism of a modern society we need forms of primary energy source capable of generating an adequate (energy carriers) throughput per hour of labor (a viable technology in relation to internal constraints) and a throughput per hectare of managed land compatible with the available land (a feasible technology in relation to external constraints). This double compatibility can only be obtained by energy sources having a large ratio “Gross Output”/“Gross Output – Net Output”. For example, a technology for the direct use of solar energy which implies a deficit in the overall balance of energy over its life cycle assessment would be feasible, but not viable, *since other types of energy carriers coming from outside the direct use of solar technology are required for its operation*. According to Georgescu-Roegen, in human history, we had only three Promethean technologies: (1) husbandry (agriculture), (2) the mastery of fire, and (3) the steam engine (or more in general the mastery of internal combustion engines) coupled to

fossil energy. These technologies share a common explosive characteristic: “with just the spark of a match we can set on fire a whole forest. This property, although not as violent, characterizes the other two Promethean recipes” (Georgescu-Roegen, 1992a). Land is the special fuel for agriculture. Fossil fuels are the special fuels for modern industry. Due to the hypercyclic nature of Promethean technology (they generate a surplus several times larger than the input they require), humans were able to get into the Malthusian instability trap quickly by depleting the special stocks of “fuels” associated with these different technologies. In particular, the explosive characteristic of the petroleum-based metabolism of modern society, due to the abundant supply of high quality oil in the past sixty years and the continuous supply of technological efficiency improvements, has been boosting the phenomena associated with Jevons’ paradox worldwide (Jevons, 1865; Polimeni et al., 2008): increases in efficiency do not reduce the trend toward larger energy consumption of human societies: more efficient cars will drive more miles, or will become larger in size! We believe that, for responsible development, it is reflexivity that is required to deal with the issue of sustainability. Technological improvements and increases in efficiency will not do it. Therefore, we hope that policy-makers, the scientists giving them advice and other powerful stakeholders will take heed of Jevons’ paradox. In fact, the effect of Jevons’ paradox will always be with us no matter what new energy sources and silver bullets we will come up with in the future. Let alone if after all this effort, humans will discover another Promethean technology . . .

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