Integrated System Approach to Sustainable Development, Bio-fuels and Bio-refineries

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ABSTRACT

The most efficient approach to organize and communicate knowledge between different disciplines and help in innovation and the creation of new knowledge is the system approach. Sustainable Development (SD) is cross-disciplinary by its very nature requiring close collaboration between all engineering specializations as well as other disciplines. Efficient engineering and Environmental Engineering (EE) are important, necessary but not sufficient conditions for sustainability. Sustainability requires the use of Renewable Resources (RRs) to satisfy the needs of society especially with regard to renewable Bio-Fuels (BFs). The use of RRs which are edible agriculture products to produce BFs is not a strategic solution because of the negative socio-economical impact of using "food" for "fuel". The most strategically promising rout is the use of wasteful biomass and/or energy crops planted in lands and using water not suitable for agriculture of edible products. BFs are location sensitive and therefore will all co-exist and different technologies for their production will also co-exist due to sensitivity of the technology choice to available capital and market. Modern societies will move from the present matrix of dirty and non-renewable fuels to a matrix of clean and renewable fuels. It is important to realize that societies do not live only on fuels/energy introducing the concept of Integrated Bio-Refineries (IBRs) producing a wide range of Bio-Products (BPs) in addition to BFs and Direct Energy (DE) to achieve overall SD and not only sustainability with respect to fuels. BFs and IBRs based on waste RRs as feedstock do not only produce useful BFs, BPs and DE but also solve environmental problems through this useful utilization of the waste materials.

Keywords: bio-fuels, bio-refineries, system theory, sustainability.

1 SYSTEM THEORY, SUSTAINABILITY AND BIO-REFINERIES

System theory is the basis of the Integrated System Approach (ISA) which is the most efficient methodology for knowledge classification, organization, transfer and exchange. The ISA is very valuable in both research and education. In research, it is one of the most important tools for the development of new knowledge and novel processes, especially in areas where cross-disciplinary research and development is a must for innovative solutions. Sustainable Development (SD) is one of those areas which are cross-disciplinary by their very nature.

SD as a system is formed of a number of subsystems each of which is formed of its own elements. Subsystems of SD include both technical and non-technical categories, e.g.: technology, socio-economic, political, ethical/moral, etc. Focusing on any one of the SD subsystems can only be successful within a framework that has the other subsystems as a background. Within the technological subsystem of SD, a structural hierarchy of subsystems down to the elements (which depend upon the level of analysis) gives the structure and boundaries of this important subsystem, especially from an engineering point of view. It is useful in this regard to use terminologies and classifications of system theory coupled to terminology of non-linear dynamics and stability theorem. As an example we can consider efficient engineering as a subsystem of Environmental Engineering (EE), representing necessary but not sufficient condition for clean/green technology. This is due to the simple fact that applying efficient engineering without taking environmental constraints into consideration can achieve maximum productivity that would not necessarily be environmentally clean. Clean/green technology will need efficient engineering as a pre-requisite. Also we can consider EE as a subsystem of Sustainable Engineering (SE), representing necessary but not sufficient condition for sustainability. This is due to the simple fact that EE without using Renewable Resources (RRs) can achieve clean/green and maximum productivity, but is not
necessarily sustainable, SE will have both efficient and environmental engineering as pre-requisites. The utilization of RRIs is at the heart of sustainability, this leads to the crucial importance of Bio-Fuels (BFs) at one level and Integrated Bio-Refineries (IBRs) at higher levels as discussed here using ISA as an efficient tool.

2  BASIC PRINCIPLES OF SUSTAINABLE DEVELOPMENT AND BIO-FUELS

The above simple analysis highlights the following basic principles:

1- SD is a system formed of technological and non-technological subsystems we give special emphasis to the technological subsystem with the other subsystems in the background.
2- SE is a subsystem of the technological subsystem of SE
3- SD can also be divided into:
   a. SD with respect to production, which is our main emphasis.
   b. SD with respect to consumption, which is in our background.

Sustainable Production and Consumption (SP&C) emerged as a key issue on the SD agenda at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. The agenda called on governments, business and others to implement measures to promote efficiencies in production and encourage sustainable patterns of consumption. An international agenda had been introduced by the UN Commission on Sustainable Development (UNCSD), in cooperation with national governments; the Organization for Economic Cooperation and Development (OECD) and others, responded to this mandate with an international work program and recommendations for action including:

- pricing reforms to internalize environmental costs and remove subsidies that generate unsustainable consumption;
- “green” public procurement policies;
- extending producer responsibility for the lifecycle environmental impacts of goods and services;
- eco-labeling programs.

The UNCSd has called specifically upon business to:

- integrate environmental criteria into its purchasing policies;
- design more efficient products and processes;
- increase the life-spans for durable goods;
- improve its after-sales service;
- reuse and recycle;
- promote sustainable consumption through advertising, marketing, and product information.

4- Efficient engineering is a subsystem of EE which is a subsystem of SE. In other words, efficient engineering is necessary but not sufficient for EE which itself is necessary but not sufficient for SE aiming at sustainability.

5- Metrics are necessary for measuring sustainability. Metrics for sustainability are usually divided into three groups: environmental indicators; economic indicators and social indicators. This emphasizes the fact that EE is necessary but not sufficient for sustainability. However, these three categories do not show explicitly the importance of RRIs for sustainability.

6- RRIs represent a crucial component of SE and thus SD. Green technology based on non-RRIs may be satisfactory from an EE point of view but not sustainable.

7- Renewable Clean Fuels (RCFs) is a very important subsystem of Renewable Clean Energy (RCE) which is a very important subsystem of SE and thus SD. A national Renewable Fuel Program (also known as the Renewable Fuel Standard Program or RFS Program) will increase the volume of RCFs required to be blended into gasoline, starting with 4.0 billion gallons in calendar year 2006 and nearly doubling to 7.5 billion gallons by 2012. Bio-Fuels (BFs) represent a very important subsystem of RCFs, which is our main emphasis with other subsystems of RCFs in the background. There is a large number of BFs; each one of them can be produced through different routes. All BFs and all technologies to produce them will have their positions in the renewable clean fuels matrix of the future.

8- BFs (e.g.: bio-ethanol) can be produced from: renewable food (e.g.: corn bio-ethanol), renewable waste (e.g.: cellulosic bio-ethanol) or renewable energy crops (e.g.: cellulosic bio-ethanol from switchgrass). The most promising is the cellulosic bio-ethanol from waste followed by that from switchgrass and the one from food is not desirable because it creates a contradiction between food and fuel.

9- There are two types of bio-diesels, the strategic bio-(Fischer-Tropsch) FT-diesel and the non-strategic bio-diesel from the trans-esterification of vegetable oils. A third type of bio-diesel which may prove to be more strategic than both is the Algae bio-diesel.

3  BIO-FUELS AND INTEGRATED BIO-REFINERIES

Sustainability does not depend only upon sustainable fuels, but also on sustainability of other commodities. This important simple fact leads to the important concept of IBRs producing not only sustainable Bio-Fuels (BFs)
but also other sustainable Bio-Products (BPs) and Direct Energy (DE). A production facility for sustainable BF is a subsystem of an IBR, the implications of this are:

- A sustainable BF facility built today should be planned with its growth into an IBR in mind.
- Sustainable BF production will almost always be a part of IBRs
- An advanced definition of IBRs and their subsystems including BF should be developed together with a clear definition of BF and BPs.
- A clear definition of sustainability and quantification of these definitions into suitable metrics should be developed.

IBRs represent an integral critical subsystem of SD, which is a cross-disciplinary system by its very nature as discussed earlier. We engineers are most interested in the technology part (subsystem of the SD system), but with a background understanding of other subsystems and collaboration with other disciplines, as discussed earlier. RRs represent a storage tank for solar energy through biosynthesis; CO₂ and other nutrients. The ultimate aim for BF is to produce as much CO₂ as consumed in the biosynthesis of the biomass that produced it. This, with maximum efficiency, may lead to the approach of zero net CO₂ emission. We cannot really dispose of any CO₂ resulting from fossil fuel, it only keeps circulating from one form/place to the other, except with sequestration by injection under the bottom of the oceans which is expensive; its side effects are not known and can only be practiced by very large companies.

4 CONCLUSIONS

Sustainable Development (SD) is crucial for the development of human societies and it is cross-disciplinary by its very nature. ISA based on system theory is the most efficient approach to study and develop the different components (subsystems) of this complex cross-disciplinary system. For engineers the most important subsystem is the technology one and SE is a subsystem of it. Bio-fuels is one of the most important subsystems of SE, however their development is not sufficient for sustainability; other BPs and DE from RRs are essential leading to the concept of IBRs which is very important for sustainability. BF represents an integral part of BRIs. Well directed innovative researches in all subsystems of BRIs are essential taking into consideration the other subsystems of SE as well as the non-technical subsystems of SD.