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. **S**ustainable **D**evelopment (**SD**) is **cross-disciplinary** by its very nature requiring close collaboration between all engineering specializations as well as other disciplines. Efficient engineering and **E**nvironmental **E**ngineering (**EE**) are important, necessary but not sufficient conditions for sustainability. Sustainability requires the use of **R**enewable **R**esources (**RR**s) to satisfy the needs of society especially with regard to renewable **B**io-**F**uels (BFs). The use of **RR**s which are edible agriculture products to produce **BF**s 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 editable products. **BF**s 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 **I**ntegrated **B**io-**R**efineries(**IBR**s) producing a wide range of **B**io-**P**roducts (**BP**s) in addition to **BF**s and **D**irect **E**nergy (**DE**) to achieve overall **SD** and not only sustainability with respect to fuels. **BF**s and **IBR**s based on **waste RR**s as feedstock do not only produce useful **BF**s, **BP**s 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 **I**ntegrated **S**ystem **A**pproach **(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. **S**ustainable **D**evelopment **(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 **E**nvironmental **E**ngineering (**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 **S**ustainable **E**ngineering (**SE**), representing necessary but not sufficient condition for **sustainability.** This is due to the simple fact that **EE** without using **R**enewable **R**esources **(RR**s**)** 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 **RR**s is at the heart of **sustainability**, this leads to the crucial importance of **B**io-**F**uels (**BF**s) at one level and **I**ntegrated **B**io-**R**efineries (**IBR**s) 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 **SD**

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 **P**roduction and **C**onsumption **(SP&C)** emerged as a key issue on the **SD** agenda at the **U**nited **N**ations **C**onference on **E**nvironment and **D**evelopment **(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 **U**N **C**ommission on **S**ustainable **D**evelopment **(UNCSD),** in cooperation with national governments; the **O**rganization for **E**conomic **C**ooperation and **D**evelopment **(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, theses three categories do not show explicitly the importance of **RR**s for **sustainability.**

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

7- **R**enewable **C**lean **F**uels **(RCFs)** is a very important subsystem of **R**enewable **C**lean **E**nergy **(RCE)** which is a very important subsystem of **SE** and thus **SD.** A national Renewable Fuel Program (also known as the **R**enewable **F**uel **S**tandard Program or **RFS** Program) will increase the volume of **RCF**s 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. **B**io-**F**uels (**BF**s) 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 **BF**s; each one of them can be produced through different routes. All **BF**s and all technologies to produce them will have their positions in the **renewable clean fuels matrix** of the future.

8- **BF**s (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 switch-grass). The most promising is the cellulosic **bio-ethanol** from waste followed by that from switch-grass 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-**(F**ischer-**T**ropsch**) 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 **IBR**s producing not only **sustainable B**io-**F**uels **(BFs)**

but also other **sustainable B**io-**P**roducts **(BP**s**) and D**irect **E**nergy **(DE).** A production facility for **sustainable BF**s is a subsystem of an **IBR**, the implications of this are:

- A **sustainable BF**s facility built today should be planned with its growth into an **IBR** in mind.
- **Sustainable BF**s production will almost always be a part of **IBR**s
- An advanced definition of **IBR**s and their subsystems including **BF**s should be developed together with a clear definition of **BF**s **and BP**s**.**
- 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**; CO_2 and other nutrients. The ultimate aim for **BF**s is to produce as much **CO_2** as consumed in the **biosynthesis** of the biomass that produced it. This, with maximum efficiency, may lead to the approach of **zero net CO_2 emission. We can not really dispose of any CO_2 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 **BP**s and **DE** from **RR**s are essential leading to the concept of **IBR**s which is very important for **sustainability**. **BF**s represent an integral part of **BRI**s. Well directed innovative researches in all subsystems of **BRI**s are essential taking into consideration the other subsystems of **SE** as well as the non-technical subsystems of **SD**.