Growing Fuel, Fuelling Growth

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There are often various drivers when developing flowsheets; these could be maximizing profits, minimizing greenhouse gas emissions or conserving the chemical potential of the feed in the products. The thermodynamic quantities Enthalpy (H) and Gibbs Free Energy (G) can be used to develop flowsheets[1,2]. The approach uses what is called the GH – space and represents processes as vectors and uses vector geometry to consider the thermodynamic interactions of unit processes from the very earliest stages of design; breaking the mould of sequential design methodologies where such interactions are typically considered at the very end of the design, if they are considered at all.[3,4]

The question then becomes, what is the importance of considering such interactions? In recent years new challenges are being faced by the next generation of designers; one of the most significant is the issue of environmental impact. There is ever increasing pressure that processes be designed to have minimal environmental impact. While the issue is still largely a political one, this is an issue that is becoming increasingly more difficult to ignore[5]. In addition to these environmental concerns, industries must still be as productive, efficient and profitable as possible.

The GH-space approach will tend to find the best flowsheet and conditions for the process. The best may not always be attainable in practice but in identifying what is best, the foundations for understanding what modifications need to be made and why are laid. Knowing what the theoretical limits of performance are also provides great insight in process development and also provides an invaluable basis of comparison for existing designs.

The GH-space is a dynamic and flexible synthesis technique that allows designers to apply sound judgment and innovation from the very outset of a design project, providing an understanding of the interactions between individual process units and their contributions to the process as a whole. Thus the material, energy and work balances are used to determine the process flowsheet. This is opposite to the traditional approach where the process flowsheet is used to determine the material, energy and (occasionally) work balances. In doing so the flows of material, energy and work within the process can be understood and manipulated in such a way as to allow the design of a process that has a high degree of reversibility and carbon efficiency (possibly to the point of being carbon negative).

We will illustrate this technique on case studies, and in particular we will look at the conversion of biomass, in the form of agricultural and municipal waste to various products, such as synthesis gas, electricity and synthetic crude oil.

Foliage in plants collect solar energy and convert this to chemical energy in the form of biomass. The question is how efficiently can we use the energy stored in biomass. Unfortunately the material is not in a form to satisfy the energy needs of either a modern or underdeveloped society; namely heating/refrigeration, electricity and liquid fuels.

Waste collection and disposal are also major problems all over the world and particularly in developing countries. All different size producers of waste need to be able to turn their waste into products for their economic benefit locally as the transport of low value, low density material to a central location is both uneconomical and produces greenhouse gas emissions. Using waste as a feedstock to produce energy reduces the consumption of fossil fuels thereby reducing the emissions carbon dioxide while cleaning up the environment and reducing the amount material going to landfill. Making liquid fuels that have a high energy density, are very marketable and can easily be transported fits in very well with the current infrastructure. It is estimated that there is in the order of 140 billions tons of agricultural waste and 2 billion tons of garbage produced annually. If this waste is used as a feedstock, this could be converted into approximately 100 billion barrels of synthetic crude oil per annum.

Poorer people in rural and isolated communities all over the world, but particularly in developing countries, have very little opportunity to become economically active in modern society. It has been identified that a lack of affordable energy resources (electricity and fuel) is one of the main reasons for being stuck in poverty. Providing affordable energy resources that can be used locally by the community or sold as a cash source becomes a priority for overcoming this underdevelopment.

We will examine the efficiency of using biomass-based materials to make fuel gases, electricity and liquid fuels. We show that these feeds can be converted to more convenient forms of energy small distributed plants. Furthermore we will show that we can build small chemical plants that are relatively efficient and cost effective using the process synthesis concepts discussed in this work. These chemical plants would be suitable for use in isolated rural areas and in developing countries where there is not the required infrastructure to provide these services. Using the GH-space concept, we will show how one can design plants over a range of scales to be reasonably efficient, cheap to build and easy to operate.

What is needed is to make this technology fit-for-purpose, at scales appropriate for the available resource, be it small for rural communities or larger communities in cities. Using this renewable resource will not only help clean up the environment but provide energy to those who need it most.

References

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