6-11-2018

Sustainability in Chemical Engineering

Alec T. Raber
University of Dayton

Research Article

Sustainability in Chemical Engineering

Alec T. Raber, University of Dayton

Introduction

For much of the past century, the world has seen industrial and technological progress that has helped make life better for humans but hurt the environment while doing so. Once people realized the damage that was being done, it was observed that this kind of development was not sustainable, meaning it did not "meet the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 3). While different experts may define the term "sustainability" (or "sustainable development"), differently, they will all share the substance of Brundtland's definition. Ever since the light was shed on the importance of sustainable development, professionals from a large array of fields have focused their attention on what can be done to ensure what humans from their generation do will not put future generations at a disadvantage.

In this article, I analyze what role chemical engineering and chemical processes have on striving towards sustainability. I will do this by first, looking at what sustainability means, and the different aspects of it, unpacking a number of concepts that have been created to help chemical engineers to operate in a sustainable way. These concepts include industrial ecology, green engineering, and looking at sustainability though an economic lens.

Being an aspiring chemical engineer starting to learn more about the field, I figured that chemical engineers could contribute towards sustainability. My thoughts were confirmed by Sikdar (2003), who wrote, "it is by creating economic value through the development of environmentally preferable technologies that

chemical engineers can participate in the process of sustainable development" (p. 1). Woinaroschy (2012) reinforces the idea, stating,

> In the sustainable development of society chemical engineers play a main role, due to the requirements to use renewable raw materials and energy resources, to reduce number and amounts of secondary undesirable products and the pollution risks, to realise new renewable materials with high properties, etc. (p. 1)

Overall, it appears that chemical engineers have the ability to contribute towards sustainability not only by coming up with processes to use resources more efficiently or reducing harmful waste, but primarily by making these processes economically favorable. This coincides with a common theme found throughout literature about sustainability: that it is part social, part environmental, and part economic (García-Serna, Pérez Barrigón, & Cocero, 2007; Sidkar, 2003; Woinaroschy, 2013). A specific example of what chemical engineers have done to make industrial processes greener comes from García-Serna et al. (2007). The industrial solvent ethyl acetate has increased in use in recent years because it has replaced more hazardous solvents. Chemical engineers and chemists have figured out a way to produce ethyl acetate from alcohol, such as ethanol, as opposed to acetic acid. This is much more environmentally friendly because ethanol can be produced by fermentation, which harnesses starch produced by plants from photosynthesis, which happens to use carbon dioxide (Garcia-Serna et al., 2007). Not only is this an environmentally friendly process (because it is using natural processes to produce resources), but it is economically sustainable as well because several operating plants have opened using the same process.

Industrial Ecology

There are many frameworks through which writers in sustainability in chemical engineering see environmental progress happening. One of these frameworks is industrial ecology, which is described by Jin, Wang, and Wei (2004) as a framework to integrate industry along with its products and wastes in a more organic connection with nature. This can be an effective way to set targets for the development of sustainability; an example is a type of recycling known as industrial ecology cycling. Industrial ecology cycling is using waste from one industry as fuel

for another industry (Jin, Wang, & Wei, 2004). One place where industrial ecology cycling can be seen is at an industrial complex in Lebei, China, where many different products are synthesized through chemical reactions. Here, a process has been implemented that uses sulfuric acid to make phosphate fertilizers, and fuel the production of sulfur dioxide and lime. The lime is used to make cement, and the sulfur dioxide is able to be transformed to sulfuric acid, which is used to start the cycle over again (Jin, Wang, & Wei, 2004). This is a good example of how industrial ecology can be successful because the complex was able to reduce their impact on the environment as well as be economically favorable. If chemical engineers could continue making developments within this template, that would reduce waste as well as the amount of raw materials needed for industries, both of which are obviously environmentally friendly practices.

Green Engineering

Another way to think about sustainability in relation to chemical engineering is green engineering (García-Serna, Pérez Barrigón, & Cocero, 2007; Jin, Wang & Wei, 2004). Green engineering can be defined as "the design, commercialization, and use of processes and products that are feasible and economical while minimizing pollution at the source and risk to human health and the environment" (Allen & Shonnard, 2002, p 2). Essentially it is optimizing processes and products so that they do not harm what is around them but are still profitable. This would generally be a useful format for chemical engineers to follow, as it would naturally make engineering more environmentally friendly. Also, it aligns nicely with a traditional definition of chemical engineering as "a broad discipline dealing with processes involving the transformation of matter or energy into forms useful for mankind, economically and without compromising environment, safety, or finite resources" (Worchester Polytechnic University, 2004, para. 1). This definition implies that green engineering is part of the job of chemical engineering, which is a solid philosophy for thinking about sustainability. One example of a green engineering project is the Holland Energy Park in Holland, MI. This park is part of a long-term plan for sustainable energy and will provide affordable energy for many years to come (Brumbaugh, 2017). The chemical engineering behind this plant is that it uses "combined cycle, natural gas generating technology to produce up to 145 megawatts of power to meet the needs of a growing community" (Brumbaugh, 2017, para. 6). By doing this, once fully functional, the plant will be twice as fuel

efficient as the past power generation system, thus cutting the carbon emissions in half (Brumbaugh, 2017). For its impressive showcase of sustainability, the plant became the first plant and park to be named an Envision Platinum award winner. Envision is a system designed by The Institute for Sustainable Infrastructure that measures the sustainability of infrastructure projects by using ratings (Platinum being the best) (Brumbaugh, 2017). Hopefully this award can help Holland Energy Park show other engineers and firms what favorable results could be achieved when they use green engineering. When many individual chemical engineers work within a framework that focuses on taking care of the environment as part of engineering, great progress will be made collectively.

Economics/Business in Sustainability

The literature on the topic makes it clear that chemical engineers have the ability to assist with the sustainable development of society. However, most chemical engineers work for a company whose main goal is to make a profit. This may be the main reason that being economically sustainable is one of the three branches of sustainability. The question then becomes: can chemical engineers develop environmentally friendly methods that reach all three aspects of sustainability, and if so how? Garcia Serna et al. (2007) answer this question by saying, "'Green' could even be profitable provided that it becomes a central strategy for those firms in terms of policy" (p. 3). What they appear to hold is that if a company goes "all in" on being green and makes it a part of their company identity, they can increase their profits by being environmentally friendly, thus reaching sustainability.

An applicable example of how a company committing to achieving all three aspects of sustainability is what the department store giant Wal-Mart has been doing since 2005. That year, Wal-Mart decided to make sustainability part of who they were are as a company. In a speech given that year to suppliers and employees, CEO Lee Scott clearly stated Wal-Mart's dedication to going green, and laid out ambitious goals going forward (Scott, 2005). He introduced the concept of being environmentally friendly first by saying, "As one of the largest companies in the world, with an expanding global presence, environmental problems are our problems" (Scott, 2005, para. 20). He then went on to lay out three bold, main idea type goals: For the company to be supplied completely by renewable energy in the near future, for the company to achieve zero waste, and to sell products that sustain their resources and the environment. These goals were followed by more specific,

short term goals, which Wal-Mart has done an at least reasonable job of following through on since, and benefited because of it. From 2010-2015, Wal-mart eliminated 28.2 million metric tons of greenhouse gas emissions from its supply chain, exceeding its goal of 20 million (Makower, 2015). One reason for this reduction is the improved fuel efficiency if its fleet, which has doubled since 2005, when the initiative began, and has saved the company an estimated one billion dollars. As of 2015, 26 percent of Wal-Mart's energy is now renewable, and in the year 2014 they diverted 82.4 percent of their waste in the United States (Makower, 2015). That second percentage is particularly impressive, and of central focus because less waste means less money spent on dealing with it. As mentioned before, another way Wal-Mart has become more sustainable is by trying to make the objects they sell more environmentally friendly. Mike Duke, the Wal-Mart CEO at the time, gave an example of this in an interview with *The Wall Street Journal.* Duke said that they worked with companies to try to make detergents and bleaches more concentrated. As a result, smaller bottles can be used but still do the same number of loads, which is better for the environment and saves money (Wall Street Journal, 2014). This is where chemical engineers can have an impact by working to make the detergent or bleach more concentrated without sacrificing quality or money. When Lee Scott started Wal-Mart's sustainability initiative, he did it believing that it would help the company all around, saying "being a good steward in the environment and in our communities, and being an efficient and profitable business are not mutually exclusive. In fact they are one in the same" (Peterson, 2012, p. 358). This statement is very similar to that of Garcia Serna et al. (2007) quoted earlier. In fact, it is essentially the theory being put to practice. In this case the theory seemed to be correct; as mentioned above, many of the environmentally friendly improvements benefitted the company monetarily as well.

More evidence for the focus on sustainability helping the company all around is the increase in stock value compared to the competition. From 2005 (when Wal-Mart devoted themselves to sustainability) until now, Wal-Mart's stock has gone up almost 100 percent. This is significantly more than their competitor Target, whose stock has gone up a mere 7.8 percent in the same time period. The reasons for this may be because once a company dedicates themselves to being green, they become more efficient at it and save money. Also, having a reputation of being a green company can increase marketability and make people more likely to buy your product.

In a company where the platform is clearly about being green and sustainable, or in a company supplying a company with such an attitude, chemical engineers on the ground level can feel a lot freer about implementing environmentally friendly practices. In fact, the philosophy of increased sustainability coming from the top seems to be a widely accepted idea. In an interview I asked Bruce Hitchens, Vice President of PUR Product manager of PET, and Global Operations PO for Convestro AG (a materials science company), how sustainability can be improved in the chemical industry. His response centered around the idea that for sustainable progress to happen within the company, "you need a strategic direction from the very very top." That is exactly what happened to Wal-Mart, as their CEO gave a speech making it very clear that they were going to make sustainability part of who they are. This sense of direction towards sustainability coming from the top allows the chemical engineers to commit fully to making processes and products more sustainable.

The previously mentioned industrial ecology fits into this mold of reaching all three aspects of sustainability, as described by Sidkar (2003), "by co-locating manufacturing plants so as to minimize waste (so-called industrial ecology), or by establishing waste exchange, industries can achieve the three-fold goal of economic development, environmental stewardship, and social good" (p. 2).

Even though many writers agree with this optimistic theoretical idea that going green can be profitable, the issue of sustainability is seen in many different ways. Jin et al. look at the problem in a more realistic sense of what is currently occurring. The article brings up the tragedy of the commons that since the capacity of the Earth and its resources are limited, every use or damage of them decreases their availability to others (Hardin, 2009). This idea by Hardin goes along with the idea that industry today is producing negative externalities that hurt common property such as Earth's oceans and atmosphere. Jin et al. mention that this is a problem because there is yet no value on the Earth's services of dealing with these externalities. Jin et al. (2004) call the system of sustainability that seems to be most popular today *mainstream sustainability*, which is the idea that we can continue to focus on economic growth, but we will solve the issue of limited capacity and resources by increased efficiency through technological developments.

One pillar of the argument that pure integration of economic growth and sustainability can work is that economic growth in the end will lead to more sustainability. The thinking behind that being, once more of the world develops and gets out of poverty, people will have the luxury to care about the environment,

whereas now they do not. However, Jin et al. (2004) state the main belief or assumption of mainstream sustainability is that positive externalities in the future will be able to make for previous negative externalities. They say that technological advancements will improve ecology, come up with new resources, partially eliminate previous damages done, etc. to make up for the damage done before them. According to Jin et al. (2004), this system of mainstream sustainability is what is currently in place and has been for some time. This means that future generations will not only have to be sustainable themselves, but also make up for previous generations' damage.

Discussion

Through my research, I have discovered that chemical engineers do, in fact, have a large role to play in sustainable development. In general, the way in which they can improve sustainability is by optimizing chemical processes so that they are safe, environmentally friendly, and economically favorable (Sikdar, 2003; Woinaroschy, 2012). Naturally, the part of sustainable development that most people believe is often lacking is the process of being eco-friendly. That is probably because the negative effects are much less direct and short term when the environmental part of sustainability is neglected than when either of the other two parts are neglected. Two concepts that have been created to help facilitate environmentally sustainable development along with economic sustainability and societal safety are *industrial ecology* and *green engineering*. Both of these concepts are easily applied to chemical engineering. Industrial ecology creates a way for chemical engineers to make chemical processes efficient by using what would be waste to fuel other reactions (Jin, Wang, & Wei, 2004). Green engineering gives chemical engineers a framework to work through in order to make sure they do as little damage to the environment and society as possible (García-Serna, Pérez-Barrigón, & Cocero, 2007). As mentioned before, the definition of green engineering is very similar to the definition of chemical engineering. The similarity between them could imply that chemical engineers are not only *able* to contribute to environmental sustainability, but are expected to as part of their job. However, most chemical engineers do not get to operate however they want because they have people above them giving them expectations regarding costs and the quality of the products. This leads to another, possibly more effective way at looking at sustainability in chemical engineering: analyzing how the role of chemical

engineers is affected by economics and business. Though economics is clearly tied into the other frameworks, looking at suitability without all of the scientific details can be useful. From the success Wal-Mart experienced after the decision by their CEO to go green (Scott, 2005), it can be concluded that the most effective way for a company to improve sustainability is with a clear message from the top of the company. It makes sense that the executives of a company declaring that the company is focused on sustainability would allow chemical engineers on the ground to implement environmentally friendly ideas like industrial ecology and green engineering. Economics would still have to be a major aspect of what the chemical engineers do, but it would be clear that profits are not the sole focus. Once the company makes it clear that sustainability is the goal, it is up to the chemical engineer to successfully make chemical processes more environmentally friendly.

Jin et al. point out that with mainstream sustainability being the most popular form of sustainability right now, humankind is still doing more damage to the environment in hopes that scientific and technological advances in the future will be able to clean it up. That means that fields, such as chemical engineering, which are tasked with coming up with technologies, products, processes, etc. that are more environmentally friendly, will have an important role in sustainability for years to come. It will be up to chemical engineers to design and implement ways to not only make chemical systems sustainable, but also potentially make up for the lack of sustainability of many generations.

References

Allen, D. T., & Shonnard, D. R. (2001). *Green engineering. Environmentally Conscious Design of Chemical Processes*. Pearson Education.

Brumbaugh, G. (2017, April 18). *5 Essential Green Engineering Innovations*. Retrieved November 15, 2017, from http://news.asce.org/5-green-engineering-innovations-to-consider-for-your-next-project/

Brundtland, G. H. (1987). Our common future—Call for action. *Environmental Conservation, 14*(4), 1-12.

García-Serna, J., Pérez-Barrigón, L., & Cocero, M. J. (2007). New trends for design towards sustainability in chemical engineering: Green engineering. *Chemical Engineering Journal, 133*(1), 7-30.

Hardin, G. (2009). The Tragedy of the Commons. *Journal of Natural Resources Policy Research, 1*(3), 243-253.

Jin, Y., Wang, D., & Wei, F. (2004). The ecological perspective in chemical engineering. *Chemical Engineering Science, 59*(8), 1885-1895.

Makower, J. (2015, November 17). *Walmart sustainability at 10: An assessment*. Retrieved November 13, 2017, from https://www.greenbiz.com/article/walmart-sustainability-10-assessment

Peterson, M. (2012). Sustainable enterprise: A macromarketing approach. *Sage Publications.*

Sikdar, S. K. (2003). Sustainable development and sustainability metrics. *AIChE journal, 49*(8), 1928-1932.

Scott, L. (2005, October 23). Twenty First Century Leadership. Retrieved November 13, 2017, from https://news.walmart.com/executive-viewpoints/twenty-first-century-leadership

Wal-Mart's Green Initiative: Status Report. (2014, April 8). *Wall Street Journal*. Retrieved November 13, 2017, from https://www.wsj.com/articles/wal-marts-green-initiative-status-report-1396982845

Woinaroschy, A. (2012). Sustainability in chemical engineering. *Asociatia Generala a Inginerilor din Romania*, 1-8. Retrieved November 13, 2017, from http://www.agir.ro/buletine/1988.pdf