Sustainability in the Chemical Engineering Capstone Course

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Introduction

Our project focuses on incorporating concepts of sustainability in senior chemical engineering capstone experiences. Through field trips, lectures, formative assessments, and senior projects, students will learn about the three pillars of sustainability – environment, society, and economics. The relationship of these fundamentals are ongoing individually and as teams over two semesters with industry projects and advisors. Outcomes of this work include students learning a measured amount about sustainability and leveraging improved instruction methods for the betterment of our department and college.

Sustainability is also a large part of local and global engineering and more academic teams are recognizing this as industries shift their front-of-house operations to appeal to consumer demand and expectations of sustainability.

Methods

Concepts of sustainability have been blended with almost every aspect of the Chemical Plant Design course (senior capstone experience) including the following:

1) introductory module of sustainable product and process engineering [includes 12 principles of green chemistry and 12 principles of green engineering as a foundation],
2) a field trip to our campus power plant that uses advanced thermodynamic cycles [the Cheng Cycle] and a gray water recycling system,
3) guest lectures on corporate sustainability,
4) scenarios of sustainable design utilizing process simulation,
5) small course assignments to familiarize government policy, energy, and materials considerations applied to sustainability,
6) senior capstone projects.

Figure 1 highlights the overlap of principles discussed thus far in the course series, showing work, carbon, water, emission, and energy footprints crossed with the economic dimension. All of these are topics of the course, and an emphasis of sustainable energy use was woven throughout the fall semester. Figure 2 shows a high-level view of the energy demands of any plant – internal and external heating and cooling. Figure 3 shows a photo of the SJSU Utility Plant where the field visit took place.

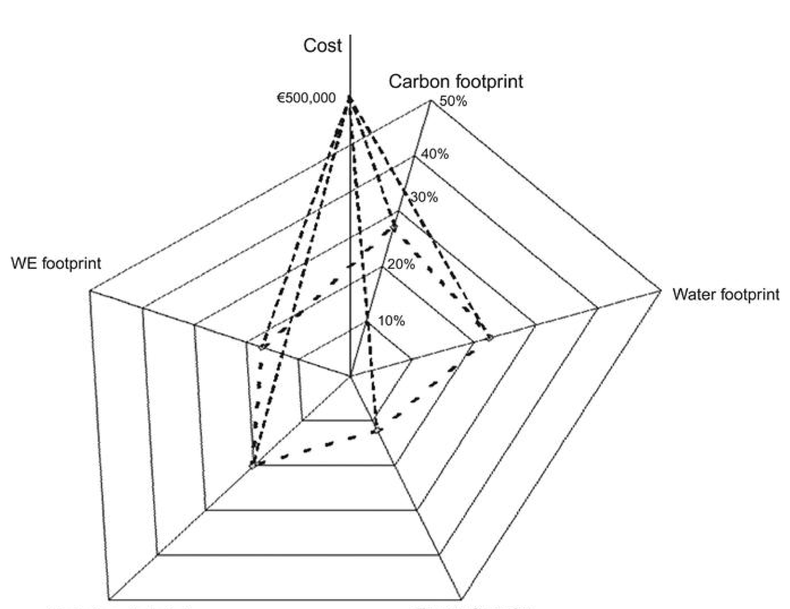

Figure 1: Environmental Performance Strategy Map with additional dimension of engineering cost. [1]

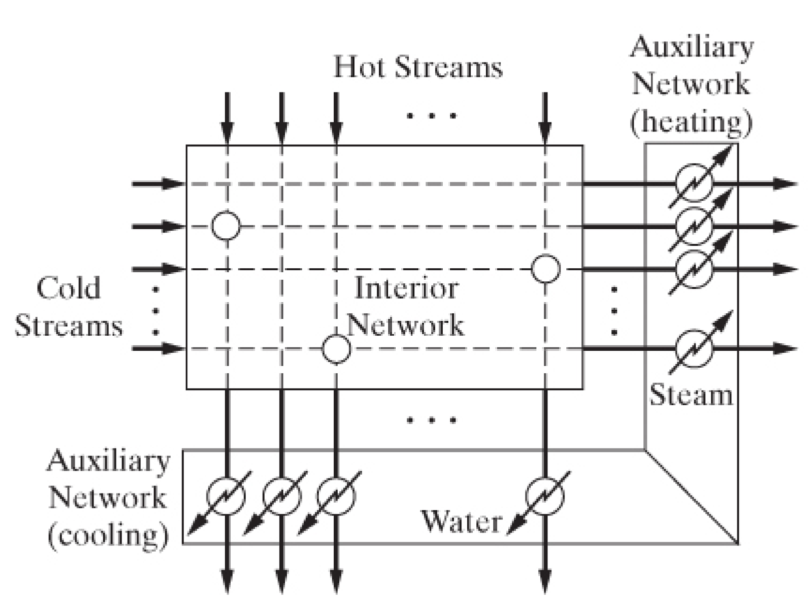

Figure 2: Heat integration schematic of interior and auxiliary heating and cooling requirements. [2]

Progress and Plan for Scaling Up

Enrollment of the senior capstone course is typically 30-40 students. The 2022-2023 cohort has never been formally introduced to concepts of sustainable engineering at San Jose State University, providing the perfect group to assess the impact of the developed modules. While some students may have taken general elective courses that focus on sustainability, they have not had the opportunity to enroll in a technical course (based on knowledge of courses offered in the past two years within our College of Engineering).

Faculty reached by these efforts varies widely at the moment. Two faculty members will benefit from the modules this academic year; one teaches Safety and Ethics and is a co-instructor of the senior capstone course, the other teaches Chemical Reaction Engineering and Reactor Design.

The Chemical and Materials Engineering Department anticipates future incorporation of the EOP Framework in the senior year courses. SJSU-internal reporting will highlight the utility and ease of adopting the framework to promote its use in other College of Engineering departments. While I will remain a lecturer at SJSU, I am moving to an R1 university in 2023 where I will teach the same Chemical Plant/Process Design course and transfer the EOP Framework and knowledge.

Figure 3: Photo of San Jose State University's advanced variable-speed chiller within the Central Utilities Plant. [3]

Acknowledgements

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Evaluation and Impact

San Jose State University's Office of Sustainability identifies more than 1,530 sustainability-related or -focused courses in 67 out of 73 total academic departments. These courses incorporate all 17 United Nations Sustainable Development Goals. We are committed to providing relevant and up-to-date instruction regarding the concept of sustainability, recognizing that it has different meanings to other colleges and disciplines.

As a dual minority-serving institution (Hispanic-serving and AANAPI-serving), we share a vision of increasing the number of well-qualified STEM graduates, especially underrepresented minorities and women. Diverse high school and community college districts constitute much of San Jose State University's student body and allow SJSU to attract an ethnically and socioeconomically varied population of students. While the university is 50.2% female, college and chemical engineering program figures are lower at 23.5 and 31%, respectively; these data are for Fall 2021 enrollment. Focusing on the chemical engineering program, students identify as Asian (31%), Black or African American (8%), Hispanic/Latinx (31%), White (16%), and Other (14%) with more than 50% of these students being first generation.

These demographics signify the importance of incorporating principles of justice, equity, diversity, and inclusion (JEDI). Meaningful incorporation will include practices of actively recognizing the importance of community-building performed via senior projects. A required aspect of these projects is the discussion of how society and the environment are affected; this can be in terms of market/economic analyses or using engineering principles. Additionally, JEDI practices include guest lecturers representing the student body, acknowledging limitations, and identifying opportunities for understanding and improvement.

Overall, the project had a positive impact on the students with a lot of informal comments throughout the semester reinforcing the inclusion of sustainable concepts. Changes will be made for future cohorts in the form of evolving and timely examples, efforts made for off-campus field visits, and senior projects with sustainable companies. Efforts are currently being made to publish survey results in a similar form as Burkholder et.al. [4] with the main author, Eric Burkholder. Future impact will be measured in the same manner as this year to gauge effectiveness; minor alterations to instruction are expected.

References

[1] Klemes, J. Assessing and Measuring Environmental Impact and Sustainability. Butterworth-Heinemann, 2015.
[2] Seider, Seader, and Lewin, Product and Process Design Principles: Synthesis, Analysis and Evaluation. Wiley, 2016.
[3] "San Jose State University Chiller Plant Improvements" https://greenbuildings.berkeley.edu/bestpractices/2015/sjsu-chiller-plant-improvements.html
[4] Burkholder, E., Hwang, L., and Wieman, C., Evaluating the problem-solving skills of graduating chemical engineering students," Education for Chemical Engineers, *34*, 2021.