Impacts of Social and Equity-Centered Instruction on Students' Ability to Navigate Related Tradeoffs in Systems-Level Design

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Abstract

Engineers effective at creating value for society must frame their work through a lens of equity and social justice. They need to identify who is affected positively and negatively by their solutions across all stages of development: manufacture, distribution, use, and disposal. In this work-in-progress paper, we examine the first stage of a four-year curriculum initiative to develop these skills in engineering students. Specifically, we have implemented several assignments in an upper-level Sustainable Energy Systems Design course where students must address equity concerns in four project assignments.

This work-in-progress paper presents assignments used elicit the students' ability to navigate complex questions of equity and the related trade-offs. We conduct an initial assessment of the students' capacity to identify design alternatives to mitigate the negative effects on marginalized populations. The paper provides re-designed activities based on this analysis along with a proposed pre- and post-assessment of the student's ability to transfer these skills to new projects. In this assessment, the students would be given parallel design challenges at the beginning and end of the semester, to measure the effect of specific Sustainable Energy Systems Design course assignments on the student's ability to identify and articulate appropriate concerns and solutions.

Introduction

The need for integrating issues of diversity, equity, and inclusion (DEI) in engineering is well documented. ABET is currently giving institutions due for accreditation visits in 2023-24 and 2024-25 the option of having DEI reviewed in the areas of curriculum (Criterion 5) and faculty (Criterion 6). Within Criterion 5, ABET is looking for evidence that supports that the curriculum, "ensures awareness of diversity, equity, and inclusion for professional practice consistent with the institution's mission" [1]. Many in the engineering community recognize the need for developing engineering skill sets that address societal impacts within the design process. Not only should engineers be aware of the potential negative consequences of their designs, but they should also seek opportunities to create value and benefits for under-served populations.

The body of research on social justice in engineering design is well documented [2, 3, 4, 5, 6]. In particular, human-centered design has emerged as a favored approach for students to approach the design process in capstone courses[7, 8, 9, 10]. Other best practices in engineering education to

promote DEI tend to focus on supporting marginalized populations in the curriculum and ensuring the classroom environment is safe, welcoming, and validating for all students. Some promoted best practices include incorporating diverse, particularly, non-white, non-western examples of scientific or engineering knowledge and highlighting non-white, non-male people with STEM expertise [11, 12]. Others recommend using an inclusive course design checklist that includes careful consideration of syllabus language, assessment practices, assignment submission policies, and the incorporation of active learning strategies [13, 14].

These extensive resources provide effective approaches to centering the design process on human needs and structuring classroom environments and experiences for diverse students. Still, there remains a need for complementary resources that provide classroom activities and materials that bridge the gap between technical content and DEI. Resources that support the integration of DEI in technical, content-focused courses where students perform smaller-scale system-level design projects are more difficult to find. These engineering science courses present an opportunity for students to connect technical design with social impacts as stepping-stone activities ahead of a comprehensive human-centered design capstone project. Introducing such activities could provide additional reinforcement of DEI principles, and help emphasize the need to always consider the human impact of our work.

We are aware of a limited set of activities that directly relate to engineers' design decisions relating to infrastructure and renewable energy projects. The Center for Infrastructure Transformation and Education (CIT-E) developed a community of practice that provides classroom activities, resources, and training on teaching the social impacts of infrastructure, such as how highway construction contributes to systemic racism [15]. We sought to develop a parallel resource relevant to a wide range of engineering disciplines with tools for addressing the social impacts of engineering design as an integral part of responsible engineering at the outset of new renewable energy projects.

Of note, many engineering programs serve majority white and majority male student populations where there are limited opportunities to engage with other students from underrepresented backgrounds. As a result, it is even more important that these students engage with the complexities of designing for populations with life experiences different from their own. It is in this environment that we are studying the impact of specific classroom activities that provide a structured framework for students to identify who is impacted and how when considering design choices. We will determine if the assignments utilized in a Sustainable Energy Systems Design course result in students being more proficient in identifying impacted communities and applying this knowledge in other courses and contexts.

Elizabethtown College where this study is being conducted is a private comprehensive university with a liberal arts focus. This institution offers a multidisciplinary engineering major with approximately 200 students in the program. The Greenway Institute , a satellite campus of Elizabethtown College also offers a study away opportunity for engineering students where they spend a semester away and earn credits towards their engineering degree in an entirely project-based format. The satellite program pays particular attention to issues of sustainability and equity in the design process. In this unique setup, students complete projects and learn the technical skills needed as engineers as they work on their design challenges.

Methods

We have first implemented this work-in-progress in the Sustainable Energy Systems Design course at Elizabethtown College, which is a required multidisciplinary course that covers system-level design of photovoltaics and wind farm siting and design (Table 1). Additionally, the course focuses on designing systems to minimize harm and maximize benefits to communities.

Table 1: Project Timeline

Spring 2023	initial implementation	this paper
Fall 2023	remote site implementation and development of new activities	this paper
Spring 2024	Implementation of revised activities, pre-/post-assessments	future paper
Spring 2025	remote site implementation of new activities	future paper

In Spring 2023 the class consisted of 31 junior and senior-level engineering students. Four students took the course at a remote location at Greenway Institute in an entirely project-based format in Fall 2023. The Spring 2024 class at Elizabethtown has 50 students enrolled. Students complete a series of three assignments targeting unique aspects of DEI in design.

The IRB process was completed and categorized as exempt. The study consists of the analysis of pre and post-assessment of student work.

Data Collection

We collected data from student work submitted during Spring 2023 offering of the course from the assignments described in the section below. We will continue to collect data from the Spring 2024 assignments that were updated based on the findings from Spring 2023. With these student artifacts, we will quantitatively measure the students' (1) identification of effected parties (2) the positive and negative impacts that populations face by counting the number of responses the students provided in their work. Qualitatively, we will evaluate the depth and uniqueness of the students' responses. Our aim is to determine if students demonstrate progress in their ability to identify relevant effected groups and describe the details of those effects.

Assignment Descriptions from the Spring 2023 Course

1 - Beyond the LCA: The intention behind the Beyond the LCA assignment is to extend the traditional LCA to examine human impacts. In this assignment, students were provided with the life cycle assessment (LCA) for a commercial-grade wind turbine. They worked in teams of two or three to summarize a wind turbine's environmental and economic impacts. As a first step, they completed a template in the form of a table where they summarized the environmental impacts, material inputs and outputs, and energy inputs and outputs at each stage of the turbine's life cycle: manufacturing, site set up, operation, and end-of-life (Appendix A). As a next step, the students determined what communities and individuals are affected at each stage and how those people are impacted, completing a parallel table listing who is affected at each stage of the life cycle and how. This assignment was designed to challenge the students to consider the human impact of a design we studied in class.

2 - Capstone Broader Impacts: In a follow-up assignment, students worked in teams to create a basic version of an LCA including human impacts for their senior capstone design project and write an updated version of the Social, Environmental, and Ethics Considerations section for their capstone report (Appendix B). This assignment presented an opportunity for the students to connect their work in the Sustainable Resource Engineering and Design course to their capstone design project with the intention that they would provide greater depth and insight than they had to date. Given that the students had previously used a structured approach to consider each phase of the product life cycle in the Beyond the LCA assignment, they now had an opportunity to apply that knowledge to their capstone project. In the second part of the assignment, the teams were required to write a revised Social, Environmental, and Ethical Considerations section for their senior capstone project based on this analysis. This assignment asked the students to transfer the methodology of the first assignment to another project of personal significance.

3 - Mock Public Hearing: This end-of-semester activity had students considering human impacts in a local setting. At the end of the semester the students were presented with a hypothetical situation where a community is considering developing wind and solar farms. Students were assigned an impacted party to research and develop talking points for a mock public hearing (Appendix C). The affected groups included representatives of the utility company, the engineering design team, and the installation contractors, directly affected landowners, community members either in support or opposed to the project, and other community leaders. Impacted parties with similar interests worked together to establish different arguments in favor or against the proposed project. During the final exam period, we held a mock town hall meeting. Afterward, the students reflected on why they voted as they did and how the arguments that were presented during the hearing influenced their decision (Appendix D). This final assignment was designed to help students imagine themselves as engaged citizens as they prepare to graduate and become working professionals in the community.

Results

Initial results from the 2023 Spring semester offering of the Sustainable Energy Systems Engineering course were analyzed to establish a baseline of students' understanding of the social impacts embedded in engineering design. We assessed the quantity and quality of the students' responses looking at the number of unique responses and the quality or depth of the work.

Beyond LCA Results

Students worked in teams of two to four students with ten teams total. All ten teams completed the assignment. The quantity and quality of the students' answers varied. When looking at both positive and negative impacts, most teams tended to provide one or two potential groups that would be affected. Student groups on average provided around two reasons how that group would be positively impacted (Figure 1) or negatively impacted (Figure 2).

Some answers were generic: "local residents" or "labor force," while others were more detailed and specific: "Workers employed in the decommissioning and disposal/recycling of wind plant components." While the intention behind the assignment was for the students to identify social impacts, students repeatedly used "wildlife" or "the environment" as impacted communities or individuals even though they had previously focused on environmental impacts when

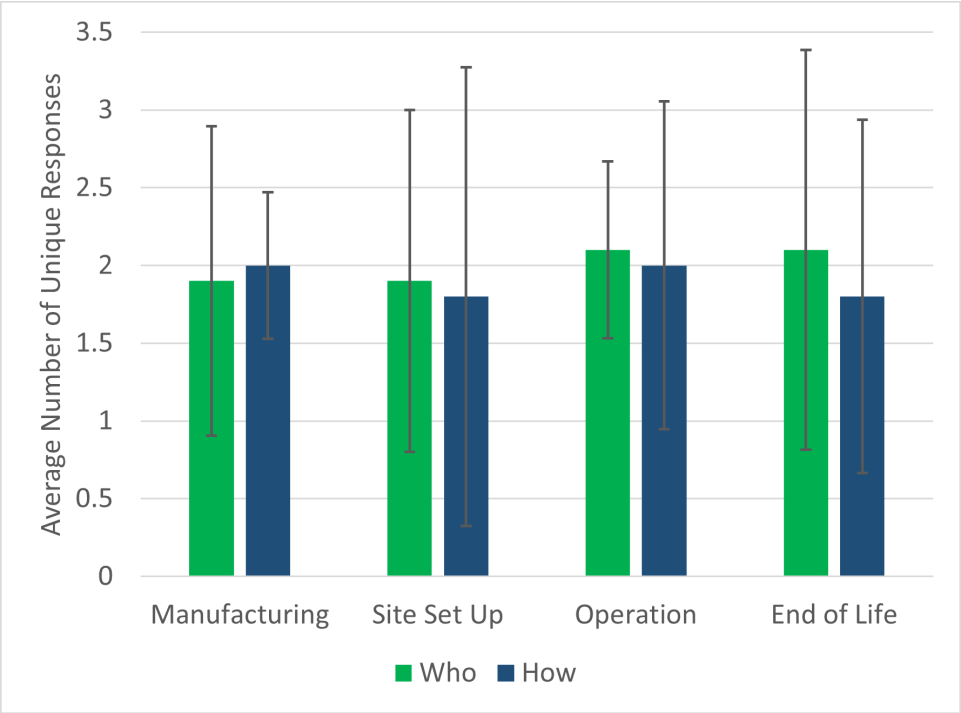

Figure 1: Average number of unique responses from each team identifying people **positively impacted** by the wind turbine at the indicated life cycle stage.

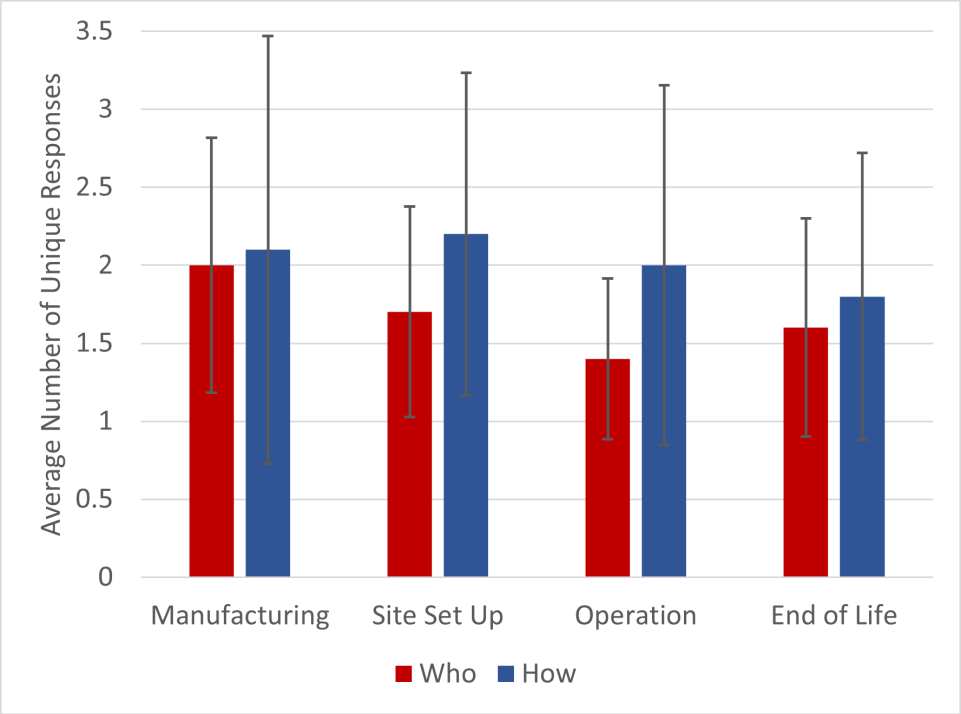

Figure 2: Average number of unique responses from each team identifying people **adversely impacted** by the wind turbine at the indicated life cycle stage.

summarizing the LCA. Some of the students' answers were incorrect: they confounded this analysis with a concurrent assignment where they reflected on a documentary on the perils of e-waste recycling in the developing world. Other answers indicated deeper thinking: students related wind turbine projects to issues of eminent domain that they had learned about in other courses. Many groups cited issues of noise pollution during operation and dust during construction as being problematic for neighboring residents.

Capstone Analysis Results

As a follow-up assignment, the students considered the life cycle impacts of their capstone design project. The results were mixed (Table 2). Ten teams completed the assignment with one student who chose not to join a team and did not submit work. As with the Beyond the LCA assignment, students identified affected parties and the ways in which they are impacted in each phase of their project's life cycle: Manufacturing, Sales/Delivery, Operation, and End-of-Life. Overall teams did a good job of identifying environmental impacts providing numerous examples but often failed to connect those impacts to people. The number of unique human affects identified and they ways in which they were affected varied dramatically ranging from zero to five responses in some life cycle stages (Table 2). Generally, teams identified fewer negative impacts and than positive ones. Surprisingly, few of the teams used their Social, Environmental, and Ethics Considerations work in their Capstone reports, submitted separately for the capstone course.

Table 2: Number of impacts identified by student groups for their capstone projects (mean±standard deviation).

	Positive		Adverse	
Life Cycle Stage	Who	How	Who	How
Manufacturing	1.3±1.7	1.1±1.0	0.2±0.4	0.6±0.8
Sales/Delivery	0.6±0.8	0.6±1.0	0.3±0.5	0.4±1.0
Operation	1.5±1.1	1.8±0.8	0.7±0.7	1.7±0.9
End of Life	0.7±1.3	0.5±0.8	0.7±1.6	0.6±1.1

Mock Public Hearing Results

The Mock Public Hearing was a five-point assignment. Students were assessed on their performance (2 points) and reflection (3 points). The performance score was based on how well the student captured their character's perspective on the proposed project and whether they provided evidence in support of their position. The reflection score was based on the students taking a position after the conclusion of the hearing and supporting that position by citing specific arguments that were presented during the public hearing. Samples of strong and weak reflections can be found in Appendix E. Overall, the class performance on the Mock Public Hearing was strong with 74.2 percent of the students earning a 4.5 or 5 out of 5 on the assignment and reflection (Table 3). Three students opted not to complete the last assignment.

Table 3: Student performance on the Public Hearing assignment.

Score	Number of Groups
5.0	14
4.5	9
4.0	2
3.5	3
1-3	0
0.0	3

Discussion and Conclusions

Despite the relatively small sample size, the pilot data presented provided valuable insights for designing these types of assignments. Throughout the three assignments, students did adequately but well below our hopes. Most of the people groups identified as affected by the designs were obvious, on the surface response. For example, those hired to work in the factory are positively affected by the manufacturing stage of the life cycle. Students generally were better at identifying people affected positively (2.0 groups identified per stage) over those affected negatively (1.7 groups identified per stage), although these results were not statistically significant. Students also often identified the environment or climate as a person adversely affected by the design.

Based on this experience from implementing the Beyond the LCA, Capstone Broader Impacts, and Public Hearing assignments that focused on the human impacts of renewable energy projects, we will refine this approach to better ascertain the impact of these activities on students' ability to consider the social impacts of these projects. While we observed progress in the students' ability to consider social impacts from the LCA assignment earlier in the semester to the Public Hearing assignment at the end of the semester, we identified some key areas for improvement.

We will refine the Beyond the LCA and Capstone Broader Impacts Assignment prompts as follows:

- Provide a detailed rubric that defines expectations for mastery-level and acceptable-level work.
- Emphasize that students need to provide human impacts.
- Provide more guidance on the level of detail expected. For example, "labor force" versus "wind turbine technicians" or "local community" versus "neighbors living adjacent to the wind turbines."
- Provide specific tools including the "Fifty-Five Prompt Questions for Identifying Social Impacts of Engineered Products" [16] to help the students broaden their perspective on who would be effected and how.
- Give class time for students to work in groups to discuss the social impacts of design.

We were surprised that students did not implement their revised Social Impacts section in their junior or senior final capstone reports in Spring 2023. We recognize that students tend to silo their

coursework and did not recognize this opportunity to improve their reporting on the capstone. Therefore, we plan to share this assignment with the junior and senior project advisors and ask that they include language in their final report prompts that specifically asks for the revised version of the Social Impacts section based on the Sustainable Energy Systems course.

During the Spring 2024 semester, we will conduct pre- and post-assessments to measure students' ability to generate potentially impacted parties (positive and negative). As a pre-assessment, we will start the semester by posing a design scenario. The students will be asked to identify as many impacted parties as possible and describe how that group is positively or negatively impacted. We will evaluate these pre-assessments by counting the number of unique communities that the students correctly identify (Appendix F). Then we will determine the level to which their responses convincingly describe how the communities are impacted. Later in the semester, the students will complete the updated Beyond the LCA and Capstone Broader Impacts assignments. We expect the new guidance and tools will lead to improved performance on these exercises. At the end of the semester, we will conduct a post-assessment where the students are given a different design scenario but the same challenge prompt (Appendix F). Again, they will be tasked with identifying impacted parties and how those groups are positively or negatively affected. We will determine if there was a change in the number of impacted groups that the students listed and if the quality of the description of how those groups are affected changed. We hypothesize that our focus on the social impacts of design in the course and the students' practice with identifying impacted groups will result in the students generating a higher number of responses with more detail and specificity. As part of this evaluation, we will measure the unevenness of students' answers.

In our first offering of this course at the Greenway Institute we were able to engage with the state legislature to explore how people are affected by sustainable energy policy both positively and negatively. Students interviewed legislators and wrestled with how various socioeconomic stakeholders are impacted by policy decisions. We also hypothesize that as we continue to build on this experience at the off-site program with activities parallel to the primary offering, students at the Greenway Institute will demonstrate a higher proficiency at identifying affected parties and their impacts as their entire curriculum is built upon a focus on equity and sustainability.

We will also run this assessment in a few select project courses in the fall of the first year, the spring of the second year (coupled with the implementation of Human Centered Design practices in a community-based project course), and in the fall semester of the senior year as part of the capstone. This will allow us to see where in the curriculum students are developing these skills and measure the particular role of the focused instruction in the Sustainable Energy Systems Design course.

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Appendix A - Beyond the LCA Prompt

Part 1

During class, your team will complete the table shown below using the LCA Wind Turbine V112-3.3.pdf Download LCA Wind Turbine V112-3.3.pdf. Write an executive summary of the LCA based on your team's table. Upload the executive summary and table to Canvas.

	Manufacturing	**Site Set-up**	**Operation**	**End of Life**
Environmental Impacts				
Material inputs/outputs				
Energy inputs/outputs				
Economic Impacts				

Reflect on the documentary shown in class.

Broadly: We often have positive feelings about recycling, we put aside our electronic waste for recycling - what happens to that e-waste? Where does it go? Who does it impact? How? What is the environmental impact? Why as an engineer is it important to consider the human and social implications of how a design is manufactured, implemented, and reused, recycled, or landfilled?

Specifically: What steps could be taken to design, manufacture, or implement wind turbines that address the societal concerns identified in the table below?

In Class: Add to your table from Part 1:

	Manufacturing	**Site Set-Up**	**Operation**	**End of Life**
Who benefits? (individuals & communities)				
How?				
Who is adversely affected? (individuals & communities)				
How?				

Appendix B - Capstone Broader Impacts Prompt

For this five-point assignment, you will be working on expanding and improving the broader impacts discussion for your final EGR 301 or 402 report. If any of your EGR 301 or 402 teammates are in the class, you will work with them on this assignment: sign up as a Capstone Broader Impact Group. This assignment will be assessed for quality/quantity in proportion to the number of people working on it.

Conduct an LCA for your EGR 301 or EGR 401/402 project. Start by creating a flow chart that details the different life cycle phases of your team's project. Identify the functional unit for your

project. Define the scope of your project. Then describe the material inputs/outputs and energy inputs/outputs of your team's design. You are not required to quantify these inputs and outputs. Think about the life cycle of your product manufactured on a large scale, not the life cycle of your prototype. Upload a file that contains the flow chart, functional unit, scope, and table of material and energy flow analysis.

Update your EGR 301 or 401/402 Broader Impacts discussion in light of the wind turbine LCA you performed. Describe how your capstone project's design positively or negatively impacts people and communities throughout each stage of the product's life cycle. Your project may be specifically designed for one person or a small group of people, but you need to detail the impacts if this project were implemented or manufactured on a large scale. How could your product be misused? Who might that impact? How? Upload the updated Broader Impacts discussion.

Appendix C - Public Hearing

The State Public Electric Utility is partnering with 2 Energy Production companies to propose a publicly funded $40M renewable energy project for a midsized Midwest municipality. This proposal will convert 75% of the electric load of the communities served by this sector of the state utility to renewable sources and lock in electric rates at no more than 50% for households living at or below 1.5x the US poverty line, 80% for all other households and 90% for commercial users compared to the current 6-year average rate for the next 20 years (if average rates decrease the rate will never be more than 110% of the average rate for the state). The proposal is to install PV modules over several large surface parking lots (at shopping centers, etc.) and in 4 public parks neighboring residential areas. The proposal also calls for six 5000-acre wind farms outside of town in agricultural plots. These plots are a combination of publicly owned lands currently leased to farmers and privately held lands where property owners will receive an annual stipend from the energy companies.

Part 1 Individual Assignment (3 points) - Use the library's research guide for this course and other public-access local newspapers, TV, and radio reporting to find at least 10 news stories about community perceptions of wind or solar farm projects. In a Word document list the interested parties and their perceptions and arguments. Cite each source (IEEE formatting).

You will use this information on Wednesday when you find out what community you are representing.

Note: deadline for submission is Wednesday at 12:30 pm - no grace period, must complete before class on Wednesday.

Part 2 On your assigned team develop characters that each member will play (one specific community member per student) at the Public Hearing. Create a list of talking points and review those with others who are in the same group – coordinate your collective strategy. Prepare a two-minute presentation (simple oral statement – no PowerPoint) arguing your character's point of view on the proposed solar and wind project. Stronger presentations will provide facts and evidence in support of the position being presented. Be prepared to respond to others' arguments.

Interested Parties

- Representatives of the utility company, engineering design team, and the
- installation contractors
- Landowners who receive lease payments from PV or Wind turbine
- installations
- Community members in support of the project because of economic benefits
- Concerned neighbors of either wind turbines or PV installations
- Community members concerned with economic costs and the use of public funding for the project
- Activist community members – Environmentalists and social justice advocates
- Community members who are renewable energy skeptics
- Local trade union leaders and members of the local Chamber of Commerce

Appendix D - Public Hearing Reflection

After hearing the arguments, what position would you take and why? Cite specific arguments from the hearing. Try to approach this assessment as a neutral party. Which side made the more compelling case? Why? If you were a council member on the fence regarding this project, who would have convinced you to vote their way?

Appendix E - Sample Public Hearing Responses

Strong Sample 1

As a council member, after hearing all of the arguments I have decided to vote in favor of the $40M renewable energy project. The most influential factors that led to this decision were the economic and environmental benefits associated with the project. Economically, it was very reassuring to learn that the cost of renewable energy per kWh was expected to decrease by $50 by 2030, which will lead to decreased electrical bills. These benefits are in addition to those listed in the proposal description, including how electrical rates will lock in at 50% for houses at or below the US poverty line, 80% for all other households, and 90% for commercial users compared to current the 6-year average for the next 20 years. I really appreciated how beneficial this policy is to those in need, and this is a big reason for my support of the project. In addition, I am in support of the project because of all the jobs that will be created, including field engineers, electrical engineers, solar panel installers, solar project managers, office engineers, and quality control inspectors. Its anticipated that 200 jobs will be created during the 4-8 year contruction (sic) process. Environmentally, solar and wind energy will result in lowered greenhouse gas emissions, which is extra important since glaciers lost more ice than they gained each year from 1997-2020. This clean, sustainable power will decrease our community's reliance on fossil fuels and help our community to be more environmentally friendly. Also, with expected future legislation for large increases in state carbon tax, this project will put us in a good position to

avoid this hefty tax while promoting sustainable energy production. Another reason I voted in support of the project was how many of the complaints from concerned neighbors were met by business leaders. For example, the construction of the project will be completed in phases, which should minimize noise. Also, lease payments should be enough incentive to get land owners to support the project, and jobs in the fossil fuel industry will be protected since back-up fossil fuel plants will be needed alongside the solar panels and wind turbines. Business leaders also assured us that turbine location will be selected to minimize any annoyance it may cause nearby residents. Overall, I believe the community members in support because of economic benefits made the most compelling case. Its pretty clear how electrical rates are expected to decrease over time, but the argument that really stood out to me was when they referenced future carbon taxes that could be emplaced (sic). That made me realize that if we do not go forward with the project, we could end up having to pay a large carbon tax in the future, which would hurt our economy mightily. I believe this is a very good argument, and that this would be the argument that sways council members on the fence to vote for the project.

Strong Sample 2

After hearing the arguments presented during the public hearing, I would side with the concerned neighbors and community members. The community members I believe should have the most say in new construction. It is impacting the views they have every day and if they do not wish to have wind turbines and solar panels installed in their field of view, they should be able to decline the product. One citizen presented the issue of high upfront costs to install this farm. If the project were to be publicly funded, this has the potential to increase taxes on the community. It is also disrupting the food production within the community as the proposed turbine locations are in the middle of current fields. Another presented the argument of noise turbines generate when operating is similar to an air conditioner. They will have to hear an air conditioner running whenever they on their property and this is a nuisance. There may also be impacts to the local wildlife. Wind turbines kill night migrating birds such as songbirds and wind turbine blades cannot be recycled. Burying wind turbine blades could have significant impacts on the community. Solar panels also may create water runoff problems for the community. Some of the counter arguments included local job creation for constructing the wind and solar farms as well as contributing to a more sustainable future by offsetting 75% of the communities energy consumption. However, these arguments do not offset the negative community impacts. When the community members originally purchased their land, they did not anticipate wind and solar farms being created and it they wish to not have them created, they should have the ability to stop the creation of turbines if they desire. If I were a council member on the fence about approving the project, I would listen to the community and vote with what they wanted. If most community members were in favor of constructing the farms, I would side with them. If they opposed, I would also side with them.

Weak Sample 1

When trying to listen to everyone's points towards being for or against renewable energy and wind turbines, it is hard to not focus on all the negatives because they tend to stick out more. One of the main negative arguments was that we would have to use up some farmland that is currently in use and that would take away some of our farm production. One of the compelling arguments for the transition to renewable energy was that it would create a lot more jobs and promote

economic growth. I believe that the people presenting the pros made the more compelling argument because I thought that their points outweighed the cons of renewable energy. Renewable energy is better in the long term and most of the cons presented were concerns that were more focused on the current times. If I were a council member on the fence, I would lean towards the production of the wind turbines because they are better for the environment long term.

Weak Sample 2

After listening to everyone's speeches today, I will be taking a stance against the proposed solar and wind project for several reasons. First, the startup cost of this project is insane; it would cost us about 1 million dollars per megawatt to build the turbines. Next, animal deaths caused by turbines are astronomically high as anywhere from 150,000 to 500,000 birds are killed every year by turbines, a lot of them endangered or threatened species. Renewable sources are also extremely inefficient when compared to conventional sources, at varying rates from 20 to 50% when compared to 90% in the conventional energy sector. Turbines and solar panels require massive amounts of land, typically owned by farmers. These farmers would be forced to abdicate portions of their land, used for food production, to energy companies who just want to turn a profit. My last, and most favorite point, is the renewable energy paradox. Solar panels and wind turbines can physically alter the temperature and actually counteract their true purpose, sending the world into an ice age instead of an era of irreversible global warming. Considering the last ice age ended 20,000 years ago, maybe it would soon be time for another one were this project to occur.

Appendix F - Example Design Equity Challenge

You have been hired by a start-up to advise them on product impact. The company is producing a new 3D printer for textiles. It can produce custom-woven garments of all types. They are considering models for manufacturing scale, local storefront shops, and even home use. It can use a variety of fibers, natural and synthetic, and can print multi-color designs.

Identify people and briefly (1-2 sentences) explain how each group is affected by this product in

1. Material Sourcing
2. Manufacturing
3. Operation and Use
4. Disposal

Given these impacts what do you recommend ranging from "shut down operations" to "no holds barred"? Explain.

Submission format *.docx or *.pdf. Follow the style guide.