DATA AND DIALOGUE: STRATEGIES FOR ENGAGING UNIVERSITY COMMUNITIES IN CLIMATE ACTION

by

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This thesis seeks to establish the best practices for environmental communication, data visualization, and stakeholder engagement. The first subject investigated is the theoretical foundation and practical applications of engagement strategies that involve a wide range of university stakeholders: students, teachers, and support staff. This section explores transparency, inclusiveness, and ongoing dialogues as some strategies to build support for sustainable development. The importance of data visualization is also discussed, showing a need for clear, accurate, and accessible visual tools that can simplify complicated information into actionable insights.

Furthermore, an analysis is conducted on the effectiveness of analogies as a tool for explaining technical concepts to broad audiences. These techniques are then applied to the University of Oregon thermal system transition, wherein the university investigated options to update its current central heating plant into one that will use more sustainable technologies. The proposed options are dissected and evaluated based on the effectiveness of the task forces' communication and engagement efforts. Then, a conceptual interactive dashboard that addresses critiques of the task force's presentation strategy is introduced.

The findings demonstrate how well-designed, comprehensive communication strategies can help build informed, supportive communities around sustainability initiatives. The

conclusion is composed of recommendations for future enhancements to these strategies. It proposes improved methods of implementing sustainable practices in higher education institutions by combining interactive tools, continuous stakeholder engagement, and clear communication. This case study provides valuable insights into guiding other universities facing similar challenges in their sustainability efforts.

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Introduction

The escalating urgency of climate change presents a challenge that demands immediate and sustained action. As institutions of education, research, and community engagement, universities are in a position to lead by example in the global fight against climate change. They have the potential to drive innovation, influence public policy, and cultivate the next generation of leaders committed to environmental sustainability. The literature I explore in this thesis contributes to a plan for achieving meaningful and lasting reductions in carbon emissions. These strategies are crucial in the global fight against climate change, as they contribute to mitigating the effects of global warming and help prevent further environmental degradation.
However, achieving meaningful and lasting reductions in carbon emissions requires technical solutions and effective strategies for engaging stakeholders, communicating complex information, and encouraging a shared sense of responsibility and action.

In this thesis, the University of Oregon is used as an example of the challenge of involving an expansive university community in switching from less carbon-intensive heating systems. This challenge involves communicating the intricacies of climate change and sustainable efforts to different groups. But it is not just about how these complexities can be expressed in an understandable and relatable language. It also involves creating an environment where students, faculty, staff, and other stakeholders are motivated to participate in decision-making processes and support sustainable practices.

This commitment by the University of Oregon to reduce its carbon footprint has been formalized through the implementation of the American College and University Presidents Climate Commitment (ACUPCC), and the Climate Action Plans (CAPs) that followed. The second CAP, commonly referred to as CAP 2, outlines a goal for the university to transition from a gas-fired steam-based district heating system to more environmentally friendly alternatives. This is, therefore, a complex challenge that involves technical feasibility, financial accountability, and environmental stewardship. Establishing the Thermal Systems Transition Task Force in 2022 marked a step in addressing this challenge. The task force evaluated multiple options for modernizing the university's heating infrastructure and recommending a sustainable path forward in line with the charge set by the university.

To support the decision-making process, this thesis draws on a combination of theoretical insights and practical strategies in environmental communication, data visualization, and stakeholder engagement. This project consists of four key chapters:

1. Strategies for Engaging Students in Climate Change Education: This chapter examines how to engage university audiences in climate change education by addressing their perceptions, knowledge gaps, and emotional responses. It explores using interactive learning, digital media, and supportive learning environments to cultivate long-term behavioral change and a commitment to sustainability.

2. Designing Effective Data Visualizations for Climate Communication: Recognizing the complexity of climate-related data, this chapter focuses on the principles and techniques of effective data visualization. It discusses how clarity, accuracy, consistency, and engagement can transform complex datasets into understandable and actionable insights, particularly in climate change communication.

3. Effectively Communicating Complex Environmental Concepts: This chapter delves into the power of analogies to simplify complex environmental concepts and make them more relatable to non-expert audiences. It provides practical guidance on crafting effective analogies and explores case studies where these strategies have been successful.

4. Applying Engagement, Visualization, and Analogy Strategies to the University of Oregon's Thermal Systems Transition: The final chapter applies the theoretical frameworks and strategies discussed in the previous chapters to the specific context of the University of Oregon's thermal systems transition. It evaluates the effectiveness of the task force's engagement efforts, data visualizations, and communication strategies. It then proposes an interactive dashboard concept to improve decision-making and stakeholder involvement.

This thesis attempts to contribute to a more informed and engaged university community. Specifically, universities nationwide are currently trying to investigate similar, less carbon-intensive heating solutions to reduce their carbon output. While the University of Oregon is used as a case study in this thesis, this work has implications beyond Oregon. My goal is for this project to serve as a reference for future climate science leaders on university campuses to refer to as inspiration for improving their engagement and presentation strategies. As universities in a similar position to the University of Oregon navigate the complexities of transitioning to sustainable practices, this research underscores the importance of bridging the gap between technical expertise and public understanding by utilizing clear communication, effective data visualization, and stakeholder engagement strategies. These approaches simplify complex scientific concepts, which makes them more accessible to the public and fosters a collective commitment to addressing the global challenge of climate change.

Chapter 1: Engagement Strategies

Institutions of higher learning should encourage their students to become informed, active citizens on the issue of climate change. This encouragement of university audiences to take up climate change as a relevant issue goes beyond the classroom; it must also involve imparting urgency, responsibility, and the ability to effect positive change. This section reviews research on strategies and techniques that enable university educators and student leaders to connect others to the issue. This section investigates student perceptions of the problem and gaps in knowledge of climate change. I then describe methods to reach university audiences and encourage further involvement from this target audience. Integrating digital/multimedia platforms and supportive learning environments will be explored as they may reveal effective engagement strategies. For the effect to be long-lasting, it must have deep meaning for the student (Cordero et al., 2020). Thus, multidimensional approaches drawn from recent studies are used as a foundation for better practices and to fill the gaps in present educational approaches.

Strategies for Engagement

Assess Baseline Knowledge and Address Misconceptions

One must understand student perceptions and baseline knowledge regarding climate change to engage a broad collection of students. Once we have this baseline understanding, we can identify common misconceptions and develop targeted interventions to address knowledge gaps. Although this task is easier said than done, the existing research on this topic allows us to learn from successful engagement initiatives from around the world and to apply the strategies used in these initiatives to the cause of climate change and, in so doing, to cultivate a more informed and proactive student population.

Students often have more misconceptions about climate change than they might think. One study found that student participants "confuse weather patterns with long-term climate trends” (Schuster & Filippelli, 2008, p. 311). Students' incomplete comprehension of fundamental scientific ideas and the complexity of climate systems frequently cause these incorrect notions. One prominent example is how students pay special attention to isolated aspects of climate change. It is common for students to be upset by headlines such as "the melting of polar ice" or the "increases in global temperatures." However, they often fail to understand the broader "interconnectedness of Earth's systems" that drive these changes (Schuster & Filippelli, 2008, p. 313). While concern about specific issues like melting polar ice is a first step, focusing solely on these isolated aspects can lead to a fragmented understanding. Students may miss the bigger picture without recognizing how various Earth's climate system components interact. For example, melting ice contributes to rising sea levels, affecting global weather patterns, ecosystems, and human communities.

Furthermore, misconceptions about climate change often include the belief that the issue is distant rather than immediate (Harrod and Rolland, 2021). In one study, students "conflate ACC [anthropogenic climate change] with other environmental issues" or see it as "a problem for future generations" (Harrod and Rolland, 2021, p. 417). This misconception can dilute the perceived urgency of addressing climate change and, if not addressed, could lead students down a path of climate change denial. Therefore, the connection between climate change and its current impacts should be made more explicit within the education system. Educators must find ways to highlight the fact that "the success of mitigating anthropogenic climate change (ACC) depends on peoples' understanding and knowledge of the issue and their willingness to participate in mitigation efforts" (Harrod & Rolland, 2021, p. 417).

Additionally, while many students acknowledge climate change, some mistakenly believe there is "significant doubt among scientists as to whether ACC is real" (Harrod and Rolland, 2021). This misconception complicates efforts to cultivate a sense of responsibility and action among students. It creates additional barriers to understanding the issue's urgency. This misconception did not arise in a vacuum; it has been widely promoted by famous public figures with questionable motives to sow doubt and confusion about the scientific consensus on climate change. Therefore, climate education must communicate the human role in driving climate change and actively work to dispel these deliberately propagated misunderstandings. By correcting these falsehoods, we can ensure that students fully grasp the seriousness and immediacy of the issue, paving the way for informed and proactive engagement.

Empower Students with Social Learning Strategies

Educational experiences are cognitive and emotional encounters that influence students' engagement with climate change. Based on a survey of students' perceptions, many students feel "disempowered" by traditional climate education, which often neglects the emotional dimensions of learning (Jones and Davison, 2020). This neglect can result in feelings of powerlessness and frustration. Thus, incorporating social learning strategies, such as peer-group discussions and collaborative projects, could help students better manage these emotions. Additionally, the survey indicated that encouraging a sense of collective responsibility and action can assist students to "overcome feelings of disempowerment" and engage more effectively with climate change issues (Jones and Davison, 2020).

In my experience at the University of Oregon, The Grove Garden, a student-led community garden, is a compelling example of a successful collaborative project that encourages a sense of collective responsibility. The Grove Community Garden is a collective effort;

members are held accountable for the garden's upkeep. The result is a tight-knit community of individuals passionate about sustainable practices. Of course, this concept is good in theory, but it only works if students show up. From what I've seen, students who join the Grove Garden independently typically have a positive experience because of the community aspect. As a result, they invite their others to join the garden because it's a positive community to be a part of. I argue that community projects like this one, which brings students together on a sustainable hobby, make participants want to engage others in the project simply because it's enjoyable. There is also research on educational interventions in botanical gardens, which showed that "even short-term digital engagements" can lead to "significant and lasting knowledge gains" about climate change (Sellmann & Bogner, 2012, p. 417).

Role-playing and practical exercises are additional strategies that can encourage climate change education, as they help students engage with the material on a deeper level by simulating real-world scenarios. Siperstein (2016) suggests that "student-centered teaching activities that use role-play are one potential avenue through which environmental educators can help students develop the skills and confidence to have productive conversations about climate change" (p. 285). By adopting different perspectives, students may better understand the challenges of climate change communication. This approach can help them develop empathy for various viewpoints.

Furthermore, one study found that hands-on, practical experiences have been shown to improve students' understanding and encourage further actions related to climate change. In the study, students were observed and measured before and after engaging in a climate change curriculum, including energy audits and urban tree field studies. The researchers of this study, McNeill and Vaughn (2010), found that students who participated in these activities increased their understanding of climate change compared to their knowledge before the curriculum. Furthermore, these students were more likely than before the intervention to report that they were now engaged in actions to limit their impact on climate change (p. 379). Thus, these practical exercises improved students' conceptual understanding and inspired them to take actionable steps in their own lives.

There's also some evidence in support of Education for Sustainable Development (ESD) strategies to effectively engage students in climate change education, specifically through "flipped classrooms." A flipped classroom is a pedagogical model that inverts traditional learning environments by moving the content acquisition, such as watching lectures and reading books, to pre-class study. As a result, the class time is freed up for interactive and hands-on activities. ESD is a holistic educational approach that empowers students with the knowledge, skills, and values necessary to contribute to a sustainable future. However, how effective is it in practice?

In a case study on implementing active learning exercises within a flipped classroom framework for ESD at the university level, Howell (2021) found that incorporating problem-based learning, collaborative projects, and role-play improved student engagement and made the material more memorable. According to self-reports, over 90% of students felt that these in-class active learning exercises improved their retention of information and provided valuable opportunities to apply their knowledge in practical, real-world contexts.

This study also suggests that this hands-on approach may have deepened students' understanding of complex climate change issues. However, this conclusion is based on students' perceptions rather than objective measures of learning outcomes. This approach also made students feel better equipped to address complex challenges in their future careers. Howell emphasizes the importance of reflective practices and the role of incentivizing pre-class preparation through graded assessments, which further support student learning and engagement.

Leveraging Emotional Connection to Improve Motivation

Negative and positive emotional responses could influence individuals' willingness to act on climate change. Emotional reactions to climate narratives are "strongly associated with the acceptance of the reality and risks of climate change" (Wong-Parodi and Feygina, 2021, p. 571). This study found that participants exposed to narratives that elicited fear or concern were more likely to acknowledge the reality of climate change. The participants also expressed a greater willingness to engage in pro-environmental behaviors. Those who experienced hope or optimism in response to climate narratives also showed increased motivation to act, but through a more positive lens. Thus, strategically crafted messages that trigger specific emotional reactions can be an effective tool in climate change communication.

Further support for this concept comes from a survey done on adolescent youth’s responses to climate change. Participants who described climate change using “near” discourse reported more concern than those who used “distant” discourse (Busch and Chávez, 2022). While this study does not offer enough evidence to establish a causal relationship, adolescents' emotional engagement with climate change, particularly their concern and anxiety, may contribute to their behaviors and attitudes toward the issue. They believe that "emotional closeness to climate change" is a strong predictor of "pro-environmental behavior" (Busch and Chávez, 2022, p. 352). This insight highlights the need to create educational experiences that connect students emotionally to climate change and improve their motivation to engage in positive, productive, sustainable practices.

Educational programs that inform and support students' mental well-being can help them develop resilience in climate-related challenges. Evans (2019) discusses the projected behavioral impacts of global climate change, highlighting environmental stressors such as temperature elevation, extreme weather events, and air pollution play a role in mental health and social behavior. Moreover, Evans (2019) points out that "extreme weather events, such as floods and severe storms, not only diminish the quality of life but also exacerbate stress and elevate the risk of interpersonal and intergroup conflict" (p. 6.5). This heightened stress can lead to feelings of powerlessness, making it difficult for individuals to engage in meaningful climate action.

Additionally, recreational activities that maintain psychological well-being are impacted by climate change. For example, "outdoor activities can be severely curtailed by extreme weather and rising temperatures," which further limits opportunities for stress relief and social interaction (Evans, 2019, p. 6.13). This reduction in recreational opportunities can contribute to a cycle of stress and disengagement from climate issues. Educational initiatives incorporating stress management techniques and promoting mental health awareness can play a role in breaking this cycle and empowering students to take action.

Create an Inclusive and Safe Space for Dialogue

Creating inclusive and safe spaces for dialogue in climate change education allows students to explore their thoughts and feelings about the issue openly. McGhie (2018) argues that "students must feel safe and supported to express their concerns and questions about climate change" (p. 82). This sense of safety encourages an environment where diverse perspectives can be shared and explored, which is necessary for a comprehensive understanding of climate issues. However, I need to clarify that creating such spaces is not about encouraging the acceptance of false narratives or misinformation, such as climate change denial. Instead, it ensures students can ask questions and express uncertainties without fear of judgment, leading to more productive learning and understanding.

In addition to safety, educational environments should foster inclusivity. More inclusive educational environments may be necessary; "quality education should not only provide knowledge but also develop the skills necessary for students to participate meaningfully in society" (Anderson, 2010, p. 4). Creating these inclusive spaces for dialogue allows students to engage with climate change personally, helping them build the confidence needed to participate in broader societal discussions and actions on the topic. Furthermore, Students and even teachers often struggle to "distinguish among related environmental issues," which can lead to confusion and miscommunication during discussions on climate change (Fortner 2001, p. 18). Therefore, educational settings should be designed to encourage open dialogue and provide the necessary support for all participants to clarify and expand their understanding of complex environmental issues.

Encourage Diverse Perspectives

Incorporating diverse perspectives into climate change education encourages a more comprehensive and empathetic understanding of global environmental issues. Mochizuki and Bryan (2015) assert the importance of adopting an "interdisciplinary and systems perspective" in climate change education, which allows students to appreciate the issue's "scientific, ecological, economic, political, ethical, and social dimensions" (p. 7). This approach enriches students' understanding and encourages them to consider how different cultural and social contexts influence responses to climate change.

By creating educational environments where diverse perspectives are valued, students can develop a deeper appreciation for the complexities of climate change and the importance of global cooperation in addressing it. That is, "inclusive education should provide students with the opportunity to engage with multiple viewpoints" and to "critically examine how climate change disproportionately affects different communities" (Anderson, 2020, p. 5).

Demographic factors also influence shaping students' attitudes and behaviors toward climate change. One study found a correlation wherein "educational systems that adapt to the learning styles and perspectives of different demographic groups" are more effective in promoting pro-environmental behavior (Braun et al., 2019, p. 72). Thus, educators can cultivate a more inclusive and action-oriented approach to climate change education by encouraging students to explore and understand diverse perspectives.

The role of personality traits in shaping students' pro-environmental behaviors is also a consideration. Feelings of "openness and conscientiousness" were predictors of students' likelihood to engage in environmentally friendly actions (Yu and Yu, 2017). These qualities suggest that climate change education could be more effective if tailored to individual differences among learners, enabling a more personalized approach that aligns with students' inherent dispositions towards environmental responsibility.

Focus on Long-term Impact and Behavior Change

Understanding the continued effects of educational interventions can refine strategies and ensure that such knowledge translates into sustained pro-environmental actions. Longitudinal studies on climate change education and research on its long-term impacts enable us to conclude what makes for lasting behavior change; these findings must be considered and used to devise sustainability-themed curricula.

Effective climate education must encourage long-lasting behavioral changes. In a study that adopted a desk methodology, or more commonly, a secondary data collection, Misingi

(2024) found that community participation plays a role in climate change education, particularly in encouraging long-term pro-environmental behaviors. Their study indicates that when students are actively involved in community-based projects and local environmental initiatives, they are more likely to connect with the immediate impacts of climate change in their surroundings. This connection may increase the relevance and urgency of the learning experience.

Climate change education has the potential to instigate meaningful and lasting behavior change. Cordero et al. (2020) conducted a study examining the long-term effects of a university climate change course on students' behaviors, finding that graduates reported "a strong personal connection to climate change solutions," which reflected in their daily habits and professional decisions. The study also quantified the reduction in the cumulative effect of individual carbon emissions, showing that such educational programs can have a measurable impact comparable to other large-scale mitigation strategies.

Additionally, one-off interventions seem to be insufficient and sustained engagement, and education is necessary to maintain pro-environmental behaviors over time. Potentially, "permanent changes in behavior are only possible if education continues continuously" (Howell, 2014, p. 280). Thus, we see a need for ongoing educational efforts that reinforce the importance of climate action and ensure that behaviors are adopted during educational programs after the program ends.

Utilizing Digital and Multimedia Platforms For Long Term Impact

Digital storytelling and interactive media have become relevant tools in climate change education, providing innovative ways to present complex scientific data and engage students. Social network sites (SNSs) offer promising contexts for learning by "supplementing school-based experiences" and providing students with platforms for identity formation and informal learning (Greenhow and Robelia, 2009, p. 121). These platforms enable students to explore their identities and demonstrate 21st-century skills, which can leverage their understanding of climate change through personalized and relatable content.

Digital tools can also encourage sustainable behaviors, noting that "digital platforms can be effective in promoting peer learning and community engagement" (Klaniecki et al., 2019, p. 5). They argue that integrating these tools into climate change education can broaden the scope and influence of such programs, making science more accessible and appealing to students. Educators can create a more immersive learning experience that resonates with students' everyday digital interactions by engaging students in interactive simulations and digital storytelling.

In addition, platforms like Twitter can serve as "imagined communities" where users coalesce around shared interests and concerns, such as climate change (Gruzd et al., 2011, p. 1295). These online communities can amplify the reach of educational content and encourage collective action, making them a powerful tool in the fight against climate change. Educators can tap into students' digital habits by integrating digital storytelling and interactive media into climate change education and creating more engaging and compelling learning experiences. These tools improve understanding and cultivate a sense of community and collective responsibility among learners.

Utilize Interdisciplinary Approaches

Achieving long-term influence and change in conduct through climate education requires integrating knowledge from various disciplines. "Climate change is a problem that touches every area of life, and therefore, it should be integrated into every subject area" (Molthan-Hill et al., 2021, p. 4) This interdisciplinary integration allows students to see the relevance of climate change to their specific fields of study, whether in the arts, sciences, or humanities, thereby encouraging a more comprehensive and engaged approach to learning.

Climate change education should not be confined to the natural sciences, social sciences, health sciences, political perspectives, or ethical and humanistic viewpoints should also be included (Cantell et al., 2019, p. 717). This holistic approach ensures that students understand the broad implications of climate change, including its impact on different sectors of society and the various strategies needed to address it. Furthermore, "students need to be exposed to the complex interrelationships between different ecological, social, and economic systems to fully grasp the challenges posed by climate change" (Anderson, 2020, p. 5). This understanding helps develop practical solutions informed by various perspectives and expertise.

Practical Recommendations

Based on the comprehensive analysis of student engagement strategies, several practical recommendations can be drawn to improve the effectiveness of climate change education in higher learning institutions:

1. Tailored Educational Approaches: Educational strategies should be designed to clarify the distinction between weather and climate, the role of human activities in global warming, and the interconnectedness of Earth's systems. This can be achieved through interdisciplinary learning that integrates climate change's scientific, social, and ethical dimensions.

2. Interactive and Social Learning: Incorporate problem-based learning, collaborative projects, and role-playing exercises to engage students cognitively and emotionally. These methods have been shown to improve understanding and empower students to apply their knowledge in real-world contexts. Results showcase long-term pro-environmental behaviors.

3. Community-Based Learning: Encourage students to participate in community-based environmental projects. Such initiatives make the learning experience more relevant by connecting students to the immediate impacts of climate change. Sustained behavioral changes are also promoted.

4. Emotional and Psychological Support: Recognize the psychological barriers to climate action, such as anxiety and feelings of powerlessness. Integrating stress management techniques and mental health support into the curriculum can help students build resilience and maintain their engagement with climate issues over time.

5. Utilization of Digital Tools: Leverage digital storytelling, interactive media, and social media platforms to broaden the reach and impact of climate education. These tools make complex scientific information more accessible and engaging. They also cultivate a sense of community and collective responsibility among students.

6. Creating Inclusive Spaces: Develop safe and inclusive learning environments where students can openly discuss climate change, explore diverse perspectives, and examine how different communities are affected by climate change. This approach empowers students to engage meaningfully with the issue and contribute to global climate solutions.

7. Long-Term Educational Strategies: Implement continuous and sustained educational interventions reinforcing pro-environmental behaviors. Education should not be a one-time event but an ongoing process that supports students in maintaining their commitment to lifelong climate action.

Conclusion

A multifaceted approach is required to effectively engage university audiences in climate change education. Such an approach requires tailored educational strategies, interactive and social learning, emotional engagement, and interdisciplinary perspectives. Higher learning institutions must go beyond mere instruction to create supportive environments where students are empowered to explore, understand, and act on climate issues. By integrating these strategies, educators can cultivate a generation of informed, resilient, and proactive citizens equipped to tackle the complex challenges of climate change. Ultimately, the goal is to create a lasting impact beyond the classroom, inspiring students to lead sustainable lives and contribute meaningfully to global efforts to combat climate change.

Chapter 2: Data Visualization Strategies

It takes more than just getting the data for individuals to appreciate the complex nature of climate change and how it can profoundly affect people. This chapter explores methods for turning scientific data into user-friendly, interpretable information. These methods can facilitate the acquisition of concrete knowledge and make abstract ideas more readily understandable. The following sections will describe these methods' research basis and practical uses. These ideas will then be applied to the specific case of communicating the issues involved in deciding between options for building a sustainable power plant for the University of Oregon.

Data visualization can play a primary role in making elaborate data sets more understandable. Proper data visualization is often necessary to help individuals synthesize environmental information and make informed decisions. The purpose of visualization is to simplify complex ideas and display them in a manner easily understood by others. Visualization techniques can aid public discourse and, in so doing, improve policy-making decisions. The insights described in this section serve as a guide for producing impactful visual representations of climate data.

Principles of Effective Data Visualization

Select Appropriate Charts and Highlight Crucial Information

Selecting the appropriate type of chart for the data is a foundational first step of designing visual representations of information. Bar charts are, in practice, particularly effective for comparing quantities, while line graphs are ideal for showing trends over time. Choosing the wrong type of chart can lead to misinterpretation of the data, as each has strengths and weaknesses depending on the data it represents. Huang (2014) also discusses the cognitive benefits of using specific chart types, noting that visualizing temporal data with line graphs, for example, aligns well with the human tendency to perceive time as linear, enhancing comprehension.

Creating explicit annotations and labels that highlight important data points and offer context should be considered. Well-placed labels and annotations can guide the viewer's attention to the most crucial aspects of the data, which enhances understanding (Huang, 2014). Similarly, concise and informative annotations can make complex data more accessible. This practice helps ensure that users do not miss information and can more easily interpret the data presented.

Keep the data/ink ratio high

All visual elements should directly contribute to information communication. Non-essential decorative elements should be minimized. Edward Tufte emphasizes that "Less is more" in visual communication (Tufte, 1983). Any elements that do not aid in understanding the data should be removed. This is relevant when dealing with complex data involving multiple variables this. For example, 3D effects (see Figure 1) might improve the appeal of data visualizations, but they often complicate interpretation when representing 2D data. 3D effects can distort the viewer's perception and make accurate comparisons more challenging (Tufte, 2006; Nguyen et al., 2021). For instance, a 3D bar chart can obscure the relative sizes of the bars, leading to a "false impression of a substantial and continuous increase" Tufte, E. R. (2001).

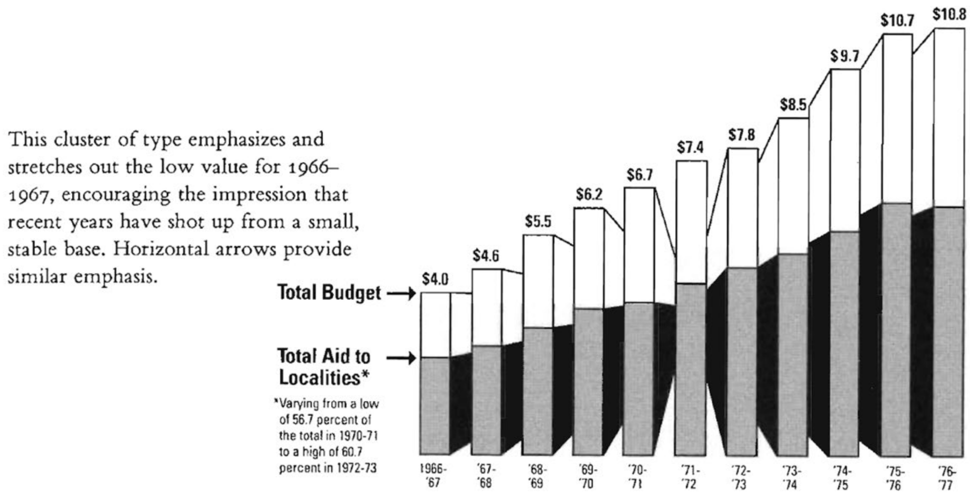

Figure 1: New York Times, February 1, 1976, p. IV-6

Tufte, E. R. (2001). uses this Fiscal 66-76 New York State Total Budget Expenditures and Aid to Localities (In billions of dollars) graph to demonstrate how data placed in a 3D space, such as in the graph above, can create a false sense of "budgets towering over the older ones."

Figure 2 shows how the data from Figure 1 would appear with the 3D effect removed. The increase from year to year is much less dramatic than in the former 3D display of the information. This common mistake of overcomplicating visualizations with too many elements or data points is famously criticized and named "chartjunk" (Tufte, 2001). This includes unnecessary or overly complex decorative elements that do not contribute to understanding and detract from the data. Visualizations cluttered with excessive labels, colors, or lines can overwhelm the viewer, making it difficult to discern the main message. The key is to focus on clarity and simplicity, ensuring that every element of the visualization serves a purpose and contributes to the overall understanding of the data.

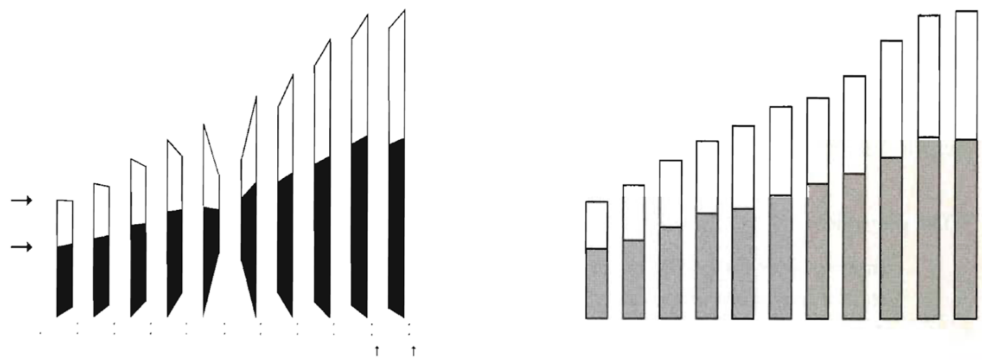

Figure 2: Fiscal 66-76 New York State Total Budget Expenditures and Aid to Localities (In billions of dollars) with “chartjunk” removed.

This approach aligns with similar guidelines from other data visualization professionals like Kelleher and Wagener's (2011). Their guidelines stress the importance of avoiding redundant elements in data visualizations. They argue that adding unnecessary features to a graph complicates the display and detracts from the data's intended message. For example, they warn against using complex, multi-layered charts when simpler alternatives, such as bar or line charts, could convey the same information more clearly.

Maintain Consistent Scales and Visual Elements

Shared visual language, where elements like colors, scales, and symbols are used consistently to help viewers connect across different visualizations, needs to be ensured (Tufte, 1997). This consistency not only aids in comparison but also comprehension, allowing the audience to trace trends and patterns more easily. It also helps to build familiarity, which in turn improves understanding. For example, using the same color scheme across a series of related charts can help viewers quickly identify and compare related data points, making the overall message of the visualization more impactful.

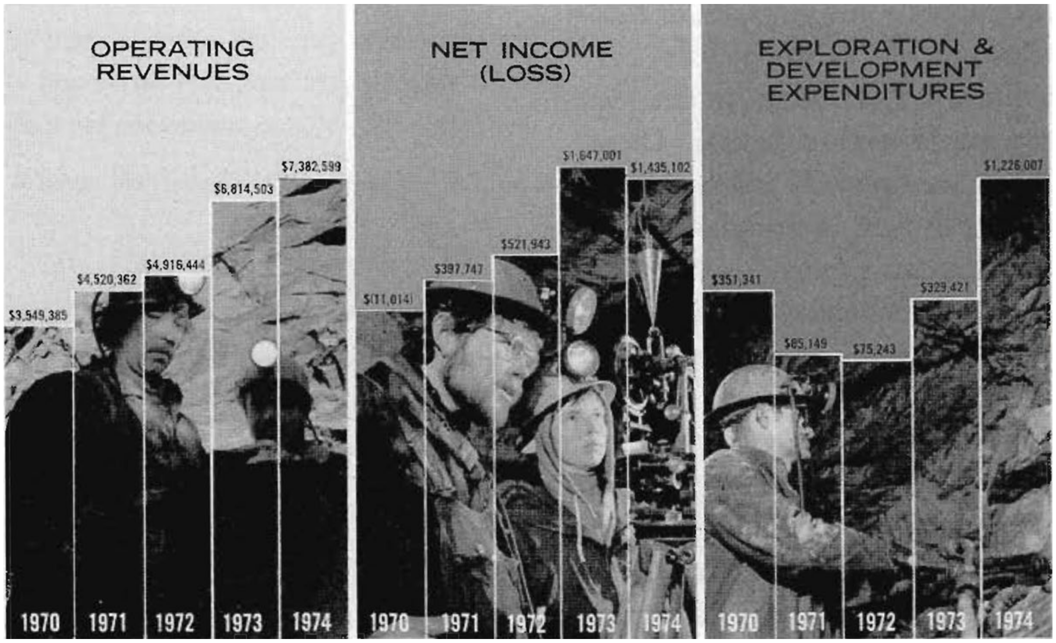

Figure 3: Day Mines, Inc., 1974 Annual Report p. 1.

This is an alarming display of misleading quantitative information due to inconsistent baselines. "The disappearing baseline in the annual report of a company that would just as soon forget about 1970. A careful look at the middle panel reveals a negative income in 1970, which is disguised by having the [bar for Net Income in 1970] begin at the bottom at approximately minus $4,200,000" Tufte, E. R. (2001)

One of the most frequent errors in data visualization is the manipulation of axes or scales, which can distort the viewer's perception of the data. For example, the Day Mines, Inc. annual report (Figure 3) shows the misleading effects of not maintaining a consistent baseline. The result is a disguised negative income in 1970. Truncating the y-axis or exaggerating scale differences can create misleading impressions of the data, making changes appear more dramatic than they are (Nguyen et al., 2021). This can lead to incorrect conclusions, especially in contexts where precise interpretation of data trends is needed. This is particularly problematic in scientific publications, where precision is paramount. The consensus among experts is clear: Visualizations must present data truthfully, without manipulation or distortion, to maintain the audience's trust and ensure that the data serves its intended purpose.

Proper Use of Color and Potential Cultural Implications

Using color in data visualizations must be deliberate and based on understanding cognitive and perceptual factors. Different color scales, such as multicolored versus ordered brightness scales, can affect a viewer's ability to perform identification and comparison tasks (Breslow et al., 2009). For example, multicolored scales are more suitable than ordered brightness scales for identification tasks, where users must determine specific values. In contrast, ordered brightness scales are better than multicolored scales for relative comparisons, such as deciding which of two items is more valuable to highlight. Additionally, visual elements such as color, shape, and layout can impact the viewer's ability to interpret the data accurately (Marchak et al., 1993). For instance, contrasting colors can help differentiate between different data sets, making it easier for the viewer to compare and analyze the information.

When designing data visualizations for a global audience, one should consider the cultural implications of color choices. Colors can carry different meanings across cultures, impacting how visualization is perceived and understood. For example, in many Western cultures, red signifies danger or a need to stop, while green conveys safety or a signal to proceed. However, in some Eastern cultures, red is associated with good fortune and celebration. Although red has been adopted for stop signs by most countries, there is still potential for different interpretations of the exact visualization. Designers must be aware of these potential cultural differences to avoid miscommunication. One approach to mitigating this risk is to use more neutral colors that carry less cultural baggage and to ensure clear legends and explanations that guide interpretation are provided.

Additionally, designers should consider the context in which the visualization will be used. If design elements can be interpreted differently due to culture, they should be avoided. By being mindful of these cultural factors, data visualizations can be made more universally accessible and meaningful, ensuring the intended message is communicated to all viewers.

Reduce Mental Effort with Effective Cognitive Models

One of the central concepts in cognitive psychology relevant to data visualization is cognitive load theory (CLT), which refers to the amount of mental effort required to process information. According to Akram and Fang (2015), visualizations should be designed to minimize extraneous cognitive load, allowing users to focus on the correct aspects of the data. Well-structured and intuitive visualizations can reduce the mental effort required to interpret complex information, thereby improving comprehension and retention (Akram and Fang, 2015).

Using the insights from psychological researchers, one can apply specific cognitive models to designing data visualizations. Cognitive models such as working memory and attention processes are used to understand how users process visual information. Hegarty (2011) explains that compelling visualizations should help offload cognitive tasks, such as searching for data or comparing values, by presenting the data spatially to organize information clearly and intuitively. For example, graphs can offload cognitive effort by grouping similar entities spatially, reducing the cognitive load required to search for relevant data. The combination of perceptual processes and prior knowledge enables users to create meaningful interpretations of complex data, making visualization a more effective cognitive tool. Additionally, visualizations can take advantage of automatic perceptual processes, such as detecting trends in a line graph, facilitating quicker understanding without overwhelming cognitive capacity (Hegarty, 2011). By being mindful of these cognitive models, designers can create visualizations designed to maximize clarity and reduce mental effort.

Guide the Viewer's Decision-Making

Compelling visualizations guide the viewer's attention to the most crucial aspects of the data, ensuring that the essential information is not overlooked (Alhadad, 2018). In complex visualizations where multiple data points are presented simultaneously, the viewer should not have to exert much energy to uncover insights. Effective data visualization should present information and weave it into a compelling narrative that resonates emotionally with the audience (Krum, 2014). By framing data within a narrative context, visualizations become more engaging and memorable, enhancing the overall impact and persuasiveness of the information conveyed.

Furthermore, data visualizations can be a powerful, persuasive tool when designed with specific goals. Visual representations, particularly charts and graphs, influence an audience's attitudes and decisions compared to textual data (Pandey et al., 2014). However, this should not be interpreted to mean that text-based tables are never helpful. While graphs are effective for illustrating general patterns and trends, tables are better suited for making precise comparisons and presenting detailed numerical information. In contexts such as climate change communication, where the goal is to persuade diverse audiences to take action based on scientific data, graphs and tables might be necessary. Visual data may be more persuasive for those without pre-existing solid opinions, but tables are useful when accuracy and detailed comparisons are required. Combining both formats allows for a more comprehensive and effective communication strategy.

The impact of data visualization on decision-making is also evident in its ability to simplify complex data sets into more digestible formats. Visualizations can make large-scale data more accessible, allowing users to quickly grasp trends and insights (Pandey et al., 2014).

However, not all data can be simplified without losing details. In such cases, the key is to provide users with the specific data they need to make informed decisions. For instance, if a decision requires understanding a cost-benefit ratio, the visualization should present that ratio directly rather than forcing the user to calculate it from separate components. If the individual parts are also necessary, they should be displayed alongside the ratio to provide a complete picture. This approach ensures that decision-makers can access the relevant information in a form that supports effective decision-making, especially in complex areas like climate change communication**,** where data complexity often overwhelms both expert and non-expert audiences.

Incorporate User Feedback to Address Cognitive and Perceptual Needs

User-centered design (UCD) in data visualization is an approach that prioritizes the needs, preferences, and cognitive styles of end-users interacting with the visualized data. By focusing on the user, designers can create visualizations that are effective in communicating information and accessible, engaging, and tailored to the specific audience.

A fundamental aspect of UCD is understanding the cognitive and perceptual needs of the users. Users process information differently, influenced by their prior knowledge, cognitive styles, and professional background. Users' cognitive styles, whether analytical or holistic, can impact how they interpret data visualizations (Huang, 2014). Analytical users prefer detailed visualizations that allow for deep data exploration, while holistic users benefit more from summary visualizations that present the big picture. Recognizing these differences enables one to cater to the diverse cognitive needs of an audience.

Additionally, UCD practices encourage incorporating user feedback throughout the design process. Visualization designs should not be static but evolve based on how users interact with them. This applies to both static visualizations and computer-based interactive displays This iterative design process involves creating prototypes, gathering user feedback, and refining the visualization to meet user needs better. User testing is used to identify usability issues early in the design process. Through user testing, designers can observe how users interact with the visualization, where they encounter difficulties, and how they interpret the information presented (Perdana et al., 2019). This feedback is invaluable for making adjustments that improve the overall user experience.

However, there’s a distinction between what users need to make informed decisions and what they prefer regarding visual design. While users' preferences should be considered to improve engagement and satisfaction, the primary goal must always be to ensure that users have access to the information they need for decision-making. The iterative approach increases the likelihood that the final product is user-friendly, visually appealing, highly functional, and aligned with the users' decision-making goals. By prioritizing the delivery of information in an accessible format, this user-centered refinement process helps fine-tune the visualization’s effectiveness, ultimately supporting more informed and effective decision-making.

Balance Complexity and Usability Through Interactive Displays

Interactive elements, such as clickable data points or adjustable parameters, can improve user engagement and decision-making outcomes (Perdana et al., 2019). This interaction can support a deeper engagement with the data and helps users uncover insights not apparent in static visualizations. However, the effectiveness of these interactive displays can be limited for naive audiences who may not know how to interact effectively with the data. Without proper guidance, users might miss comparisons or fail to explore aspects of the data. This challenge can be addressed by incorporating a guided tour or animation before users are allowed free interaction.

This can provide context and direction, ensuring users make the most of the interactive features and enabling them to uncover insights not apparent in static visualizations.

A note on interactive displays is that while this approach could transform passive viewers into engaged participants, this method is limited by the necessity for digital displays. Even though most university students own personal laptops or similar technologies, this cannot be an assumption. Interactive displays have many benefits, but there needs to be static versions of the displays or accommodations for students without access to the necessary technologies. Furthermore, while interactive displays might create new barriers, they could also address some. For example, for people with vision impairments, digital zoom features can make interpreting visualizations more accessible (Marchak et al., 2011). Hewett (1999) adds that the increasing diversity of users and the abstractness of data representations demand interactive tools that can adapt to different cognitive styles and user needs.

When designed thoughtfully, interactive displays can facilitate better cognitive processing by allowing users to simultaneously explore different data dimensions (Wickens et al., 2021). This is particularly relevant when the data involves multiple variables that are difficult to represent in a traditional two-dimensional format. Wickens and his co-authors highlight that while such interactive elements can improve user engagement and comprehension, they must be carefully crafted to avoid overwhelming the user and to ensure that the information is easily accessible. Integrating these principles into data visualization strategies can improve the user's understanding and interaction with complex datasets, ultimately leading to more informed decision-making.

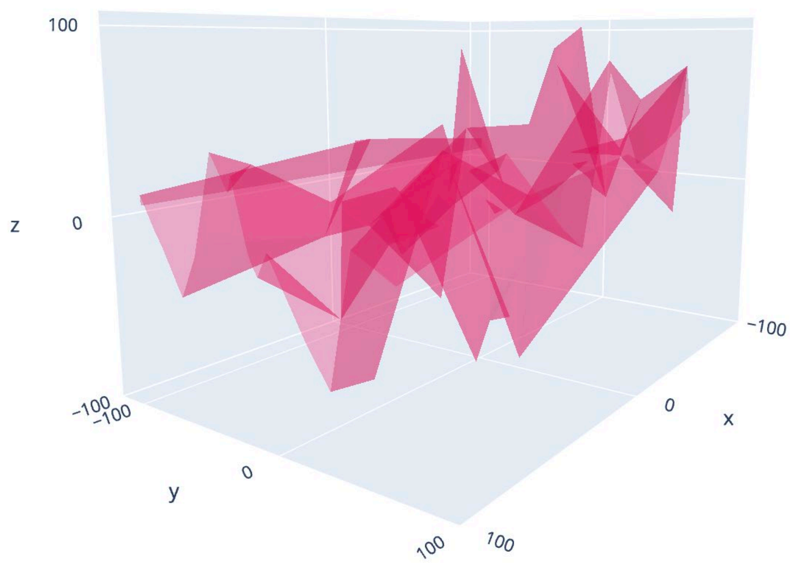

Figure 4: 3D Visualization Example Using Plotly Python Library

When attempting to visualize data in multiple dimensions, seeing all data points on one static graph is impossible. For example, using the plotly library, a multidimensional plot (see Figure 4) can be created with only a few lines of code. The benefits of features made available through interactive displays are valuable when dealing with multidimensional data that must be presented in a two-dimensional format. Figure X can be rotated on any axis to better view the data. One could also hover over a specific location within the graph and receive the related information in a pop-up. Engaging with multiple aspects of the data within a single display partially overcomes the inherent challenges of representing complex, multidimensional information on a flat surface. By enabling users to explore specific aspects of the data in greater detail, these interactive elements make visualizations more informative and personalized.

Practical Applications in Climate Change Communication

Data visualization plays a large role in effectively communicating the complexities of climate change to a wide range of audiences, including policymakers, scientists, and the general public. By transforming intricate datasets into accessible visual formats, these tools help convey the urgency of climate issues and support informed decision-making.

One practical application of data visualization in climate change communication is representing greenhouse gas emissions data. Visualizing emissions data across different sectors or geographic regions can highlight the most impactful contributors to global warming, making it easier for policymakers to identify priority areas for intervention. For instance, interactive maps that show real-time emissions data allow users to explore how emissions vary by country, industry, or period, providing a clear and compelling narrative of where and how reductions are most needed. This can be particularly effective in international negotiations, where visualizations can clarify the commitments and progress of different nations.

Another application is in visualizing the impacts of climate policies. Visualizations can demonstrate the potential long-term benefits or consequences of different policy choices by comparing scenarios with and without specific interventions. For example, line graphs showing projected temperature increases under various emissions scenarios can help policymakers and the public understand the stakes involved in delaying action versus implementing aggressive climate policies now. However, a component often omitted from these projections is the estimated variability or uncertainty in the data. This omission can lead users to perceive the projections as certainties falsely rather than understanding that any forecast has inherent and quantifiable uncertainty. Incorporating this variability into visualizations can provide a more nuanced view, helping to convey that while a particular trend is likely, the exact outcome may vary. This approach makes abstract concepts like future temperature rises more concrete and relatable and facilitates better-informed discussions and decisions by accurately representing the complexities and uncertainties involved.

Data visualizations are also instrumental in educating the public about the effects of climate change on local environments. Interactive tools that allow users to see how climate change could impact their specific regions, weather patterns, sea level rise, or shifts in local ecosystems can make the issue more tangible and personal. This localized approach helps to overcome the psychological distance often associated with climate change, making it more likely that individuals will engage with and support climate action.

Moreover, visualizations can help bridge the gap between scientific research and public understanding. Complex climate models, which predict future climate conditions based on various inputs, can be challenging to interpret without appropriate visual aids. By translating these models into clear, easy-to-understand graphics, scientists can more effectively communicate their findings to non-expert audiences. For instance, using simplified visual models to illustrate the relationship between carbon emissions and global temperature increases can help demystify the science behind climate change, encouraging broader public support for necessary mitigation measures.

Data visualization is an indispensable tool in climate change communication. It provides clarity and accessibility to complex data, making climate information more understandable and actionable. Visualizations improve public awareness and empower decision-makers to implement effective climate policies.

Conclusion

Data visualization is a powerful tool that transforms complex datasets into understandable and actionable insights. It plays a pivotal role in various domains, particularly climate change communication. By adhering to the principles of clarity, simplicity, accuracy, consistency, and engagement, data visualizations can effectively convey information to diverse audiences, from policymakers to the general public.

Applying well-chosen techniques, such as appropriate chart selection, careful use of color, and interactive elements, ensures that visualizations are informative but also engaging and accessible. Additionally, the psychological and cognitive aspects of how individuals process and retain visual information must be considered to maximize the effectiveness of data visualizations.

User-centered design further improves visualizations' impact by tailoring them to meet different users' specific needs and preferences, ensuring that the information presented is understandable and relevant. By prioritizing the user experience, data visualizations can become more intuitive, inclusive, and effective in supporting decision-making processes.

In the context of climate change communication, data visualization can translate complex scientific data into compelling visual narratives that can drive informed action. Whether through visualizing emissions data, illustrating the impacts of climate policies, or educating the public about local climate effects, these tools are vital for engaging audiences and promoting sustainable solutions.

Ultimately, data visualization in climate change communication can bridge the gap between scientific knowledge and public understanding, encouraging a more informed and proactive global community.

Chapter 3: Effectively Communicating Complex Environmental Concepts

Environmental issues, like many complex problems, are difficult to contextualize, presenting challenges when engaging broad audiences. In an era where democratic institutions increasingly rely on technological and scientific sophistication, the challenge of effectively communicating these issues is becoming more pressing. Standard communication approaches often rely on scientific terminologies and in-depth figures, which may not resonate with non-experts. This is not limited to environmental communication; it's a broader challenge affecting many domains where specialized knowledge supports informed decision-making.

To bridge this gap, analogies have emerged as "mental tools that assist in demystifying complex ideas by linking them with more familiar concepts" (Jones et al., 2011, p. 46). The effectiveness of an analogy hinges on its ability to draw parallels between a source domain (familiar) and a target domain (unfamiliar), allowing individuals to construct new knowledge structures that align with their existing cognitive frameworks. This strategic use of analogies might improve comprehension when engaging university audiences, a group characterized by their varying levels of prior knowledge, diverse disciplinary backgrounds, and potential for future leadership in addressing global challenges.

The role of analogies as fundamental aspects of environmental communication will be examined in this chapter. I start by investigating the psychological basis of analogies and evaluating the pros and cons. Then, I use the research insights to offer suggestions for crafting successful analogies, with examples from real-life illustrations that have worked in the past. Even though this discussion concentrates on the college audience, these findings and examples utilize commonly known concepts and vocabulary. Thus, they can be applied to engaging people from diverse backgrounds in constructive talks about ecological sustainability. The aim is to empower educators and communicators with resources for inspiring different kinds of public towards environmental responsibility learning for sustainable solutions.

Theoretical Foundations of Analogies

The Brain's Natural Tendency to Use Analogies

In education and communication, analogies are highly effective because they leverage the brain's natural tendency to recognize patterns and make associative connections. According to Bar (2007), the human brain is "wired to use analogies and associations to generate predictions" (p. 280), which might explain the effectiveness of analogies in facilitating understanding. Analogies can improve comprehension and memory retention by linking new information with pre-existing cognitive structures.

Neural Networks and Cognitive Structures

Cognitive science research reveals that analogies activate neural networks related to familiar concepts, providing a foundation for understanding new information. García-Carmona and Acevedo (2016) emphasize that analogies are particularly potent when they are "accurate, interestingly crafted, and capable of correct extrapolations from known to unknown" (p. 1002). This process improves comprehension and memory storage, making analogies valuable in educational settings.

Contextual Relevance and Cultural Appropriateness

For an analogy to be truly effective, it must be contextually relevant and culturally appropriate. Comfort and Park (2018) assert that selecting a familiar source domain is helps ensure that the audience can quickly grasp the target concept. This selection aids in understanding and raises levels of cognitive engagement, which helps convey complex environmental concepts.

Simplifying Complex Concepts

In environmental communication, analogies are powerful because they translate complex scientific ideas into practical, understandable terms. For instance, comparing the Earth's atmosphere to a greenhouse vividly illustrates how greenhouse gases trap heat, leading to global warming. This analogy effectively breaks down the science behind the greenhouse effect, making it understandable for non-experts (Nisbet & Scheufele, 2009).

The strength of analogies lies in their ability to translate complex scientific phenomena into simple, everyday terms. For example, explaining ocean acidification by likening it to adding lemon juice to water, which increases its acidity, helps clarify how carbon dioxide dissolving in the ocean impacts marine life. This approach simplifies the science while illustrating the potential consequences in a way that is both memorable and understandable (Feinberg & Willer, 2013).

Moreover, analogies may help highlight the cascading effects of environmental changes. Describing deforestation as "taking out the lungs of the world" succinctly conveys forests' role in absorbing carbon dioxide and producing oxygen. This analogy helps people quickly grasp the broader environmental impact of deforestation, making the concept more relatable and urgent (Clayton, 2010).

Relating to Everyday Experiences

Furthermore, analogies can demonstrate how individual actions affect the environment. For example, the analogy between energy conservation efforts and "going on an energy diet" effectively communicates the need to reduce energy consumption to mitigate environmental impacts. By associating energy use with the everyday experience of managing a diet, this analogy makes the abstract notion of energy conservation more concrete and actionable (Spence & Pidgeon, 2010). This approach emphasizes the broader implications of personal behavior on environmental sustainability, encouraging a deeper understanding and commitment to responsible energy use.

Enhancing Retention and Recall

Analogies can improve memory retention by creating vivid and relatable mental images. Comparing new information to what is already known prompts deeper cognitive processing, leading to improved comprehension and retention. This is particularly beneficial in environmental communication, where scientific concepts are often challenging to convey to a broad audience. However, the effectiveness of an analogy hinges on its accuracy and relevance. Misleading analogies can lead to misunderstandings if the connection to the target domain is tenuous or if the analogy implies inaccuracies when applied to the concept. While analogies are invaluable in making complex scientific information more accessible, their utility depends on their aptness. Analogies must be carefully crafted to ensure they accurately represent the target concept, avoiding any potential for misinterpretation or confusion.

Furthermore, not all analogies are equally effective. While popular, the "carbon footprint" metaphor may not fully capture the lasting impact of human activities on the environment. Footprints, by nature, are transient and do not convey the permanent damage that carbon emissions can cause. A more impactful analogy might be likening carbon emissions to a "carbon tattoo," emphasizing the enduring and often irreversible mark our actions leave on the planet.

Moreover, analogies can create emotional connections that strengthen retention. For instance, the metaphor of biodiversity loss as the "disentangling of life's fabric" evokes a powerful image of the intricate interrelation between species and ecosystems. This metaphor emphasizes how unraveling one part of the natural world can lead to the collapse of others, encouraging a more profound emotional commitment to addressing environmental issues.

Crafting Effective Analogies for Environmental Issues

Identify the Core Message

The first step is to identify the central message or concept that needs to be communicated, which forms the basis of a good analogy. This initial stage helps keep the analogy on track and avoid confusion or misinterpretation (Spence & Pidgeon, 2010). For instance, in explaining climate change, one may need to convey that greenhouse gases have accumulated over time as key information for laypersons.

To communicate such an idea effectively, complex scientific details should be simplified into their basic building blocks. The present technique revolves around understanding the most relevant parts and how they relate. By dividing the scientific notion into more manageable pieces, analogies can become more accessible with familiar experiences or objects (Jones et al., 2011). This clarifies the central theme and lets audiences quickly understand what is at stake in any message transmitted.

Select Relatable Comparisons

The chosen analogy must be culturally and contextually relevant to be easily understood and related. When creating comparisons, the audience's backgrounds and previous experiences should also be considered. Analogies built on universally experienced situations or widely understood concepts have higher chances of success across diverse audiences. For instance, likening the movement of pollutants in a water body to how ink spreads in water when one drops one is an easy yet powerful way of explaining diffusion and environmental pollution (Nisbet & Scheufele, 2009).

Balance Accuracy and Simplicity

Analogies are used to simplify complex issues so that lesser mortals might comprehend them. If an analogy is oversimplified, it may lead to misunderstandings, undermining its educational value. Good analogies, however, aim to bring out the meaning in simple terms by maintaining their meanings about science (Jones et al., 2011). For example, the "greenhouse" analogy would be suitable for explaining the greenhouse effect, but it must be coupled with compensating explanations showing its limitations and specifics.

Analogies best serve as a helpful starting point, prompting a more profound exploration on a subject matter. This means providing more context and detailed explanations after introducing the analogy to ensure the audience also gets the clarifying information. According to Spence and Pidgeon (2010), such a layered approach enriches the initial explanation and can stimulate further inquiry and education. While it is an exciting idea that an analogy requiring additional explanation could engage more attention and interest, this is more of a theoretical suggestion rather than a claim backed by substantial empirical evidence. Therefore, while complex analogies may encourage deeper engagement for some, they might also risk losing the audience if not handled carefully.

Test and Refine Analogies

To create effective analogies in environmental communication, gathering feedback from various audiences and refining the analogies accordingly enables better outcomes. This process, often iterative, ensures that the analogies are understandable, engaging, and capable of effectively conveying the intended message (Bar, 2007). Methods such as surveys, focus groups, and pilot studies can be instrumental in assessing the impact and comprehension of the analogy. Through feedback, communicators can identify areas that may be unclear or need improvement, making the analogy more meaningful and accessible (Nisbet & Scheufele, 2009).

It should be recognized that a single analogy might not resonate equally across different groups. Other audiences may interpret analogies differently based on their backgrounds, disciplines, and familiarity with the topic. Therefore, communicators should consider tailoring analogies to fit the context and audience. This approach may involve creating different analogies for diverse groups rather than attempting to devise a one-size-fits-all solution.

Crafting successful environmental communication analogies requires a deliberate and systematic approach. The key is clearly identifying the central message, selecting applicable comparisons, balancing simplicity and accuracy, and continuously refining the analogy based on feedback. While striving for accuracy, one must consider the trade-off between being entirely precise and ensuring understandability. The goal is to remain truthful and accurate while making the concept accessible. This careful balancing act ensures that analogies effectively improve understanding and retention of complex ecological issues.

Examples of Effective Environmental Analogies

Classic Climate Change Related Analogies

The Greenhouse Effect is one of the most well-known analogies used to describe Earth's climate change. It compares the Earth's atmosphere to a greenhouse, illustrating how certain gases like carbon dioxide and methane trap heat from the sun. This trapped heat leads to global warming, like how a greenhouse retains heat to sustain plant growth. The effectiveness of this analogy lies in its ability to distill complex scientific processes into a visual and easily understandable concept. By framing the atmospheric accumulation of greenhouse gases in this way, the analogy helps people understand the importance of reducing emissions to mitigate climate change (Nisbet & Scheufele, 2009). However, while greenhouses are used to nurture life, the unchecked accumulation of greenhouse gases could have catastrophic effects on life as we know it. Thus, while the analogy is effective, it oversimplifies the potential consequences, highlighting the challenge of determining when an analogy is "close enough" to be helpful.

Another common analogy is the Carbon Footprint, which explains individual and collective carbon emissions by comparing them to footprints that leave marks on the environment. This metaphor simplifies the abstract concept of carbon emissions by likening them to physical footprints, emphasizing our actions' lasting impact on the planet. Just as footprints in the sand show where we have been, carbon emissions illustrate the environmental impact of our behaviors. The analogy makes the issue personal and relatable, encouraging sustainable actions to reduce one's "footprint." However, a fundamental limitation of this analogy is that footprints in sand eventually disappear, leaving no permanent damage, whereas carbon emissions can cause long-lasting environmental harm. This raises the question of how close an analogy must be to convey an issue's seriousness effectively.

Biodiversity and Ecosystems Related Analogies

The metaphor of an Ecosystem as a Web is a powerful tool for discussing biodiversity and ecosystem interdependencies. This analogy presents ecosystems as complex webs where each strand represents a species or ecological process, and the interconnectedness highlights how disturbances in one area can affect the entire system. For example, when comparing an ecosystem to a spider's web, the analogy suggests that if one strand is severed, the balance of the web—and, by extension, the ecosystem—is disrupted. This analogy is effective because it simplifies the complexity of ecological relationships and makes the concept accessible to a broader audience. However, the analogy has limitations. At the same time, the image of a collapsing web effectively conveys the idea of fragility; in reality, ecosystems often possess resilience, much like how a spider can quickly repair its web (Norgaard, 2010). This nuance, especially when addressing audiences with a deeper understanding of ecological systems, underscores the balance between conveying simplicity and maintaining scientific accuracy.

Keystone Species is another analogy that compares these species to a keystone in an arch, thus maintaining the structure's integrity. Just as removing the keystone can cause an arch to collapse, losing a keystone species can lead to disruptions in an ecosystem. This analogy emphasizes these species' roles in maintaining ecological balance, highlighting the potential consequences of their decline or extinction. This comparison is particularly effective in illustrating the concept of environmental balance to non-expert audiences. However, while keystone species are vital, ecosystems may not collapse instantly without them; instead, they may gradually degrade, which is a distinction for scientific accuracy (Clayton, 2010).

Pollution and Waste Management Related Analogies

The Earth's Circulatory System analogy is particularly apt when discussing pollution and waste management. It compares water pollution to toxins in the human bloodstream, illustrating how pollutants can spread through water systems and affect various ecosystems. Just as toxins in the blood can harm different organs, contaminants in water can disrupt the health of numerous ecosystems. This analogy is effective because it directly connects human and environmental health, making the issue more relatable and urgent for the audience (

, 2018). However, the analogy also broadens concern beyond human health, prompting consideration of the environment as an interconnected system where the well-being of one part affects the whole.

Another powerful metaphor is Trash as a Boomerang, which illustrates how poor waste management practices eventually lead to environmental degradation that ultimately affects human health and quality of life. The boomerang analogy emphasizes that environmental negligence has direct and indirect consequences, reinforcing the importance of responsible disposal practices. This metaphor is particularly effective in communicating the long-term impacts of pollution, making the consequences of inaction clear and immediate for the audience (Norgaard, 2010).

Sustainable Practices Related Analogies

The Energy Diet analogy is a relatable and compelling metaphor for discussing sustainable practices. It likens the effort to conserve energy to dieting, where reducing energy consumption is akin to cutting calories for better health. This analogy is powerful because it connects the abstract concept of energy conservation to a familiar and concrete human experience, making reducing energy use more accessible and actionable for individuals. However, while the metaphor is effective, it may oversimplify the complexities of energy conservation, which involves systemic changes and individual actions.

Another vital metaphor is the Ecological Footprint analogy, which uses the image of a footprint to represent the impact of individuals' and societies' actions on the environment. This metaphor effectively translates the abstract concept of ecological impact into a tangible and visual form, prompting people to consider the environmental consequences of their behaviors. The analogy encourages people to adopt more sustainable practices by making this abstract concept more relatable. However, while footprints are typically temporary, the environmental impacts represented by the metaphor can be long-lasting, which is a distinction for understanding the true nature of our ecological footprint.

Analogies can be a powerful tool for engaging a broad audience on technical topics. Now that successful analogies have been established that we can refer to, let’s move forward into chapter 4 and begin applying the theory from the first three chapters to the University of Oregon Thermal System Transition.

Chapter 4: Applying Engagement, Visualization, and Analogy Strategies to the University of Oregon's Thermal Systems Transition

The previous chapters have explored the theoretical foundations and practical strategies for engaging stakeholders, effectively visualizing data, and utilizing analogies to communicate complex ideas. These approaches can be applied in real-world scenarios, such as the University of Oregon’s effort to transition its thermal systems to more sustainable practices. This chapter applies these strategies to a concrete case, illustrating how they can improve decision-making and stakeholder engagement in a university setting.

This chapter attempts to apply the engagement, visualization, and analogy strategies discussed in the previous chapters to the specific context of the University of Oregon’s thermal systems transition. Furthermore, this chapter bridges abstract principles and their real-world application, demonstrating how engagement, visualization, and analogy can improve decision-making and stakeholder involvement in institutional sustainability efforts.

Following this overview, the chapter delves into Engagement Strategies for the University of Oregon’s Thermal Systems Transition. This section discusses the importance of stakeholder engagement in ensuring that the chosen thermal system aligns with the university community's values and concerns. It outlines the specific engagement strategies employed by the task force, such as public forums, surveys, and targeted outreach. It assesses their effectiveness in encouraging a well-informed and supportive community.

The following section, Data Communication Strategies for the University of Oregon’s Thermal Systems Transition, focuses on the role of data visualization in making complex information accessible to a broad audience. It reviews the various graphs and charts the task force used to communicate the proposed options' financial implications, emissions reductions, and other key aspects. This section evaluates the effectiveness of these visualizations in conveying information and enabling stakeholders to make informed decisions.

Finally, the chapter introduces an Interactive Dashboard Concept to address the limitations identified in the task force’s visualizations. The dashboard provides a more dynamic and user-friendly platform for exploring the trade-offs between different heating system options. The Dashboard Concerns and Areas for Improvement section further critiques the dashboard’s design, offering suggestions for enhancing its effectiveness as a decision aid by aligning metrics with decision criteria, incorporating user-specific considerations, and improving interactivity and transparency.

Contextual Overview

The University of Oregon has long been committed to addressing climate change, a global challenge that requires bold and innovative approaches. This commitment was formalized in 2007 when the university adopted the American College and University President's Climate Commitment (ACUPCC), leading to the development of its first Climate Action Plan (CAP 1). CAP 1 set the ambitious goal of eradicating institutional greenhouse gas (GHG) emissions by 2050. Despite the progress, it became clear that more aggressive and practical measures were necessary to meet these objectives.

In response to these challenges, the University of Oregon launched its second Climate Action Plan (CAP 2) in 2019. A key focus of CAP 2 was reducing the emissions from the university’s steam-based district heating system, a large contributor to its carbon footprint. This system relies on natural gas and has been identified as an obstacle to achieving the university’s sustainability goals.

Affiliated Engineers Inc. (AEI) conducted an initial study in 2022 to explore viable alternatives, identifying multiple pathways for transitioning to a lower-emissions heating system. Building on these findings, the university engaged Burns & McDonnell to perform a more detailed cost-effectiveness and feasibility analysis of the proposed options.

Recognizing the complexity and magnitude of the decisions ahead, Interim President Phillips established the Thermal Systems Transition Task Force in late 2022. This task force, included students, faculty experts, senior administrators, and members of the Board of Trustees. Its charge was to review technical studies and regulatory and market structures, identify additional analyses needed, and create a forum to inform the university community on the options available for replacing the University of Oregon's heating infrastructure. Furthermore, the Task Force was tasked with incorporating public input and recommending a long-term plan to the President. This plan needed to balance multiple factors: the reduction of greenhouse gas emissions, assessment of technical feasibility risks, the resiliency of campus heat production to energy market fluctuations and natural hazards, minimal disruption to the student campus experience, and maintaining appropriate fiscal stewardship.

The charge given to the Thermal Systems Transition Task Force directly intersects with the core themes of engagement, visualization, and analogy strategies explored in the preceding chapters. The task force's mandate to balance environmental sustainability, technical feasibility, financial responsibility, and minimal disruption requires clear communication and active stakeholder engagement—areas where effective data visualization and analogy can improve decision-making. This chapter attempts to demonstrate how these strategies can be applied to support the task force in fulfilling its charge, ensuring that the recommended solutions are technically and financially sound, well-understood, and supported by the university community.

By applying these strategies, this work seeks to contribute to a more informed and engaged decision-making process, ultimately aiding the university in its commitment to sustainability and responsible governance.

Background: Proposed Options

In alignment with the University of Oregon's commitment to reducing greenhouse gas emissions and transitioning to a more sustainable campus heating system, the Thermal Systems Transition Task Force was charged with evaluating a range of proposed options. These options were developed through a series of technical studies, including those conducted by Affiliated Engineers Inc. (AEI) and Burns & McDonnell. Each option presents a distinct approach to modernizing the university's heating infrastructure, with varying implications for cost, feasibility, emissions reduction, and impact on campus life.

The proposed options considered by the task force include:

1. Business as Usual (BAU): This option involves maintaining the current steam heating system, which operates on natural gas. While this approach incurs minimal upfront costs and avoids disruptions to campus operations, it fails to advance the university's sustainability goals, continuing to emit approximately 25,000 tons of greenhouse gases annually. The reliance on fossil fuels also exposes the university to potential regulatory and market risks.
2. Option 2A: 18 MW Electrode Steam Boiler: This option proposes installing an 18 MW electrode steam boiler while retaining the existing steam distribution system. By reducing the university's reliance on natural gas, this approach is projected to cut annual emissions by 78% compared to the BAU scenario. However, it requires a substantial investment in

electrical infrastructure, leading to an increase in yearly operating costs by approximately $8.2 million.

3. Option 2B: 8 MW Electrode Steam Boiler: Similar to Option 2A, this proposal suggests installing a smaller 8 MW electrode steam boiler. This option offers a 46% reduction in emissions annually, with an increase in operating costs of $4.5 million annually. Although this approach is less scalable and provides a smaller reduction in emissions than Option 2A, it avoids some of the more costly upgrades associated with electrical infrastructure.
4. Option 3: Hot Water Distribution System with Heat Recovery Chillers: This option involves converting the current steam-based heating system to a hot water distribution system that utilizes heat recovery chillers. This approach promises a 56% reduction in greenhouse gas emissions and improvements in energy efficiency. However, it comes with a complex and lengthy implementation process, estimated to take 12 years, and requires substantial initial investment, potentially disrupting campus operations during the transition.
5. Option 4: Hot Water System with Geoexchange Thermal Storage**:** Building on Option 3, this proposal includes adding a 1,400-borehole geoexchange thermal storage system. This option offers the greatest potential for emissions reduction, with a projected 75% decrease, and maximizes energy efficiency. Nonetheless, it is also the most expensive option, with upfront costs and a complex implementation process that poses long-term financial and logistical challenges.

Each option presents a set of trade-offs, reflecting different priorities such as cost, emissions reduction, and operational impact. The task force's responsibility is to carefully evaluate these factors, balancing the university's environmental commitments with technical and financial feasibility, to recommend a sustainable and resilient solution for the campus heating infrastructure.

Engagement Strategies for the University of Oregon’s Thermal Systems Transition

Effective stakeholder engagement is relevant to the decision-making process, especially in projects with far-reaching environmental, financial, and social implications, such as the University of Oregon's thermal systems transition.

Engaging stakeholders in this context is a goal for the task force since these decisions will have long-term impacts on the university's environmental footprint, operational costs, and campus life. Moreover, stakeholder engagement fosters a sense of ownership and responsibility, encouraging the university community to actively participate in and support the transition to a more sustainable heating system. Successfully implementing any chosen option will be a smoother experience if stakeholders are engaged in the decision-making process, as it will reduce resistance to change and promote a culture of sustainability on campus.

However, engaging a diverse university community in such a complex and technical issue presents several challenges. Students, for example, may feel disconnected from the project's long-term benefits, focusing instead on immediate concerns such as tuition costs and campus disruptions. Faculty and staff might be more interested in how the changes will affect their work environment and research activities. Additionally, the highly technical nature of the proposed options can make it difficult for non-experts to fully grasp the implications of each choice, leading to potential misunderstandings or apathy.

To address these challenges, the task force must employ a range of engagement strategies that inform and actively involve stakeholders in the decision-making process. These strategies should be designed to make the complex technical details accessible and relevant to each group, ensuring that all voices are heard and considered. By doing so, the task force can build a broad support base for the chosen heating system, making the transition smoother and more effective.

Engagement with Stakeholders and Community: Actions and Effectiveness

Throughout the Thermal Systems Transition Taskforce's 14-month due diligence process, extensive efforts were made to engage students, the university community, and external stakeholders. These engagement activities were designed to gather feedback, cultivate dialogue, and ensure that the perspectives of all relevant parties were considered in the decision-making process.

Engagement Strategies Employed

1. Public Forums: The task force organized multiple public forums throughout the project, with participation from the university community. These forums provided students, faculty, and staff a platform to express their views, ask questions, and offer feedback on the proposed options. The forums were scheduled strategically to coincide with noteworthy phases of the task force's work, ensuring that community input could influence the task force's deliberations.
2. Surveys: The task force also conducted surveys to capture the opinions of the university community. These surveys were disseminated through various channels, including class presentations, student organizations, and online platforms, ensuring broad reach. The surveys included questions that allowed the task force to gauge the priorities and concerns of different stakeholder groups.
3. Class Presentations and Targeted Outreach: Recognizing the importance of engaging students in their academic settings, the Taskforce members gave presentations in

numerous classes across disciplines. These presentations aimed to educate students about the complexities of the heating transition and to solicit their feedback in a structured and informed manner. Additionally, the task force held targeted meetings with key stakeholder groups within the university, such as student-facing units, facilities and operational users, and academic leadership.

4. Online Communication Channels: To maintain transparency and accessibility, the task force established an email address where university community members could submit feedback. Regular updates were also posted on the university's website, providing stakeholders with ongoing access to information about the task force's progress and findings.

Effectiveness of Engagement

The effectiveness of these engagement strategies was mixed, with several positive outcomes as well as challenges that highlighted areas for improvement:

- Positive Outcomes:
    - High Levels of Participation: The public forums were well-attended, with some sessions drawing over 100 participants. This level of engagement demonstrated strong interest in the heating transition project and ensured that a wide range of perspectives were considered.
    - Student Support for Sustainability: The feedback gathered through forums and surveys revealed that students were particularly supportive of options prioritizing reductions in greenhouse gas emissions, even if those options required substantial financial investment or caused temporary disruptions to campus life. This strong

preference for sustainability underscored the importance of aligning the university's actions with its environmental commitments.

- Transparency and Trust: The Taskforce's commitment to transparency, particularly in sharing detailed information and updates, was generally well-received. Participants appreciated the clarity and depth of the presentations, which helped build trust in the task force's processes and recommendations.

- Challenges:
  - Concerns About Financial Impact: Despite the positive reception of sustainability-focused options, there were concerns about the financial implications, particularly regarding potential tuition increases. Stakeholders needed more transparent communication about how the project costs would be managed and how they might affect students financially; potential tuition increases were mentioned briefly during public forums, but no data or other information was provided beyond the seed thought.
  - Need for More Targeted Communication: While the task force made considerable efforts to reach the university community, there were calls for even more targeted and accessible communication strategies. Some students and campus staff reported difficulty finding updates on the project. The task force told the audience updates would be posted on the Campus Planning & Facilities Management page within the University of Oregon website, but the speed at which the project was progressing resulted in an often-out-of-date webpage. This led to a perception that the process could be more transparent.

- Balancing Immediate and Long-Term Goals: The Taskforce faced challenges in balancing stakeholder preferences for immediate action with the realities of long-term planning. Some students expressed frustration with the timeline for implementing certain options, particularly those that would take longer to reduce emissions. This frustration is unique because it's simply a frustration with the reality of the proposed solutions. This emotional response indicates an opportunity to improve the communication strategy for the option trade-offs.

Overall, the task force's engagement efforts sparked some dialogue with the university community, and a semi-broad range of stakeholder impact informed the final recommendations. However, the process also highlighted the need for continuous and adaptive communication strategies, particularly in addressing the financial concerns of stakeholders and managing expectations about the pace of the transition.

Application of Engagement Strategies

By applying the engagement strategies drawn from the theories discussed in Chapter 1, the challenges discussed above could increase the task force's effectiveness in encouraging a well-informed and supportive community.

Addressing Concerns About Financial Impact

Stakeholders expressed concerns about the financial implications of the sustainability-focused options, particularly potential tuition increases. This concern aligns with the broader challenge of communicating the financial realities and long-term benefits of climate action to a diverse audience. According to Howell (2021), integrating interactive and social learning approaches, such as community-based projects and problem-based learning, can help students and stakeholders understand financial trade-offs in climate action. By involving the university community in discussions about the financial aspects of the transition, the task force could have used these educational strategies to demystify the economic challenges and illustrate the long-term cost savings and environmental benefits.

Moreover, the task force could have employed emotional engagement strategies (Wong-Parodi and Feygina, 2021) to frame the financial investment in sustainability as a moral and ethical responsibility. By highlighting the long-term benefits of reducing greenhouse gas emissions and the potential for UO to become a leader in sustainability, the task force could have fostered a stronger emotional connection to the project, alleviating concerns about short-term financial impacts.

Enhancing Targeted Communication

Although the task force made considerable efforts to engage the university community, there were calls for more accessible, transparent, and regularly updated communications. Part of this complaint is simple to address. More "accessible" in this context relates to the location of the information online. Thus, a solution as simple as a handout with a QR code could be beneficial. Furthermore, the infrequent communications issue also requires a simple solution (in theory): a section of the website could be designated for recent updates. The concept involves having a box on the landing page of the site with one-line updates the task force can post as they arise. This might also help address the concerns about transparency.

Additionally, using social media and online communities, as discussed by Gruzd et al. (2011), could have improved the reach and impact of the task force's communication efforts. By creating online platforms for ongoing updates and discussions, the task force could have provided a more transparent and interactive space for stakeholders to engage with the project, ask questions, and provide feedback.

Balancing Immediate and Long-Term Goals

The task force faced challenges in balancing stakeholder preferences for immediate action with the realities of long-term planning. This challenge is mirrored in the broader context of climate change education, where educators must balance the need to convey urgency with the necessity of long-term, sustained engagement. According to Howell (2014), sustained educational interventions can help maintain pro-environmental behaviors over time. The task force could have applied this principle by clearly communicating each proposed option's timeline and expected outcomes, emphasizing how immediate actions would lay the groundwork for future benefits.

Moreover, role-playing and practical exercises, as discussed by Siperstein (2016) and McNeill and Vaughn (2010), could have been used to help stakeholders understand the complexities and trade-offs involved in the decision-making process. By simulating different scenarios and their long-term impacts, the task force could have provided stakeholders with a deeper understanding of why certain options might take longer to implement but offer more long-term benefits.

Conclusion

The task force's efforts to engage the university community in the Thermal Systems Transition were informed by the challenges of addressing financial concerns, improving communication, and balancing immediate and long-term goals. By applying the engagement strategies discussed in Chapter 1, such as interactive learning, digital media, emotional engagement, and sustained educational interventions, the task force could have more effectively addressed these challenges. These strategies improve stakeholder understanding and support and contribute to a more informed and proactive community better equipped to support the university’s sustainability goals.

Data Communication Strategies for the University of Oregon’s Thermal Systems Transition

Building on the engagement strategies discussed in the previous section, the task force recognized that effectively communicating complex data was necessary for encouraging a well-informed and supportive community. The University of Oregon’s thermal systems transition involves intricate considerations—ranging from financial implications to emissions reductions. The task force utilized various data visualization methods to make these topics accessible to a broad audience. This section explores the specific graphs and charts presented to the public, assessing their effectiveness in conveying information and enabling stakeholders to make informed decisions. By examining these visual communication methods, we can understand how they reinforced the task force's engagement efforts and set the stage for the subsequent discussion on Communicating Difficult Concepts, which will delve into the detailed analysis of the proposed options.

Data Communication Techniques Employed

In its efforts to engage stakeholders and effectively communicate the complexities of the proposed thermal systems transition, the task force utilized various data visualization techniques. These techniques were partially effective in presenting the financial implications, carbon emissions, and comparative analyses of different options to the university community. The following section reviews these methods, evaluates their effectiveness, and discusses how they contribute to a broader transparent and informed decision-making strategy.

Visualizing Financial Implications

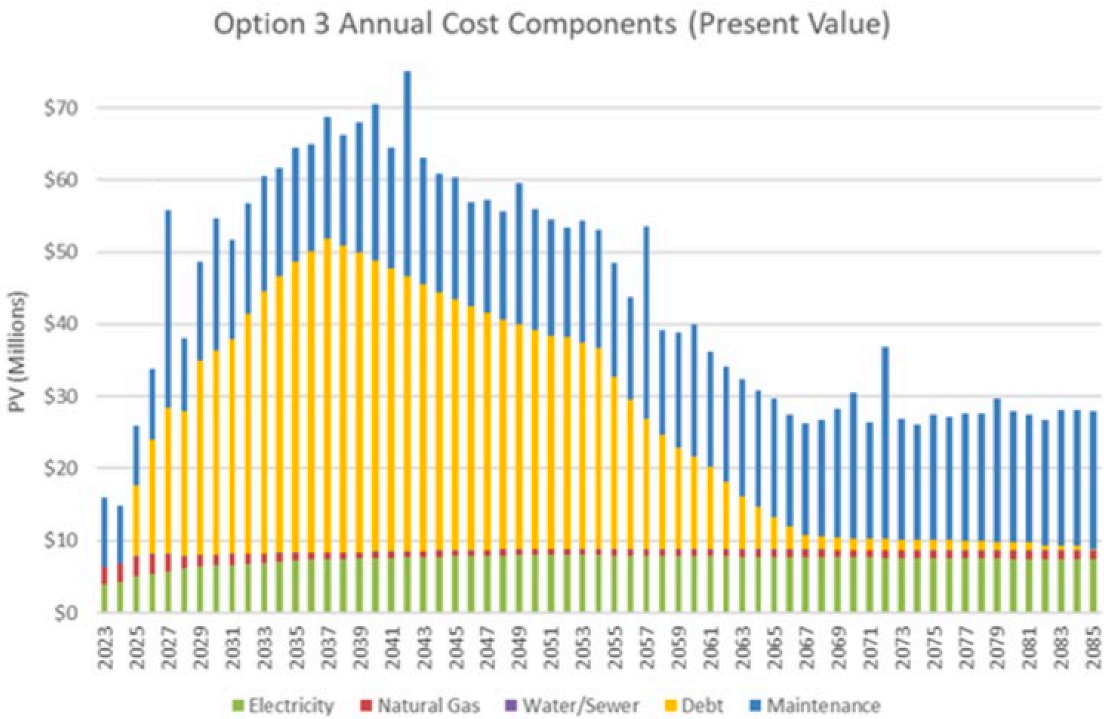

Figure 5: Option 3 Annual Cost Components

The task force presented several charts and graphs to illustrate the financial aspects of each proposed option. For instance, the "Option 3 Annual Cost Components" chart (Figure 5) provided a detailed breakdown of costs, including electricity, natural gas, water/sewer, debt, and maintenance over an extended period. Similar graphs were shown for each option. While these visualizations effectively communicated the total financial burden and its distribution across different components, the specific cost details were easily mixed up by audience members. This mix-up was due to this graph's similar visual form factor compared to the annual cost component graphs for the other options. For participants who looked at these bar charts side by side, especially with the particularly long time interval, the information often became hard to remember. Displaying static graphs of this type potentially attempted to communicate too much information to audience members at public forum meetings. Distributing these charts as part of a document brief allows stakeholders to understand where the largest costs would arise and how they would evolve. However, they may not communicate information as effectively when used in presentations.

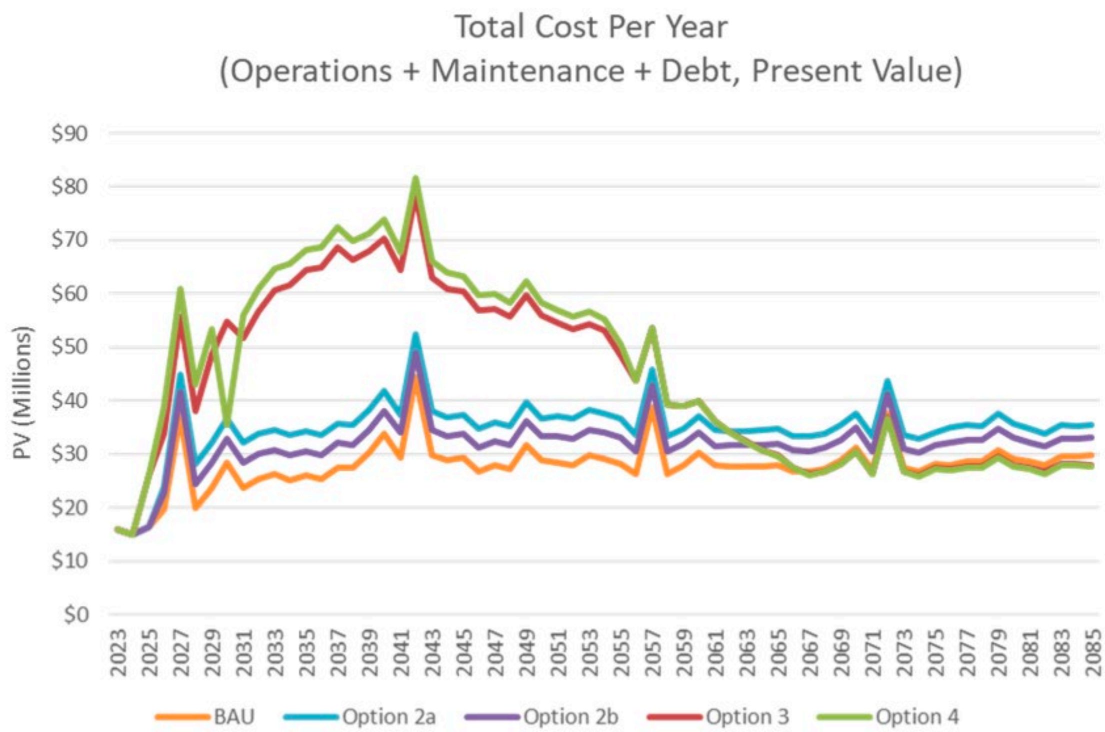

Figure 6: Total Cost Per Year

Similarly, the "Total Cost Per Year" chart (Figure 6) compared the overall costs of various options, including maintenance and debt. By overlaying the cost trajectories of different options, this graph enabled stakeholders to compare the financial viability of each path at a glance. The peaks and troughs in the graph highlighted the periods of highest financial impact, which were used in discussions about budget planning and potential tuition increases. Figure 6 shares problems like those in Figure 5 in that too much information is communicated in a presentation format. However, Figure 6 communicates information better than Figure 5 by comparing multiple options simultaneously, giving audience members a better overview.

Highlighting Emissions Reductions

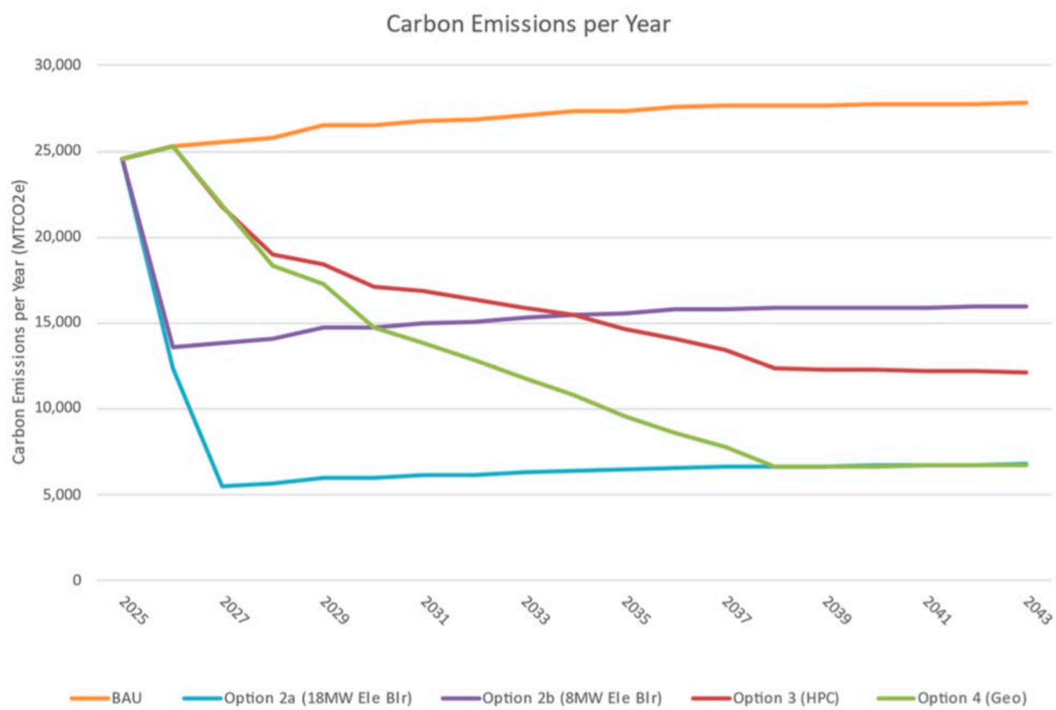

Figure 7: Carbon Emissions per Year

Another key area of focus was the potential for carbon emissions reduction. The "Carbon Emissions per Year" graph (Figure 7) demonstrates the environmental impact of each option over time. This visualization was particularly effective in aligning with the university's sustainability goals by showing which options offered the most considerable reductions in greenhouse gas emissions. The graph's straightforward design, with distinct lines representing different options, allowed stakeholders to easily track the progress of each scenario, reinforcing the urgency of adopting more sustainable practices. This straightforward design, however, caused issues by not communicating enough information. For example, some students observed that Option 4 will result in the highest reduction in carbon emissions by 2043. This made Option 4 the clear choice to many. However, Figure 7 does not highlight information such as cumulative carbon reductions, immediate versus long-term carbon reductions, price, or campus impact. To be clear, no single graph can communicate all these topics simultaneously. The issue, potentially, was in how much emphasis either students or the task force puts on this graph specifically. The necessary context of the tradeoffs relevant to each option is a prerequisite to interpreting this graph effectively.

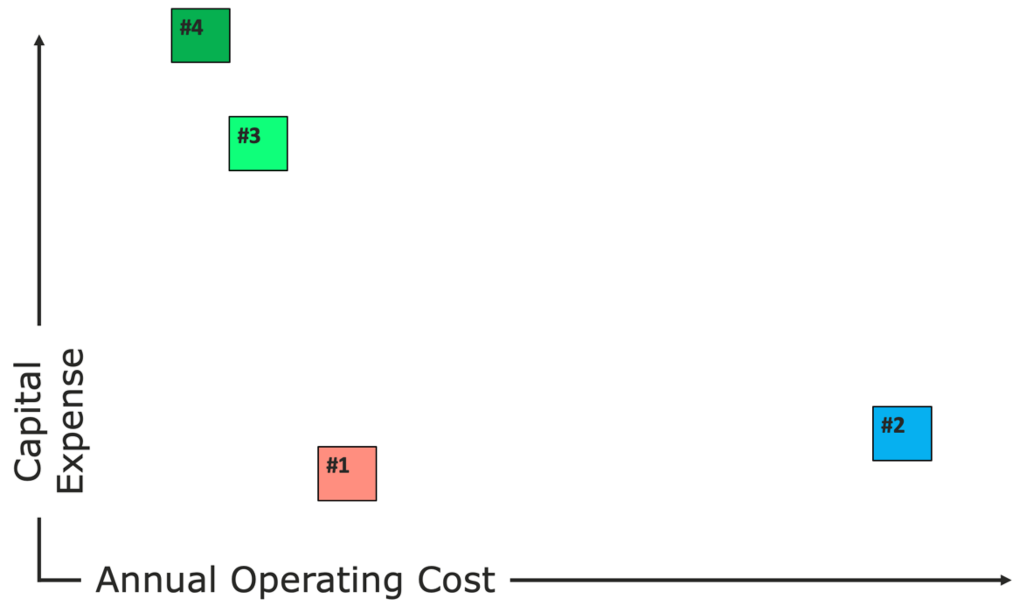

Figure 8: Capital Expense vs. Annual Operating Cost

The "Capital Expense vs. Annual Operating Cost " chart (Figure 8) also provided a comparative analysis by plotting the capital expense for the four options against the annual operating cost. The concept of this graph is good in theory; it represents an attempt to simplify some of the information stakeholders need in order to weigh the trade-offs between financial costs. In practice, this was a poor visualization to present, and the graphs of this format sparked much confusion from the audience. The scale used in this graph does not represent the actual capital expense vs. annual operating cost. For this graph to be accurate, options 3 and 4 need to be much higher on the vertical axes.

Furthermore, there is no time scale representation. Annual operating cost is inherently a time-based variable, and a third data dimension is necessary here to represent this information accurately. I need to note that this graph was not created to be accurate. Its intended purpose was to simplify a single point: option two would involve long-term additional annual operating costs, but options 3 and 4 have high upfront capital expenses. The problem occurred when people referred back to this graph and due to the lack of legend or other necessary information, it became regularly misinterpreted. Some students felt that using overly simplified graphs of these types was not transparent enough, while others greatly appreciated the simplified overview.

Comparative Analysis and Simplification

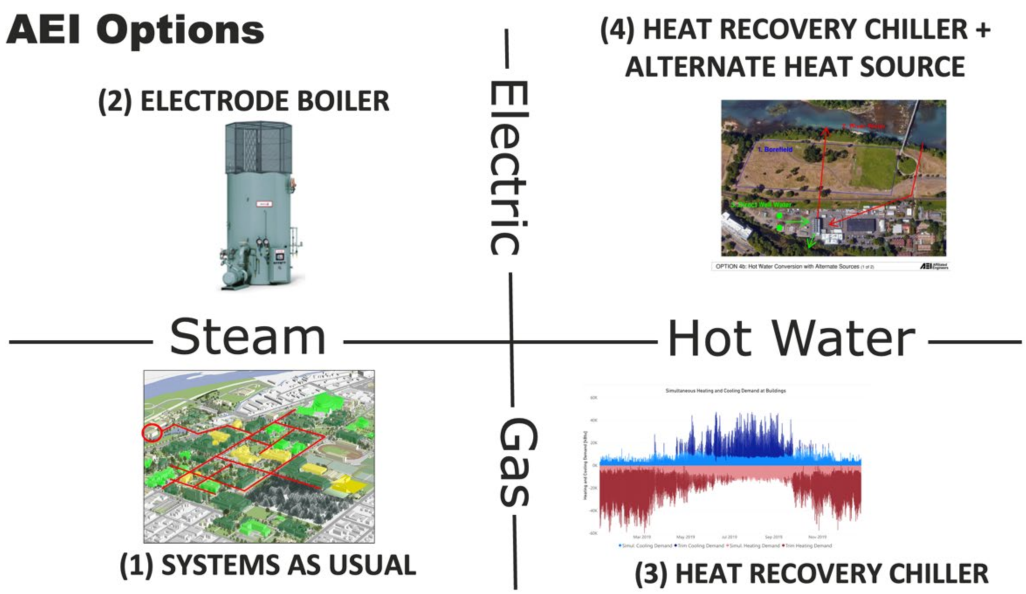

Figure 9: Option comparison grid

The task force utilized simplified comparison charts (Figure 9) to aid decision-making further, providing a high-level overview of each option. These charts categorized options based on their reliance on steam or water systems and electric or gas sources, making it theoretically easier for non-expert stakeholders to grasp the fundamental differences. In reality, insufficient details prevented audience members from engaging in productive discussions. The intention of this graph and what was actually communicated didn't line up in all cases. Some parts of the graph communicated correct information effectively. For example, the vertical groupings of options 1 and 2 represent maintaining the current steam-based infrastructure, while options 3 and 4 commit to a hot water infrastructure. This wasn't the case for the horizontal grouping of options. Options 2 and 4 utilize a shift to electric energy consumption, but option 3 doesn't rely on natural gas and only includes utilizing natural gas as a backup if the system requires support. This contrasts option 1, which fully utilizes natural gas to power the system. This distinction was unclear based on this graph, so confusion resulted.

Effectiveness of the Visualization Strategies

The task force's visualization strategies were partially effective in communicating the complex data related to financial implications, emissions reductions, and other key topics to the University of Oregon community. These strategies were designed to make the information more accessible, allowing stakeholders to understand the long-term impact of each proposed option. Based on the feedback collected through various forums, surveys, and stakeholder engagements, it is evident that these visualizations were generally misinterpreted and that there were areas for improvement.

Positive Outcomes:

1. Clarity in Presentation: The visualizations, particularly the cost and emissions charts, were well-received by technically educated audience members for their effectiveness in distilling complex data into understandable formats. Survey responses indicated that participants appreciated the clarity of the graphs and charts, which helped them grasp the financial and environmental trade-offs between different options. This review was not shared by all participants.
2. Support for Immediate Emissions Reductions: The emissions reduction graphs, which clearly illustrated the timeline and magnitude of emissions reductions for each option,

shaped stakeholder preferences. Survey respondents overwhelmingly supported options that provided immediate and substantial emissions reductions, indicating that the visualizations effectively communicated the urgency and impact of each choice.

3. Engagement and Feedback: The visual tools used in the presentations facilitated engagement by providing some basis for discussion. Participants at public forums and those who responded to surveys expressed that the visualizations made it easier to compare the options and understand their long-term implications.

Challenges and Areas for Improvement:

1. Labeling and Detail: While the visualizations were generally effective, some survey respondents indicated that the charts could have been better labeled and more detailed. Feedback suggested that it was difficult to track the different options across the various graphs, as the numbering or color-coding was not always intuitive. Improving the labeling and adding more detailed explanations directly on the charts could improve their effectiveness.
2. Complexity and Accessibility: Despite the overall positive reception, some stakeholders expressed concerns that the visualizations were still too complex. The survey responses highlighted a need for more straightforward, accessible visual tools, particularly for non-expert audiences. Some participants suggested that breaking the data into more granular, easily digestible parts would have helped them engage more deeply with the material.
3. Transparency and Trust: Feedback from the forums and surveys emphasized the importance of transparency in the decision-making process. The visualizations needed clarification, and there was a call for more detailed breakdowns of the costs and benefits of each option, particularly regarding how these would impact tuition and other financial

aspects. Students required a breakdown of how much these projects would cost them individually. Furthermore, the guaranteed tuition program at the University of Oregon did not prevent student concern. Students were worried about their individual tuition and wanted to make informed decisions for future students. This suggests that while the visualizations effectively communicated broad trends, they could be improved with more specific, actionable details.

Overall, the visualization strategies employed by the task force could be improved by making them more accessible and detailed and ensuring that all stakeholders can fully understand the implications of each option. By addressing these challenges, future communications could improve transparency and stakeholder trust in decision-making.

Addressing Concerns on the Effectiveness of Taskforce's Visualization Strategies

The evaluation of the task force's visualization strategies, as detailed in the previous section, offers a valuable opportunity to apply principles and insights from the literature on data visualization discussed in Chapter 2. These principles provide a framework for understanding why certain visualization approaches were practical and where improvements could be made.

Clarity and Simplicity: The feedback from the University of Oregon community highlighted the clarity of the visualizations, particularly in presenting complex data on financial implications and emissions reductions. This aligns with Tufte's (1983) concept of the "data-ink ratio," which advocates for minimizing non-essential elements to focus on the key data. The positive reception of the graphs and charts suggests that the task force successfully adhered to the principle of clarity, making complex information more accessible. However, the suggestion from some respondents that labels and details could be improved points to a need for further simplification and clarity in line with Kelleher and Wagener's (2011) recommendations to avoid unnecessary complexity that could detract from the data's message.

Accuracy and Consistency: The importance of accuracy in data visualization cannot be overstated, as it ensures the integrity of the information presented. The Taskforce's visualizations, while clear, received feedback suggesting that specific details, such as the labeling and numbering across different graphs, could be improved for consistency. Tufte (1997) emphasizes the need for a shared visual language, and labeling or color-coding inconsistencies can confuse the narrative and viewers. Ensuring that visual elements like colors, scales, and symbols are used consistently across all charts and graphs would improve the overall coherence and comparability of the visualizations, thereby improving their effectiveness.

Cognitive Load and Accessibility: As discussed by Akram and Fang (2015), the principle of reducing cognitive load is could help make visualizations more easy to understand. The feedback indicating that some visualizations were too complex for non-experts suggests that the cognitive load was higher than optimal for some audiences. Simplifying the visualizations and breaking down the data into more granular, easily digestible parts could reduce cognitive load and make the visualizations more accessible. This approach would align with the principles of user-centered design, which prioritize the needs and cognitive styles of the end-users.

Transparency and Trust: The feedback from stakeholders emphasized the importance of transparency, particularly regarding the financial implications of the proposed options. While the visualizations were clear, there was a call for more detailed breakdowns of costs and benefits. This need for transparency helps build trust, as highlighted by Nguyen et al. (2021), who caution against any visualization practices that could distort the interpretation of data. Providing more detailed and transparent visualizations would help to build trust and ensure that stakeholders fully understand the implications of each option, thereby supporting more informed decision-making.

Engagement and Interactivity: The literature underscores the value of engagement in data visualization. Marchak et al. (2011) and Krum (2014) advocate for interactive elements that allow users to explore data more deeply. While the Taskforce's visualizations were well-received for their ability to facilitate engagement and discussion, the feedback also pointed to a desire for more accessible and interactive tools, particularly for non-expert audiences. Incorporating interactive elements, such as clickable data points or zoom functions, could have improved user engagement and made the visualizations more informative and personalized, aligning with the concept of "storytelling with data" that resonates emotionally with the audience.

Conclusion: The visualization strategies employed by the task force were generally effective in communicating complex data to the University of Oregon community. However, several areas for improvement can be identified by applying the principles and insights from the literature on data visualization. Enhancing clarity, consistency, and engagement while reducing cognitive load and ensuring transparency would further strengthen the effectiveness of these visualizations. These improvements would not only make the visualizations more accessible and informative but also build greater trust and confidence among stakeholders, ultimately supporting more effective decision-making and encouraging a more informed and engaged community.

Interactive Dashboard Concept to Further Address Concerns

In response to the feedback regarding the visualizations used by the task force, I developed an interactive dashboard designed to improve data communication and stakeholder engagement. This dashboard addresses some limitations identified in the task force’s visualizations, including the need for more accessible and detailed representations of the trade-offs between different heating system options. The interactive dashboard potentially addresses the following concerns raised by stakeholders:

1. Accessibility and Complexity: The dashboard simplifies the complexity of the data by offering an interactive platform, allowing users to engage with the information at their own pace. The ability to toggle between options reduces cognitive load and makes the information more accessible to a broader audience, including those without technical expertise.
2. Detailed Analysis: The dashboard provides a more granular data analysis, breaking down the costs and emissions over time. This level of detail addresses the need for transparency and helps build trust by providing a clear and comprehensive view of the trade-offs involved in each option.
3. Engagement and Feedback: The dashboard's interactive nature encourages engagement by allowing users to explore the data actively and see the immediate effects of their selections. Additionally, the dashboard includes links for users to submit feedback directly to the task force, facilitating ongoing dialogue and ensuring stakeholder voices remain heard throughout the decision-making process.

Dashboard Overview

The interactive dashboard allows users to explore the trade-offs in carbon emissions and additional annual costs for each proposed heating system option. By selecting different options, users can compare the impact of each scenario over time, providing a clear and dynamic understanding of the long-term implications. The dashboard includes the following features:

1. Dynamic Graphs: Using the Plotly Python library, I created graphs that allow potential users to click on specific dates on the graph and view detailed information on the option projections for that point in time. The dashboard displays carbon emissions and additional annual costs side by side, updating in real time as users select different options. The benefit of coding these graphs using Plotly is that users can also zoom in on specific sections of the graph, highlight particular information they are curious about, and even take screen captures. This feature lets stakeholders see how each option compares to others, highlighting the environmental and financial implications.
2. Contextual Descriptions: Each option is accompanied by a detailed description that explains the technology, associated trade-offs, and relevant analogies to help non-expert audiences understand the complex technical details. Using the Dash Python Library, I was able to run 3 separate programs at the same time, culminating in a streamlined user experience. I programmed the dashboard using HTML and CSS to display relevant information in the top right-hand corner. This contextual information is designed to make the data more relatable and accessible.
3. Improved Labeling and Clarity: The dashboard addresses concerns about labeling and detail by providing precise and consistent labels, legends, and annotations. The color-coding of options is intuitive, and the graph titles are descriptive, ensuring that users can easily track and compare the different scenarios.

Visual Examples

Below are screenshots from the interactive dashboard, showcasing how it displays data for different heating system options:

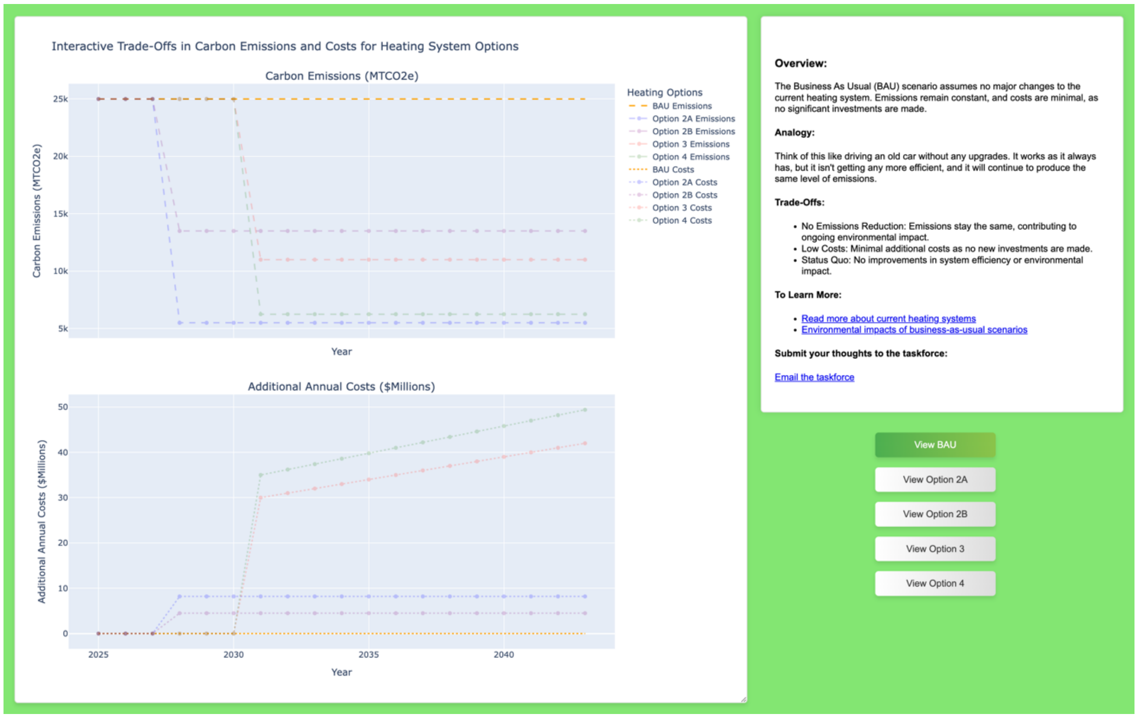

Figure 10: Dashboard Screenshot: Business as Usual (BAU) button selected

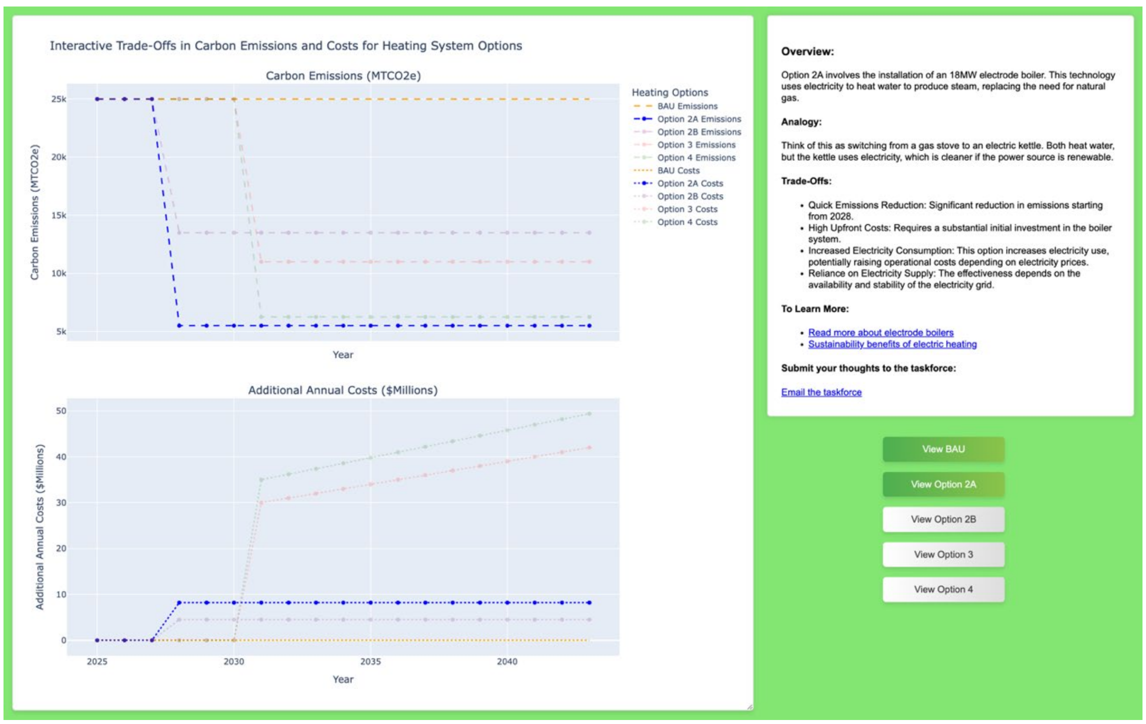

Figure 11: Dashboard Screenshot: Option 2A (18MW Electrode Boiler) button selected

Figure 12: Dashboard Screenshot: Option 2B (8MW Electrode Boiler) button selected

Figure 13: Dashboard Screenshot: Option 3 (Heat Recovery Chiller) button selected

Figure 14: Dashboard Screenshot Option 4 (Geoexchange System) button selected

Literature Support for Dashboard Concept

The interactive dashboard developed to compare the University of Oregon's heating system options is firmly grounded in the principles and techniques of effective data visualization discussed in this thesis. The literature emphasizes that clarity, simplicity, accuracy, consistency, and engagement produce impactful visual representations, particularly in climate communication (Tufte, 1983; Kelleher & Wagener, 2011). These principles have been rigorously applied in the dashboard's design, ensuring that it addresses the specific issues with the task force’s visualizations.

Clarity and Simplicity: The dashboard prioritizes clarity by avoiding unnecessary decorative elements and focusing on essential data. This aligns with Tufte’s (1983) concept of the “data-ink ratio,” which advocates for minimizing non-essential ink. The clear, simplified graphs in the dashboard reduce cognitive load, allowing users to focus directly on the trade-offs between emissions and costs, as Kelleher and Wagener (2011) recommended.

Accuracy: The dashboard maintains accuracy by ensuring that the axes are correctly scaled, and that the data is presented without distortion. This can help build trust and ensure stakeholders can make informed decisions based on reliable information (Nguyen et al., 2021). The absence of misleading 3D effects and the careful selection of chart types (line graphs for trends) further reinforce this commitment to accuracy.

Consistency: The consistent use of colors and symbols across the different options in the dashboard allows users to trace trends and patterns easily, enhancing their ability to compare and contrast the various heating system scenarios. As Tufte (1997) emphasizes, this consistency is vital for creating a coherent narrative across multiple visualizations.

Engagement: The interactive elements of the dashboard, such as the clickable options to view different heating scenarios, improve user engagement. According to Marchak et al. (2011) and Krum (2014), interactive features draw users in and encourage deeper data exploration, making the visualization more informative and personalized. The dashboard’s design allows users to actively engage with the data, which can lead to a better understanding and retention of the information presented.

The dashboard also applies the Techniques for Creating Effective Data Visualizations discussed in Chapter 2, such as appropriate chart selection and deliberate color use (Evergreen, 2019; Breslow et al., 2009). By aligning the design with these established principles and techniques, the dashboard effectively addresses concerns about the task force's visualizations, making complex data more accessible and actionable for stakeholders.

Literature Supporting the Descriptions and Analogies in the Dashboard

The descriptions and analogies associated with each graph in the dashboard are informed by the Chapter 3 literature on effectively communicating complex environmental concepts. For instance, analogies make the technical details of each heating system option relatable to a non-expert audience (Jones et al., 2011; García-Carmona & Acevedo, 2016).

Simplifying Complex Concepts: The dashboard uses analogies, such as comparing an 18MW electrode boiler to switching from a gas stove to an electric kettle, to simplify the complex technical aspects of the heating systems. This approach aligns with the benefits of analogies to make abstract environmental issues more tangible and understandable, as Spence and Pidgeon (2010) highlighted.

Relating to Everyday Experiences: The dashboard descriptions draw on relatable everyday experiences to help users grasp the implications of each option. For example, describing energy conservation efforts as “going on an energy diet” makes the concept more accessible and emphasizes the importance of reducing energy use.

Enhancing Retention and Recall: The dashboard's analogies are designed to create vivid mental images that improve memory retention. For instance, comparing the gradual reduction in emissions to a “hybrid car that reuses energy” helps users visualize the long-term benefits of the proposed systems. This approach is consistent with the literature's emphasis on the role of analogies in improving comprehension and retention of environmental information (Akram & Fang, 2015).

By integrating these analogies and descriptions into the dashboard, the design communicates the technical details of the heating options and makes the information more relatable and memorable for users. This approach engages a broad audience and supports informed decision-making, as discussed in Chapter 3. The dashboard's design, informed by the literature on environmental communication, ensures that the complex concepts involved in the university's thermal system transition are effectively communicated to all stakeholders.

Dashboard Concerns and Areas for Improvement

While the interactive dashboard offers advantages when compared to the University of Oregon's heating system options, there are areas where its design could be refined to serve as a better decision aid. The current focus on displaying annual costs and emissions is a strong starting point, but it may not fully align with the decision-making needs of all users. This section highlights several key concerns and suggests areas for improvement.

1. *Aligning Metrics with Decision Criteria*

The dashboard currently emphasizes two primary aspects: annual costs and annual emissions. While these are two of the most important factors, their presentation may not fully support users in making informed decisions. Users may develop different decision criteria beyond identifying the lowest annual costs or emissions. For example:

- Cost/Year and Emissions/Year: Users might prioritize options with the lowest cost and emissions for a given year, seeking the point at which these are minimized. However, this approach may overlook the importance of cumulative impacts.
- Emissions/Cost Ratio per Year: Some users might be interested in understanding the efficiency of emissions reductions relative to costs. Presenting an emissions-to-cost ratio could provide a more nuanced perspective, highlighting the trade-offs between financial investments and environmental benefits.
- Cumulative Emissions and Costs: The cumulative impact of each option over time may be more relevant to certain stakeholders, particularly those concerned with long-term sustainability. Displaying cumulative emissions or costs and their ratios could help users identify the options that offer the best overall value in the long run.

By expanding the dashboard to include these additional metrics, users can better tailor their decision-making processes to their specific priorities, whether focusing on short-term gains, long-term sustainability, or cost-effectiveness.

2. *User-Specific Considerations*

Another consideration is the potential variation in user concerns. For example, students and staff may be particularly interested in how the costs will translate into direct financial impacts, such as tuition increases or additional fees. The dashboard could be improved by incorporating features that allow users to estimate the "cost to you," providing a more personalized view of the financial implications. This could involve calculating potential student cost increases based on projected changes in university expenses.

Additionally, the dashboard should address the assumptions underpinning the forecasts. For instance, are the costs presented in 2024 dollars without accounting for inflation? Is the model assuming stable energy needs and a consistent number of students? Clarifying these assumptions is beneficial for transparency and will help users understand the limitations and context of the data.

3. *Enhancing Interactivity and Customization*

The current dashboard's interactivity is a strong feature, but there is room for improvement in how it engages users in defining their decision criteria. Instead of providing static graphs of yearly costs and emissions, the dashboard could be more dynamic, allowing users to specify their preferences and display the most relevant information accordingly. For example:

- Customizable Metrics: Users could select which metrics they are most interested in—yearly data, cumulative impacts, or specific ratios—and the dashboard would adjust the visualizations to highlight these factors.
- Acceptable Emissions or Costs: Users might want to set "acceptable levels" for emissions and costs. The dashboard could allow users to input their thresholds and display which options meet these criteria, helping them quickly identify viable choices.

The dashboard can serve as a more effective decision aid by prioritizing the display of quantities that people need rather than requiring them to piece together disparate information. It can guide users toward the most relevant data for their specific decision-making processes, thereby enhancing the tool's utility and usability.

4. *Clarity and Transparency of Assumptions*

Given the long-term nature of the forecasts, communicating the assumptions should be done to prevent issues. Users should understand whether the data assumes constant energy needs, a stable student population, or other fixed variables. Additionally, if the dashboard presents financial data in current dollars without adjusting for inflation, this should be explicitly noted. Users must be aware of these factors to make informed decisions, especially when considering long-term commitments.

5. *Evaluating User Needs and Feedback*

Finally, while the current design offers valuable insights, it is important to assess whether it aligns with what users need to make their decisions. The dashboard could benefit from iterative feedback from users to ensure it meets their expectations and decision-making criteria. Gathering data on user preferences and decision-making strategies would provide valuable insights into how the dashboard can be further refined to serve its intended audience better.

Conclusion

While the interactive dashboard is a powerful tool for comparing heating system options, several areas for improvement can improve its effectiveness as a decision aid. By expanding the metrics presented, personalizing the financial impact, improving interactivity, clarifying assumptions, and incorporating user feedback, the dashboard can better support informed, sustainable decision-making for the University of Oregon's future.

Conclusion

This thesis explored how a university can effectively engage its community in the transition to less carbon-intensive heating systems, using the University of Oregon's efforts as a case study. By integrating strategies from environmental communication, data visualization, and stakeholder engagement, this research demonstrates that successfully addressing complex sustainability challenges requires more than technical solutions alone. It necessitates a holistic approach that includes clear communication, stakeholders' active involvement, and tools that make complex information accessible and actionable.

The transition to a sustainable thermal system at the University of Oregon is symbolic of the broader challenges and opportunities that institutions of higher learning face in addressing climate change. Universities are centers of research, education, and large-scale operations with equally large environmental footprints. As such, they are responsible for leading by example in the global effort to reduce carbon emissions. However, the path to sustainability is fraught with technical, financial, and social challenges, all of which must be carefully navigated to achieve lasting impact.

Key Insights and Contributions

1. Engagement as a Catalyst for Change: One of the central findings of this thesis is the role of stakeholder engagement in the success of sustainability initiatives. The University of Oregon's Thermal Systems Transition Task Force recognized the importance of involving students, faculty, staff, and the broader community in decision-making. By employing a range of engagement strategies—including public forums, surveys, and targeted outreach—the Task Force was able to gather diverse perspectives, build support for its

recommendations, and cultivate a sense of shared responsibility for the university's environmental impact.

2. The Power of Effective Communication: Another key insight is the necessity of effective communication in making complex information understandable and actionable. The Task Force's use of data visualization to communicate the financial and environmental implications of different heating system options highlights the importance of clarity, simplicity, and accuracy in data presentation. However, the feedback also revealed areas for improvement, particularly in ensuring that visualizations are accessible to all stakeholders and effectively convey the trade-offs involved in decision-making.
3. Analogies as Tools for Simplification: Analogies in environmental communication emerged as a powerful tool for simplifying complex concepts and making them more relatable to non-expert audiences. Analogies help bridge the gap between specialized knowledge and public understanding by translating technical details into familiar terms. This approach is particularly valuable in a university setting, where diverse audiences may have varying levels of familiarity with the subject matter.
4. A Comprehensive Approach to Sustainability: Applying these strategies within the specific context of the University of Oregon's thermal systems transition illustrates the value of a comprehensive approach to sustainability. By combining engagement, communication, and visualization strategies, the university is better equipped to make informed decisions that balance environmental responsibility with financial and operational feasibility.

Recommendations for Future Action

While this thesis has provided valuable insights into the engagement, communication, and visualization strategies that can support a sustainable transition at the University of Oregon, there is still work to be done. The following recommendations outline steps that can further improve the university's efforts:

1. Improved Interactive Tools: Developing and deploying interactive tools, such as the proposed dashboard, can greatly improve stakeholder engagement and understanding. These tools should allow users to explore different scenarios, customize their decision criteria, and receive personalized insights, making the decision-making process more transparent and inclusive.
2. Ongoing Stakeholder Involvement: Sustainability initiatives should not be one-time efforts but part of an ongoing dialogue with the university community. Regular updates, feedback loops, and continued opportunities for involvement help maintain momentum and ensure that the chosen path remains aligned with the community's values and priorities.
3. Focused Communication Strategies: Future communication efforts should prioritize clarity and accessibility, ensuring that all stakeholders, regardless of their technical background, can engage with the information. This may involve breaking down complex data into more digestible parts, using more intuitive visualizations, and employing a variety of communication channels to reach different audiences.
4. Long-Term Vision and Commitment: The transition to sustainable heating systems is part of a broader, long-term commitment to reducing the university's carbon footprint. This

vision should be clearly articulated and regularly reinforced, helping to sustain the community's commitment to environmental stewardship over time.

Final Thoughts

The University of Oregon's journey toward a more sustainable campus is a microcosm of the broader global challenge to address climate change. As institutions of higher learning grapple with their role in this ongoing issue, the insights gained from this thesis can serve as a guide for similar initiatives at other universities. By encouraging a culture of engagement, leveraging the power of effective communication, and making complex information accessible through thoughtful visualization, universities can create a more sustainable future.

Ultimately, the success of these efforts depends on the willingness of all stakeholders to come together, share their perspectives, and work collaboratively toward a common goal. The University of Oregon has already taken steps in this direction, but the road ahead will require continued dedication, innovation, and leadership. As this thesis has shown, the tools and strategies to succeed are available—what remains is the collective will to apply them effectively and make meaningful progress in the fight against climate change.

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