Prospectus

Naturally Pressurized Passive Stabilizer for Floating Offshore Wind Turbine Substructures
(Technical Topic)

Anticipatory Governance in California Energy Transitions
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

California began its journey to state-wide decarbonization upon passing the California Global Warming Solutions Act of 2006. This set the goal of reducing carbon emissions to 1990 levels by 2020, “a reduction of approximately 15 percent below emissions expected under a ‘business as usual’ scenario” (California Air Resources Board, 2020). Since then the state has expanded this goal to include having 60% renewable energy in its portfolio by 2030 (California Public Utilities Commission, 2020). There follows a need not only in California but around the world for a relatively inexpensive way to produce large amounts of low-carbon electricity to shift away from fossil fuels.

As with any energy infrastructure, production of such systems requires tradeoffs in land-use, efficiency, and stakeholder concerns. Land-based wind power systems can offer a viable solution at least technologically to the issue of magnitude, reliability, and proximity of power production to demand hubs, though such developments have spurred large amounts of opposition from a variety of stakeholder groups (Lost Coast Outpost, 2019). Be it environmental, cultural, aesthetic, safety, or economic concerns, these groups have disputed aspects of land-based wind power system technology that lead to not only delays but millions of dollars lost in pursued but ultimately abandoned projects (KCET, 2012). For example, TerraGen spent millions assessing a large wind farm development in Humboldt County, California, that ultimately was denied by the City Council because a key piece of development land was a sacred prayer ground for a local indigenous population. Seeking to avoid this barrier to implementing low-carbon energy technologies, local and state entities have started to look for ways to produce the massive amounts of power needed to meet carbon reduction goals that do not spur such a magnitude of social resistance.

The support for Offshore Wind Turbines (OWT) comes from such impetus, seeing that the turbines may be placed out of sight while also accessing consistent and powerful wind resources relatively near to load centers (Margaronis, 2020). Developing this technology at a commercial scale is necessary to produce competitively priced power, and such projects are underway along the East Coast. In California, however, the dramatic deepening of ocean waters beyond the thin Continental Shelf has delayed progress. National Renewable Energy Laboratory analysis reveals that 96% of the wind resources lie in these waters prohibitively deep for traditional OWT technologies (Butterfield et al., 2007). The need for floating systems thus becomes clear, as social opposition is too high on land and wind power is a needed component of California's renewable energy portfolio based on its characteristic time and amount of production.

The technological possibility of Floating Offshore Wind Turbines (FOWT) has already been confirmed through years of successful Oil and Gas industry technologies. Greater challenges exist in finding inexpensive ways to produce such turbines at scale as well as effectively consider social implications of implementing such technology (Butterfield et al, 2007). FOWT substructures are one of the main components of total system cost, and thus are an inhibitor to more quickly deploying this technology. Until FOWTs are able to have a Levelized Cost of Energy, the total energy production in reference to lifetime costs, comparable to current energy technologies, they will require large amounts of external financial support and thus be more at risk of losing investor interest/momentum (Butterfield et al, 2007). Seeing that a wide variety of stakeholder values will ultimately oppose or allow such designs to be developed, these considerations must also be anticipated in order to lower overall costs. This paper proposes technological concepts to passively stabilize the system for overall lower cost and environmental impact as well as a methodology to more meaningfully consider stakeholder values relating to pathways for Californian electric grid decarbonization.

Passive Stabilization of Floating Offshore Wind Substructures

Three dominant concepts for stabilizing FOWT structures have emerged since early development: ballast, buoyancy, and mooring line stabilized (Figure 1). The first large-capacity floating turbine, Hywind, became operational in September 2009 and utilized a "ballasted catenary" layout with 60-ton weights hung from the midpoint of each anchor cable for added tension (Wikipedia Contributors, 2020). It was deployed in the North Sea near Norway for a two-year test period, and cost around $62 million to build and deploy. It survived 11-meter waves in 2010 with seemingly no wear and exhibited a capacity factor, a metric relating percent of incoming wind energy converted to outgoing electric energy, of 41% (PHYS, 2009). This communicates stability success, especially seeing that average on-land turbine systems for projects built between 2014 and 2017 was 41.9% (University of Michigan Center for Sustainable Systems, 2017). Since Hywind's implementation, there have been a number of other FOWT concepts developed and piloted, and a variety of stability concepts investigated. One of the current frontrunners is the WindFloat technology from the international company Principle Power, as pictured in Figure 2 (Principle Power, 2019).

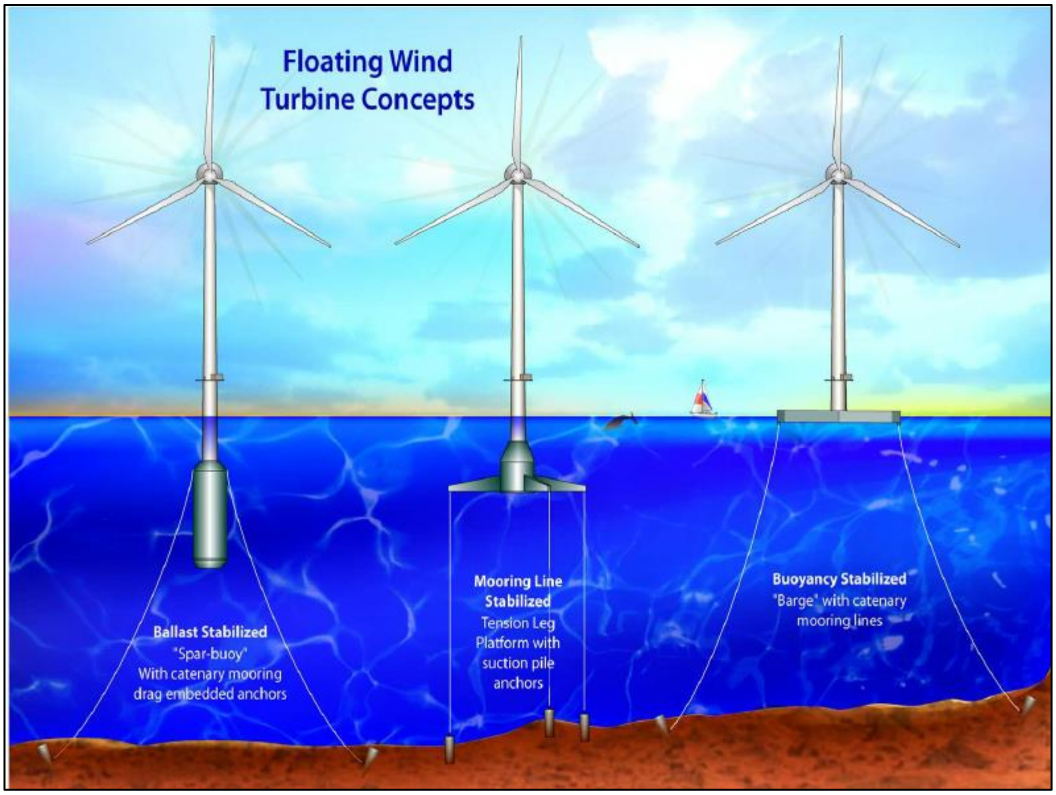

Figure 1. Floating Wind Turbine Concepts (Image source: Butterfield et al., 2007)

Figure 2. Principle Power Floating Offshore Wind Turbine Design (Image Source: Wikimedia Commons, 2020)

This system utilizes a combination of active and passive methods for stabilization. One particular component that sets this technology apart from other systems is its shifting of ballast water between each of the three columns in response to changes in loads on the turbine and foundation (Principle Power, 2019). More traditional control strategies in similar scenarios de-power the turbine to prevent any forces from the turbine that might cause it to tip over, and thus by avoiding this the new design allows for greater and more consistent overall power outflow from the system.

Although this active stabilization may allow for more energy to be pulled from the turbine overall, it still requires a portion of the turbine's produced energy to operate. Furthermore, components of active stabilization (pumps, motors, etc.) are more expensive to manufacture and maintain than passive methods, which entail utilizing physical principles to stabilize the system through structural design rather than mechanized parts. Therefore, our group has focused on testing concepts of passive stabilization that may either be incorporated into the WindFloat design or the next most innovative technology.

Our team underwent a process of ideation in which each member produced 10 designs for substructure stability, then these were evaluated across criteria we defined for success. These metrics were stability for high waves, stability for high winds, cost effectiveness, durability, environmental impact, portability, flexibility in location placement, ease of maintenance, and sustainability of materials. All designs were compared in reference to Principle Power's WindFloat as the state of the art. Ultimately ideas were combined and scored such that three concepts prevailed, and that which I have been tasked with designing and testing is the Naturally Pressurized Passive Stabilizer (NPPS).

The NPPS concept utilizes principles of fluid mechanics and viscous water flow to damp the motion of the substructure as it tilts in the water. In simple terms, water does not "want" to flow through the hourglass - shaped cutouts in the structure, and will resist this by imparting a force on the structure opposite to that of its motion. This is favorable because the force will always oppose any tilting of the structure, an undesirable dynamic that results in lower turbine power production (Butterfield et al., 2017). Furthermore, as water accumulates in the upper chamber, once the platform tilts in the other direction the weight of the water left in the chamber will impart a force on the side of the structure that is sticking out of the water. This in theory should produce an overall effect of less substructure motion.

This design won out over others because of the expected ease of manufacturing and portability both to and from the port and if the turbines needed to be relocated. It also can be made with existing and already-tested materials such as steel, reducing the costs for specialty equipment. It theoretically should have a low environmental impact seeing that it is meant to be deployed in the open ocean where there is a lower concentration of small marine life that could be harmed if they were to flow into one of the chambers. The NPPS also addresses social aspects of FOWT design, effectively anticipating needs of stakeholders affected by FOWT development. Specifically, it facilitates the moving of offshore wind technologies out of sight from the coast to avoid visual pollution, utilizes known manufacturing materials such that jobs may be filled from local communities rather than requiring specialists, and possesses no known acute environmental impacts for groups concerned about endangered species protection.

Figure 3 shows both the upper and lower chambers as well as a mockup turbine tower and turbine circular path for reference. Figure 4 shows the upper interior chambers and Figure 5 the view of the system from the bottom.

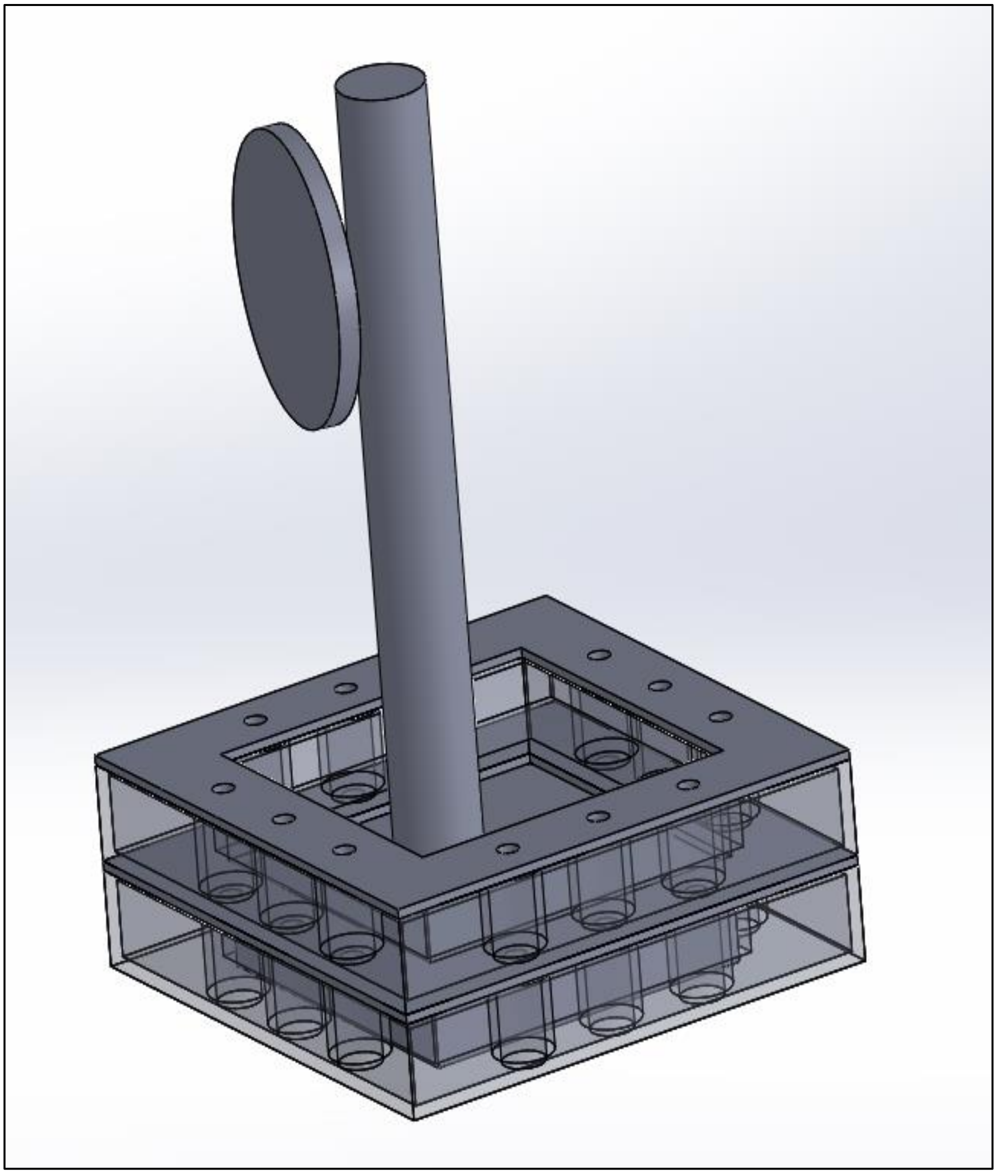

Figure 3. Computer-Aided Design of Naturally Pressurized Passive Stabilizer Base with Representative Turbine Tower and Blade Circle (Image Source: Golson, 2020).

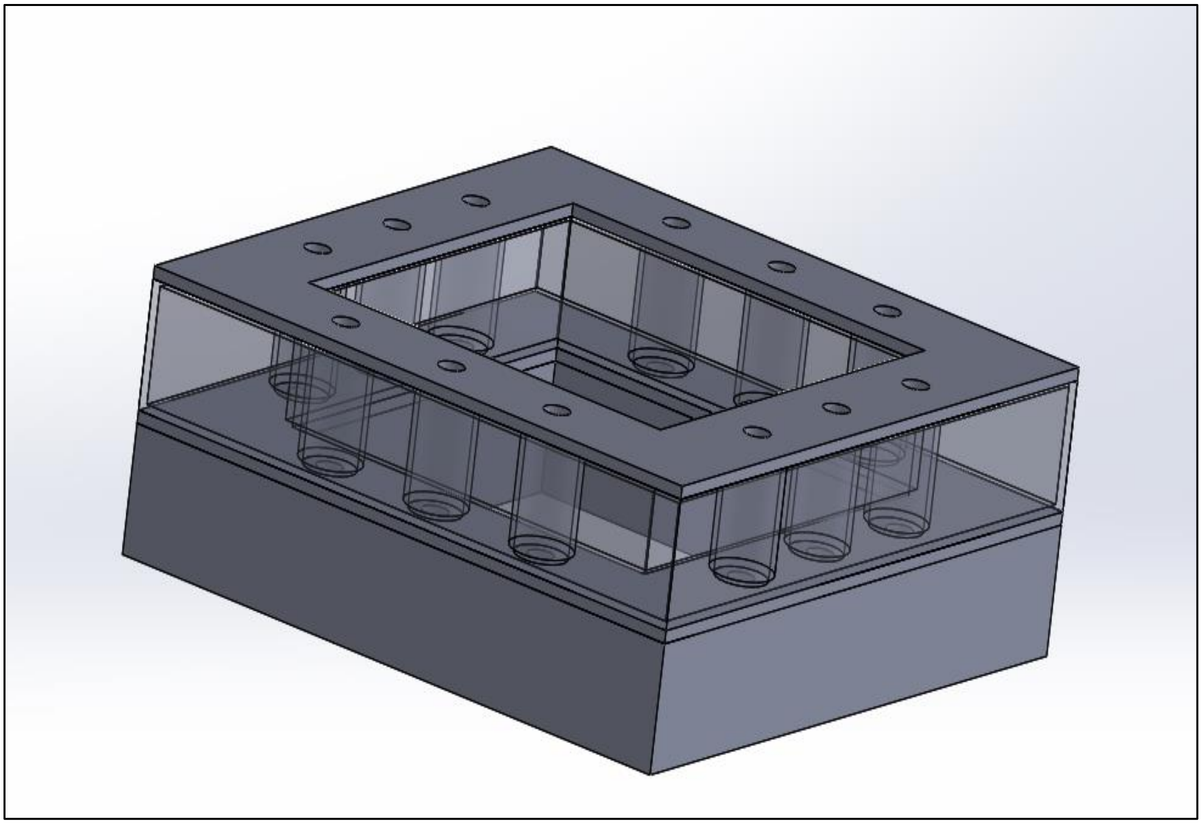

Figure 4. Computer-Aided Design of Naturally Pressurized Passive Stabilizer Base

(Image Source: Golson, 2020).

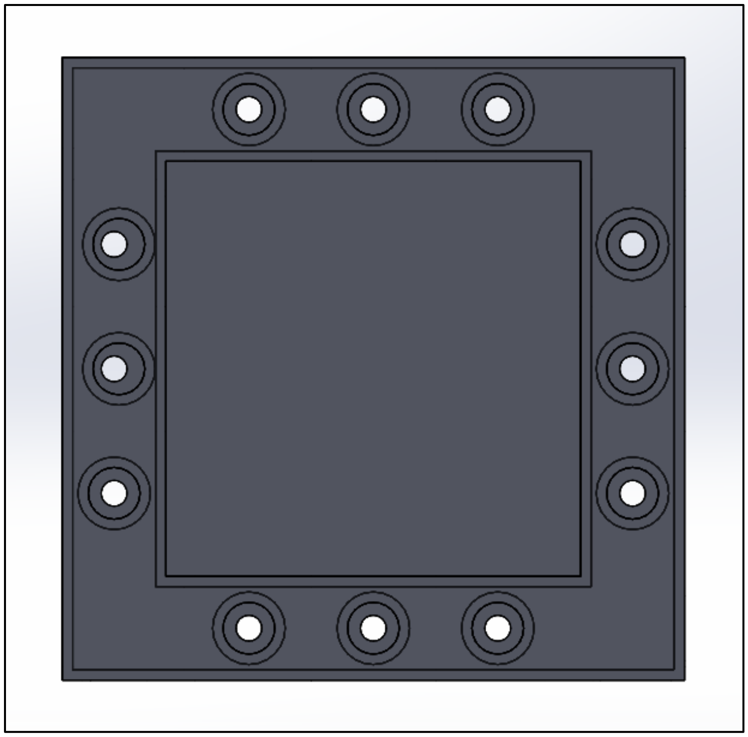

Figure 5. Computer-Aided Design of Naturally Pressurized Passive Stabilizer Base from Bottom (Image Source: Golson, 2020).

The NPPS design overall hopes to contribute to quickening the transition to cleaner electricity generation in California particularly through lowered costs of operation and manufacturing. Even with this intelligently designed technical system, however, the social dimensions surrounding FOWT development must be analyzed in further detail to ensure that social opposition does not bar technology implementation.

Anticipatory Governance for California Energy Transitions

Floating Offshore Wind (FOW) systems and their technological developments in the United States (U.S.) exist as part of a greater effort to transition electric grids across the world to lower carbon sources. Energy transitions are about more than just greenhouse gas reductions, however. They entail processes largely disruptive to current norms and traditions of providing and accessing energy in the U.S. today, a system in which one's source of energy is largely out of sight and out of mind (Stirling, 2014). Furthermore, the significance and uses of energy, regardless of source, are highly specialized based on geographic area and cultural norms (Walker et al., 2007). Niche aspects of the energy itself, be it frequency reliability or price or power capabilities, may be of utmost importance to one stakeholder group and yet entirely insignificant to another. And yet, action is necessary across this broad range of experiences to reduce U.S. carbon emissions in conjunction with a world-wide effort to mitigate climate change. The result of failure may be catastrophic loss of human life and the destruction of many of Earth's ecosystems.

Responding to a lack in federal action, US state and local governments have declared goals for carbon emission reductions in a seemingly grassroots-based effort to mitigate climate change. Such ambitions largely gloss over nuanced barriers to achieving the desired shifts, however. Technological solutions to cutting carbon and other greenhouse gas emissions are touted as silver bullet solutions, while in reality the much more ambiguous challenge of incorporating such technologies into local cultural systems lacks attention both in the press and in research funding. In fact, a meta-analysis of climate change research indicated that between 1990 and 2018 "770% more funding" was allocated to the natural and technical sciences than the social sciences (Overland et. al, 2020). The power of attitudes, norms, incentives, and politics in a given area to influence technological development seemingly surprises renewable energy developers again and again as they fail to consider these factors in assessing the viability of projects and ultimately waste time and money pursuing projects bound to garner social opposition. Such dynamics appear to have influenced the general migration of large generation technologies away from public eye, and in California has contributed to efforts to move wind energy production offshore despite the cost of developing and testing newer FOWT technologies (Gottschamer, 2020).

Thankfully this issue has begun to be recognized and efforts to include stakeholders' opinions increased in California renewables development. In 2016 a task force was created to bring together federal, state, and local agencies to determine the best locations for offshore wind energy development in California, including local tribal governments in the mix (California Energy Commission, 2020). Despite this, local NGOs have raised concerns about the application of an international wind developer, Ideol, to lease 40 square miles of space off of the central coast for floating turbine farms in August of 2019 without their ongoing consultation as to the socio-cultural impacts such a project would have (Savage, 2019). A coalition formed between Audubon, Natural Resources Defense Council, The Nature Conservancy, Center for Biological Diversity, the California Coastal Protection Network, and Surfrider to ask for a continuance of the lease application until the California State Lands Commission's (SLC) next meeting in October. This resulted in further delays to the offshore wind development process. SLC staff and Ideol representatives ultimately contacted this coalition to ensure all stakeholders had adequate opportunity to weigh in, though such reactive methods of stakeholder inclusion failed to preemptively recognize the need for a plurality of viewpoints and social group buy-in to successfully develop energy infrastructure (Savage, 2019).

Addressing climate change is a challenge with a timeline seeing that extensive carbon reductions must be made within the next decade to meet Paris Climate Accords goals of limiting warming to 1.5 degrees Celsius. Therefore, it is of interest how values across geographic localities in California may be preemptively assessed and populations engaged in the process of energy infrastructure planning before major decisions have been made to prevent delays as these values ultimately surface through public opposition. The framework of Anticipatory Governance applies nicely to this dilemma, defined as “a method of decision making that uses predictive measures to anticipate possible outcomes to then make decisions based on the data provided” (Quan, 2010). Anticipatory Governance supports engagement, foresight, and integration as concepts to bring stakeholder inclusion earlier into the process of low-carbon energy technology implementation and prevent costly reevaluations both in time and money down the line (Davies, 2012). Engagement entails active public deliberation and discussion around project planning in ways that are meaningful rather than performative, such as before key decisions have been made. Foresight involves “futuring” (imagination of the future) and scenario-building to generate ideas of possible outcomes, and elucidates the values that stakeholders hold with regards to the system. The concept of integration aims to bring these together and respect the plurality of ways in which stakeholders know and experience energy systems while also providing an actionable path forward for development.

The framework of Anticipatory Governance connects directly to the technical improvement of Floating Offshore Wind platforms, seeing that the designs make tradeoffs between already communicated stakeholder concerns: environmental impacts of implementation, distribution of economic benefits, sustainability of materials, impact on visibility from coast, etc. Its true strength, however, comes from its ability to predict which decarbonization technologies may be the most amenable to local values based on data from engagement processes. This could prevent attempted development of, for example, a large wind array in an area where centralized power generation does not fit with the community’s values of independence and autonomy.

Research Question and Methods

The Californian entities driving wind turbine development appear to be open to stakeholder engagement, but seem to lack the procedures by which to include early and productive consideration of stakeholder values, concerns, and ideas for the direction of future energy pathways. A key challenge is the lack of productive dialogue between groups of different views and approaches to engage such groups in those dialogues. Therefore, I will research the following question with the hope of developing a set of criteria for more productive interactions specific to Californian dynamics: How could concepts of Anticipatory Governance support the transition of California's electric grid to lower carbon sources? Could they help to better balance the transition's speed, efficiency, and inclusivity?

The current process for transitioning Californian energy infrastructure away from fossil fuels causes delays and increased costs due to late or nonproductive consideration of impacted social group value systems. Furthermore, the process causes a disconnection from the true purpose of "sustainability", to empower "democratic process for determining plural human and ecological ends" (Stirling, 2007). If we as a global society are to address what is defined as a threat to our current cultural existences, we must do so in a way that intentionally builds the systems more favorable to pass down to our future generations: inclusive of those diverse cultural expressions, values, identities, and goals. If we are also to address the threat of massive loss of human life and destruction of ecosystems due to climate change, however, we must find a way to compromise quickly between these diverse values and goals.

A study focusing on stakeholder engagement in the California offshore wind industry will be performed with a particular focus on Humboldt County. This area has had a number of attempted and yet abandoned wind development projects due to strong social opposition tying back to ignoring community values early on in the project assessment process. Now the area is being considered for one of California's first floating offshore wind farms seeing that Humboldt Bay possesses the necessary port infrastructure and could benefit from the economic stimulation.

Data for the study will be gathered from the ongoing stakeholder engagement process in California surrounding FOWT development. I will analyze videos of online public comment events, which are opportunities for groups within the community regardless of affiliation to voice their values and opinions on FOWT development. From this I will determine what groups are currently engaged or excluded, the types of knowledge that they possess, and where value negotiation occurs. I will also research how knowledge dissemination happens regarding current FOWT developments in the area, and ways in which future consequences are explored or ignored. Further sources of evidence will include counts of stakeholder hearings, public comment hearings, etc. as well as time allotted to different social groups. Thematic and content analysis will be performed on agency reports and media accounts to elucidate if patterns emerge in procedural power structures among involved social groups that might lead to unfavorable or unjust engagement conditions. The analyses will focus on what groups are mentioned as being considered in the decision-making process, and how the voicing of different value systems is portrayed (I.e. "Not in My Backyard" or NIMBYism, or as valid concerns of the public). From this I will create a set of recommendations for how the Anticipatory Governance ideas of engagement, foresight, and integration can be worked into the process to aid in conversation productivity and ultimately infrastructural decision-making.

A timeline for data collection and analysis is as follows:

February 1 - 10: Accumulation of online written commentary surrounding FOWT development and stakeholder involvement. Identification of key stakeholders and potential values. Thematic analysis of public comment recordings, media accounts, and agency reports.

February 10 - 15: Power mapping surrounding the current process by which energy infrastructure changes are proposed, commented upon, and approved. Assessment of how stakeholder groups have attempted to let their values be known if there is no formal way for them to do so.

February 15 - 30 : Analysis of process timeline and opportunities for prevented delays. Determination of suggestions going forward in technological implementation.

Conclusion

Particularly once technological systems reach the size at which energy infrastructures operate, there simply can be no implementation of wide-scale changes without extensive community engagement. These systems are so ingrained in much of United States society that social groups are bound to oppose any projects they perceive as not aligning with their values. If states are to achieve their goals for carbon reductions, they must use concepts such as Anticipatory Governance to preemptively consider these factors in the designing and placement of lower-carbon generation technologies. A successful execution of such holistic design will assuredly be noted internationally as entities look for solutions to similar dilemmas across the globe. The product could be not only a safer and more stable atmosphere in the future, but also societal systems built for inclusion of a multitude of values, identities, and goals that we may be equally proud of.

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