Solar Installation on Ivy Landfill
(Technical Topic)

**From NIMBY to Neighbor:
Social Dynamics and Public Perception in
Green Infrastructure Development**
(STS Topic)

A Thesis Project Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Erik Hammerquist

Fall, 2024

Technical Project Team Members: Anusha Jain, Caroline Maher, Demari Johnson, Maggie Collins, Mina Gorani

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.

Signature ______________________

Approved ______________________ Date ______________
William Davis, Assistant Professor of STS, Department of Engineering and Society

Approved ______________________ Date ______________
Leo Liu, Associate Professor, Department of Civil and Environmental Engineering

Introduction

Across the globe, the growing climate crisis is spurring investment and exploration into novel solutions for a more sustainable future. Our growing demand for energy and reliance on fossil fuels are currently, and historically, the primary contributors to climate change. As we transition away from these sources, we must reckon with the technological and social challenges of their replacements. Photovoltaic solar cells and wind turbines in particular are significant engineering innovations which have shown potential in meeting the technological needs of this transition. These technologies are becoming so prevalent in fact that the International Energy Agency (IEA) found in their 2024 World Energy Investment report that they attracted $650 billion in investments from 2024, dwarfing the $70 billion invested into fossil fuel generation (p. 63).

However this is not solely a problem of engineering facilities made of steel and silicon, but also attitudes and behaviors of the people affected by such projects. Community opposition to renewable energy projects often arises due to complex concerns surrounding the economic, environmental, and social ramifications, leading to project delays and increased costs of 10 - 29% (Jarvis, 2024, p. 5). With the IEA's 2024 World Energy Outlook forecasting investments of $20 trillion into renewable power generation between 2024 and 2040, these increases in costs could be very significant. While optimizing the location of renewable facilities is essential given the economic and physical realities of energy transmission, addressing the concerns of the affected people is equally important from both an economic perspective and that of social wellbeing.

Green energy initiatives have gained significant traction in recent years across the developed world, examples of which can be seen in the United Kingdom where recent investments have resulted in an astounding 14.7 gigawatts of energy from offshore wind which has the potential to power over 5 million homes (RenewableUK, 2024). In contrast, the United States has so far developed three offshore wind farms, capable of producing a combined 0.174 gigawatts or around 116,000 households worth of power (NREL, 2024, p.8), but not without significant community pushback. This disparity isn't due to greater innate support for renewables in the UK but rather reflects a more nuanced, collaborative approach by developers and government to include local stakeholders throughout the development process. This paper aims to explore and highlight some of these methods which have managed to successfully turn the tide of public opinion and garner real grassroots support from the people most directly affected.

Technical Topic

In the push towards a greener and more sustainable future, effective land use and renewable energy are key means of reducing carbon emissions. The placement of large scale solar facilities has been a significant challenge, especially near population centers where efficiency is highest but land values and opposition higher. However, some 'brownfield' sites, like contaminated industrial areas and landfills, offer potential for green energy development. The EPA (2019) defines brownfield sites as areas that "are or may be contaminated with hazardous substances, pollutants, petroleum, or other contaminants" and that they are typically located in struggling neighborhoods with deteriorating infrastructure. (p. 1).

The EPA (2022) has stated that defunct landfills are particularly advantageous because they are often located near pre-existing critical infrastructure, near population centers, have minimal grading at ≤ 2%, have lower land costs, and are able to accommodate the scale necessary to service large populations (p. 3). There are however technical challenges associated with this type of redevelopment that should not be underestimated. When these landfills are decommissioned and capped, the cap cannot be penetrated and has low comparative compressive strength which reduces its ability to bear loads. Additionally, existing infrastructure responsible for venting methane produced by the anaerobic organisms present in the subsurface municipal waste must be preserved and accessible.

Following the passing of the *Small Business Liability Relief and Brownfields Revitalization Act* in 2002, the EPA has worked closely with communities to provide funding and technical assistance in the redevelopment of brownfield sites around the nation. One of the pilot projects for this program was conceived in 2008 in the city of Houston, Texas and focused on transforming the 300-acre Holmes Road Landfill site, located just 10 minutes from downtown Houston, into a 10 MW facility (EPA, 2008). This plan, developed by SRA international in conjunction with EPA, presented two means of securing photovoltaic arrays: with poured concrete footings 3 feet deep, requiring significant filling and compaction of additional soil to prevent penetrating the cap, or with a shallow concrete foundation slab, which would require significantly more materials and greatly increase impervious surface area of the site (EPA, 2008, p. 14). Both of these methods were deemed far too costly for the city of Houston and plans for redevelopment were consistently abandoned as construction costs were simply too high with contemporary construction methods (Ihejirika, 2021).

To surmount this challenge, engineers in recent years have devised novel methods of securing solar arrays to the earth that do not rely on traditional subsurface anchoring techniques. One way this has been achieved is by using above-ground ballasts which use the force of gravity to secure the array to the ground. These ballast footings can have much smaller footprints than larger poured foundations, can be constructed on site of various materials to meet specific design or budgetary needs, and pose no risk of penetrating a landfill's cap layer (EPA, 2022, p.53; SF Bay Engineering, 2024). However, ballasted anchor systems come with their own set of constraints and vulnerabilities. They can only be safely sited in areas with a ground slope of less than 10% and leave arrays vulnerable to wind uplift if not sized properly. Though these constraints are generally minimized and non-limiting for landfill sites as the median slope is low and they typically already have wind mitigation measures, such as tree windbreaks, since wind is detrimental to containing waste.

Advancements in solar ballast design and social programs in support of green energy have even been significant enough to resurrect the previously mentioned Holmes Road Landfill development project as the Sunnyside Landfill Solar Project in 2021. This reimagined and reinvigorated project will utilize a ballasted mounting design which significantly increases the developable area on the cap, increasing the potential output of the project to over 70 MW, enough to power 12,000 homes in the local community and offset 120 million pounds of atmospheric CO2 emissions (C40, 2020).

STS Topic

Any development near a human habitat will encounter individuals with strong, often diverse opinions about both the specific and broader implications of the project. These reactions are frequently driven by immediate emotional responses to perceived environmental changes, resulting in a shift from logical analysis to affective risk perception. This effect intensifies when coupled with the psychological effect of seeing specific groups or individuals — such as landowners or fishermen affected by offshore wind projects — as being directly negatively impacted, known as the identifiable victim effect. These strong reactions foment a mindset which can dissociate from one's personal values, such as previous support for climate initiatives and renewables, and turn towards direct opposition (Pjeczka 2018).

Interestingly, studies reveal a disconnect between personal and perceived public attitudes toward renewable energy. For example, a survey of New England residents found that while 80-89% of local stakeholders support wind power development, they believed that the broader community views it unfavorably (Sokoloski et al., 2018, p. 46). This “individual gap” reflects a divergence between personal beliefs and perceived popular belief, shaped by two psychological phenomena: pluralistic ignorance, where individuals wrongly assume their views are in the minority, and false consensus, where they overestimate the extent to which others share their perceived opposition (Sokoloski et al., 2018, pp. 47-48). Understanding this gap is crucial, as it underscores the importance of fostering productive and open dialogue to counter misconceptions which exacerbate resistance to green projects.

Evidence shows that more often than not opposition movements are not homogenous groups, holding differing and even contradictory views (Pol et al., 2006). These motivating views are often complex and can be informed by perceptions of local environmental quality, risk orientation, opinions on climate change, and trust in energy companies (Koninsky et al., 2020). Designing effective engagement strategies that address these different viewpoints - such as direct public involvement, education, and consultation efforts - can increase trust and reduce opposition by leveraging social theory to constructively engage with communities. An example of how this is being achieved in other nations can be found in 'renewable energy communities', a term coined by the 2019 European Union Renewable Energy Directive which provides a framework to assist and facilitate direct investment by communities into local projects as partners. Reframing the relationship between developers and communities as a collaborative effort creates opportunities for the norms and needs of that particular community to be respected and supported in the management and operation of the project (Verde et al., 2020, pp. 5-6). By turning stakeholders into partners, communities are empowered to make decisions which directly benefit them, mitigating the typically stratified power differential between developers and community members which can reinforce oppositional attitudes.

Combining Actor Network Theory, Social Exchange Theory, and Social Representations Theory offers a comprehensive framework for addressing community opposition to renewable energy projects. Actor-Network Theory emphasizes understanding renewable projects as networks of interconnected human and non-human actors, highlighting the importance of aligning new developments with existing community relationships and identities (Latour, 2005). Social Exchange Theory emphasizes the importance of structuring development projects as reciprocal relationships, where community support is encouraged by the prospect of direct, tangible benefits. Academic literature suggests that one of the core reasons for NIMBY opposition is because residents adopt a 'place-protective' posture, focusing on the general perceived threat that development brings to the established physical, cultural, and economic norms of an area (Devine-Wright, 2009, p. 12). These principles can be leveraged by project managers to anchor their proposals in a way that enhances, rather than threatens, the cherished characteristics of these communities. Social Representations Theory highlights the necessity of positively framing renewable energy projects within these established community narratives, social structures, and shared meanings, facilitating local acceptance through familiarity rather than resistance (Moscovici, 1988). Applying this concept to green energy projects, studies have found communication of community benefits to have a more substantial impact on influencing individual attitudes if the community is seen as having a high level of control in development and operation (Walker et al., 2014). By creating a climate of collaboration and reciprocity, developers can transform community members from passive bystanders into active partners and opponents into allies. Together, these theories underscore that green infrastructure initiatives are more successful when communities perceive them as collaborative efforts, inspiring a sense of shared responsibility, trust, and mutual benefit rather than top-down imposition.

Domestically, projects in the United States have begun employing similar methods of creating and communicating direct benefits to local communities. The EPA provides a rough framework for the development of brownfield sites in which it states that the development of an effective community engagement plan to build public support is crucial to creating community buy-in, reducing delays, and minimizing risks (2019, p. 5). In the case of Houston's Sunnyside Energy Project, developers sought to bridge the gap in trust that tends to exist between developers and communities who tend to view them as transient and opportunistic by continuing to manage the project over its lifespan (Stone et al., 2021). By committing to long term involvement and regularly engaging locals in a two-way dialogue, developers hope to build their image among the community as a good neighbor that cares about the needs of the people. This has manifested in commitments to hiring local contractors and sourcing materials from local distributors, creating an extensive job training program through the local community center, and the inclusion of an 'Agricultural Hub and Training Center' to provide locals with access to community gardens and fresh produce free-of-charge (Stone et al., 2021). Developers have also realized the potent benefit of having stakeholders directly involved in the project's development, not just as consumers and beneficiaries but as partners, by giving the community direct partial ownership (Ihejirika, 2021). These initiatives have fostered a sense of trust and private-public collaboration as local citizens are left with a feeling of pride that comes with having a direct hand in the growth of their community, overcoming the common fears of exploitation and loss.

Conclusion

In conclusion, the transition to renewable energy is not only a technological pursuit but also one of social engagement and negotiation where successful implementation hinges on designing effective engagement strategies that intersect with local perceptions and cultural nuance. Large-scale solar initiatives, like those transforming brownfield sites, demonstrate the immense potential of renewable energy to simultaneously address pressing environmental concerns while fostering local enrichment. However, success will depend on more than technical innovation and physical engineering; it will require deliberate, inclusive strategies that prioritize trust-building, cultural sensitivity, and genuine collaboration with stakeholder groups. By designing projects in a way that respects local values, addresses specific community needs, and offers tangible long-term benefits, developers can shift the narrative from exploitation to partnership. By facilitating community buy-in and finding a definition of success that works for all stakeholder groups, engineers can continue to push for a future that is sustainable, resilient, and equitable.

References

C40 Cities Climate Leadership Group. (2020). Reinventing Cities: Sunnyside Landfill. https://www.c40reinventingcities.org/en/professionals/winning-projects/holmes-road-landfill-1271.html

Devine-Wright, P. (2009). Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action. Journal of Community & Applied Social Psychology, 19(6), 426–441. https://doi.org/10.1002/casp.1004

Energy Pulse Report. (2024, October 8). Global Offshore Wind Pipeline. RenewableUK. https://www.renewableuk.com/energypulse/reports/global-offshore-wind-pipeline-october-2024/

Environmental Protection Agency (EPA). (2008, August). Technical Assistance: Solar Power Analysis and Design Specifications. https://www.epa.gov/sites/default/files/2015-09/documents/houston_solar.pdf

Environmental Protection Agency (EPA). (2019, June). Anatomy of Brownfields Redevelopment. https://www.epa.gov/sites/default/files/2015-09/documents/anat_bf_redev_101106.pdf

Environmental Protection Agency (EPA). (2022, May). Best Practices for Siting Solar Photovoltaic (PV) on Municipal Solid Waste Landfills.

Ihejirika, M. (2021, September 28). Through a solar transformation, a former landfill is poised to become a community lifeline. Natural Resources Defense Council. https://www.nrdc.org/stories/through-solar-transformation-former-landfill-poised-become-community-lifeline

International Energy Agency (IEA). (2024, June). World Energy Investment 2024. https://iea.blob.core.windows.net/assets/60fcd1dd-d112-469b-87de-20d39227df3d/WorldEnergyInvestment2024.pdf

International Energy Agency (IEA). (2024). World Energy Outlook 2024.

Jarvis, S. (2024, August 21). The Economic Costs of NIMBYism: Evidence from Renewable Energy Projects. *Journal of the Association of Environmental and Resource Economists*. https://doi.org/10.1086/732801

Konisky, D. M., Ansolabehere, S., & Carley, S. (2020). Proximity, NIMBYism, and Public Support for Energy Infrastructure. *Public Opinion Quarterly*, 84(2), 391–418. https://doi.org/10.1093/poq/nfaa025

Latour, B. (2005). Reassembling the Social: An Introduction to Actor-Network Theory. Oxford University Press.

McCoy, A., Musial, W., Hammond, R., Mulas Hernando, D., Duffy, P., Beiter, P., Perez, P., Baranowski, R., Reber, G., & Spitsen, P. (2024). Offshore Wind Market Report: 2024 Edition. National Renewable Energy Laboratory. https://doi.org/10.2172/2434294

Moscovici, S. (1988). Notes Toward a Description of Social Representations. *European Journal of Social Psychology*, 18(3), 211–250. https://doi.org/10.1002/ejsp.2420180303

Pjeczka, K. (2018, August 1). Support and Opposition to Offshore Wind Power in the U.S.: A Clash of Perceptions and Reality. *Yale Environment Review*. https://environment-review.yale.edu/support-and-opposition-offshore-wind-power-us-clash-perceptions-and-reality

Pol, E. (2006, March). Psychological Parameters to Understand and Manage the NIMBY effect. *European Review of Applied Psychology*, 56(1), 43–51. https://doi.org/10.1016/j.erap.2005.02.009

SF Bay Engineering. (2024, February 29). The Pros and Cons of Ballasted Solar Panel Mounts. https://sfbayengineering.com/2024/02/29/ballasted-solar-mounts-guide/

Sokoloski, R., Markowitz, E., & Bidwell, D. (2018). Public Estimates of Support for Offshore Wind Energy: False Consensus, Pluralistic Ignorance, and Partisan Effects. *Energy Policy*, 112, 45–55.

Stone, L., & Popkin, M. (2021, November 18). Turning trash into treasure: How installing solar on landfills can revitalize communities. RMI. https://rmi.org/turning-trash-into-treasure/

Verde, S. F., & Rossetto, N. (2020, August). The Future of Renewable Energy Communities in the EU. European University Institute. https://cadmus.eui.eu/bitstream/handle/1814/68383/QM-04-20-447-EN-N.pdf

Walker, B. J. A., Wiersma, B., & Bailey, E. (2014). Community Benefits, Framing and the Social Acceptance of Offshore Wind Farms: An Experimental Study in England. *Energy Research & Social Science*, 3, 46–54. https://doi.org/10.1016/j.erss.2014.07.003