WORKING TITLE: TOWARDS A HOLISTIC INTEGRATION OF ENERGY SYSTEM ENGINEERING AND ENERGY JUSTICE

BY

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PRELIMINARY EXAMINATION

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[F]or the kids like me who got ADHD

— Joyner Lucas, "Isis"

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The literature review in Chapter ?? characterized the wicked problem of climate change, identified the current gaps in energy system optimization model (ESOM) methods, and motivated the need to incorporate ideas from a energy justice and other non-engineering discplines, in order to fully apprehend the challenge. Chapter ?? detailed the development of `Osier`, a novel ESOM framework designed to incorporate conceptions of energy justice. This chapter outlines the future work to deepen the theoretical foundation of this thesis, improve `Osier`'s functionality, and validate `Osier` as a useful framework for enhancing decision-making processes for more just outcomes.

2.1 Expanding the theoretical basis of this work

This section elaborates on how I will expand the theoretical basis of this thesis.

How will I expand the theoretical basis of this work? Or, rather, what theoretical areas will my dissertation explore and expand?

1. Provide a detailed outline of the nuclear energy debate. What are the normative assumptions at play on both sides?
2. Give a case study on the ways traditional decision making processes in nuclear energy (e.g., Yucca Mountain) led to poor outcomes, and show positive examples of inclusive processes (i.e., consent-based siting) producing superior outcomes.
3. Provide a detailed outline for the challenges associated with solar and wind.

2.1.1 What drives opposition to new energy projects?

Observing the dissonance between the awareness of anthropogenic climate change and policy actions to mitigate the effects of climate change is one of the key motivators for this work. Further, in instances where action is being taken — such as the construction of renewable energy projects following government subsidies, for instance — what drives public opposition? I will elucidate this question by incorporating literature from social movement theory [1], [2] into this thesis. Importantly, the literature shows that not-in-my-backyard (NIMBYism) is not the primary driver of public opposition to energy projects [3], rather, support for these energy projects is more strongly conditioned on genuine public participation in the decision-making process [4]–[8].

2.1.2 A tale of three uncertainties

Section ?? identified two uncertainties commonly discussed in the ESOM literature: Parametric and structural uncertainties [9]. Although these two uncertainties correspond to different aspects of energy system modeling (and models writ large), they share the important quality of being descriptive rather than prescriptive. However, even though they are primarily used to describe modeled systems, the results of modeling efforts considering these types of uncertainties are, often implicitly, prescriptive [10]–[13]. For example, although structural uncertainty acknowledges the existence of unmodeled (or unmodelable) objectives the nature of mathematical optimization requires modelers to choose at least one objective — one success criterion — to optimize. I contend that this choice is always normative. Further, articles identifying a pathway to "100% renewable energy" make an implicit normative assertion without justification or recognition of the plurality of morally valid alternatives. This suggests the existence of another uncertainty: Normative uncertainty. "Situations where there are different partially morally defensible — but incompatible — options or courses of action, or ones where there is no fully morally defensible option" [14], [15]. There is a connection between structural and normative uncertainties. Choosing one or several objectives to optimize implies a normative premise — even if the results are presented without a corresponding normative conclusion. The same could be said for any choice in the development of an ESOM: Spatial scale, time scale, which technologies are included in the model, and more. Per the recommendations of van Uffelen et al. 2024 [15], I will construct an explicit normative premise that undergirds the normative conclusions of this work to address normative uncertainty. In essence, defining what "justice" means in the context of this thesis.

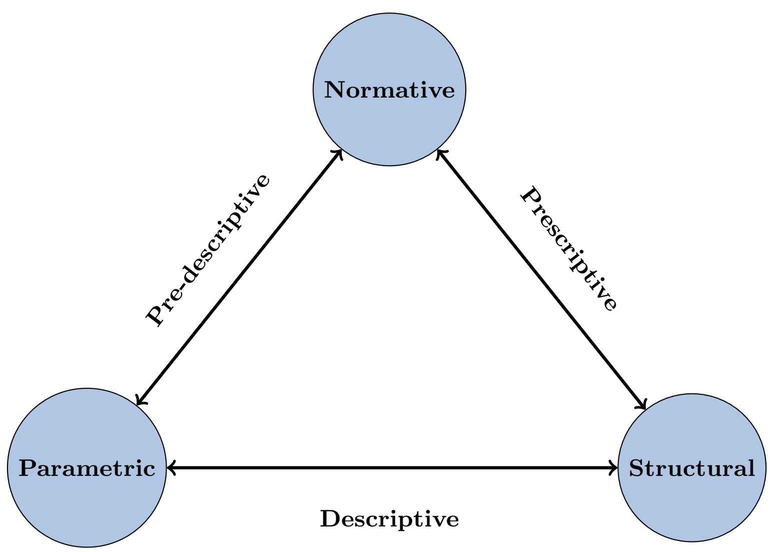

Figure 2.1: Uncertainty

2.2 Technical improvements to `Osier`

What technical features have yet to be implemented into `Osier`?

2.2.1 Parallelization

The current code is unacceptably slow for many-objective problems. The four objective model took 26.5 days to run on a computer with 32GB of memory and 6 cores. More work needs to be done on investigating the parallelizability of `CPLEX`, or employing more computing resources. Alternatively, rather than using a mixed-integer linear programming (MILP) model to operate dispatch, using hiearchical model (i.e., a "rules" based model) to dispatch energy could enable multiple processes, and reduce the computational cost of the problem. Additionally, this type of model is conceptually simpler than MILP. The combination of reducing computational cost and theoretical overhead would make `Osier` more accessible, which is consistent with the ethos of this work.

2.2.2 MGA enhancement

The MGA algorithm could yet be improved by developing a selection strategy that more accurately captures the spirit of MGA by identifying *maximally different solutions in the design space* [9], [16]. In this application, discussions generated by presenting maximally different alternatives could alleviate normative uncertainty as described in Section 2.1.2. I will accomplish this by implementing an algorithm from computational geometry that is frequently used in topological data analysis known as greedy permutation, or farthest-first-traversal [17], [18].

2.2.3 Data transparency

Quality data is essential to generating trustworthy results. The Annual Technology Baseline (ATB) produced by National Renewable Energy Laboratory (NREL) is considered the gold standard for cost projections for electricity generating technologies [19]. `Osier` will directly integrate data from the ATB to its built-in technology classes.

2.3 Validating `Osier`

`Osier`'s primary purpose is to translate policy preferences of the lay-public into actionable energy visions for a given municipality. The idea is that if decision-makers used a tool like `Osier` to support their decisions and incorporate ideas from their constituents — ideas that may be distinct from the preconceptions of decision-makers themselves — then stronger actions toward addressing climate change may be taken with more just outcomes. The last, and arguably most important, component of this thesis is to validate `Osier`'s usefulness in this regard. I propose validating `Osier`'s usefulness with a case study of the energy visioning processes of three municipalities: Urbana, Champaign, and the University of Illinois Urbana-Champaign (UIUC). The research question is then: "Do decision-makers or energy planners perceive that `Osier`, or tools like it, would be useful in enhancing collaboration between decision-makers and their constituents?" Although this case study focuses on a small sample, these paradigmatic cases could be used to generalize the usefulness of `Osier` to other locales [20]. The precise formulation of this research question (or questions) is subject to change between now and the beginning of this study. Since this research involves human participants it must be reviewed by an ethics board.

2.3.1 Reviewing the energy visions for each municipality

Before conducting interviews with people that may use a tool like `Osier`, I will research the background of each municipality considered by reviewing published documents related to their energy visions, such as UIUC's Illinois Climate Action Plan (iCAP) [21], Utilities Master Plan [22] or the City of Champaign's Comprehensive and Sustainability Plans [23], [24]. I will also compare the stated energy visions for each community with the literature [25]. In addition to energy *visions*, I may evaluate the decision making process for specific energy projects. Such as the microreactor project at UIUC or the recent solar farm being constructed on Market Street in Champaign. How do these projects fit with the stated energy visions for their respective communities? How involved was the lay-public in making these decisions? Who were the stakeholders? This step is important for developing a grounded decision-making process that incorporates `Osier` or a similar decision support tool.

2.3.2 Develop the hypothetical `Osier` procedure

Before interviewing decision-makers and asking if `Osier` would be useful to them I need to formulate a hypothetical decision-making process that includes `Osier`. Further, there are a few ways results (i.e., energy futures along the Pareto-front or in the near-optimal space, as described in Section **??**) from `Osier` could be used in a decision-making process. The results could be presented in more of a raw, descriptive, form. Similar to the presentation in Chapter **??**. Alternatively, whoever organizes the planning process (e.g., city councils, planning departments, etc.) could distill the complete set of results into a manageable subset accompanied by an explanatory narrative. MGA automates part of this option. The former presentation admits less normative uncertainty from pre-filtering the simulation results, but is arguably less understandable by the lay public. The latter is more explicit but an explanatory narrative presents more opportunity for politicization. Unfortunately, adequately addressing this question is out-of-scope for this study. However, I will present interviewees with both options to create a partial answer.

2.3.3 Deciding the interviewees

In order to gauge the `Osier`'s usability, I will interview public facing figures from each municipality involved in the energy or community planning processes for their respective communities. Table 2.1 lists potential interviewees.

Table 2.1: Potential interviewees to evaluate the usefulness of `Osier`.

Name	Title	Affiliation	Note
Bruce A. Knight	Planning & Development Director	City of Champaign	Directs the Champaign Planning department
Lacey Rains Lowe	Senior Planner for Advanced Planning	City of Champaign	Participated in creating the Champaign sustainability plan
Jeremy Guest		UIUC	
Maddhu Khanna		UIUC	
Luis Rodiríguez		UIUC	
Kevin Garcia	Principal Planner	City of Urbana	

The list in Table 2.1 merely indicates who might be good participants in this case study. Ideal candidates would have direct experience developing an energy vision for their community and engaging with the public.

Additionally, the final list should be demographically diverse, to the extent possible, in order to enhance the generalizability of this case study.

2.3.4 Conducting the Interviews

Interviews will be conducted and analyzed with the awareness that the questions I ask, my choice of wording, and my demeanor when asking, all have an affect on the answers generated by interviewees.

Questions about current planning processes

The following questions are aimed at interviewees responsible for guiding the planning process in each community. For example, they may be urban planners or in charge of public engagement. These questions are not appropriate for an external party that may be involved in the execution of an specific energy goal but are nonetheless excluded from the initial decision making process.

1. How would you describe your community's energy vision or priorities?
2. How did your community develop these priorities (or this vision)?
3. Does your community have current best practices for making planning decisions?
4. How does your community use modeling software to support its vision, if at all?
5. What are the pain points you experience in developing these visions?
6. What is the role of expert testimony/consultation/input in creating an energy vision?
7. How do you percieve the dialogue between community members and its decision-makers?
8. Does it seem like preferences or concerns from the community are incorporated?
9. Do members of your community understand why a particular decision was reached?
10. How does the energy visioning process in your community consider the impact on its neighbors?
11. Should there be more collective planning among the three communities?

Questions and discussion about modeling tools and `Osier`

The previous set of questions set a foundation for energy planning from the perspective of a decision-maker or planner. This set of questions deals specifically with the usefulness of `Osier`

1. (After presenting results from this model in two ways) Which presentation do you think would best facilitate dialogue between the lay-public and decision-makers?
2. What objectives do you think would be important to model in designing an energy vision for your community?
3. Would your municipality use this tool?
4. If not this specific tool, is there a tool that exists/doesn't exist that is/would be useful?
5. What changes would need to be made to `Osier` for it to be useful to you?
6. How would employing this tool differ from existing visioning strategies or processes?

2.3.5 Generate insights with thematic analysis

The interviews will be recorded and I will use the responses from interviewees to conduct a theoretical thematic analysis [26]–[28]. Thematic analysis is a qualitative method for determining patterns in a data corpus [28].

The general process from Braun & Clark 2006 [29] is to

1. familiarize yourself with the data,
2. develop codes (I will be using an open-coding strategy where codes are developed in the process of reviewing transcripts, rather than being pre-determined [27]),
3. identify themes,
4. review themes
5. define themes,
6. locate exemplars.

2.3.6 Draw conclusions

The conclusions of this study will have descriptive and normative components. The latter will be understood in the context of the normative premise constructed in light of the suggestion in Section 2.1.2.

The results of this analysis could take the form of:

1. "These are the stated energy goals of this municipality."
2. "This is how the results from `Osier` would change decision-making procedures." (Results in this case includes the "optimal" solutions for an energy future *and* the ways the process itself would change.)

2.3.7 Research limitations

What is outside the scope of this study? Although the intention behind `Osier` is to help translate policy preferences of the lay-public into actionable energy visions for a given municipality, interviewing and surveying members of the public is out-of-scope for this project. Further, determining the needs of a group before developing code in earnest is essential for developing an effective and procedurally just framework. This co-design practice is important for future development of decision-support tools [30], [31].

Also outside the scope of this project is determining which form of the results is most accessible to lay-audiences. Ideally with a much larger number of participants I could do a/b testing to tease out an answer to this question.

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