FREEING ENERGY
+
MICROGRIDS

SUS8502: Sustainable Energy Management
Professor Dariush Rafinejad

WRITTEN BY:
Adam Mason | Douglas Perry | Prabhjot Sandhu | Scott Oltmann

INDUSTRY MENTOR:
Bill Nussey of Freeing Energy

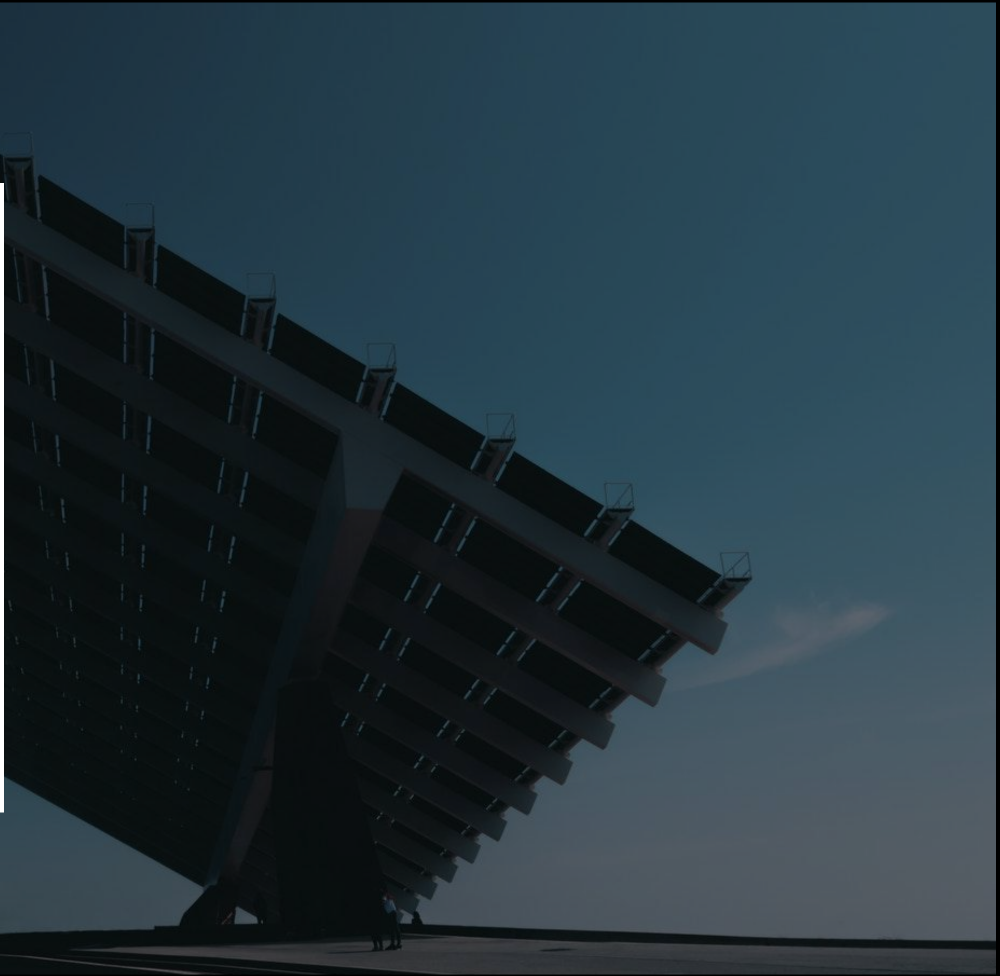


TABLE OF CONTENTS

BACKGROUND

As the U.S. economy continues to grow over the next 10 years, and the risks of climate change become increasingly prevalent, both the energy required and the need for effective energy solutions will also increase. In the wake of Hurricane Maria, that left 3.7 million U.S. citizens in Puerto Rico without power, the need for massive infrastructure investment in the near and medium-term future has become a much bigger part of the conversation. This includes an exploration of more decentralized models of energy generation and distribution. These events, along with a number of other converging factors, are breathing new life into an old concept, microgrids.

The Department of Energy (DOE) has established microgrids as an important focus area for research and development, recognizing that they improve power quality and reliability, increase system energy efficiency, and provide the possibility of grid-independence to individual end-user sites (Ton & Smith, 2016). In addition to federal programs, the private sector and other institutions are also increasing microgrid development and deployment. Collectively, within the next two years, microgrid capacity is expected to reach 3.71GW (Walton, 2016), and over the next 4 years more than $12bn will be invested into the development of microgrids adding to the already 1,623 currently in operation in the United States (Wood, 2017). Technological advancement in this space is a major factor contributing to this rising trend, such as more controllable and adaptable electricity use systems, decrease in cost of small and community-scale electricity generators and energy storage get, as well as intelligent integration enabled by software, AI, and machine learning (Roberts & Chang, 2017).

It is well understood that the development and implementation of microgrids will further improve reliability and resiliency of the grid, help communities better prepare for future weather events, and keep the United States moving towards a cleaner energy future (Office of Electricity Delivery & Energy Reliability, n.d.). However, in order to scale adoption, it will take more than financial backing and technological improvements.

One of the biggest challenges the group identified was the lack of widespread understanding of microgrids from interested parties. There is not currently an accessible, user-friendly way to evaluate a site, building, or group of buildings for its microgrid suitability. There are various inputs and outputs that can be optimized in concert to create a microgrid solution, but they are unique to each site. ‘If you’ve seen one microgrid, you’ve seen one microgrid’ as the saying goes. The data that drives these inputs and outputs is either publicly available or privately held by the interested party. If publicly available, it is held by various sources and repositories in disparate locations and can be difficult, time consuming, and costly to gather and analyze. We believe this data wrangling and analysis creates a significant barrier for those interested in exploring microgrids at commercial and industrial sites.

OBJECTIVE

"To create the architecture for a wiki-enabled, web-based tool for residential, commercial and industrial microgrid feasibility assessment in the United States."

To address these barriers we set out to create the architecture for a wiki-enabled, web-based tool for residential, commercial and industrial microgrid feasibility assessment in the United States. For our purposes, feasibility is the ability of a microgrid to provide improvements for three key user needs: resiliency, clean energy, and cost effectiveness. The tool aggregates various source data on factors relevant to building microgrids in the U.S., which includes local regulations and policies, energy load profile of the user's facility, local grid conditions such as cost and carbon intensity, as well as the local generation capacity from renewable resources like solar (a full list of data is available in the tool).

The tool also accounts for the goals of the user, allowing them to optimize for resiliency, carbon intensity reduction, or cost efficiency. Users might include facilities managers/owners or a sustainability/energy procurement professional looking for a first pass screen to understand how well a microgrid might satisfy their optimization and load needs. Politicians could also use the tool to identify how to improve their local policies to promote local generation, or businesses could use it to identify target markets that would benefit from microgrids or an understanding thereof.

With the aggregated information, the tool analyzes the inputs based on location, and then provides a microgrid feasibility score of 1-5 ("5" being the best) and a letter grade (A-F). The grade is based on three main categories: resiliency, cost, and clean energy. Finally, the tool provides next steps to take by providing links to relevant resources particular to the user's needs and location.

SUCCESS METRICS

Success for our semester end team project was self-defined as a functional spreadsheet that can demonstrate an architecture for a wiki-enabled, web-based tool for residential, commercial and industrial microgrid feasibility assessment in the United States. Given the time-bound nature of the semester project, we strove to create a functional and adaptable model framework rather than to ensure 100% accuracy of the tool in its current state.

Determining it's accuracy in assessing feasibility will be a key success metric for the final web-based tool. The tool should be tested against existing sites with quantifiable metrics and available historical performance. Such a retrospective testing for accuracy should be enough for an initial launch. Next steps should include an after launch surveillance to validate the ongoing accuracy of the tool by randomly selecting tool results and verifying against other databases. Successful microgrid implementation on sites deemed feasible by the final tool would be the gold standard for post-launch accuracy validation, but will take years to validate. Another metric for success determination is the user adoption rate which can be documented by measuring user growth per quarter. Although growth rate is a direct function of marketing efforts, it also represents the user engagement, satisfaction, and referral to new users. We can quantify the usability of the tool by measuring user satisfaction and time spent to test a site's feasibility. Finally, the tool has to be scalable to be used nationwide in the United States covering all zip codes including Alaska and Hawaii. Ultimately, the goal of the tool is to increase the implementation of new microgrid sites and one of the most important success metrics is the number of potential new microgrid sites identified by the tool.

CHALLENGES

Aggregation and sorting of the unstructured raw data was the biggest challenge. Existing data across states, especially regulatory data, needed to be on the same scale for comparison. Determining the best practices for comparing and contrasting variables that were not on the same level was a rigorous task that required reaching out to multiple field experts.

Defining the terms such as ‘feasibility’ and ‘resilience’ in the context of our tool was another daunting task, followed by finding the correct mix of inputs to accurately reflect feasibility. Eventually, we chose to also let the user change the default weight given to the three measures of feasibility (resilience, clean energy, cost effectiveness) for a more personalized feasibility analysis and because we identified various use cases with as many goals as use cases. For instance, a campus may have a goal to be 100% powered by clean energy by a certain date with little regard for cost, while a corporate building operator/developer may be looking for the most cost effective way to create resiliency for their building in a location susceptible to natural disaster and thus grid intermittency.

Putting together the various variables and data input sources created a complex web of information that interact in ways in the real world that no model can truly capture. Keeping in mind that the tool is a first step and cannot accurately reflect the reality of any specific microgrid site without more data and analysis was crucial. We had to stay high level enough to build a tool that has functionality and value without getting bogged down in details that could ultimately green or red light a specific project. For instance, a project might not have access to PACE financing, but does have access to a source of capital independent of what is captured by the tool, thus the model may be overly punitive about the “cost effectiveness” of the project. It is important to understand the limitations of the model and that it can only serve as a proxy in assessing feasibility.

Depth and breadth of the discussion around microgrid feasibility analysis exceed the time limit put on us by the semester. But again, a goal is merely a dream with a time limit. In that sense, we have accomplished the goal we intended at the beginning of the semester.

PROCESS

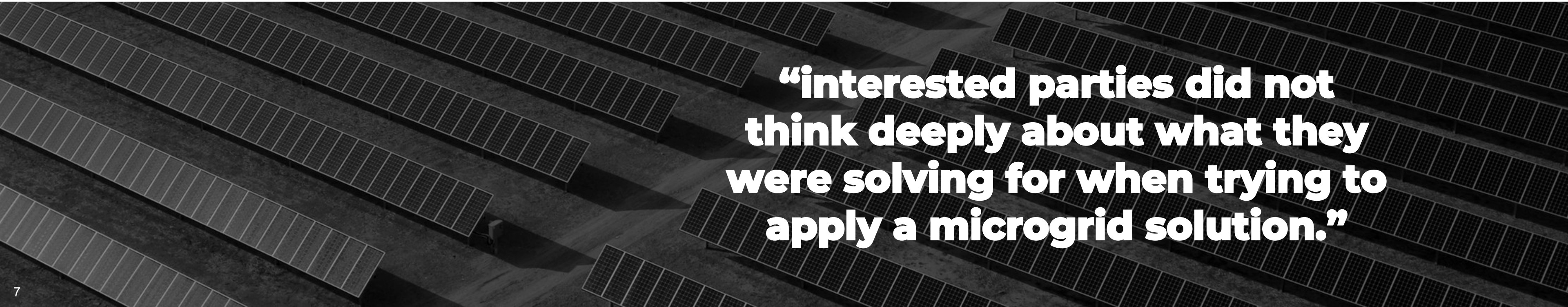
The team conducted both primary and secondary research as part of the discovery process to understand the factors that affect microgrids, the important characteristics of microgrids that are markers for adoption, and who can influence their adoption. The process was iterative and presented many barriers by forcing the team to navigate both deep and broad learning. We strove to understand market and business forces, regulatory frameworks, and technical aspects of electricity and the grid. The class learnings and resources contributed to the acceleration of this learning cycle along with secondary background research, primary research, and bringing it together through discussions. Some of the most instrumental sources of data were the Database of State Incentives for Renewables and Efficiency (DSIRE), the State Policy Opportunity Tracker (SPOT), the U.S. Energy Information Administration, the Environmental Protection Agency (EPA), and Freeingthegrid.com. Significant time and energy was spent understanding the data held and communicated by each of these sources, how they differ, how they're similar, and how they might interact with each other to serve our purpose of understanding all of the factors that impact the cost effectiveness, resiliency, and cleanliness of a microgrid's energy production.

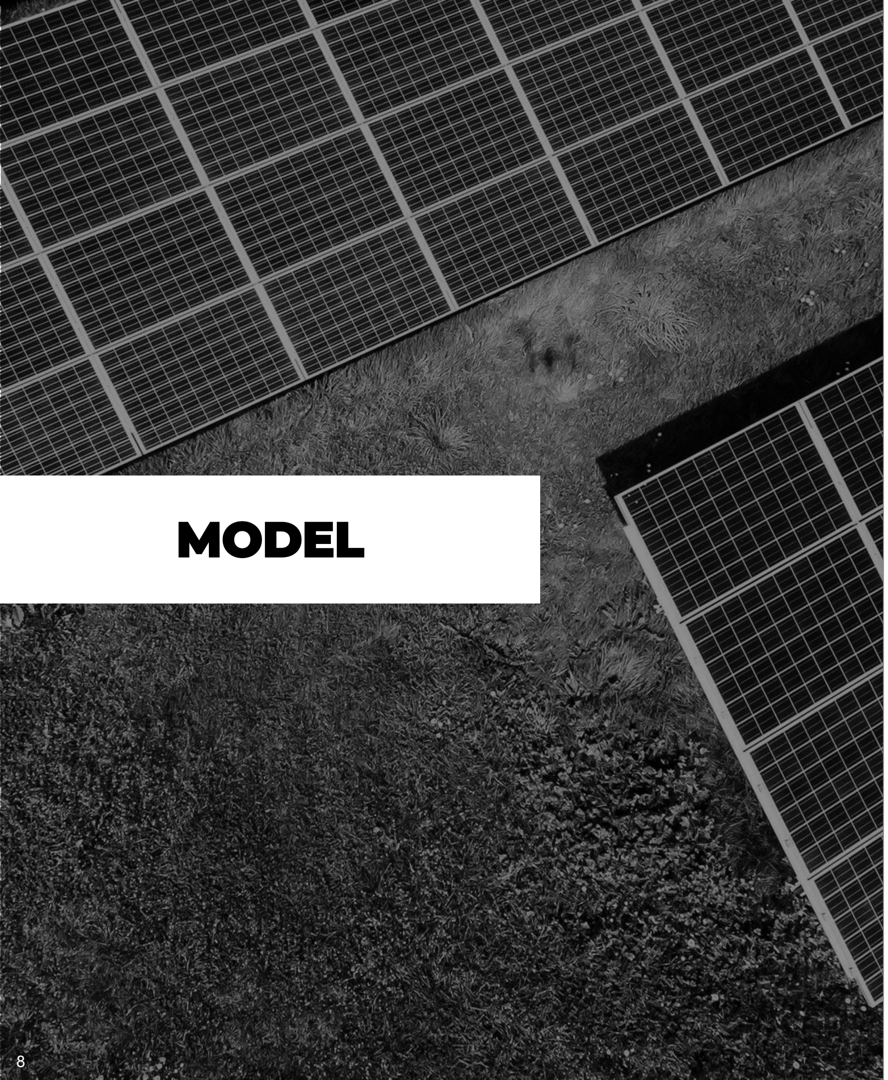
A full list of sources and databases access is available in Appendix A and in the model. There are additional sources that were not integrated into the model data for one reason or another. Some provided data that was less easy to wrangle, some conflicted with other sources or was provided with a different lens (i.e. for a different purpose), and some we just didn't have time to fully explore. Examples of these data sources include the Institute for Local Self-Reliance, Interstate Renewable Energy Council, and data sets within the U.S. EIA and EPA. There is a report protected by a paywall produced by Greentech Media that aggregates data on microgrids that exist in the United States. This could be a great proxy for feasibility, but we were unable to get access. This project was an exercise in filtering and wrangling data as much as it was an exercise in data discovery and learning the various aspects that impact microgrid feasibility.

To accelerate our filtering and focus throughout the project, we leveraged networks of experts and their knowledge. Early on, we connected with a few key experts that helped guide our project in the right direction.

Peter Lillianthal of HOMER Energy, a microgrid modeling firm selling their software package and services to microgrid designers, engineers, and architects was able to provide valuable feedback on the landscape as he has seen it change as well as how the tool might be useful in driving adoption by being a funnel for interested parties to understand microgrids better. Baird Brown, a friend of Bill Nussey, provided a complex and comprehensive view on the legal aspects of microgrids and is one of the foremost experts on the regulatory landscape of renewable energy and microgrids. A grid edge expert at PG&E expressed concern around the viability of microgrids as a part of the electric grid of the future and had experienced many conversations with interested parties that did not think deeply about what they were solving for when trying to apply a microgrid solution. That helped us think through what problem this project was addressing and how to frame that for the potential users. Speaking with DSIRE's team helped us understand the importance of integrating live data updates in a rapidly changing regulatory landscape. The DSIRE team highlighted the variability of regulations by state and by utility, impressing upon us another order of complexity we'd have to address as we assessed and integrated the data.

Overall, the learning process was very informative and we quickly appreciated the complexity of interrelated forces and frameworks within the energy industry. From that learning, we were able to stay high level and create a model that is accessible and useful enough to point someone in a productive direction (which in many cases may simply mean more education and discussion).





MODEL

Because this is a high-level tool for use by non-experts, it is designed to be as simple and user friendly as possible. It uses 5 questions in order to understand a user's load profile, and the local environmental, regulatory and economic conditions affecting microgrid desirability for a given building type at a given location. The tool generates scores from these conditions across a number of different variables to assess how well a microgrid could provide three primary benefits to the user: improved resiliency, clean energy, and cost effectiveness. From these three desirability category scores, it gives the user a Microgrid Feasibility score both as a 1 - 5, and A - F. It also produces a list of useful resources based on the user's location and sector.

INPUTS

To generate a proxy for each individual use case, the tool allows a user to input up to 3 different building types per facility. The user will answer the use questions for each of the included building types, as seen in the highlighted table.

Zip Code: Enter 5-digit zip code for the property in question

Building Type: Choose most relevant building type from drop down list. These building types are taken from EIA sector surveys, and adapted to better estimate time-of-use.

% Total Use: Enter percentage of total facility square footage used for this building type.

Critical Load (% of Energy Use): Enter percentage of the average daily energy use absolutely necessary for the building to continue its functional use

Building Size (Relative to Type): Relative to other similar building types, how large is the facility in question?

Zip Code	
Building Type 1	Hotel
% Total Use	50%
Critical Load (% of Peak Demand)	50%
Building Size (Relative to Type)	Medium
Building Type 2	Education (Night Classes Offered)
% Total Use	25%
Critical Load (% of Peak Demand)	25%
Building Size (Relative to Type)	Medium
Building Type 3	Education (Day Classes Only)
% Total Use	25%
Critical Load (% of Peak Demand)	25%
Building Size (Relative to Type)	Medium

MODEL SCORING

Variable Categories

The five previous questions generate scores for 32 variables across four variable categories.

1

Load Profile

The amount and timing of energy used have a significant effect on the potential to meet facility demand with on-site generation. It is more difficult for a building requiring substantial power at night to remain online during a grid outage than a building using a small amount of energy during the day. Night time use also requires either a lot of battery storage, or a number of natural gas or diesel generators which impact a facility's ability to lower both its carbon intensity and its cost effectiveness.

The model uses the building type and size in order to generate a proxy for the user load profile.

2

Resource Availability

The availability of renewable resources (particularly solar) also affects each desirability category. More solar energy increases a building's ability to remain operational when disconnected from the grid. It also allows it to generate less of its energy from fossil fuels such as natural gas or diesel. And, the more energy produced per solar panel, the lower the levelized cost of energy, which increases cost effectiveness.

The model uses data from NREL aggregated by state in order to approximate the availability of renewable resources.

3

Regulation

The regulatory environment surrounding microgrids is incredibly complex, varying drastically by region and by sector. For any user moving forward with microgrid installation, local policy will have a significant effect on every aspect of design. It affects a user’s ability to connect a microgrid with the local grid as well as its ability to reduce its carbon footprint compared to the local grid. Because there is significant capital cost, access to financing and incentives plays a critical role in the economic viability of installing a microgrid.

The model uses data from State Policy Opportunity Tracker and Freeing the Grid to understand the regulatory profile within each state.

4

Local Energy Grid Conditions

The state of the grid within each state has a substantial impact on whether or not a microgrid stands to actually help a particular site. For locations where the grid is relatively less carbon intense, a microgrid will score lower on clean energy, because a microgrid will not help a user improve. Similarly, the lower the cost of energy of the local grid, the harder it is for a microgrid to reach cost parity. And so, states with a lower average cost of energy (differentiated by sector) score lower on cost effectiveness.

The statewide energy prices are taken from EIA, while the local carbon intensity is from the Emissions and General Resource Integrated Database (eGRID).

MODEL SCORING

Desirability Categories

This microgrid feasibility assessment tool strives to score the desirability of implementing a microgrid at a particular site. To do this, we had to understand what drives people to implement a microgrid. The tool analyzes the potential benefits of a microgrid to improve a site’s resiliency, carbon intensity, and cost effectiveness. The drivers for each of these desirability categories, while overlapping, are substantially different. As such, the model assesses each of them independently to provide the user with more information on how a microgrid may be useful to them.

1 Resiliency

In light of the the economic and social costs of disruptions to the power grid, the ability to minimize the number and duration of outages is an important consideration when designing any energy system. For a microgrid to provide improved stability it is important to understand the users use profile including information such as their critical load, as well as their night time demand. Renewable resource availability is also important as it allows a user to meet their demand through onsite generation while cut off from outside resources.

2 Clean Energy

As people look for ways to decrease their carbon footprint, a microgrid may provide substantial improvements. To understand its potential impact, the model looks at the renewable resource availability to know whether additional fossil fuels like natural gas or diesel may be needed supplementarily. It also considers the emissions of the local grid because the degree to which a user may decrease their carbon intensity is relative to their starting point.

3 Cost Effectiveness

Lastly, and likely most important for most users, the model considers the cost effectiveness of a microgrid. To generate specific cost figures is incredibly complex and would require significantly more detailed information than we are asking of the user. To generate a proxy for this cost, we look at every variable category. This includes the user’s load profile to understand both their overall demand and need for battery storage, the local solar availability to determine the potential levelized cost of energy per installed solar panel, and the regulatory support through financing and incentive policies. It also considers the price of energy from the local grid, because similarly to clean energy, the tool is striving to give the user a sense for the relative improvement potential from creating a microgrid.

Because there are a number of reasons a user may be interested in implementing a microgrid, the tool allows for the user to adjust the weightings on the relative importance of each of these factors to account for their own personal motivations.

Feasibility Score Weighting	
Resiliency	0.15
Clean Energy	0.7
Cost Effectiveness	0.15

OUTPUTS

Building Type

Each building type is scored with a weighted average of the desirability categories according to the weights assigned by the user as described in this table.

Building Type		
Hotel		Score
	Resiliency	3.3
	Clean Energy	2.9
	Cost Effectiveness	4.0
Education (Night Classes Offered)		Score
	Resiliency	3.8
	Clean Energy	3.0
	Cost Effectiveness	4.0
Education (Day Classes Only)		Score
	Resiliency	4.2
	Clean Energy	3.3
	Cost Effectiveness	4.1

OUTPUTS

Microgrid Feasibility Score

As the regulatory, technological, economic and environmental conditions affecting microgrids and the wider energy market are all changing rapidly, these scores are not absolute, and will vary over time. An “F” today, may be an “A” tomorrow.

A final score is determined by taking a weighted average of the building type scores (above) according to the percentage of the facility designated for that use. The raw scores will fall between 1 - 5. This is then converted to a letter grade, with each letter receiving an equal share of the possible scores. An “F” indicates to a user that based on their facility profile, and what they hope to achieve through its installation, a microgrid is not the solution for them. Conversely, an “A” would tell a user that the installation of a microgrid would provide substantial improvements to the considerations most important to them.

Microgrid Feasibility	**3.28**
Letter Grade	**C**

Confidence Level

Currently the tool is ready to begin Beta testing. We have not analyzed it in any statistically significant way for accuracy. As data sources continue to be refined, and users provide feedback based on their real world experience, the model’s accuracy stands to improve substantially.

Designers of the tool are not responsible for any actions taken by the user as a result of the use of this tool.

RESOURCES

Ultimately, this tool is intended to be the first stop for a user on their path towards a microgrid. Regardless of their score, in order to make sure they continue along this path, the tool will not only provide a microgrid score, but perhaps more importantly, it provides additional next step resources through a wiki-enabled database.

Some of these resources will be universally beneficial and displayed to all users. These include design tools, such as HOMER or NREL's Systems Advisor Model (SAM), regulatory databases such as DSIRE, as well as general microgrid information resources like the Institute for Local Self Reliance (ILSR).

Other resources will be specific to a user's location and sector. For example, Solar Power Rocks is a fantastic resource for regulatory information specific to the residential sector, but has no information for commercial or industrial users, and so only users with a residential building type in their profile will be directed there.

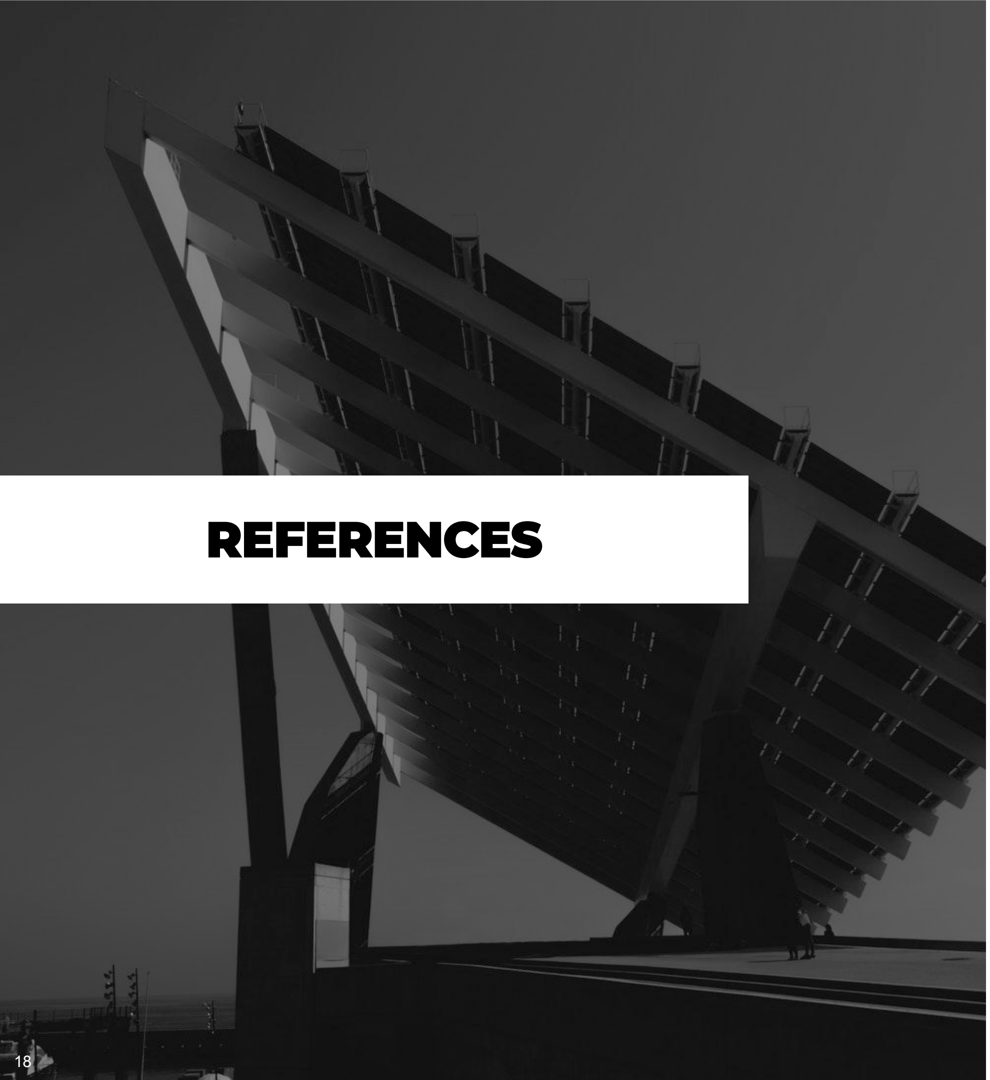
This resource list is intended to be wiki-enabled to allow the microgrid community to continue building it out over time. Anyone with a resource may add it to our database and while doing so, they will indicate which sectors this resource is relevant for and in what geographic regions, so that it may be shown to the appropriate users.

NEXT STEPS

The team was able to create a model framework that can be built upon in a few important ways. The first is to build out a user interface that can allow universal access and communicate the results of the model clearly. The next is to continue researching the model drivers and check them against other data sources (as mentioned in Process section) to find what policies and regulatory frameworks might allow for stronger microgrid adoption in particular locations. One particular piece of additional research that can be done is to find more accurate energy intensity weightings by building type and size (potentially on a per square foot basis). From a technical perspective, an important next step is creating automatic integration between the raw data and the model to allow for live updating in the rapidly evolving regulatory and market environment.

In the interest of iteration, users can begin testing the tool as is. This will provide meaningful feedback on its structure, usability and ability to communicate the user's "microgrid feasibility" and "next steps" as well as instigate users to begin building out the "next steps" section with their own knowledge in a wiki-style format. The "next steps" section for the user is potentially one of the biggest value generators for the tool as it can set up further action by the user and empower them with tools and guidance. There are a plethora of available and growing resources that can be leveraged for use that we have compiled and that can be built upon.

It is also important to reiterate that while the tool provides a functional framework in pursuit of the stated goal of assessing the feasibility of a microgrid, the various sources of data and their interaction has yet to be validated as accurate and as such, this tool should be thought of more as a finger in the wind than an anemometer. Rigorous testing of various assumptions needs to be performed to test the model's output and optimize the variables. That is beyond the scope of this project and would be a significant undertaking and value add to the model and its users. With the current model framework in place and varying levels of valid data being used to provide the results of the tool, a project team could continue to iterate on this model and improve its functionality and reliability in assessing microgrid feasibility across the three categories.



REFERENCES

Office of Electricity Delivery & Energy Reliability (n.d.). The role of microgrids in helping to advance the nation's energy system. Retrieved on May 7, 2018 from https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping

Roberts, D., Chang, A. (2017, December 29). Meet the microgrid, the technology poised to transform electricity. Retrieved May 2, 2018 from https://www.vox.com/energy-and-environment/2017/12/15/16714146/greener-more-reliable-more-resilient-grid-microgrids

Ton, D., Smith, M. (2016, June). The U.S. Department of Energy's Microgrid Initiative. Retrieved May 1, 2018 from https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf

Walton, R. (2016, June 3). Microgrid capacity to exceed 3.7 GW by 2020, a new study says. Retrieved April 25, 2018 from https://www.utilitydive.com/news/microgrid-capacity-to-exceed-37-gw-by-2020-a-new-study-says/420284/

Wood, E. (2017, November 30). New GTM report forecasts $12.5B microgrid investment within U.S. by 2022. Retrieved April 28, 2018 from https://microgridknowledge.com/microgrid-investment-gtm/

APPENDIX A

Sources & Databases

Allied Solar Professions. (n.d.). Retrieved from https://irecusa.org/

Center for Sustainable Energy. (n.d.). Retrieved from https://energycenter.org/

Center for the New Energy Economy. (n.d.). Retrieved May 11, 2018, from http://cnee.colostate.edu/

Clean Edge. (2018). Retrieved May 11, 2018, from https://cleanedge.com/

Community Power Map. (n.d.). Retrieved from https://ilsr.org/community-power-map/

Database of State Incentives for Renewables & Efficiency®. (n.d.). Retrieved May 11, 2018, from http://www.dsireusa.org/

Emissions & Generation Resource Integrated Database (eGRID). (2018, March 13). Retrieved May 11, 2018, from https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Freeing the Grid. (n.d.). Retrieved May 11, 2018, from http://freeingthegrid.org/#state-grades/

Grid Wise. (n.d.). Retrieved May 11, 2018, from http://www.gridwise.org/

Jansky, D. (n.d.). Comparison of Solar Power Potentialby State. Retrieved May 11, 2018, from http://www.neo.ne.gov/statshtml/201.htm

Microgrid Portfolio of Activities. (n.d.). Retrieved May 11, 2018, from https://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0

Nussey, B. (n.d.). The Freeing Energy Project. Retrieved May 11, 2018, from http://www.freeingenergy.com/

Offshore Energy Outlook. (n.d.). Retrieved May 11, 2018, from https://www.iea.org/

Solar and Energy Storage for Resiliency (Solar Resilient). (2018, March 06). Retrieved from https://sfenvironment.org/solar-energy-storage-for-resiliency

Solar Power - Clean Energy Authority. (n.d.). Retrieved from https://www.cleanenergyauthority.com/

Solar power and solar panel rebates, tax credits, and production info. (n.d.). Retrieved May 11, 2018, from https://solarpowerrocks.com/

Solar rebates and incentives. (n.d.). Retrieved from https://www.cleanenergyauthority.com/solar-rebates-and-incentives

SolarResilient™ - a sizing tool for solar PV and battery storage systems. (n.d.). Retrieved May 11, 2018, from https://solarresilient.org/

SPOT. (n.d.). Retrieved May 11, 2018, from https://spotforcleanenergy.org/

Trends and Analysis. (n.d.). Retrieved from https://www.aeltracker.org/p/trends-analysis

U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (n.d.). Retrieved May 11, 2018, from https://www.eia.gov/electricity/monthly/