Hydropower Collegiate Competition

The Reservoir Rulers

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Table of Contents

INTRODUCTION

Our project, aimed at revolutionizing sustainable clean energy, is a collaborative effort by a team with diverse backgrounds and expertise. Winston, our team leader, provides direction, guidance, and motivation to the other team members. Evie, our treasurer, is responsible for managing the project's finances including, budgeting, financial planning and monitoring expenditures. Zongha Ouyang, our secretary, is in charge of keeping track of the official records and documents relating to the project. Together, we form a cohesive unit committed to achieving our project’s objectives. Our goal aligns with the Hydropower Collegiate Competition guidelines which consists of three main challenges. The first challenge is to select a non-powered dam site that has the potential to be a hydropower dam. The second challenge consists of creating an overall conceptual design of the potential hydropower site. The third challenge involves community connections including industry interviews and a community engagement activity. Throughout this project, we will work together to meet the needs of our client, Carson Pete. Professor Carson Pete is our advisor for the competition giving us guidance and suggestive relief for issues that we encounter as we build our research, but does not strictly provide us with requirements and needs as that is the job of the competition rulebook. This concept is actually relatively new, following decades of abusive dam building and destruction of ecosystems we now look to attempt at remedying these dams. The conversion of a NPD to a hydropower dam is a new concept with relatively few previous projects for us to pull from. However, we have still been able to find enough resources that have given us good estimation values and expectations of our project. We have already finished our first challenge, dam selection, and we picked the granite reef diversion dam.

PROBLEM STATEMENT

STATEMENT OF NEEDS

The Hydropower collegiate competition is a new competition that will be going into its second year, with new requirements and goals to reach from last year's competition. Hydropower currently generates about 6.2% of all energy production within the United States and upwards of 28% of all renewable energy production. This proves that hydropower is a real and effective way for humans to harness and use power from naturally occurring and renewable sources without the need to burn fossil fuels and create pollution. Currently in the United States there exist more than 90,000 dams nationwide, of these dams, we find that less than 2,300 produce power. These non-powered dams are used for many activities such as water recreation, flooding control, irrigation, and much more. However, these activities are only so useful with a growing demand in America for more and more power as we become more reliant on our technology in everyday life. With almost 100.41 quadrillion btu used in America in 2022 through various energy needs, it's obvious this need will only increase with every passing year.

This is the reason for the creation of the HCC competition, with so many non-powered dams speckling the country there is a new demand for conversion of these non-power producing areas to be refitted with the means to supply communities around them with power. There is also the increasing age of the hydropower demographic that is desperately in need of young workers to take over jobs and operations as older employees begin to retire. With nearly 26% of the workforce in hydropower being over the age of 55 there is a large push to get the younger generations interested in the interworking of hydropower production and distribution.

Within the 10-month period we have been assigned to this project we are expected to produce a proposal and presentation at an industry event in the spring of 2024 for the conversion of a current non-powered dam into a power-producing dam for a community in need. Not only is there a need for more power but the conversion of a dam already built requires much less planning and most importantly much less money.

We have been tasked with 3 main passages for our presentation and write-up and 1 optional design challenge from the stakeholders. All of which require their own specific market requirements, needs, and stakeholder expectations.

1.) Siting Challenge: Teams will evaluate potential sites to choose an NPD site that fits the challenge requirements. Scoring will be based on thoroughness of assessment and not feasibility.

o   Find a location out of the 80,000 plus currently nonpower-generating dams in the United States.

- Potential to produce between 100 kilowatts and 10 megawatts of power.

- Co-development opportunity at the NPD site
    - Hybrid designs (wind, solar, storage, hydrogen, etc.)
    - Environmental improvements
    - Recreation
    - Species rehabilitation
    - Food/energy security
    - Tourism
    - Workforce development or education and more

- Location chosen

- Risks to install power generating systems and mitigation.

- NPD site selection requirements
    - Level of cost
    - Resource/generation availability
    - Safety and geotechnical data
    - Transmission/grid lines
    - Cultural effects
    - Social metrics
    - Operation and patience requirements
    - And more

2. Design Challenge: Teams will complete a detailed design of a singular hydropower concept within their selected NPD site or an overall conceptual design of the full powerhouse.

- Track 1: Facility Conceptual Design:
    - Equipment selection
    - Conceptual drawings
    - Detailed feasibility assessment (socioeconomic, technical, and operational)

- Track 2: Hydropower Component Deep Dive:

    - Component or system of selected dam conversion
    - Engineering designs
    - Drawings
    - Cost estimates
    - Relevant models

3. Community Connections Challenge: we are tasked with creating connections among HCC teams, the hydropower industry, students, and local communities.

- Communities understand the needs/impact of hydropower development
- Industry interviews
- Website
- Social media
- Community engagement activity:
    - Raise student awareness of hydropower
    - Inspire new students to participate in the competition
    - Educate and excite younger students about opportunities in hydropower
        - Kidwind hydropower event
        - Local school or university event

4. Optional Build and Test Challenge: Our team will have to decide whether to participate or not in this section of the competition where we will build a scaled prototype of their concept and perform a series of tests.

- Scaled prototype of the proposed concept

Dimensions

- Available budget

For our final report, we have been given the rubric on which we are to be graded during our presentation at the final HCC convention.

- Siting challenge – 33% of the overall grade
- Design challenge – 39% of overall grade
- Community connections challenge – 27% of the overall grade

LIMITATIONS

When considering the conversion of a non-powered dam into a power-producing dam, many concerns and limitations exist in the project.

Limited availability of sites – Not every location is suitable or even needs a power-supplying dam. The site selection holds some of the most limiting requirements of the entire project. Is the environment suitable for a dam? Are there nearby communities in need of power or even transmission lines or substations to distribute our newly produced power?

Environmental complications – As many dams were built in the early 1900's barely little if any environmental concerns were considered. Poorly placed dams can produce entire lists of issues as far as the environment goes. From destroyed habitats for fish as we have seen in the northwest with destroyed natural salmon runs. Protecting vulnerable species is one of the most important aspects of modern dam building. Other issues include water storage, dam breaks, water quality, precipitation, climate change, and much more.

Social Concerns – dams built in areas where they affect everyday life from traffic, to land used for power transmission, there are plenty of social concerns with the building of a dam. Protected land also holds an important aspect of social concerns with protected cultural sites, dam safety, jobs, ecosystem disruption, and many more aspects that are important to weigh when making a final decision.

Economic feasibility – will this dam even be worth it in the long run? Will it be able to produce profit for stakeholders or benefit the general population enough for large sums of cash to be spent on initial investment?

PROCESS

For our selection and design of our converted NPD, we must have meant supporting processes that also accompany our project. While we won't make the final product it is important to consider the supplemental but important supporting aspects of NPD conversion.

Design and Engineering – This includes all engineering operations for NPD conversion, from turbine design, dam type, generators, transformers, transmission, and much more go into the final decisions of designing an NPD conversion.

Construction – This process would account for all construction required in a NOD conversion, be the dam just a wall of rocks and daily maintained operation. Construction and conversion of an NPD dam will require a lot of planning to get right from excavation, concrete, and installation all will play important roles.

Maintenance and operation – This process includes all operations needed once the conversion is complete. As a power-supplying dam that's connected to the power grid, it will need constant maintenance from workers for proper operation.

Environmental management – This is a process that will take place throughout the dam's life. From mitigating the impact on wildlife from construction, environmental management impact plays a major role in NPD conversion.

STATEMENT OF OBJECTIVES

Our primary goal is to excel in the DOE's Hydropower Collegiate Competition and have a significant and lasting impact on our community, the environment, and our personal growth as engineers. We are committed to creating a sustainable and innovative solution aligned with industry standards that demonstrates the benefits of clean energy generation.

We aim to achieve our objectives by conducting extensive research, utilizing online resources, relevant textbooks, and professionals in the field. In addition, we will be actively seeking collaboration with NAU's Energy Club and graduate students to gain expertise and experience that helped NAU win third in the 2022-23 competition.

Our project aligns with the DOE's climate and emissions reduction goals by addressing the crucial role of hydropower in achieving a 100% clean energy economy by 2035. We recognize the untapped potential in the hydropower industry, imperative for a carbon-pollution-free power sector, and we look forward to contributing to its growth through innovation.

The competition has three core objectives, to bring together diverse groups of students from various fields of study. Another is to encourage real-world concept development experiences related to hydropower. Lastly, to inspire future innovators to tackle the challenges and opportunities in hydropower development.

There are three required challenge categories in the competition, the sitting challenge, design challenge, and community connections challenge.

In the sitting challenge, our goal is to perform hydropower site selection for non-powered dams, producing between 100 kilowatts and 10 megawatts of power, and develop a feasibility assessment for the selected site. In the design challenge, we will choose between two tracts. Track 1 is a facility conceptual design with the goal of creating a conceptual design of the selected hydropower site. Track 2 is a hydropower component deep dive with the goal of producing a final design package for an individual component or system related to the selected hydropower site's development.

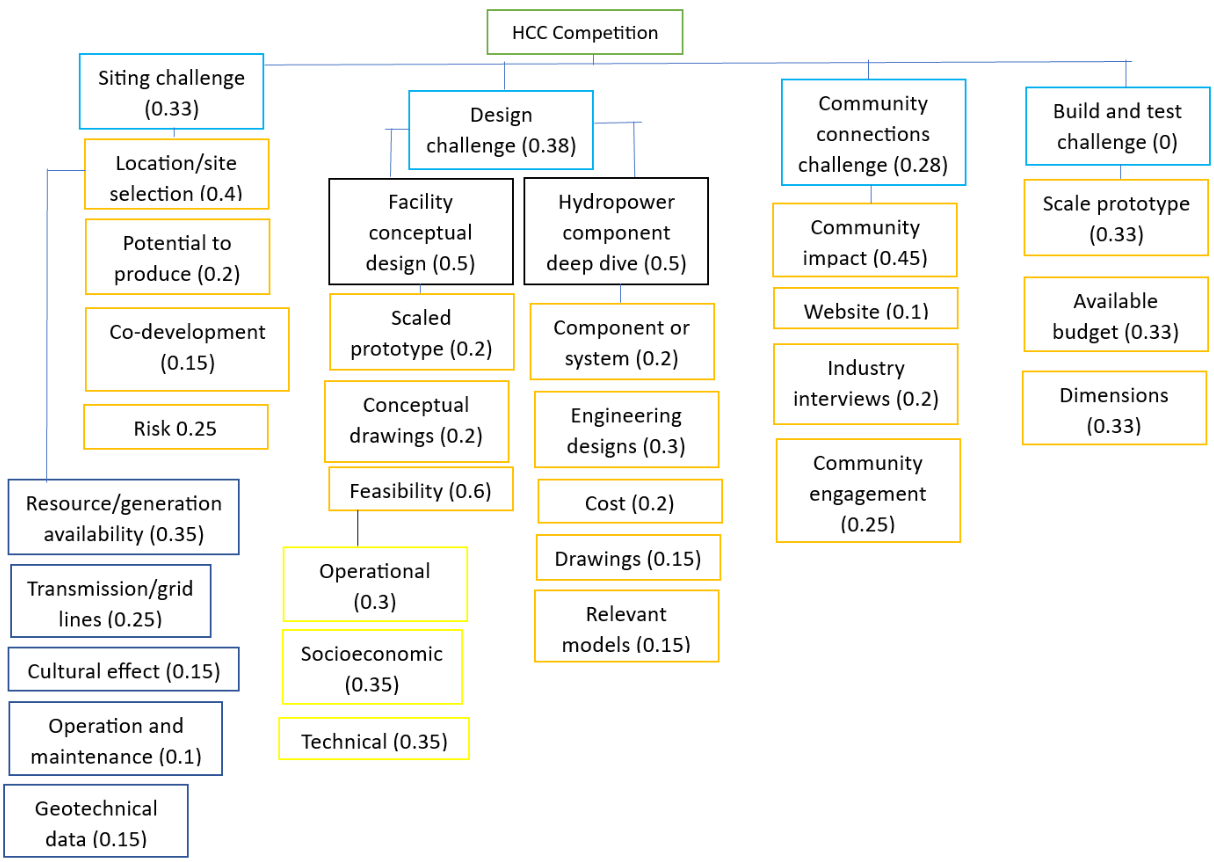
In the community connections challenge, we will achieve two goals, establish connections with professionals in the hydropower and broader clean energy industry. As well as promote the benefits of clean energy technologies within our community through public events, social media, media outlets, newsletters, and other channels.

Although not required, there is an optional build and test challenge that our team intends to participate in. In this challenge, our goal will be to construct a scaled prototype of our conceptual design or the selected hydropower component, including conducting a series of tests to demonstrate our innovation's practicality.

Our ultimate goal in the competition is to maximize learning. We aim to gain valuable knowledge, skills, and experience while inspiring future generations to engage in clean energy innovation. Our project represents our commitment to make a lasting impact and contribute to the transition to a sustainable, clean energy future.

OBJECTIVE TREE AND MATRIX

	Sitting Challenge	Design Challenge	CCC	sum	weight
Sitting Challenge	1	4/5	3/2	3.13	0.33
Design Challenge	5/4	1	3/2	3.58	0.38
CCC	2/3	2/3	1	2.67	0.28
				9.38	



SYSTEM REQUIREMENTS

ENGINEERING TRADE OFF MATRIX

	Energy Output	Enviromental Impact Mitigation	Efficiency	Social Community Impact	Feasibility	Site Interconnectivity
Energy Output		-	++	+	=	=
Enviromental Impact Mitigation			+	-	--	-
Efficiency				=	-	+
Social Community Impact					++	=
Feasibility						=
Site Interconnectivity						

Here we have our engineering trade-off for 6 of the most important elements we believe will impact this project. The symbols displayed are self-explanatory with '=' meaning the 2 intersecting items are of equal engineering importance and +/- meaning their usual definitions of positive and negative. From the matrix, we determined that energy output is by far one of the most important engineering aspects of our final design.

ENGINEERING-MARKETING TRADE-OFF MATRIX

	Customer Weights	Weight %	Energy Output	Enviromental Impact Mitigation	Efficiency	Social Community Impact	Feasibility	Site Interconnectivity
Energy Production	10	21.28	9	3	9	6	6	3
Enviromental Impact Mitigation	8	17.02	n/a	9	n/a	6	n/a	n/a
Hydropower Dam Energy Analysis	7	14.89	6	9	6	n/a	9	9
Community Engagement	6	12.77	n/a	3	n/a	6	n/a	n/a
Scalability	9	19.15	n/a	6	n/a	n/a	9	6
Cost	7	14.89	6	n/a	6	n/a	9	6

In our engineering-marketing trade-off matrix we have our marking requirements, listed in the first column, compared to our engineering requirements, listed in the top row. We also have it shown how the marketing requirements are weighted based on the customers needs and how that correlates as a percentage. Throughout the matrix it can be seen how each of the requirements compare to each other. However, some of them are not comparable and that is represented above as well.

HOUSE-OF-QUALITY

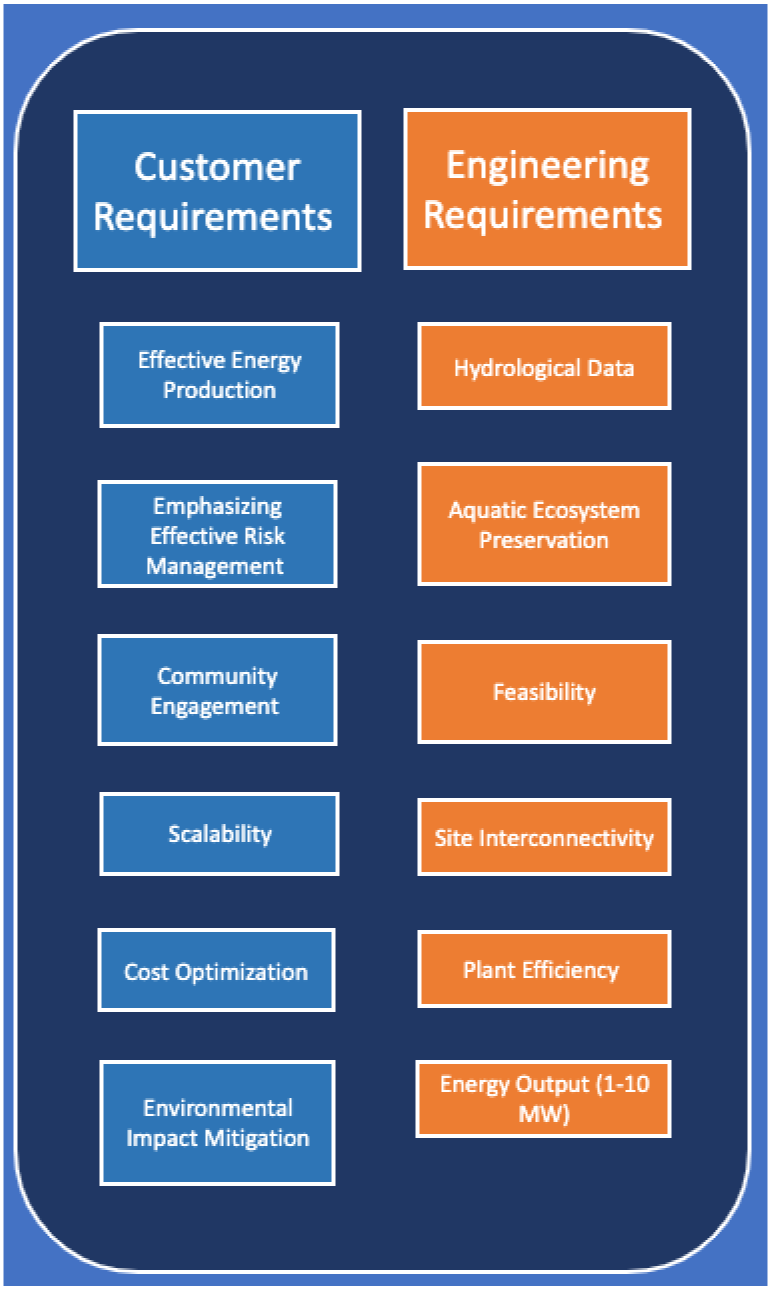
#	Technical Requirement	1	2	3	4	5
1	Energy Output					
2	Environmental Impact Mitigation	-				
3	Efficiency	++	+			
4	Social/Community Impact	+	-			
5	Feasibility		--		-	
6	Site Interconnectivity		-	+	+	++

Legend	
A	Dam 1
B	Dam 2
C	Dam 3

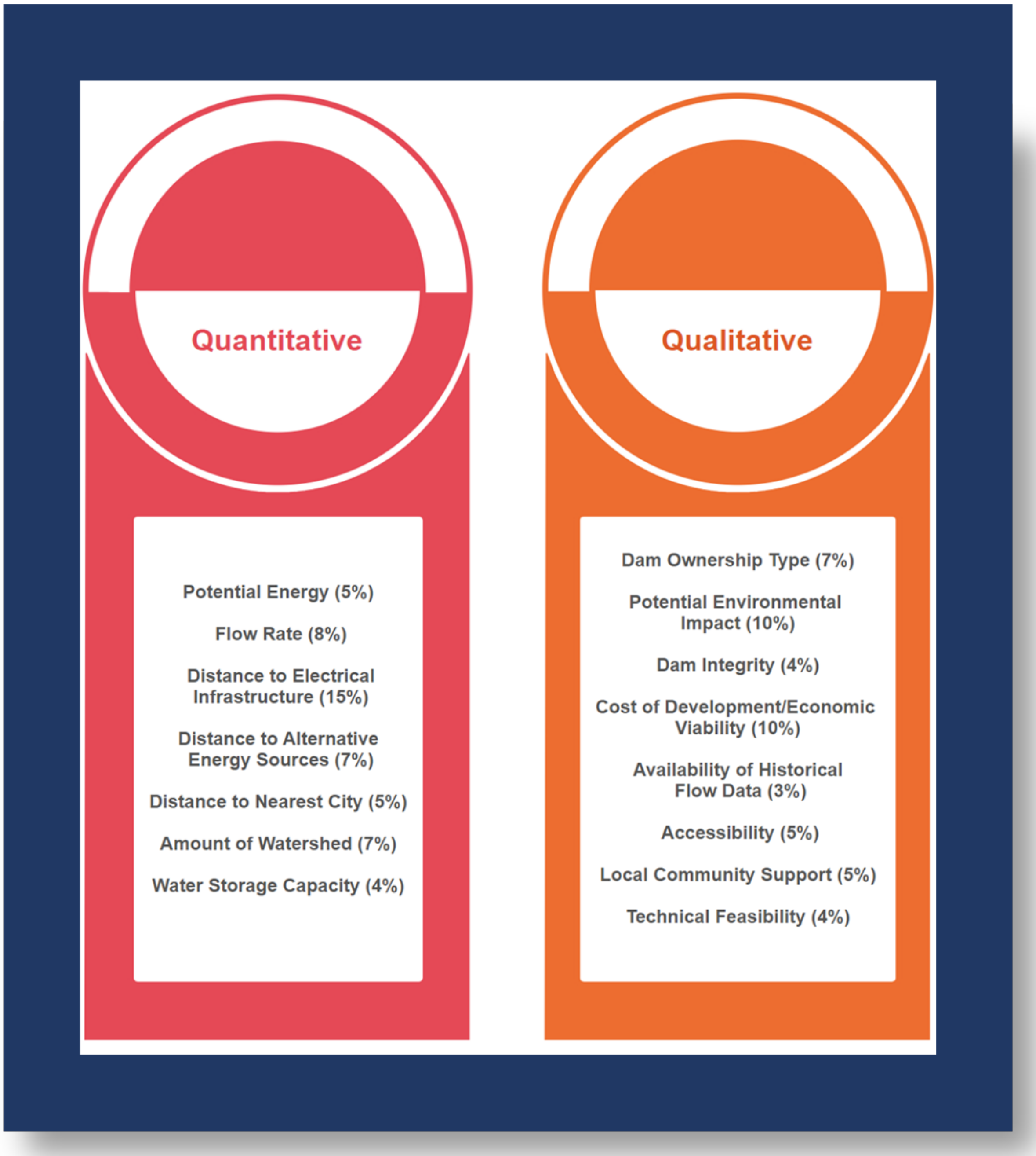
#	Customer Needs	Customer Weights	Weight %	Energy Output	Environmental Impact Mitigation	Efficiency	Social/Community Impact	Feasibility	Site Interconnectivity	1 Poor	2	3 Acceptable	4	5 Excellent
				Technical Requirements						Customer Opinion Survey				
1	Energy Production	10	21.28	9	3	9	6	6	3					
2	Environmental Impact Mitigation	8	17.02		9		6							
3	Hydropower Dam Energy Analysis	7	14.89	6	9	6		9	9					
4	Community Engagement	6	12.77		3		6							
5	Scalability	9	19.15		6			9	6					
6	Cost	7	14.89	6		6		9	6					
	Technical Requirement Units			mW	%	mWh, %	#	Years	$					
	Technical Requirement Targets			1-10 MW		>= 90%								
	Absolute Technical Importance			370.2	504.3	370.2	306.4	568.1	402.1					
	Relative Technical Importance			5	2	4	6	1	3					

The house of quality matrix weights the various needs and requirements of our project. It provides a well-organized analysis of what we need to do and what is of most importance when developing ideas and solutions for our project. As seen in the matrix we use customer needs and technical requirements for comparison. Of these, we found energy production and scalability are of the most importance to the customer, and community engagement is of the least importance. For the Technical side, we see heavy weights for energy output and efficiency with environmental impact being of least importance.

FUNCTIONAL & BEHAVIORAL ANALYSIS

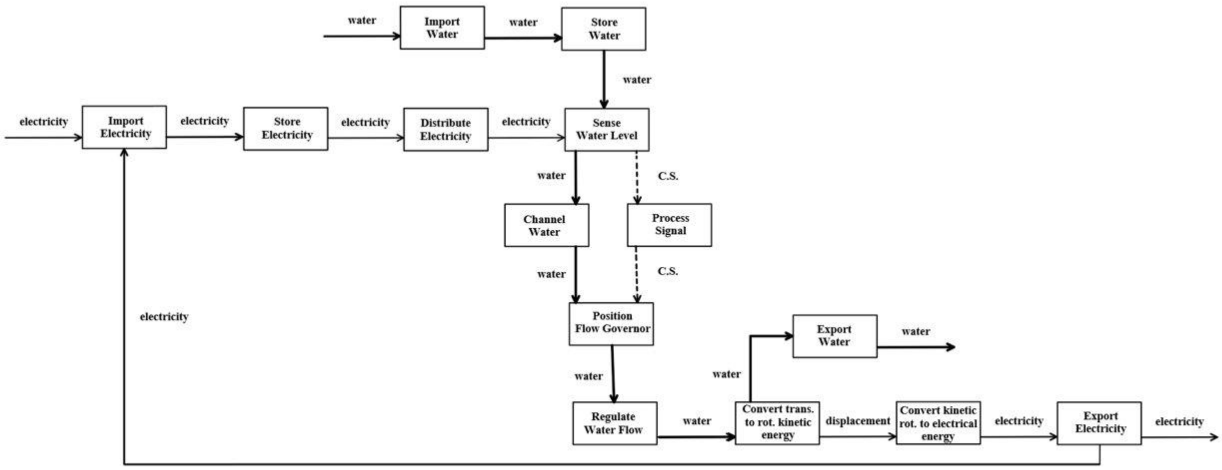


The figure above is the requirement we need to achieve for the competition. Basically, the power plant needs to be economically efficient and the potential power capacity needs to be between 100 kW and 10 MW, at the same time it should not damage the environment and have a contribution to the community nearby.



The figure above shows some of the requirements we used to assess the behavior of a dam selection process and weighted our options on what had the largest impact on site selection. Before we could settle on a location we had to assess the data and do so in a meaningful way. Creating a weighted matric containing these important criteria helped us narrow down our search, and only look at what really mattered in a sea of data.

The figure below describes the entity relationship diagram of a simple, single-turbine hydropower plant. Dam features such as fish passages, complex water intakes, and co-development functions would contribute additional functional paths, however, must be evaluated case-by-case.



CONCLUSION

Throughout this semester, our team's main focus was selecting a non-powered dam site to convert into a hydropower dam that met the criteria for the competition's requirements. We were able to narrow the pool of over 80,000 non-powered dams in the United States to just one, Granite Reef Diversion. We have also been working to create connections within the community, exploring potential avenues for our industry interviews, and creating a plan for our community outreach with an activity alongside the wind energy team designed by Kidwind for middle and high school students to engage in.

Our team will start next semester focusing on the mid-year submission for the competition that is due on January 28th. We will also be conducting multiple industry interviews as well as presenting to middle and high school students about clean energy related to hydropower dams. A major focus of the semester will be on creating an overall conceptual design of the conversion of Granite Reef Diversion from a non-powered dam to a hydropower dam. Then in April, we will be attending the National presentation in Des Moine, Iowa.

BIBLIOGRAPHY

[1] "Types of Hydropower Plants." Energy.Gov. www.energy.gov/eere/water/types-hydropower-plants#:~:text=Some%20hydropower%20plants%20use%20dams,produce%20power%20as%20of%202020. Accessed October 13,. 2023.

[2] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." U.S. Energy Facts Explained - Consumption and Production - U.S. Energy Information Administration (EIA). www.eia.gov/energyexplained/us-energy-facts/#:~:text=In%202022%2C%20total%20U.S.%20primary,equal%20to%20100.41%20quadrillion%20Btu. Accessed October 13, 2023.

[3] "Hydropower Workforce and Development: Key Trends and Findings." Energy.Gov. www.energy.gov/eere/water/articles/hydropower-workforce-and-development-key-trends-and-findings#:~:text=Approximately%2026%25%20of%20the%20hydropower,13%2C000%20will%20leave%20by%202040. Accessed October 13, 2023.

[4] "Hydropower Collegitae Competetion 2024 Rules Document." American Made Challenges. Hydropower-Collegiate-Competition-Rules.pdf (americanmadechallenges.org). Accessed October 13, 2023.