The Marine Energy Collegiate Competition 2025 (MECC25)

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Agenda

- Project Description
- Budget
- Scheduling
- Background & benchmarks
- Customer & engineering requirements
- QFD
- Mathematical Modeling
- Literature Reviews
- Q&A

Project Description

The Marine Energy Collegiate Competition (MECC)

- An annual competition organized by the U.S. Department of Energy
- Design solutions for harnessing marine energy
- Importance: 71% of the Earth is ocean

Sponsors

- U.S. Department of Energy
- Northern Arizona University
- NAU Energy Club

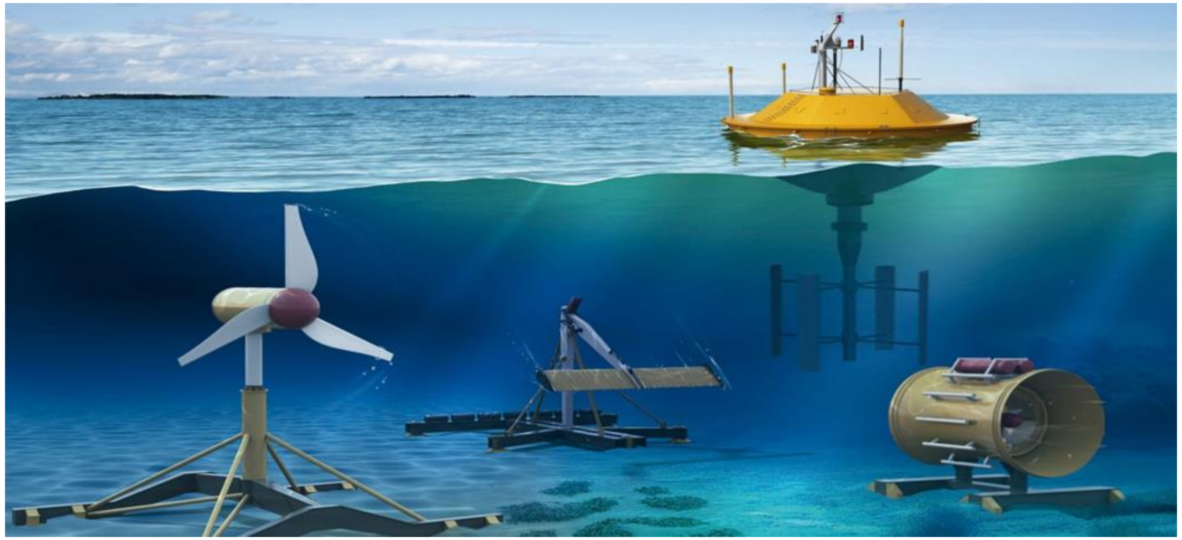

Figure [1]: Examples of marine energy generators

Budget

- **Budget given is $20,000**
  - Collaboration with NAU Energy Club (Fundraising)
  - ~$5,000 will be put away for travel to Competition (airfare, hotel, etc.)

Table [1]: Budget Disbursement

Stage	Cash Prize per Team	Total Cash Prize Pool
Application to Participate	$5,000	$115,000
January Submissions	$5,000	$115,000
February Submissions	$5,000	$115,000
Final Event	$5,000	$115,000
Grand Prize*	TBD*	$20,000*
Total	**$20,000 (+grand prize awards)**	**$480,000**

Figure [2]: NAU Energy Club Logo

Scheduling

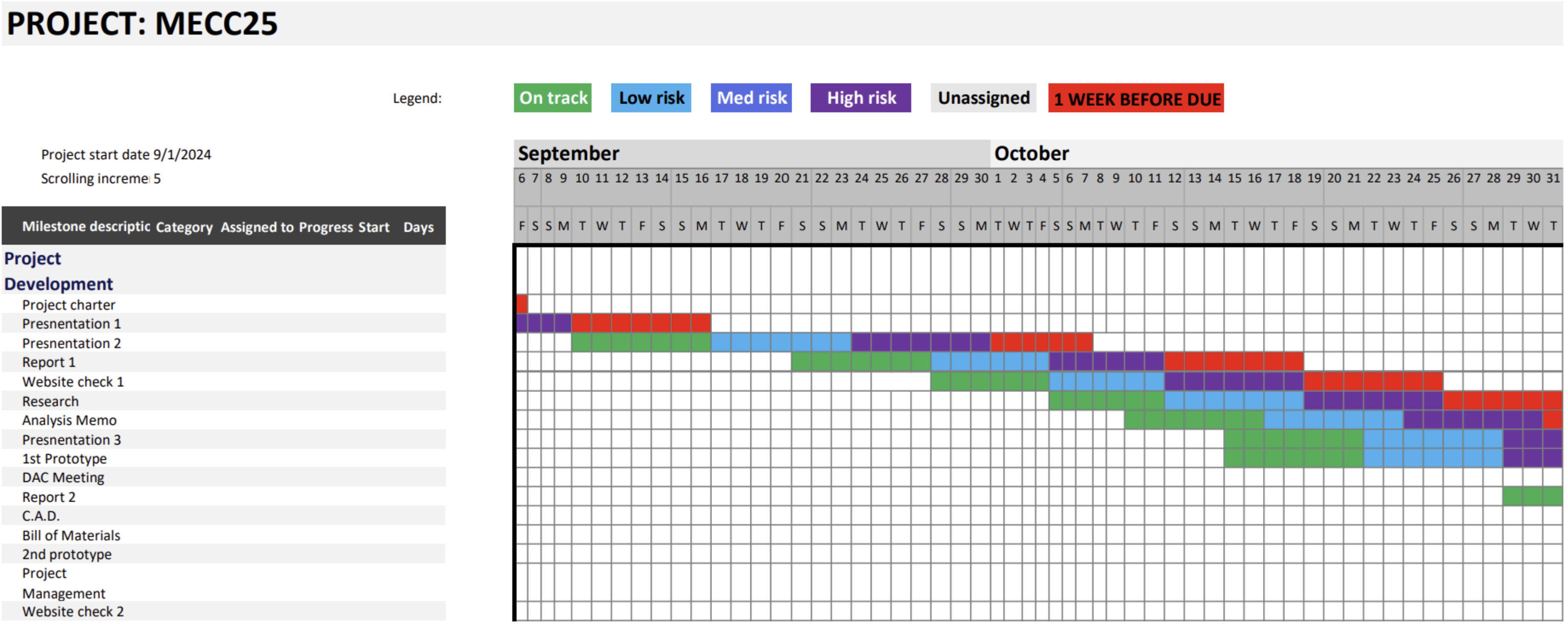

Figure [3]: MECC25 Gantt Chart

- Gantt chart for each part of Course (Class, Business, Technical Design, Build & Test, Community Connections, Poster, and Quick Pitch)
- Spans from now until competition (week after graduation)

Background & Benchmarking

- **CorPower Ocean**
  - Buoy that uses difference in wave height
  - Offshore
  - Peak power generation of 600 kW per unit
- **Sea Wave Energy Limited (SWEL)**
  - Multiple buoys attached together uses difference in wave height
  - On & Offshore
  - Over 100MW per unit
- **Eco Wave Power**
  - Crank rocker mechanism uses difference in wave height
  - Onshore
  - Approx. 325.7MW

Figure [4]: CorPower's generator

Figure [5]: Sea Wave Energy Limited's generator

Figure [6]: Eco Wave Power's generator

Customer/Engineering Requirements

Customer Requirements

- Safe to users/patrons
- Presentation type (onshore/offshore)
- Under budget
- Non-hazardous to marine life
- Aesthetically appealing to public
- Works in different climates
- Ease of manufacturing
- Easily integrable into the power grid

Engineering Requirements

- Resistant to nature (seawater/weather/etc.)
- Output type (battery or direct to grid)
- Safety/ability to shut off remotely
- Duration of use during 24-hour period
- Efficiency percentage
- Testable in a lab/tank
- Compatible in multiple environments
- Use of marine energy 51% or more

Quality Function Deployment

1: low, 5: high	Desired direction of improvement (↑,0,↓)								
Customer importance rating	Engineering Requirements (How's)→ Customer Requirements - (What's) ↓	Resistant to nature(seawater/weather/etc.)	Output type	Duration of use during 24 hour period	Possible efficiency	Testable in a lab/tank	Compatable in multiple enviroments	Use of marine energy <51%	Safety/ability to shut off remotely
5	Safe to users	4	2	2	2	2	3	3	9
2	Presentation type	6	6	4	4	5	5	5	5
4	Under budget	1	1	1	7	6	1	1	1
4	Non-hazardous to Marine Life	5	3	4	4	2	6	6	8
3	Aesthetically appealing to public	6	6	6	3	3	3	6	6
5	Works in different climates	7	7	8	9	7	8	8	8
5	Ease of manufaturing	8	8	8	8	8	8	8	8
5	Easily integratable into the power grid	7	7	7	7	6	6	7	7
	Technical importance score	184	166	171	191	166	172	186	224
	Importance %	20%	18%	18%	20%	18%	18%	20%	24%
	Priorities rank	**4**	**7**	**6**	**2**	**7**	**5**	**3**	**1**

Figure [7]: MECC NAU QFD Table

Mathematical Modelling

$Fa = \rho g V$ (Archimedes' Principle/Buoyancy Force Equation);

Buoyancy force = density of fluid displaced * gravitational pull * total volume

Fa = density of sea water * gravitational pull * volume of buoy

Fa = 1025 kg/m^3 * 9.81 kgm/s^2 * 484.78 m^3

Fa = 4,874,584.10 Newtons = 1,095,474 lbf

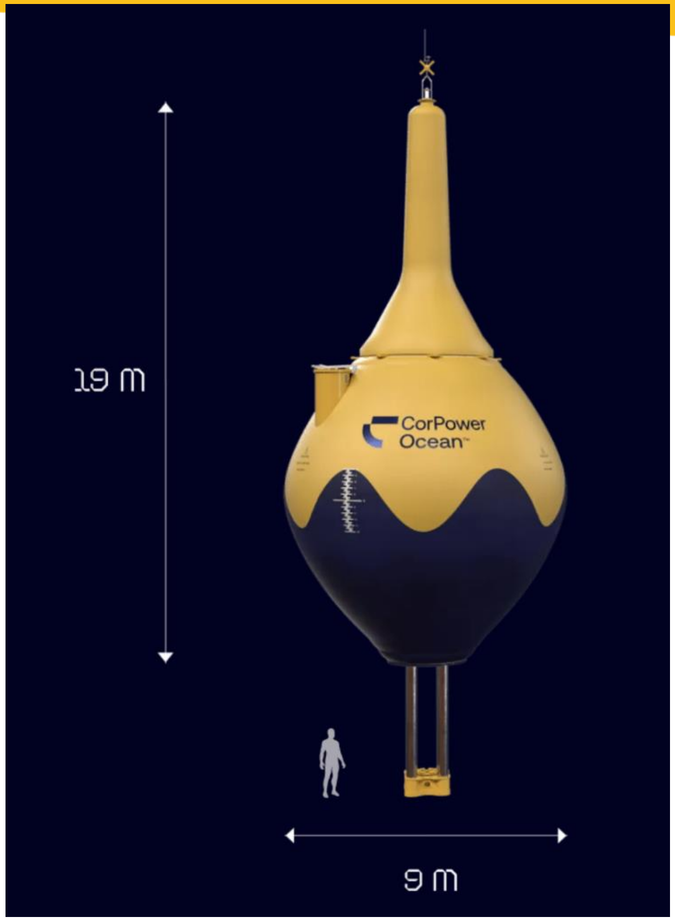

Figure [8]: CorPower Buoy Scale Model

Mathematical Modelling

$P = \frac{1}{2}\rho g H^2 \lambda b$ (Wave Power) (Aiden)

P = Power

ρ= Density

g= Gravity

H= Hight of wave

λ= Wave Length

b= Base (length under the water that wave stops)

From San Diego Beach:

ρ= 1025 $\frac{Kg}{m^3}$

H=0.9144m-1.2192m

λ=30m-40m

b= 0.9144m-1.2192m

Lower Range

P= 115316.85 $\frac{W}{m}$

Upper Range

P= 455572.75 $\frac{W}{m}$

Bechtold, Gavin. “Wave Size in San Diego: How Big Are They?” *Go Surfing SD!*, 10 Oct. 2023, gosurfingsandiego.com/wave-size-san-diego/.

Mathematical Modelling

$$F_{drift} = C_d \frac{\rho g A^2}{2}$$

F Is the force of drift

ρ Is the density of seawater

g Is the gravitational acceleration

A Is the amplitude of the wave or the wave height

C_d is the drift coefficient

Drift Force is used for positioning a Wave Energy Converter Device.

Offshore Wave Heights in Hawaii 4 ft = 1.2192m

$$F_{drift} = C_d \frac{\rho g A^2}{2}$$

$\rho = 1025 \frac{kg}{m^3}$

$g = 9.81 \frac{m}{s^2}$

A = 1.2192m

C_d = 0.5 (Arbitrary coefficient but based off cylindrical buoy geometry)

F_{drift} = 3736.65 N = 840.3 lbf

Literature Review (Patrick Grosse)

- [1] M. P. Singh and G. M. Lucas, Blade design and analysis for steam turbines. New York: McGraw-Hill, 2011.
- [2] P. Clausen, J. Whale, and D. Wood, Eds., “Small wind and hydrokinetic turbines,” in IET Energy engineering, no. 169. , Institution of Engineering and Technology, 2021, pp. 295–324.
- [3] M. J. Najafi, S. M. Naghavi, and D. Toghraie, “Numerical simulation of flow in hydro turbines channel to improve its efficiency by using of Lattice Boltzmann Method,” Physica A: Statistical Mechanics and its Applications, vol. 520, pp. 390–408, Apr. 2019, doi: 10.1016/j.physa.2019.01.034.
- [4] L. Talluri, D. Fiaschi, G. Neri, and L. Ciappi, “Design and optimization of a Tesla turbine for ORC applications,” Applied Energy, vol. 226, pp. 300–319, Sep. 2018, doi: 10.1016/j.apenergy.2018.05.057.
    - [1-4] All talk about different turbines and blade dynamics
- [5] “Updates to Marine Engineering Standards,” Federal Register. Accessed: Sep. 16, 2024. [Online]. Available: https://www.federalregister.gov/documents/2024/06/12/2024-10341/updates-to-marine-engineering-standardsFundamental fluid mechanics principals
    - Coast Guard’s rules & regulations for offshore environmental protection
- [6] G. Lemonis, “Wave and Tidal Energy Conversion,” in Encyclopedia of Energy, C. J. Cleveland, Ed., New York: Elsevier, 2004, pp. 385–396. doi: 10.1016/B0-12-176480-X/00344-2.
    - Different ways of collecting energy from the ocean
- [7] “Insights on Wave Power – CalWave.” Accessed: Sep. 11, 2024. [Online]. Available: https://calwave.energy/insights-on-wave-power/
    - Describes wave development off & on shore
- [8] “OceansMap.” Accessed: Sep. 11, 2024. [Online]. Available: https://eds.ioos.us/map/
    - NOAA map showing current direction and surf reports from buoys

Literature Review (Aiden Lee)

- [1] Dimopoulos, George G., et al. "A General-Purpose Process Modelling Framework for Marine Energy Systems." Energy Conversion and Management, Pergamon, 2 June 2014, www.sciencedirect.com/science/article/abs/pii/S0196890414003501.
  - Modeling framework for different marine energy systems.
- [2] C. F. Kutscher, J. B. Milford and F. Kreith, "Ocean, Hydropower, and Geothermal Energy Converstion," *Principles of Sustainable Energy Systems,* 3rd ed. FL, USA: CRC Press, 2019, ch. 13, sec. 13.2.
  - Calculating energy out put of waves and understanding the motion of waves.
- [3] C. F. Kutscher, J. B. Milford and F. Kreith, "Ocean, Hydropower, and Geothermal Energy Converstion," *Principles of Sustainable Energy Systems,* 3rd ed. FL, USA: CRC Press, 2019, ch. 13, sec. 13.3.
  - Calculating energy from tides and understanding the mechanics of tides.
- [4] "Taming Sea Energy: Learning Marine Renewable Energy Technologies," in Strategic Direction, 2009. [online]. Available: DOI: 10.1108/02580540910921932.
  - Aspects of UK marine energy and policies
- [5] M. Nachtane, M. Tarfaoui, D. Saifaoui, A. El Moumen, O.H. Hassoon, H. Benyahia, "Evaluation of Durability of Composite Materials Applied to Renewable Marine Energy: Case of Ducted Tidal Turbine" in *Energy Reports,* 2018.[Online]. Available: DOI: 10.1016/j.egyr.2018.01.002
  - Use of composite materials in marine structures
- [6] E. Oberg, F D. Jones, H. L. Horton, and H.H. Ryffel, " Internal Gearing" in *Machinery's Handbook, 29th ed., NY, NY, USA: Industrial Press, 2012, ch. 12, sec 3, pp. 2169-2171.*
  - *Internal Gear Standards*
- [7] U.S Department of Energy. " Ocean Energy." WBDG.org. Accessed Sept. 15th, 2024. [Online]. Available:https: //www.wbdg.org/resources/ocean-energy#:~:text=The%20first%20known%20patent%20to,energy%20is%20intermittent%20and%20variable
  - Different types of energy you can harness in the ocean.
- [8] L. Rodrigues. " Wave Power Conversion Systems for Electrical Energy Production." Repqj.com. Accessed Sept. 15th, 2024. [Online]. Available: https://repqj.com/index.php/repqj/article/view/1826/380-leao.pdf
  - Equations and models for different energy conversion systems

Literature Review (Asher Aspili)

- [1] A. O. Pecher and J. P. Kofoed, Handbook of Ocean Wave Energy. Cham: Springer International Publishing, 2017.
  - A guide for ocean energy optimization
- [2] W. G. Nickels, J. M. McHugh, and S. M. McHugh, "Chapter 13 Marketing: Helping Buyers Buy," in Understanding Business, 12th ed, New York, NY: McGraw-Hill Eduation, 2019, pp. 326–351
  - Understand how to develop a customer-oriented business model for markets
- [3] A. Barua and M. Salauddin Rasel, "Advances and challenges in ocean wave energy harvesting," Sustainable Energy Technologies and Assessments, vol. 61, p. 103599, Jan. 2024. doi:10.1016/j.seta.2023.103599
  - Ocean wave energy harvesting methods
- [4] M. S. Lagoun, A. Benalia, and M. E. Benbouzid, "Ocean Wave Converters: State of the art and current status," 2010 IEEE International Energy Conference, vol. 2, pp. 636–641, Dec. 2010. doi:10.1109/energycon.2010.5771758
  - Ocean wave energy fundamentals: wave motion converting to energy
- [5] G. Reikard, P. Pinson, and J.-R. Bidlot, "Forecasting Ocean Wave Energy: The ECMWF WAVE model and time series methods," Ocean Engineering, vol. 38, no. 10, pp. 1089–1099, Jul. 2011. doi:10.1016/j.oceaneng.2011.04.009
  - Ocean Wave Energy Forecasting/Wave Conditions
- [6] "IEEE SA - AIEE standards - electrical measuring instruments," IEEE Standards Association, https://standards.ieee.org/ieee/33/6408/ (accessed Sep. 16, 2024).
  - Electrical Measuring Instrumentation Standards
- [7] Marine Energy Glossary | Department of Energy, https://www.energy.gov/eere/water/marine-energy-glossary (accessed Sep. 15, 2024).
  - Terminology of marine energy
- [8] "EMEC: European Marine Energy Centre," EMEC European Marine Energy Centre, https://www.emec.org.uk/marine-energy/wave-devices/ (accessed Sep. 16, 2024).
  - Types of Wave Energy Converter (WEC) Devices

Thank You!
Questions?