Lionheart Renewables
REALM Project
Renewable **E**nergy for the **A**dvancement of **L**ake **M**ichigan

The Pennsylvania State University's

Project Development Report

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1.0 Executive Summary

This report presents Lionheart Renewables' (LHR) site design for a potential offshore wind farm in southern Lake Michigan utilizing the Port of Muskegon for assembly and staging. The REALM, Renewable Energy for the Advancement of Lake Michigan, Project is comprised of 52 Vestas V164-9.5MW turbines totaling 494 MW in capacity. The final site was selected after investigating the wind resource, bathymetry, geotechnical details, environmental impact, competing uses, construction, port infrastructure, and hybrid generation considerations. The project plans to make use of the Ludington Pumped Hydro facility (LPH) as an energy storage hybrid solution through an offtake agreement with Consumers Energy.

The financial analysis was completed using the Jobs and Economic Development Impact (JEDI) model[1] and the System Advisor Model (SAM)[2]. The REALM project uses a Power Purchase Agreement (PPA) partnership flip agreement with debt, partnering with relevant equity partners and achieving a flip in year 6. The projected finances for the REALM project achieve a Levelized Cost of Energy (LCOE) of 6.10 cents per kWh and a first year PPA price of 7.90 cents per kW. The lease bid for a 138 km^2 block is proposed at \$15 million. An overview of the REALM Project timeline is shown in Figure 1, encompassing roughly 10 years, with installation ending by the end of 2035.

Ancillary benefits identified in this design are addressed throughout the report and are integrated into other discussions where appropriate. **Key benefits will be bolded**.

Figure 1. Estimated Project Development Timeline

2.0 Site Description and Energy Estimation

2.1 Site Selection

LHR evaluated several potential sites across both the Great Lakes of Michigan and Superior. Early analysis[3] indicated a project in the Southcentral region of Lake Michigan, connecting to shore in the state of Michigan, would be the most suitable location, as detailed in the following sections. The final site selection was driven by one of the most significant resources in this area, the Ludington Pumped Hydro Facility (LPH), which is the proposed end use of the farm's power. Nearby Muskegon was also selected as the Port of construction, assembly, and deployment. Finally, LHR evaluated grid connection options between adding a substation at the LPH site or connecting into a retired coal generation facility with existing grid capacity. This analysis, described in section 2.1.1, resulted in the final site selection shown in Figure 2, which will connect to the grid at the site of the retired BC Cobb coal power station.

2.1.1 Proximity to Infrastructure

Final siting decisions took into consideration the proximity to both the Ludington Pumped Hydro (LPH) facility, identified as the end-use of the project's power generation, as well as Port of Muskegon, chosen for project construction, assembly, and deployment. Figure 2 shows that one of the most significant obstacles between these two regions is the shipping traffic density. The final project location is closer to the LPH facility than to the point of interconnection in Muskegon by roughly 30 kilometers. The location selected is where there was a relatively level seabed and reduced vessel traffic. Despite LPH being closer to the project, the team learned via discussion with Jason Durand[4], the plant business manager at LPH, that the currently existing infrastructure at LPH would not be sufficient to accept the additional load of 494 MW from the proposed wind farm without upgrades to the substation. Substation upgrade costs were not certain, with estimates from 12-19 million dollars[56] with some estimates much higher. These substation upgrades surpass in most cases the cost of additional cabling to send the power to the retired BC Cobb plant in the Port of Muskegon, estimated to be roughly $10 million. Even without these cost savings, there is **the ancillary benefit to reusing the existing infrastructure in the terminated B.C. Cobb coal plant, a decision that is sustainable, and LHR predicts would help gather momentum for the project.**

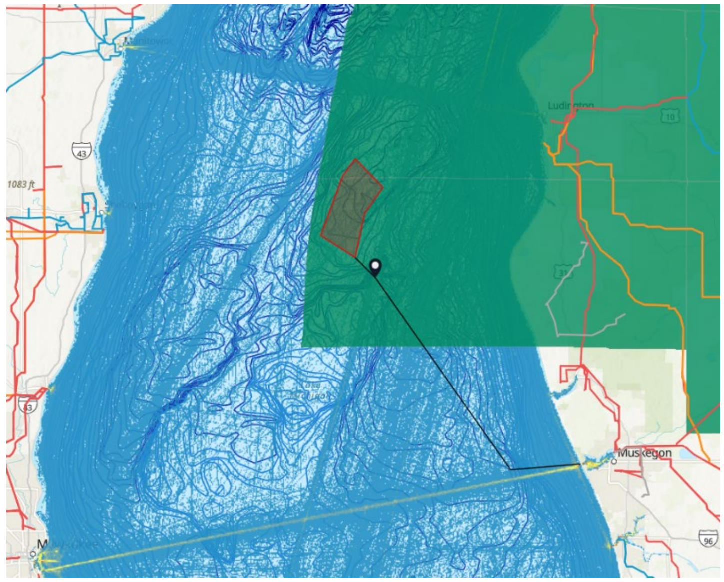

Figure 2. Selected Site Shown in Red, with cable path to shore shown in black. Black point shown is the proposed offshore substation. Dark blue contour lines describe the seafloor bathymetry while the light blue to yellow display the vessel traffic intensity in the lake. The green area is the energy community's incentive zone.

2.1.2 Shipping lanes

Figure 2 shows the final site in combination with primary vessel traffic, bathymetry, and energy communities tax incentive zones. Some of the primary vessel lanes in Lake Michigan run horizontally above the selected site from the Northeast to the Northwest and again south of the site between Muskegon and Milwaukee in the southwest. In the middle of the lake, there is a significant amount of vessel traffic on the east coast, traveling longitudinally in the most efficient path from southern Chicago to the northern tip of the lake. The selected site lies outside of these primary routes and others.

2.1.3 Bathymetry

Lake Michigan has significantly deeper water than many of the offshore projects currently being considered in the U.S., deep enough to require the use of floating platforms. The selected site lies within 160 m-175 m deep water with a relatively level seabed gradient, to ensure installation ease. When comparing with shallower sites considered of 100 m, the CapEx rose by roughly $30/kW[1] at this deeper location, in part due to the high costs of the dynamic cabling needed for floating platforms. Despite being one of the deeper locations in the lake, LHR recognizes this site as being advantageous. Seabed substrate was also an initial concern for the anchoring of the project, however, Walt Musial[7] with NREL suggested that substrate is not of significant impact to the anchoring or cabling of floating wind projects.

2.1.4 Energy Communities

The Inflation Reduction Act offers a 6% Investment Tax Credit (ITC), which is increased to 30% if the project meets minimum wage and apprenticeship requirements[20]. There is an additional 10% bonus that is available for projects meeting domestic content requirements as well as another 10% increase for projects located in energy communities as defined by the IRA[21]. **The project site selected is located in an identified non-MSA energy community**, as shown in Figure 2, which will allow the proposed project to secure a 50% ITC, assuming **domestic content requirements as well as wage and apprenticeship requirements are also met in the final design, bringing down costs to the end users of the electricity.**

2.1.5 Fishing

Lake Michigan is known for its freshwater fish such as Trout, Salmon, Walleye, and Yellow Perch. It is one of the key sites for the Great Lakes Salmon Fishery's handling of salmon and trout.[8] However, commercial catch numbers are low in Lake Michigan and generally limited to shallower waters than the chosen site.

2.2 Environmental Impacts and Mitigation

2.2.1 Species of Concern

Aquatic*:* The waters of Lake Michigan are home to many aquatic species of concern, namely the Lake Sturgeon (*Acipenser fulvescens*), Deepwater Sculpin (*Myoxocephalus thompsonii*), and Pugnose Shiner (*Notropis anogenus*)[9]. The Lake Sturgeon is listed as endangered, Pugnose Shiner is listed as endangered on the state level, and Deepwater Sculpin is identified as a general species of concern [10,11,12]. Ensuring site development does not cause the take of these species, especially Lake Sturgeon, will be vital in adherence to the Endangered Species Act.

Figure 3: Main Flyways for Migrating Birds in North America (source: Audubon)[9]

Avian: As seen in Figure 3, the Great Lakes provide essential habitat and corridors for migratory avian species, with many being endangered or threatened. This includes several species of bats, such as the Indiana Bat (*Myotis sodalis)*, the Northern Long-eared Bat (*Myotis septentrionalis)*, the Tricolored Bat (*Perimyotis subflavus)*, and the Little Brown Bat (*Myotis lucifugus*)[13,14,15,16]. All these species are listed as endangered species by the Fish and Wildlife Service, except the Little Brown Bat which is being considered for listing[13,14,17]. Each of these species have ranges within the site's area [13,14,15,16]. Several species of birds are also of concern, including the Whooping Crane (*Grus americanus*), Rufa Red Knot (*Calidris canutus rufa*), Piping Plover (*Charadrius melodus*) and Evening Grosbeak (*Hesperiphona vespertina*)[18,19,20,21]. The Whooping Crane and Piping Plover are both endangered species, the Rufa Red Knot is listed as threatened, and the Evening Grosbeak is vulnerable[16,17,18,19].

Avian species with ranges within the site are all mentioned bat species as well as the Rufa Red Knot and Evening Grosbeak [8,9,10,17,22]. Although its direct range is not near the site, there is a Fish and Wildlife (FWS) Critical Habitat for the Piping Plover off the coast of Ludington[23]. Critical Habitats are geographic areas that are vital to protecting threatened or endangered species and require special management or conservation[23].

2.2.2 West Michigan Underwater Preserve

The West Michigan Underwater Preserve is a protected shipwreck area where several ships lost in storms lay. The preserve is located along Lake Michigan's western shore near Grand Haven, Muskegon, Whitehall, and Pentwater. Additionally, there are various bottom features along the seafloor within the preserve. For instance, the Hamilton Reed is a snake-like formation made up of cement rubble and lies just 30 feet underwater near Muskegon Channel[24]. This feature provides habitat to various unique game fish. Likewise, divers often traverse a feature called the "bubbler" near Port Sheldon to look for artifacts, which also provides habitat for game fish[24]. Shipwrecks are not just important sites of maritime history, but they also serve as vital, unique ecosystems where biodiversity thrives[24]. Siting the project and placing the interconnection cable away from the preserve allows for the protection of important historical sites, rich ecosystems, and the culture of diving.

2.2.3 Mitigation Measures

LHR has selected a port that best avoids as many sensitive species as possible. In accordance with the Migratory Bird Treaty Act of 1918 and the Endangered Species Act, mitigation measures to prevent the taking of endangered species, namely via collision deaths, will be employed. In terms of stressors created by offshore wind farms for bird and bat populations, the most prevalent is collision injury and mortality[25]. Using post-construction monitoring data of bird and bat daily or seasonal patterns would help reduce risks of collision. Creating artificial nesting, roosting, and feeding areas for avian species could also draw them away from turbine, further reducing takes. Timing construction around vital breeding and migration periods would help avoid disrupting life histories of bird and bat species[25]. These are just a few of the many mitigation measures that can be implemented to safeguard avian populations.

Similarly, fish species experience several stressors from offshore wind development. Sound can disrupt fish behavior, so using sound-reducing procedures such as soft start methods can reduce aquatic noise pollution. Habitat destruction is another important stressor and can be mitigated by restoring disrupted areas to conditions most akin to their pre-construction state. Proper cable burying will also help minimize their impact on species sensitive to electromagnetic fields[25]. Artificial reef creation will also enhance fish production and biodiversity, which will help stabilize long-term populations.

2.3 Wind Resource Assessment

As previously discussed, sites in both lake Michigan and Superior were investigated, with a final site near the center of Lake Michigan. The wind resource is consistently strong across both lakes, with higher winds generally at higher latitude. The project location sees yearly average wind speeds of 8.94 - 9.05 m/s at an elevation of 120 m. Wind speed and direction data were downloaded from Wind Toolkit[26] for analyzing the detailed wind characteristics. Figure 4 was created displaying annual data broken down in a 12x24 monthly and diurnal mean wind speed chart at 120 m, and Figure 5 shows the wind frequency rose as well as wind energy by direction at 120 m. The multimodal wind direction distribution as seen in this wind rose, with significant energy seen coming from NNE, S, SW and WNW, emphasizes the need for turbine layout optimization, which will be described in detail in section 4.0.

MERRA 2 data was also downloaded using Windographer[27] for this site, providing data from 1979 – 2023 which was used for uncertainty and extreme site condition analysis. The site selected had an 0.8 coefficient of determination, or R^2, with the onsite Wind Toolkit data. A new dataset for the site was then synthesized, and by using the Periodic Maxima approach a 50-year V_{ref} of 31.7 m/s was determined. Additionally, the minimum temperature experienced was -5.35 F (20.75 C) and the maximum temperature was 88.8 F (31.56 C). These values were found to be well within the bounds of the turbine technology which LHR explored.

	Month											
Time	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
0:00-1:00	11.419	9.652	9.303	10.96	9.837	8.036	6.944	7.206	8.514	9.565	12.447	9.352
1:00-2:00	11.286	9.606	9.187	11.205	9.795	7.556	6.871	7.445	8.453	9.348	12.333	9.065
2:00-3:00	11.108	9.625	9.075	11.416	9.92	7.484	7.01	7.315	8.439	9.169	12.266	8.868
4:00-5:00	10.743	9.797	8.883	11.403	10.09	7.923	7.062	7.251	8.362	8.986	12.195	8.753
5:00-6:00	10.343	9.724	8.671	11.046	10.254	7.95	6.665	7.392	8.382	8.902	12.097	8.788
6:00-7:00	10.025	9.517	8.432	10.708	10.008	7.639	6.319	7.374	8.287	8.887	12.046	8.875
7:00-8:00	9.956	9.605	8.393	10.208	9.81	7.474	6.319	7.191	8.163	8.763	11.86	8.965
8:00-9:00	10.026	9.828	8.48	9.867	9.701	7.317	6.435	6.881	8.159	8.681	11.675	9.315
9:00-10:00	10.071	10.011	8.472	9.854	9.463	7.367	6.423	6.55	8.248	8.732	11.59	9.68
10:00-11:00	10.279	10.047	8.336	9.816	9.089	7.332	6.328	6.383	8.167	8.662	11.536	9.769
11:00-12:00	10.446	9.942	8.137	9.7	8.427	7.101	6.317	6.15	7.766	8.339	11.443	9.574
12:00-13:00	10.415	9.727	7.91	9.474	7.983	6.837	6.12	5.959	7.28	8.027	11.085	9.385
13:00-14:00	10.342	9.611	7.838	9.176	8.008	6.86	5.922	5.743	6.955	7.985	10.574	9.269
14:00-15:00	10.317	9.584	7.906	8.859	8.107	7.106	6.21	5.48	6.855	7.872	10.173	9.203
15:00-16:00	10.152	9.712	8.002	8.769	8.091	7.338	6.605	5.445	6.796	7.739	10.076	9.229
16:00-17:00	10.055	9.804	8.098	8.937	8.093	7.901	6.741	5.652	6.911	7.763	10.22	9.351
17:00-18:00	10.139	9.822	8.289	9.043	8.42	8.302	6.671	5.947	7.161	7.811	10.464	9.586
18:00-19:00	10.22	9.863	8.647	9.461	8.989	8.365	6.685	6.125	7.343	7.988	10.825	9.805
19:00-20:00	10.491	9.985	8.942	10.016	9.171	8.508	6.947	6.229	7.478	8.42	11.207	10.057
20:00-21:00	11.076	10.089	9.198	10.323	9.403	8.977	6.926	6.435	7.828	8.958	11.706	10.378
21:00-22:00	11.573	10.042	9.436	10.391	9.668	9.511	6.929	6.739	8.652	9.399	12.095	10.552
22:00-23:00	11.671	9.959	9.618	10.339	9.737	9.243	6.897	6.969	9.461	9.53	12.326	10.358
23:00-24:00	11.659	9.846	9.683	10.692	10.152	8.543	6.94	7.106	9.759	9.569	12.545	9.96
24:00-0:00	11.703	9.742	9.567	10.994	10.164	8.19	6.984	7.03	9.328	9.721	12.439	9.686

Figure 4. Monthly and Diurnal Windspeed Heatmap at 120 m

2.4 Turbine Technology

The Vestas V164-9.5 MW turbine was chosen for this project, a turbine that is being used in current floating offshore wind projects[28]. Even though the V174 turbine is also available, due to the current limitations with floating platform technology, as well as the limits on port assembly, LHR decided to use the slightly smaller V164.

A Tension Leg Platform (TLP) was selected as the foundation for this structure. A depiction of the installation process for this platform is given in section 2.6.2, Figure 7. The TLP platform has a much more manageable draft depth for port installation than the spar, and like the spar, has a minimal risk regarding icing when compared to other floating platforms[29].

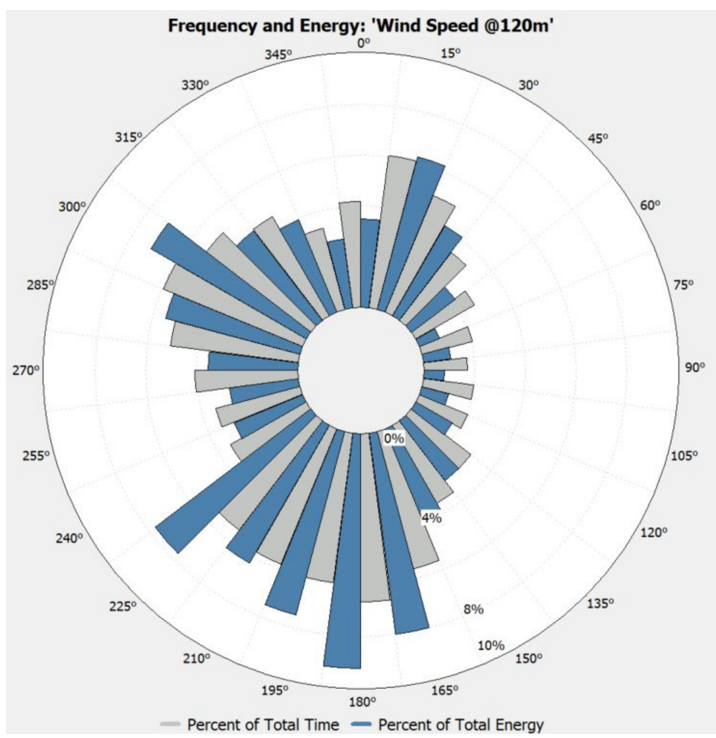

Figure 5. Wind Frequency Rose (grey) and Wind Energy Rose (blue)

2.5 Detailed Layout

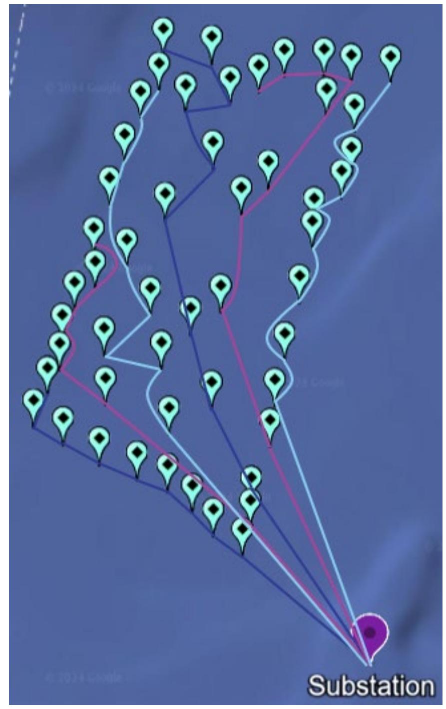

Fig 6. Turbine Layout Connections

The REALM project contains 52 turbines. The optimization procedure used to decide the specific turbine locations is described in detail in section 4.0, with a minimum separation of 4 rotor diameters. A radial delivery system will be used to collect all the wires to a fixed bottom substation located at the point shown in Figure 6. This substation is located in 100 m deep water, which is too deep for a fixed bottom turbine but not too deep for a fixed bottom substation to be economically viable at this depth.[30] The substation will have 6 XLPE 185mm 66kV[5] lines connecting to all 52 turbines. Each cable has a max capacity of 90MVA, as a result not more than 9 turbines or 85.5 MW will be placed on any individual line.

2.6 Infrastructure

2.6.1 Access to Ports

The REALM project plans to use Port Muskegon as both its Operations and Maintenance port, as well as the Installation port. Based on the geography of our potential sites, the ports of Milwaukee, Chicago, Muskegon, and Burns Harbor were all considered for construction and maintenance purposes. Once the site was selected in the waters of Michigan, LHR shifted focus to ports within the state. With the assumption that the selected port will require expansion and development to accommodate the construction of floating turbines to some degree, a port in the same state that is receiving benefits of the energy of the farm is the logical choice. The Port of Muskegon is western Michigan's largest natural deepwater port at a depth of 24 m. **It has the capacity to increase shipping and routine shipments and activity at the Port would increase jobs in the region**. According to mLIVE, "**growth of the port "ripples" prosperity throughout Michigan**.[31]" The port has roughly 100 acres (0.4 km^2) of available laydown area, and a draft depth of 8.2m[32]. The Port would require some investment and creative use of the available 500 acres (2 km^2) of nearby space available via intermodal transportation for expansion to support the proposed project scale. Transport of components to the port will be based on sourcing, which is addressed later, but should be domestic. Components that are too large to be brought into the port via boat, such as large blades, can be railed in with existing railways.

2.6.2 Port Development

Compared to many projects currently being implemented on the coasts of the United States, the ports in the Great Lakes need much more development to become an offshore wind hub. The project should see the development of the Port of Muskegon funded in part by the Port Infrastructure Development Program (PIDP)[33]. Similar projects in development of ports for offshore wind include the Baltimore County Offshore Wind Manufacturing Hub and an Offshore Wind Tower Manufacturing Port Project in Albany, NY; Receiving funding of $47,392,500 and $29,500,000 respectively. This funding will serve as a further financial incentive for this project's approval, lowering the overall cost and supporting future growth of the offshore wind industry in Lake Michigan. Additional funding, if necessary, may be possible at the state level, similar to the Maryland Offshore Wind Grant Program Portfolio[34] given the benefits Michigan will see from this project. The State of New Jersey's plan for the development of their upcoming offshore wind hub plans to use a total of 135 acres of port space for a combination of marshalling and manufacturing.[35]

The funding from PDIP should be used in three key areas: dredging, railway infrastructure to port, and heavy-duty machinery and overall development of the port. With a draft depth of 8.2 m, this may be below the projected necessary value for Tension Leg Platforms of 10 – 12 m, so dredging will be a necessary part of the development of the port. Dredging of ports to encourage development has been common in many PDIP projects. Another aspect important to the development of the port would be the revitalization of the rail infrastructure in and out of the port to support nearby component manufacturing as well as assembly. This also falls under the umbrella of funding with many examples of PDIP projects including rail improvements like the Port of Stockton Rail Rehabilitation and Upgrade Project in Stockton, CA.

2.6.3 Survey, Installation, and Operations and Maintenance Vessels

This project should not need the support of any major installation vessels. However, the installation of a conventional TLP system is a complex process. The cables that are connected to the platform are usually installed prior to the platform itself. Once the cables are prepared, the floating platforms, which are constructed at the port, are floated out to the site using tugboats. Once the floating platforms arrive at the site, the platform is de-ballasted to a draught where the cables can maintain the optimal level of tension for the TLP system. The anchors and mooring lines for TLP are more complex than other platform systems and can be a large O & M expense. This process is illustrated in Figure 7.

2.6.4 Substation Installation

To achieve the proper voltage value for the transmission of the electricity produced by the farm, the construction of an offshore substation is necessary. A conventional steel jacket substructure can be used to create a fixed bottom platform up to 150 m deep; our proposed substation site has a depth of 100 m. These are commonly used in the Gulf Coast, and a Michigan based fabrication yard could partner with a firm with experience in this construction to locally fabricate the platform. Once the platform is constructed, it can be floated out to its site and constructed with the use of an offshore crane barge. Offshore crane barges of this type currently do not exist in the Great Lakes, so the best course of action is to develop novel designs to retrofit onto existing vessels (level of effort: >$2 million, timeline: 3-5 years)[37].

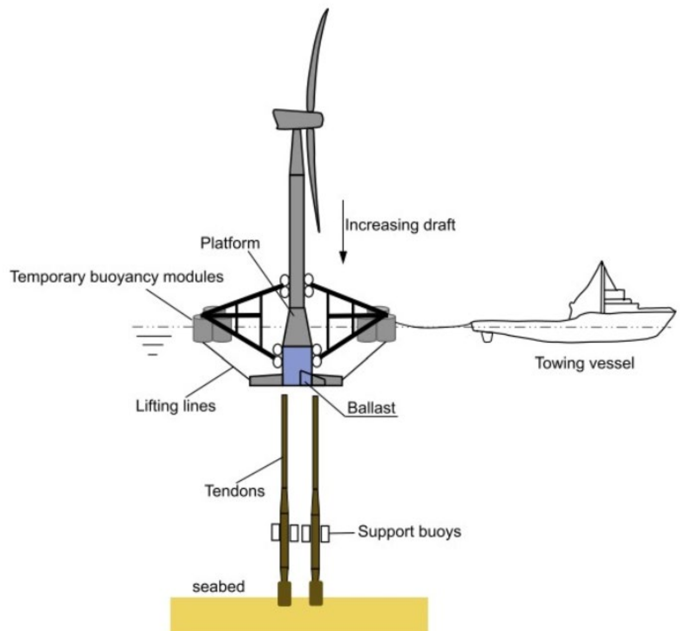

Fig. 7 Model of TLP installation process [36]

2.7 Risk Analysis

2.7.1 Weather Related Risks

Lake Michigan is the only Great Lake that has never frozen over completely[23], though the risk from ice is still a threat to the floating platforms of the turbines. According to NOAA[24], climate change has made noticeable and long-lasting changes to the behavior of the ice in the Great Lakes across the years. Tension Leg Platforms will be used which will mitigate ice impacts, as recommended by NREL[9].

Data from NOAA[25] shows that the significant wave height in southern Lake Michigan from 2003-2022 was 1.42 m, and the mean wave height was 0.75 m with a standard deviation of 0.6 m. This is below the 2 m wave height threshold[26] identified for offshore wind farms to be accessible for operation and maintenance, allowing for more periods of access. The waves are generally considered lower than what would be experienced in the ocean[27].

Previous instances of hurricanes reaching Lake Michigan are very rare and only involved remnants of hurricanes or tropical storms, with recorded wind speeds not exceeding 17.8 m/s[28,29]. As previously described a 50-year extreme wind speed of 31.3 m/s at 120 m is indicated by the wind resource assessment, which is more likely to occur during a winter, non-tropical, storm event. The low probability of extreme winds makes the site selected acceptable.

2.7.2 Military Zones

Parts of the airspace above Lake Michigan are utilized for military training and operations. The airspace region consists of the Minnow MOA (Military Operations Area) and restricted airspace R-6903. Our proposed location does not fall under the restricted airspace which extends from the surface to 45,000ft above mean sea level. The MOA, which our location does fall under, extends from 10,000 ft to 18,000 ft above mean sea level. Because the base of the MOA is 10,000ft, which is considerably higher than the height of the wind farm, impact is reduced. The project would coordinate with the Department of Defense Clearinghouse for the advancement of construction. DoD Clearinghouse approval, which is obtained by receiving input from all affected military branches, is crucial in ensuring the advancement of the REALM project.

2.7.3 Public Sentiment

Within the Ludington region, offshore wind energy development has experienced opposition from local communities. One of the most recent incidents occurred in 2010, when Scandia Wind LLC proposed a 100-200 turbine wind farm within Lake Michigan, just South of the Ludington Pump Storage facility[38]. The majority of citizens from Oceana and Mason County opposed the wind farm due to the perceived negative impact it would have on aesthetics, financial viability, and boat traffic interference. The Lake Erie Energy Development Company (LEED Co.) planned to build Icebreaker, a demonstrative wind farm in Lake Erie, by 2025[39]. This small, six-turbine development would generate 20 megawatts offshore from Cleveland. The wind farm was anticipated to create 500 jobs, bring more business to the fishing industry, and introduce freshwater offshore wind energy to North America. Despite these benefits, some residents are concerned about the raptors who rely on the lake to fish and cranes, waterfowl, and songbirds who utilize the western fringes of the lake for migration[39]. Locals view the Lake as their natural park, vehemently opposing development without proper environmental protection. Many are also worried about the project contaminating drinking water via oil spillage. In the wake of the failure of this project, the team spoke to those involved in its development, seeking advice on strategies that could be implemented to earn public approval in hindsight.

In a survey performed to gauge public perception of offshore wind energy in Michigan, about 40% of people living in Michigan believed wind farms will increase employment and the local economy [40]. However, the disruption of community harmony and aesthetics were of most concern. Michigan residents are unsure as to how aquatic life would be impacted by wind farm development, but communicating potential or perceived impacts can determine whether a project is supported or not. The survey also recorded recent changes in perceptions of offshore wind energy, which will play a vital role in the support or opposition of wind farm development. 65% stated their opinions of offshore wind would improve or strongly improve if development decreased electricity rates and local electricity generation, as this would bolster community use and economic gain[40]. Only 40% changed their opinion when told offshore wind would increase coastal property value[40]. This inelastic change in opinion is due to skepticism of increased property value or lack of coastal property ownership. One of the largest factors of wind farm opposition is harm to aquatic life, with 90% of respondents being less favorable or much less favorable if the farm would threaten aquatic species[40]. Likewise, around 85% of respondents would be less favorable or much less favorable if the farm would harm bird life, further revealing how respondents feel a sense of responsibility to maintain the Lake's ecosystem health[40]. These survey results reveal how indispensable it is for the REALM project to be incredibly diligent in consideration and mitigation of ecological impacts in order to be successful, and to ensure the public is aware that these considerations are of the highest priority, next to their own benefit.

2.8 Permitting

Establishing a process for permitting an offshore wind farm in the Great Lakes is something that has not yet begun, and thus is an open canvas of options. There are some things that the project can be certain it will need to receive approval for based on previous projects such as the Lake Erie's Icebreaker, which received all necessary permits but was delayed. Some of which are the 'Clean Waters Act Section 404' and 'Harbors Act Section 10 Permit', issued by the USACE. The project will certainly require a NEPA

Environmental Assessment, compliance with the endangered species act as well as a 'Determination of No Hazard to Air Navigation' from the FAA. Navigational permits are also likely, such as a 'Navigational Risk Assessment' and a 'Federal Navigation Project Section 408', from USCG and USACE. Using the Icebreaker Wind project in Lake Erie as an example, LHR also predicts it will need Michigan state equivalent permits to 'Certificate of Environmental Compatibility and Public Need', water quality certifications and a submerged land lease. The Michigan Department of Environmental Quality, MDEQ and the Michigan Public Service Commission, MPSC may be responsible for issuing these permits.

2.9 Additional Ancillary Benefits

The development of a floating offshore wind project can act as an artificial reef, providing a substrate for some species to attach and live on [41]. Although the impact that the type of structure has on the artificial reef effect is not currently quantified, it has been observed that macroalgae, barnacles, and muscles dominate the near water surface environment[41]. Since we have selected a floating type turbine, this near water surface zone, and its associated species, is the most significant environment to consider. **Over time, the community surrounding the turbine's foundation can become highly diversified with many species. Since many of the species are suspension feeders, they filter out particles from the water, decreasing turbidity and increasing light penetration[41]. The fecal matter created by suspension can also enrich the soft sediment surrounding the turbine, which helps to make pelagic food sources available to the benthic zone and increases macrofauna diversity and density[41].**

According to the CDC[42], Michigan is 8th in the United States in percentage of adults with asthma, with 11.5% of adults reporting as having asthma. Michigan is 10th in total population size, meaning they are disproportionately affected by this health issue. The air pollution created through burning fossil fuels can hurt people with asthma as it causes an increased number of allergies and respiratory infections, with these respiratory infections being fatal in some cases. In addition, in areas where more fossil fuels are burned, children are more likely to develop asthma. Michigan wildfires have also become more regular over the last 5 years. The Michigan Department of Natural Resources reported 227 wildfires in 2019 compared to 276 in 2023. In addition, one thousand acres of land were burned in 2019 compared to 3.7 thousand acres burned in 2023[43]. This increase in both the total number of fires and acreage of land burned in the last five years represents the escalated danger of wildfires in Michigan, a danger that is aided by fossil fuels. Fossil fuels increase the likeliness of wildfires as they raise temperatures, providing a more hospitable environment for wildfires to develop. In addition, fossil fuels make the environment drier, allowing wildfires to start up more easily**. In addition to the inherent benefit of wind energy aiding the transition away from fossil fuels, it is estimated that offsetting the generating capacity lost by the closure of the B.C. Cobb coal power plant with clean renewable energy may prevent roughly 34 deaths, 55 heart attacks, 580 asthma attacks, 25 hospital admissions, 21 cases of chronic bronchitis and 35 asthma ER visits per year.[44]**

3.0 Financial Analysis

3.1 Capital Expenditures (CapEx)

Initial costs for the proposed REALM project are estimated from NREL's Offshore Wind Annual Technology Baseline, moderate case with an offshore wind class 12 (floating case with similar annual average wind speeds) wind resource for a project being built in 2035. These costs were also validated by the Jobs and Economic Development Impact (JEDI) model and are broken down in Table 1. From the JEDI model, the total overall net capital costs are $1,982,648,992. This stems from a CapEx of $4,036/kW, with the difference making up the financing and development fees ($193,500,000). The cost per turbine is $1,301/kW, which considers the turbine components, substructure and foundation, electrical infrastructure components, assembly and installation, port and staging, development costs, and engineering and management costs. This brings total turbine costs to $642,694,000. Balance of Systems costs came to $2,343/kW and considers the substructure and foundation. The project's total BOS costs are $1,157,355,856. Soft costs are $392/kW. A detailed breakdown of the Capex from the JEDI model, as well as a percentage breakdown of costs is as seen in table 1.

Table 1: Breakdown of Capital Expenditures

CAPITAL EXPENDITURES (CapEx)			
Category	**Cost**	**Cost Per kW**	**% of Total Cost**
Turbine Component Parts			
Nacelle/Drive Train	$425,334,000	$861	21.33%
Blades	$127,452,000	$258	6.39%
Towers	$89,908,000	$182	4.51%
Total	**$642,694,000**	**$1,301**	**32.23%**
Balance of System Costs			
Substructure and Foundation	$620,030,218	$1,255	31.10%
Electrical Infastructure Components	$122,024,840	$247	6.12%
Assembly and Installation	$154,052,647	$312	7.73%
Ports and Staging	$61,500,101	$124	3.07%
Development and Other Project Cost	$165,168,050	$334	8.28%
Engineering and Management	$34,580,000	$71	1.76%
Total	**$1,157,355,856**	**$2,343**	**58.05%**
Soft Costs			
Commissioning	$13,200,000	$27	0.67%
Construction Finance	$54,900,000	$111	2.75%
Construction Insurance	$13,200,000	$27	0.67%
Contigency	$94,800,000	$192	4.76%
Decommissioning	$17,400,000	$35	0.87%
Total	**$193,500,000**	**$392**	**9.71%**
Total Capital Costs	**$1,993,549,856**	**$4,036**	**100.00%**

3.2 Annual Operational Expenditures (OpEx)

According to the NREL Annual Technology Baseline (ATB), Lionheart will be estimating an annual operating expenditure of $87.79/kW in year 2035. This is a more of a conservative estimate, with projections ranging from $73.82/kW to $106.99/kW[45]. OpEx costs include offshore maintenance, onshore electrical maintenance, operation and management costs, operating facilities, environmental, health, and safety, insurance, and annual lease fees that are all not represented in the capital expenditures.

3.3 Supply Chain Analysis

Even though equipment construction will be taking place in Port Muskegon, ships could be chartered from all over the lake to take the system out to sea. There are plenty of companies with Tug vessels, a good contender could be the “Victory” owned by Grand River Navigation Co. Located in Traverse City, MI[46]. The price per tug would vary but it could also be chartered for a whole season which may bring the price down. There are many options for importing blade material into the port i.e. railway, roadway, or waterway. Once the requisite materials are in the port, manufacturing, and assembly of the entire turbine as well as the TLP system will be performed.

3.4 Financing Plan

The financing plan used by Lionheart is developed from the National Renewable Energy Laboratory’s System Advisory Model (SAM). The ownership structure is based on a PPA Flip Structure with Debt on a project generating an AEP of 2,130,417,920 kWh, as determined by simulations in Furow. The project is financed with 64.14% equity and 35.65% debt, with Lionheart as the developer investing 20% of the required equity and relevant equity partners investing the rest of the 80%. Lionheart will partner with JP Morgan, Bank of America, and U.S. Bank due to their prospective goals in investing in the offshore wind industry. With a flip structure, this partnership will assume both an 85/1 cash and tax flip agreement. This means the equity partners listed will assume 85% of the projects cash and tax benefits up until flip year 6. Post flip year, the equity partners will only assume 1% of the benefits, with Lionheart assuming

Table 2: Summary of SAM Outputs

Metric	Value
Annual AC energy in Year 1	2,130,417,920 kWh
Capacity	494,000 kW
Capacity factor in Year 1	49.2%
PPA price in Year 1	7.90 ¢/kWh
PPA price escalation	1.00 %/year
LPPA Levelized PPA price nominal	8.56 ¢/kWh
LPPA Levelized PPA price real	6.22 ¢/kWh
LCOE Levelized cost of energy nominal	8.39 ¢/kWh
LCOE Levelized cost of energy real	6.10 ¢/kWh
Investor IRR Internal rate of return	11.44 %
Flip year	6
Investor IRR at end of project	11.48 %
Investor NPV over project life	$32,649,796
Developer IRR at end of project	13.16 %
Developer NPV over project life	$44,251,068
Net capital cost	$1,994,348,416
Equity	$1,283,385,088
Debt	$710,963,328
Debt percent	35.65%

99%. For the investors, the projects sees an IRR of 11.48% at the end of the project's 25-year analysis period, valued at $32,649,796. REALM as the developer projects an NPV of $44,251,068 at an IRR of 13.16%. In addition to the developer return, Lionheart also will make a 3% development fee ($54,004,080)

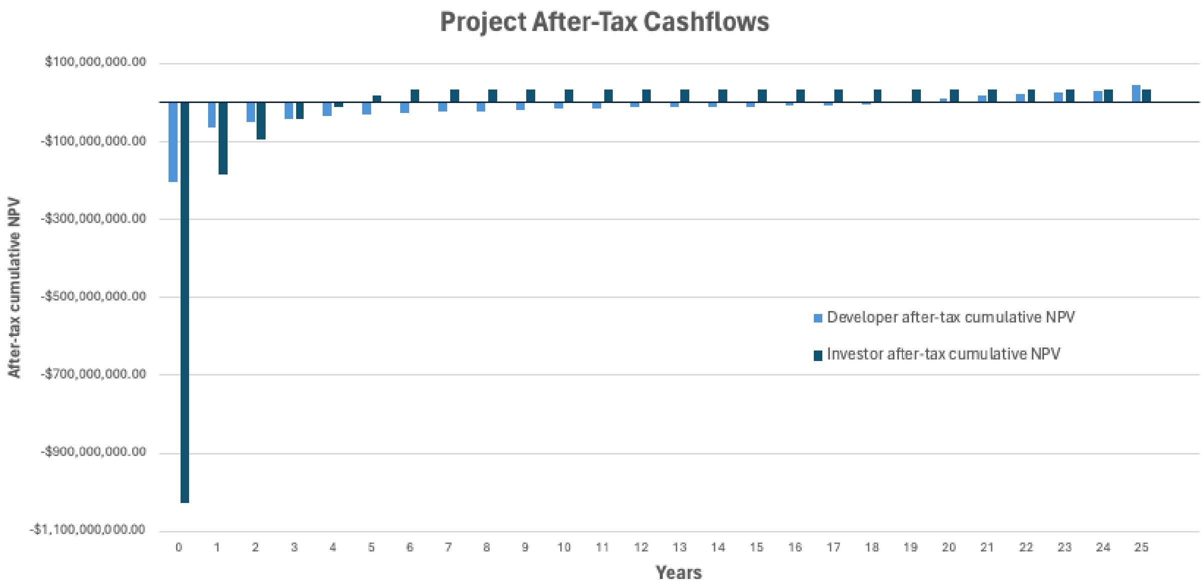

Figure 8: Cumulative Developer and Investor After-Tax Cashflow

which will be put towards covering the bid price. To be successful, an established PPA price of 7.90 cents per kWh that will escalate at 1% a year throughout the project's lifespan will be used. The project also meets a DSCR of 1.3, as well as a real LCOE of 6.10 cents per kWh.

Bank of America has already been investing in the offshore wind business and has been pushing goals towards further investments into the energy transition. JP Morgan has also been investing in renewable energy projects and holds a $200 billion-dollar clean energy goal.[47] U.S. Banks division of Community Development has previously invested $15 billion in renewable energy tax equity and pledges another $50 billion by 2030.[48] With these partners and their respective goals, Lionheart sees this as a feasible partnership to fund this project.

The project assumes a 6.5% interest rate on the debt and construction financing plan. The construction loan is borrowed 6 months before the construction phase starts with a 1% fee on the principal upfront.

Total debt borrowed to finance this project comes to $710,963,328. A summary of the associated financing fees is seen in the table in table 3.

Table 3: Summary of Financing Fees

Equity Closing Costs	$12,000,000
Debt Closing Costs	$7,100,000
Up-front Construction Loan Fee	$18,001,000

3.5 Key Assumptions & Incentives

3.5.1 Incentives

This project utilizes the Investment Tax Credits (ITC) offered by the Inflation Reduction Act (IRA) as the developers aim to begin construction before January 1st, 2026[49]. The project will achieve safe harbor for this incentive by beginning construction through purchase of 5% of project CapEx prior to expiration, such as substation components, cabling and TLP foundation components[50]. The ITC establishes a baseline credit of 6%, with an increase to 30% as this project will meet the prevailing wages and apprenticeship. An additional 10% tax credit will be added for assuming the project meets the minimum domestic content requirements, as well as another 10% due to the location of the project existing in an energy community[51]. Bringing the total ITC credit to 50%. The project will also benefit from 5 year accelerated depreciation according to the MACRS[52].

3.5.2 Taxes & Rates

This project uses the following rates in its SAM financial analysis. An income tax rate of 26% by combining Michigan's state income tax of 5% with the federal income tax rate of 21%[53]. Michigan currently has a sales tax rate of 6%[54]. This project will assume an inflation rate of 3.4%[55] with a real discount rate of 5.5% and is covered by an annual insurance rate of 2% of capital costs[56].

3.6 Hybrid Market Opportunities & Constraints

3.6.1 Power Market

Clean energy standards signed into law in the state of Michigan via SB 271 phase in a requirement that 50% of states energy come from renewable sources by 50%. This ramps up to 60% by 2035 and 100% by 2040. The average price of electricity to end-use consumers in the state of Michigan across all sectors as of December 2023 was \$137.50/MWh. Whereas the current rate which LPH is often able to provide to consumers is closer to \$50/MWh.

3.6.2 Off-taker arrangement

The project would need to connect to the grid through the Michigan Electric Transmission Company (METC) as electricity and transmission must be operated by separate companies in Michigan. The REALM project would then contract with Consumers to purchase the electricity from the project to power the LPH facility, offsetting current coal power generation capacity. The cost of this electricity would be set via an agreed upon Power Purchase Agreement (PPA) that escalates at a rate of 2% per year.

While the PPA would not be directly with LPH, it can be assumed that a large portion of the power generated would be used by the facility. The current typical mode of operation for the LPH facility is to pump, or charge, at night, when the LMP on MISO is lowest, thus charging the storage capacity, and then running the turbines during the day at times when the LMP crosses a minimum price entered into MISO. This price is determined based on the overnight price as well as the pump/turbine system efficiency. Since the wind tends to be stronger at night at the project location (as seen in Figure 4), this mode of operation lends itself to benefit from the REALM project. In fact, unless about 3500+ MW of solar were added to the system, the plant would not have incentive to flip charging times from night to day[4].

The LPH facility provides critical benefits to the residents of Michigan as it is **essential to emergency services and helps to reduce the price of electricity to consumers.** This results from the facilities' ability to ramp up extremely fast in an outage or high demand situation (2.5 MW/s vs 8MW/min for coal/nuclear) and by avoiding purchasing electricity from MISO when the load demand curve is at its highest each day.

3.6.3 Economic Ancillary benefits

An additional significant benefit to the local community lies in the jobs created by this project. The JEDI[7] model estimates 247 new jobs as a result installation, and 5206 additional jobs because of component manufacturing and supply chain support services. Installation jobs can reasonably be assumed to be mostly locally sourced while the component and supply chain jobs will be some combination of domestic and local jobs. Decisions as to where certain components are assembled will have an impact. **An additional 26 technician jobs and 197 support service jobs are estimated annually for the project operation and maintenance.** As addressed in 2.7.3. surveys suggest that the public places a very high value on local economic benefits to a project, to ensure project success, local jobs should be prioritized.

The state of Michigan currently has 3,119 individuals working in coal generation.[57] With all coal plants being phased out in Michigan by 2030[58], and specifically the J.H Campbell Consumers plant being decommissioned in the immediate region of the project, these individuals working in coal are going to lose their jobs. **The introduction of the REALM project would provide work for these individuals with experience in power generation.** A University of Michigan study found that lost jobs from retired coal plants throughout the entire U.S. can be replaced by local jobs in clean energy with an increase in cost of just 24%. [59] These costs may seem high in isolation but are small relative to the total cost of the transition of the U.S. energy system.

4.0 Optimization Process

The individual turbine locations were selected using the Furow[60] micro-siting tool. After selecting the final location, Wind Toolkit[26] data was imported into Furow, including things such as wind speed, direction, and temperature at 120 m meters. The number of turbines on the farm was limited by the 500 MW capacity available for interconnection at the B.C. Cobb coal plant. As a result, 52, 9.5MW turbines were determined to be the maximum capacity. Without the constraint of predetermined lease blocks, three sizes of 90, 105 and 138 square kilometers were selected for the overall size of the farm. These vectors were created in Google Earth[61] and uploaded into Furow as vector layers. The turbine data for the V164 was then also uploaded and 52 turbines placed within the vector layer. Simulations were then performed to assess turbine interactions and energy generation using the Jensen wake model with a maximum wake length of 50 diameters and a maximum radial distance of 2 diameters. A wake decay factor of 0.04 was input in order to simulate the open water. Optimization simulations were run for 5,000 iterations for each site.

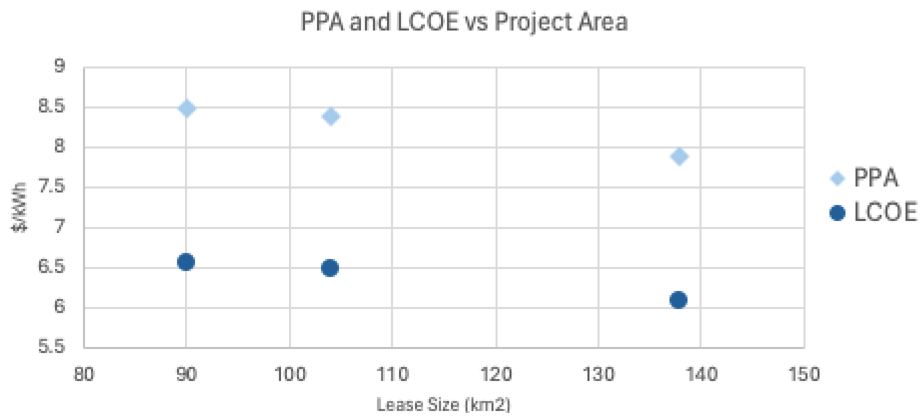

Fig 9. PPA and LCOE with Changing Site Size

5.0 Lease Bid

While there is no current auction process for offshore wind in the Great Lakes, a bid price of $15 million is proposed for the 138 km^2 site. This figure was the result of analysis of several cases, a primary factor being the Ludington Pumped Storage Facility payment to the state for the section of Lake Michigan between the pump/turbines and the breakwater. LHR scaled other known projects to their REALM equivalents, considering bids of successful floating offshore in California ($55m), successful fixed bottom in Louisiana ($10m) and the suggested bid price from the JEDI model ($24.7m). A driving factor being the information from LPH that currently leases from the state. This amounts to $7500/yr, which would scale $2.3m/yr for the REALM project. Ultimately the figure of $15 million is estimated to be a fair bid price for the plot in question, this value would be taken from the developer NPV, and likely be put toward an ecology fund. As under consideration currently in Pennsylvania (HB 524)[62], 20% of the funds could be allocated to the local county while the rest could be placed in a state environmental and clean energy funds which would be allocated to support the ecology of Lake Erie. LHR proposes that a similar fund may be implemented in the state of Michigan and for this project.

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