U.S. DEPARTMENT OF ENERGY

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

The Contribution of Environmental Siting and Permitting Requirements to the Cost of Energy for Ocean Current Devices

Reference Model #4

AE Copping
LA Hanna
SH Geerlofs

September 2013

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Summary

Responsible deployment of marine and hydrokinetic (MHK) devices in estuaries, coastal areas, and major rivers requires that biological resources and ecosystems be protected through siting and permitting (consenting) processes. Scoping appropriate deployment locations, collecting pre-installation (baseline) and post-installation data all add to the cost of developing MHK projects, and hence to the cost of energy. Under the direction of the U.S. Department of Energy, Pacific Northwest National Laboratory scientists have developed logic models that describe studies and processes for environmental siting and permitting. Each study and environmental permitting process has been assigned a cost derived from existing and proposed tidal, wave, and riverine MHK projects. Costs have been developed at the pilot scale, and for commercial arrays.

Acknowledgments

We would like to thank Brian Polagye from the University of Washington NNMREC and Glenn Cada from Oak Ridge National Laboratory for their thoughtful input on the reference model studies and costs.

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1.0 Introduction

Responsible deployment of marine and hydrokinetic (MHK) energy devices in estuaries, coastal areas, and rivers requires that biological resources and ecosystems be protected through siting and permitting processes ([7], [8]). Scoping appropriate deployment locations, collecting environmental baseline data, post-installation monitoring information, and mitigating for impacts add to the cost of developing each MHK installation, and hence to the cost of energy (COE) generated. The success of the MHK industry in the U.S. depends on a favorable comparison of COE with that of other renewable energy sources ([9]).

As provided for the first three reference models (tidal, riverine and wave), Pacific Northwest National Laboratory (PNNL) has undertaken the task of determining the preliminary costs for the major categories of environmental and site specific studies that can be expected to be needed for reference model # 4, described in Table 1 below. PNNL's approach develops logic models that describe the expected studies for siting and permitting MHK devices, driven by the siting and regulatory processes that require those studies. Each study and environmental permitting process has been assigned a cost derived from data from existing and proposed MHK projects, scaling factors, projections for future post-installation monitoring costs, and expert opinion. Cost estimates for pilot scale projects as well as small and large commercial scale projects have been developed. A range of costs is presented for each type of study and regulatory requirement to reflect the significant uncertainty that results from the generic nature of the reference model site and device. Cost estimates were reviewed by agency staff, researchers, and consultants familiar with environmental permitting processes.

Table 1. Description of reference model #4

Reference Model	Technology	Water Body	Marine Receptors of Importance
# 4 Ocean Current	Four horizontal axis turbines on a 100 meter long wing, no surface expression, anchored to bottom.	Off the Southeastern coast of Florida (Atlantic Ocean) in approximately 800 meters of water	Marine Mammals, benthic habitats such as deep water corals, sea turtles and fish.

The goals for costing the contribution to the cost of energy (COE) from siting and permitting include:

1. Determine information needs, study requirements, and costs for each reference model for 1) scoping; 2) pre-installation; and 3) monitoring and mitigation phases, in order to assign costs to each.
2. Organize costs by major regulatory drivers—determine which regulations (and required studies) are highest cost drivers.
3. Engage regulatory agencies in the flow of studies, permitting pathways, to smooth pathway to siting and permitting.
4. Create logic-model to allow comparison of real world sites to reference model sites and determine total contribution of siting and permitting costs to COE.

This report addresses the first two goals; additional funds would be required to address goals #3 and #4.

2.0 Methods

The process for costing the siting permitting contribution for COE was divided into three phases for reference model #4: 1) siting and scoping; 2) pre-installation information collection; and 3) post-installation monitoring. Costs for developing NEPA and other regulatory processes and deliverables were developed independent of the three phases.

While the specific sites and technologies will have a major influence on the costs for any project, there are many commonalities driven by regulatory requirements and information needs across projects. For the first three reference models (RM#1, RM#2, and RM#3), PNNL researchers derived cost ranges from the best available information on existing and planned MHK projects by consulting with developers and the consultants supporting them and also relied on the best professional judgment of researchers and natural resource management agency staff. For reference model #4 (Ocean Current), there are no projects in the water or in advanced stages of planning from which PNNL could begin the costing process. The basis for costs of environmental studies and processes were developed for RM#4 through extrapolation from the previous three models. While the Ocean Current model differs considerably in the size and configuration of the device from RM#1 (tidal), there are commonalities between the potential interactions of animals with the two devices. The impact of anchors and mooring lines on marine habitats in RM#4 is somewhat analogous to the lines and anchors proposed for RM#3 (wave). The ocean space occupied for RM#4 differs greatly from the previous three RMs; however the NEPA processes and study costs can be extrapolated, using PNNL staff knowledge of the oceanography of the Florida Current, informed by published studies, and modified by consultation with experts in the area ([9]).

Costs for each of the RM#4 studies and processes have been developed for a pilot project, as described. From the pilot, costs were extrapolated for small (10-50 devices) and large (> 50 devices) commercial development arrays. While the size of a pilot project differs from one technology and location to another, we have assumed that the RM#4 pilot project consists of one device, totaling less than 5MW generation capacity, and could be deployed for up to 5 years. PNNL researchers developed a set of scaling rules for the first three reference models to extrapolate from pilot project costs to those of small commercial scale and large scale commercial. For the first three reference models, costing information was developed for the early stage of pilot projects based on information from ongoing expenditures from U.S. projects; post-installation monitoring costs are also more speculative as no monitoring programs have been fully implemented to date. Reliance on scaling from other technology-dependent reference models to RM#4 adds to the uncertainty surrounding the cost estimates.

Each stage of study development (scoping and siting; pre-installation assessment; post-installation monitoring) requires documentation and adherence to processes designed to meet regulatory requirements. These include conducting public meetings, filing necessary permitting paperwork, and performing periodic checks with government agencies. Each of these processes has a cost associated with it, and has been accounted for in our costing estimates. It is assumed that almost all of the siting and permitting processes that drive costs are included under the broad umbrella of the National Environmental Policy Act (NEPA).

2.1 Pre-installation Studies, Analysis and Documentation

Pre-installation studies (also frequently referred to as baseline assessments) for a specific ocean current project or other similar projects such as large-scale deep tidal projects, will have specific siting and permitting needs site and technology-specific differences. However, in almost all cases, the environmental areas listed in Table 2 will be required by federal and state statutes. Environmental sample collection, observation, and analysis; data management and interpretation; quality assurance and quality control; and documentation for regulatory purposes, will be needed for each study.

Table 2. Pre-installation and environmental concerns that are likely to require studies and analysis to meet regulatory needs

Environmental Concern	Elements of Concern/Studies Needed	U.S. Regulatory Driver
Species under special protection	Marine animals under threat of extinction	Endangered Species Act
Marine Mammals	Concern and special societal value afforded to specific groups of animals	Marine Mammal Protection Act
Migratory Birds	Birds that migrate across regions and continents and considered at risk	Migratory Bird Treaty Act (international treaty)
Important fish and shellfish populations	Fish populations of commercial, recreational, or cultural importance	Magnuson-Stevens Fishery Conservation and Management Act (protects critical habitats and fish populations)
Habitats	Need to assess quantity and quality of habitat, due to important role in supporting marine species	Magnuson-Stevens Fishery Conservation and Management Act, other federal and state regulations
Water Quality	Cumulative degradation of water quality (dissolved oxygen (DO), nutrients, human benefits), changes in sediment transport (affecting habitats shore forms)	Clean Water Act and state equivalents

2.2 Post-installation Studies, Analysis and Documentation

Post-installation monitoring studies should be derived from the findings of pre-installation studies and other published information from relevant field and laboratory studies. For small (pilot) projects, most concerns are likely to focus close to the ocean current device (nearfield), focusing on the potential for animals colliding with devices or becoming entangled in mooring lines. As the size of the installment grows, regulations are likely to require that studies include those focused further from the devices (farfield), including assessments of biological processes such as food web effects and effects on marine

populations and communities. While site- and technology-specific differences will drive the details of such studies, in general there is likely to be a common set of requirements (Table 3). As for pre-installation studies, sample collection, observation, and analysis; data management and interpretation; quality assurance and quality control; and documentation for regulatory purposes, have all been costed for post-installation monitoring.

Table 3. Post-installation monitoring studies for ocean current project development

Target of Study	**Project Scale**	**Type of Study**	**Reason for the Study**
Marine Animals	Pilot and Commercial	Nearfield monitoring	Strike, entanglement, aggregation effects, avoidance effects.
Fish, pelagic invertebrates	Pilot and Commercial	Nearfield monitoring	
Migratory birds, diving birds, seabirds	Pilot and Commercial	Nearfield monitoring	
Sea turtles	Pilot and Commercial	Nearfield monitoring	
Benthic invertebrates	Pilot and Commercial	Underwater survey	Periodic survey and sampling to determine effects
Acoustics of the device	Pilot and Commercial	Noise coming off ocean current turbines	Change in acoustics over time: damage, harassment of marine mammals, sea turtles, fish, diving birds.
Seabirds	Commercial	Ecosystem effects	Changes to pre-installation population status, fitness, food availability and preference, reproductive success
Marine mammals	Commercial	Ecosystem effects	
Fish, pelagic invertebrates	Commercial	Ecosystem effects	
Sea turtles	Commercial	Ecosystem effects	

3.0 Results

The overall costs for environmental studies and associated processes required for reference model #4 are summarized in Table 4. Detailed spreadsheets, references, standardized protocols, and in-depth explanation of costing is available for all parts of the environmental costing process for reference model #4 (Appendix A). It should be noted that the costs listed here are not intended to make recommendations about what studies should be carried out or how much they should cost, rather they reflect cost data representative of projects carried out to date and professional judgment about how those costs might be expected to scale from pilot through small and large commercial. Real world costs may be significantly lower or higher depending on site characteristics, regulatory concerns, and stakeholder dynamics. Costs are also expected to come down over time. Numbers here represent a conservative estimate, and are not intended to inform study plan negotiations between developers and regulatory agencies.

Table 4. Ocean current summary tables

Information Need	Pilot		Small Scale Commercial		Large Scale Commercial	
	Low	**High**	**Low**	**High**	**Low**	**High**
Siting & Scoping	$165,000	$340,000	$255,000	$485,000	$270,000	$510,000
Pre-Installation Studies	$1,369,500	$2,191,000	$2,559,500	$4,611,000	$3,294,500	$6,530,000
Post-Installation	$1,050,000	$1,907,500	$10,949,000	$21,307,500	$11,449,000	$24,252,500
NEPA & Process	$800,000	$1,400,000	$1,100,000	$2,300,000	$1,300,000	$2,550,000
Total	$3,384,500	$5,838,500	$14,863,500	$28,703,500	$16,313,500	$33,842,500

Costs shown here summarize **total** costs expected at pilot and each commercial phase. As described more fully below, commercial costs were extrapolated from pilot costs under the assumption that information collected during permitting at the pilot phase would be used for permitting in the commercial phase as well, thereby achieving cost savings. Commercial costs were initially calculated as incremental costs above those incurred in the pilot; in Table 4, commercial costs were added to the pilot costs to produce the total cost for both small-scale and large-scale commercial phases.

3.1 Pilot Project Costs

Using data from representative pilot project study plans, the studies that are likely to be required were derived for each reference model stage (Table 5. Environmental studies that are likely to be required for each reference model stage); costs were then estimated for each study. The required studies and associated costs were based on assumptions derived from project experience and expert opinion; examples of the studies and the assumptions driving these costs are shown in Table 6. Cost ranges were used to represent the breadth of studies that may be required, depending on the specific animals and habitats encountered, as well as the range of materials, personnel, and equipment available. For example, if no endangered small cetaceans (i.e., dolphins, porpoises, killer whales) were found near the project site, the marine mammal surveys costs would be reduced to focus only on the presence of large cetaceans (i.e., the great whales); if a university partner or non-profit was capable of carrying out the work, costs might be less than employing a private firm. Conversely, if new instrumentation must be developed and tested expressly for the projects, costs may be higher.

Table 5. Environmental studies that are likely to be required for each reference model stage

Siting and Scoping	Pre-Installation Studies	Post-Installation Studies	NEPA Process
Preliminary resource assessment-feasibility	Detailed resource assessment	Marine mammal	NEPA document preparation
Environmental scoping	Seabed survey, mapping and bottom composition	Fish	Monitoring and study plans
Community outreach	Marine mammals	Benthos	
Regulatory outreach	Fish and invertebrates	Seabirds	
	Seabirds	Acoustic characterization monitoring	
	Turtles		
	Water quality		
	Habitat		
	Cultural resources		
	Navigation		

Table 6. Examples of pilot scale study assumptions — pre-installation (baseline) studies for fish, aquatic mammals, seabirds, and turtles

Information Need	Specific Studies	Key Assumptions
Marine mammals	Species distribution, abundance, and behavioral analysis: acoustic monitoring, shore-based observations, literature review.	Data collection and monitoring focused on migratory marine mammals as well as endangered mammals such as the North Atlantic Right Whale.
Fish and Invertebrates	Species distribution, abundance, and behavioral analysis: Split-beam hydroacoustics, grab samples for invertebrates, trawls, traps, and other sampling methods.	ESA listed and commercially valuable species will drive the studies, including highly migratory species that transit through this area. Seabed surveys will also drive up costs due to the large area of seabed used by one device and the Deepwater coral habitat areas under special protection.
Birds	Species distribution, abundance, and behavioral analysis: observation, literature review and synthesis.	Because this device has no surface expression, it is unlikely to impact seabirds. Analysis of existing data and literature may be required, but field surveys may not be necessary.
Turtles	Species distribution, abundance, and behavioral analysis of ESA-listed turtles in project area.	One year of surveys completed with marine mammals surveys. Surveys may need to be seasonal; beach surveys may also be needed to assess nesting impacts.

3.1.1 Uncertainties in Cost Estimates for Pilot Projects

There are several uncertainties in the cost estimates for pilot projects that cannot be quantified at this time. These are:

- **Monitoring Costs**. Costs for post-installation monitoring are less accurate than those for pre-installation studies because pre-installation studies that have been carried out at existing pilot projects were used to inform the costs, providing a level of confidence in the information. However, the ocean current device being proposed for reference model # 4 is unlike any other tidal or wave project with respect to its design and projected deployment area. To date, no monitoring programs have even been proposed for such a project and there are no existing technologies to act as surrogates for environmental baseline monitoring. Costs were estimated based on professional judgment and published studies. Yearly monitoring costs were estimated and extended to the proposed 5-year term of a FERC pilot license.

- **Mitigation Costs.** Mitigation costs have not been factored into the cost estimates, although mitigation for impacts to marine animals, habitats or ecosystem processes is likely to be required for most MHK projects. These costs could be added to post-installation monitoring costs, but we cannot accurately estimate the magnitude of those costs at this time.

- **Uncertainty of Costs for Regulatory Requirements.** There is considerable uncertainty associated with the costs for complying with NEPA and other U.S. federal and state regulatory mandates; meeting these mandates will require concentrated effort at each stage of MHK projects. The magnitude of these costs are dependent on the length of time these process require; while some applicable laws and regulations have established timelines for processing permits, these timelines are often exceeded to achieve alignment between the parties involved.

3.2 Commercial Scale Costs

Cost estimates for permitting and siting at a small (10 to 50 devices) and large (greater than 50 devices) commercial scale were extrapolated from costs determined for pilot-scale projects. Cost estimates assume that a pilot permitting process, associated studies, and short-term deployment have already taken place in the project area prior to development at the commercial scale. Cost estimates for commercial scale are for **additional costs** beyond the pilot study. If a developer does not follow the pilot process but goes directly to a commercial scale project (which is allowed under the FERC process), an estimate of the commercial costs for environmental siting and permitting can be derived by summing the pilot and commercial estimates.

Translating costs from pilot to commercial scale followed a number of assumptions:

- Pre-installation environmental studies carried out at the pilot scale focus on population and behavioral assessments to measure potential **direct** effects to species of concern (e.g. fish, seabirds, sea turtles, marine mammals), in order to establish a baseline for post-installation monitoring. Information gathered from these pilot studies will inform the commercial scale and studies **may not** have to be repeated; supplemental baseline information may be needed as the project footprint increases.

- At commercial scale, additional pre-installation studies may focus on understanding **ecosystem effects** from arrays. These would be **additional studies** beyond those carried out at the pilot scale.

- The threshold between a small and large commercial array cannot be viewed as absolute, and must be determined on a site-specific basis. We have chosen thresholds appropriate for the reference sites we are working at, based on overall guidance of the DOE reference model team.

3.2.1 Scaling Rules

In addition to the assumptions that lead from pilot to commercial scale cost estimates, PNNL developed a set of "scaling rules" (Table 7) to allow for consistent comparison between changes in study costs from pilot to commercial scale; this consistency allows for relative comparison, which is useful considering the uncertainty in cost estimates.

Table 7. Rules for scaling environmental study costs from pilot to commercial scale projects

Scaling Rules	Explanation	Example
Covered in pilot	Information need was covered under the pilot project licensing process. Additional funds are likely not needed for studies at the commercial scale.	Desktop studies for initial determination of economic and environmental feasibility. This information would carry over directly into commercial scale.
Continuing costs	Recurring costs that continue from pilot into commercial scale permitting processes.	Nearfield monitoring studies may continue from pilot to commercial scale, though the expectation is that pilot nearfield monitoring studies may answer many of the questions required for commercial installation, so commercial costs may be at a lower level.
Incremental increase	Additional costs associated with larger footprint of a commercial scale project. Cost increase likely to be marginal, incremental, and linear.	Resource assessment—larger project footprint may require procurement and deployment of additional Acoustic Doppler Current Profilers (ADCPs), Acoustic Doppler Velocimeters (ADVs), or other instruments, incrementally higher equipment costs and additional ship days above what would be expected for a pilot-scale project.
Multiplicative cost increase	Significant study cost increases as scale of project goes from pilot to commercial, and regulators require greater understanding of system or basin effects. Cost increase likely to be more than double the cost at the	Habitat surveys and mapping may be expected to have a multiplicative cost increase if there is a large increase in footprint from pilot to commercial scale, or if a farfield habitat baseline survey is

	pilot scale and may increase in a non-linear fashion.	required.
Additional study	Larger scale projects may require studies that are in addition to those required for a pilot project.	Farfield or ecosystem monitoring— Pre-installation studies that characterize valued species (fish, birds, marine mammals) will be needed at up to the basin-scale. If effects of a commercial project are considered to extend beyond the nearfield, or if regulators require "Before After Control Impact" (BACI)- style monitoring in the post-installation phase, completely new studies may be required.

Siting and scoping costs at commercial scale will increase incrementally over pilot scale costs, as the footprint of the ocean current farm increases. However these costs will remain a relatively small fraction of total costs.

Pilot scale pre-installation studies may satisfy many of the regulatory needs at the commercial scale. However commercial scale projects may raise new questions about farfield or ecosystem effects, and as a result, additive studies may be necessary to assess baseline health for species of concern. Detailed hydrodynamic modeling may also be needed to inform array siting and to understand potential water quality and sediment transport effects. Finally, habitat mapping costs could increase multiplicatively when device numbers cross a threshold where farfield effects might be expected; this could lead to regulatory requirements for habitat mapping and assessment of a much larger area than that immediately adjacent to the array and associated infrastructure.

As with the pilot-scale assessment, there is considerable uncertainty in costs associated with post-installation monitoring for commercial developments. Some of the post-installation studies carried out at the pilot scale are likely to continue. However, information collected during monitoring of pilot scale devices may satisfy a number of regulatory questions, particularly the risk of direct effects of devices on animals (such as blade strike). As with pre-installation studies, increases in post-installation monitoring costs may be related to additional studies to understand farfield or ecosystem effects resulting from large arrays of devices.

3.3 Profile of Post Installation Monitoring Costs

Until sufficient data exist to anticipate interactions of ocean current devices with marine animals and habitats, extensive monitoring is likely to be required during the initial years of deployment at the commercial scale, resulting in front-loading of costs in the first five years. These costs are expected to reduce sharply to an annual baseline level, with periodic increases in activity to validate the trends seen in the first five years, and to address new questions or concerns as they arise. Figure 1 shows a cost profile over the course of a thirty-year license term for the large commercial ocean current project. Note the

general shape of this graph would be identical to the monitoring costs for a small commercial ocean current project, but has higher costs at the larger scale.

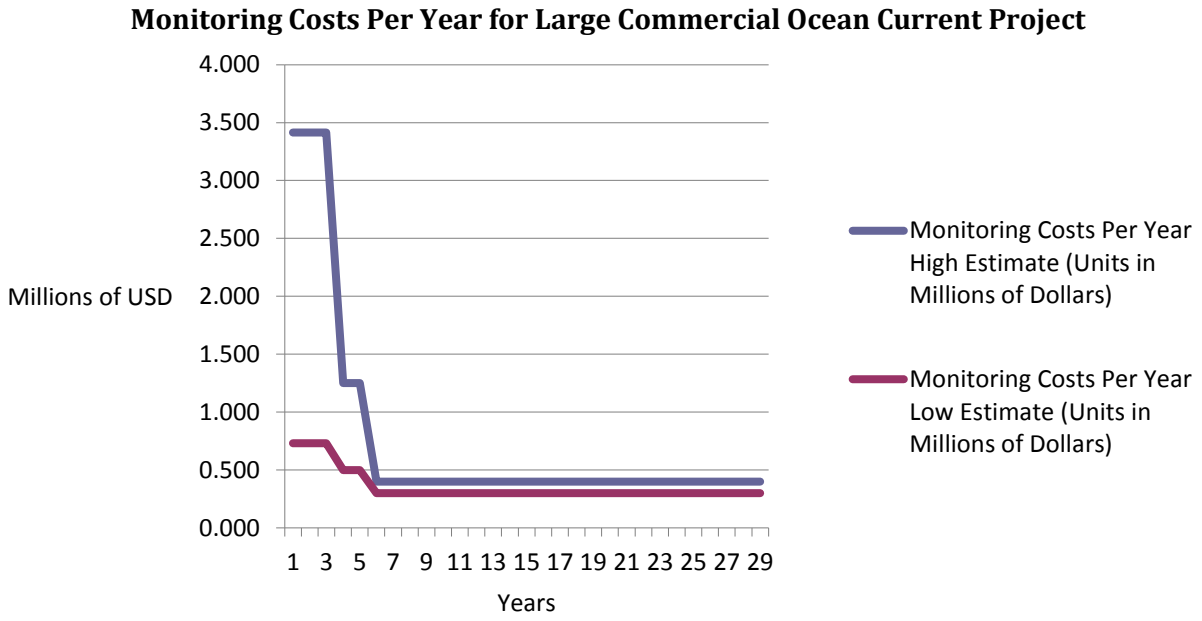

Figure 1. Hypothetical cost profile for monitoring costs over a thirty-year license term for the large commercial-scale ocean current farm

3.4 Potential for Cost Savings and Refined Estimates

The process PNNL used to estimate costs of environmental studies and permitting relied heavily on information from developers, researchers and consultants involved in facilitating deployment of MHK devices in the U.S. The variability of cost estimates shown for environmental studies and permitting are large, as reflected by the cost ranges (low estimate, high estimate) shown, and represent preliminary answers that require more investigation before they can be seen as reliable contributors to the COE. Each major study has been costed independently; in reality there may be considerable cost savings if baseline and monitoring studies for various organisms are combined. For example, combining boat-based observer assessments of marine mammals and sea turtles along an open coastline will reduce days of ship time; similarly, acoustic monitoring for aquatic mammals and fish can be conducted during the same cruise, using an array of acoustic imaging devices and hydrophones. Where possible, these potential efficiencies were captured in low cost estimates and described in the assumptions, but considerable variability can still be expected. With a limited number of U.S. MHK projects approaching deployment (and none of them planned for capturing energy from ocean currents), there have been limited sources of cost data available during this study. Future iterations of this process will help hone the costs of studies and permitting, as well as determine the proportionate contributions to the COE.

The cost ranges shown for the ocean current technology reflect choices among the studies, as indicated by the logic models. As we learn more about the conditions found at proposed MHK sites, the

potential effects of these devices on marine animals, habitats and ecosystem processes, and the studies required to understand and address these effects, the logic models could be revisited, with further refinement of the list of studies and associated costs for each stage of development. Similarly the scaling rules (Table 7) could be further refined and applied to commercial scale studies. Once sufficient study and costing data become available at the commercial scale, the scaling rules should become unnecessary and could be replaced with estimates of realistic costs.

3.5 Cost Differences among MHK Technologies

Factors such as waterbody characteristics, MHK technologies, and the marine animals and habitats indigenous to the site will be reflected in differences among permitting and siting costs for MHK projects in the U.S. As more MHK sites are chosen for development, additional permitting requirements and siting complexities may arise causing even greater divergence in permitting and siting costs.

Ocean current sites (reference model # 4) are expected to be located within powerful and consistent ocean currents at the western boundary of ocean basins. These ocean currents are often utilized by migratory marine animals. Extensive pre- and post-installation monitoring may be needed to better understand the interaction between these devices and migratory marine mammals, fish and reptiles; endangered species like the North Atlantic Right Whale and Leatherback sea turtle will also require additional baseline monitoring. Development of ocean current devices may require extensive baseline and post-installation monitoring of benthic habitats as well. The site location for reference model # 4 is located in Deepwater Coral Habitat Areas of Particular Concern, requiring benthic surveys over large areas at great depths to determine the location of these little known and elusive habitats. The presence of this special habitat may become a significant driver of pre- and post-installation monitoring costs. Because reference model # 4 does not have a surface expression and is located roughly 35-50 meters below the surface, few seabird studies will be needed. It should be noted that because no technologies or projects exist to act as surrogates for environmental baseline monitoring, there may be additional data gaps to address.

4.0 Conclusions

Estimating costs of environmental studies and permitting provides input to the COE, and also serves other purposes. These estimates may assist developers in determining upfront and ongoing costs of developing projects, as well as planning linked studies from pre-installation assessment to post installation monitoring, and developing mitigation strategies. Probably most important, the process of determining appropriate studies to meet regulatory needs can assist the standardization of a pathway for getting MHK projects in the water and expanding towards commercial production of power.

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Appendix A—Costing Tables

Summary Table of Reference Model # 4 (Ocean Current)

Costs shown here summarize **total** costs expected at pilot and each commercial phase. Commercial costs were initially calculated as incremental costs above those incurred in the pilot; commercial costs were added to the pilot costs in this table to produce the total cost for both small-scale and large-scale commercial phases.

	Pilot		Small Scale Commercial		Large Scale Commercial	
Information Need	Low	High	Low	High	Low	High
Siting & Scoping	$165,000	$340,000	$255,000	$485,000	$270,000	$510,000
Pre-Installation Studies	$1,369,500	$2,191,000	$2,559,500	$4,611,000	$3,294,500	$6,530,000
Post-Installation	$1,050,000	$1,907,500	$10,949,000	$21,307,500	$11,449,000	$24,252,500
NEPA & Process	$800,000	$1,400,000	$1,100,000	$2,300,000	$1,300,000	$2,550,000
Total	$3,384,500	$5,838,500	$14,863,500	$28,703,500	$16,313,500	$33,842,500

Pilot Costs

Pilot - Siting and Scoping

Information Need	Specific Studies	Low Cost (USD)	High Cost (USD)	Key Assumptions
Preliminary Resource Assessment—Feasibility	Desktop feasibility—resource intensity and theoretical resource	40,000	90,000	1) obtain information on gulfstream depth and location; 2) construct models); 3) calculate power density 4) report. Note: detailed turbulence and long term resource variability may not be necessary at the pilot scale. These costs are accounted for at the commercial scale.
Environmental Scoping	Desktop study—review existing information	25,000	50,000	Used for preliminary NEPA scoping and to identify key information needs for baseline.
Community Outreach	Targeted information delivery, community meetings, workshops	50,000	80,000	Development of materials and information to address anticipated stakeholder concerns (fishermen, navigational interestes, NGOs, cities and counties, and others) and frame the value of the project to the community, attending or hosting 4-8 meetings with existing organizations. Would inform NEPA process.
Regulatory Outreach	Policy and regulatory analysis, reach out to regulators for future NEPA process	50,000	120,000	Low: 6 meetings total with agency personnel (FERC, BOEM, USFWS, NMFS, FWC, FERC); High: 12 meetings total with agency personnel; Assumes all meetings are local and no travel costs
Total		**165,000**	**340,000**	

Pilot - Pre-Installation Studies

Information Need	Specific Studies	Low Cost (USD)	High Cost (USD)	Key Assumptions

Seabed Survey, Mapping and Bottom Composition	Side-scan survey of site area, ROV survey at site, compile data and create georeferenced site maps. This study will be a key regulatory need to avoid Deepwater coral reef habitat.	336,000	496,000	Cost for field work + equipment; includes 8-13 days to survey project site and cable route ($200-300 k). Mapping assumes lab work, data enter, analysis, and report writing ($60 K). This work may build and utilize data from past DOE funded work to develop a survey and site suitability assessment approach and preliminary maps for siting ocean current energy.
Marine Mammals and Sea Turtles	Baseline—distribution, species identification, and behavioral analysis: acoustic monitoring, vessel-based observation, and literature review.	630,500	806,000	1-year study. Deep water will necessitate vessel-based surveys for species of concern (North Atlantic right whales, bottlenose dolphins most common marine mammals in area; turtles species of concern include loggerhead, leatherback, green, Kemp's ridley, hawksbill). Surveys may be seasonal--for example Right whales utilize the area from December to March during calving season; sea turtle nesting season is from March to October in the Atlantic. Beach surveys may be needed to understand shoreside infratstructure impacts on nesting sea turtles.
Fish and Invertebrates	Baseline—distribution, species identification, and behavioral analysis: Telemetery and tagging for large fish of concern, grab samples for invertebrates, trawling or hook and line sampling for pelagic fish.	325,000	520,000	1-2 years of pre-installation monitoring or as required by agencies; 1) Telemetry receivers to detect species of concern (elasmobranchs), if feasible; 2) Grab sampling to assess benthic inverts; 3) Trawling or hook and line to assess pelagic fish in anticipation of FAD effects. Very difficult to sample in project area, due to deep depths and likely ephemeral nature of fish species use in mid ocean. May require development of methodlogles that differ from those presented here.
Seabirds	Baseline—distribution, species identification, and behavioral analysis: literature review.	13,000	39,000	Device unlikely to impact seabirds. Some analysis of existing data and literature will likely be required, but field surveys unlikely due to the depth of turbine operation.
Water Quality	Baseline—CTD deployed during resource assessment; water quality model coupled to hydrodynamic model to indicate relative water quality effects.	0	0	Water quality not likely a concern for open ocean device.
Habitat	Benthic surveys covered in seabed analysis above. Nearshore surveys conducted by plant ecologists	20,000	25,000	May not have to do nearshore survey if directional drilling avoids habitat effects. Botanical survey at cable landing and associated infrastructure. 1 week (5 d), assumes no new transmission line. Does not include wetland delineation.
Cultural Resources	Three phases: Inventory, testing, data recovery	15,000	195,000	Low estimate is for historic properties inventory only. High estimate reflects testing and data recovery that would only be necessary if sites are found that cannot be avoided. Estimates are for shoreline sites only; seabed survey would identify submerged cultural resources that could be avoided through siting. The coast of Florida is a hotspot for submerged cultural resources, if sites were found in seabed survey that could not be avoided, documented these and mitigating impacts could lead to higher costs.
Navigation	AIS transponder, risk assessment	10,000	30,000	Minimal effect to surface navigation expected due to lack of surface expression. Construction activities may require some areas to be avoided and necessitate a navigational allsessment. AIS transponder near project to record ship tracks; data used in Coast Guard consultation. Cable and anchors may pose a concern to Navy for submarine navigation--may need to be addressed through agency outreach.
Recreation	Recreation overview and initial impact assessment	20,000	80,000	Focus on boat-based fishing, sail and powerboat navigation. Minima; impact expected due to great depths and distance from shore. 3-9 month study, interviews, site visit, meetings with developer and staff, summary of existing data, summary report.

Total		**1,369,500**	**2,191,000**

Pilot - Post-Installation Monitoring

Information Need	Specific Studies	Low Cost (USD)	High Cost (USD)	Key Assumptions
Marine Mammal and Turtles	Monitoring—Strike, entanglement, aggregation effects, avoidance effects.	325,000	780,000	(costs are for one year of monitoring—multiple years may be required) Equipment costs includes aerial surveys, hydrophones, active acoustics, and ROV use for survey of lines (200-400k). Operating costs are recurring yearly and include surveys of lines for entanglement (100-300k). Tremendous uncertainty here—costs could be much higher depending on agency requirements.
Fish	Monitoring—strike, aggregation effects, avoidance effects.	195,000	422,500	costs are for one year of monitoring—multiple years may be required) Equipment costs includes lights and camera package (may be required if FAD effect observed), tagging, active acoustics (150-300k). Operating costs are recurring yearly (75-125k). Tremendous uncertainty here—costs could be much higher depending on agency requirements.
Benthos	Periodic survey and sampling to determine effects on benthic organisms and community	480,000	640,000	costs are for one year of monitoring—multiple years may be required) side scan and ROV survey, of site area (cable run may not require monitoring) ~4-days of survey work each time monitoring is required, likely quarterly for first year.
Acoustic Characterization Monitoring	Sound produced by turbines	50,000	65,000	(costs are for one year of monitoring—multiple years may be required) Initial equipment investment of 45-60k, then 5k recurring per year.
Total		**1,050,000**	**1,907,500**	

Pilot - NEPA and Process

Information Need	Specific Studies	Low Cost (USD)	High Cost (USD)	
NEPA Document Preparation	Consulting firm contract	600,000	1,000,000	Agency consultation, Biological Assessment, MMPA permits, 404 water quality permit, CZMA, drafts and final EIS, draft and final license agreement.Would require both BOEM and FERC documents.
Monitoring and Study Plans	Consultants or research partners	200,000	400,000	Separate study plans prepared for 1) marine mammals & sea turtles, 2) fish, 3) benthos and corals. Assumes several iterations for each study plan and validation of methodologies needed to satisfy agency concerns. Also deveopment of an adaptive management approach for post installation monitoring and mitigation.
Total		**800,000**	**1,400,000**	

Pilot - Total

	Pilot	
Information Need	Low **(USD)**	High **(USD)**
Siting & Scoping	$165,000	$340,000
Pre-Installation Studies	$1,369,500	$2,191,000
Post-Installation	$1,050,000	$1,907,500
NEPA & Process	$800,000	$1,400,000
Total	**$3,384,500**	**$5,838,500**

Commercial - Siting and Scoping

Information Need	Specific Studies	Small Scale Commercial (Low Estimate, USD)	Small Scale Commercial (High Estimate, USD)	Large Scale Commercial (Low Estimate, USD)	Large Scale Commercial (High Estimate, USD)	Scaling Rules—Scaling up from pilot
Preliminary Resource Assessment—Feasibility	Desktop feasibility—max flow rate, cross sectional area, length of channel: Theoretical resource	0	0	0	0	**Covered in Pilot—**Study at pilot scale directly applicable to small- and large-scale commercial.
Environmental Scoping	Desktop study—review existing information	10,000	15,000	15,000	20,000	**Incremental Increase—**Pilot study $25k-$50k provides most of the necessary information, will need to be updated for the commercial process due to larger project foot print. Also, large scale ecosystem questions may need to be scoped at the commercial scale that could be ingored for pilot.
Community Outreach (Note: Community outreach continues through all project phases)	Targeted information delivery, community meetings, workshops	50,000	80,000	60,000	100,000	**Continuing Cost, Incremental Increase—**Pilot costs: $50k-$80k: Outreach budge will continue and may increase for commercial scale, based on the difference in length of permitting process— Longer process will required more in-depth outreach, more public meetings, greater need for facilitated stakeholder interactions. Potential for broader stakeholder group.
Regulatory Outreach	Policy and regulatory analysis, reach out to regulators for future NEPA process, (ongoing agency communication during study period and development of study plans accounted for under NEPA and Process)	30,000	50,000	30,000	50,000	**Continuing Cost, Incremental Increase—**Pilot costs: $50k-120k: Regulatory analysis completed during pilot, however, additional agency interaction around project scoping likely needed at small and large commercial scale. Majority of costs associated with agency interactions and studies are accounted for under NEPA and Process phases.
Total		**90,000**	**145,000**	**105,000**	**170,000**	

Commercial - Pre-Installation Studies

Information Need	Specific Studies	Small Scale Commercial (Low Estimate, USD)	Small Scale Commercial (High Estimate, USD)	Large Scale Commercial (Low Estimate, USD)	Large Scale Commercial (High Estimate, USD)	Scaling Rules—Scaling up from pilot
Detailed Resource Assessment	ADCPs, ADVs and ECMs to characterize flow and turbulence at the site. May require several moorings or ship-based deployment over large area of Gulf Stream	300,000	600,000	600,000	900,000	**Incremental Increase**—Pilot Costs: $40-90k: Desktop preliminary resource assessment in pilot phase would have assessed available resource; at commercial scale, necessary to undersand turbulence and variability. Cost scaling is a factor of site size. Additional ship time and equipment is needed for larger site surveys. This assumes 2-4 different sites; each site requiring 4-days ship time for deploying and two days for retrieving instruments, plus data processessing.
Hydrodynamic Modeling—Maximum Available and Extractable Power (model could also be used in water quality tasks)	Modeling natural hydrodynamic conditions at the site as well as wake effects of proposed arrays and effects of energy removal. Would also inform site selections, as verified against field measurements.	80,000	200,000	80,000	200,000	**Additive Study**—Would not be likely in pilot-scale, detailed hydrodynamic modeling would be more useful at commercial scale.
Seabed Survey, Mapping and Bottom Composition	Side-scan survey of site area, ROV survey at site, optional survey of bottom composition below seabed	320,000	640,000	640,000	1,600,000	**Incremental Increase**—Pilot costs $336-496K. Great depth of site and distance required between devices requires significant spacing between devices at small and large commercial scale. Because of sensitivity of deep sea coral habitat, detailed site surveys would likely be required for anchoring each device and all cable runs. Would necessitate additional ship time and potentially additional ROV survey to facilitate siting.
Marine Mammals and Sea Turtles	Baseline Health—Population analysis, food availability and preference, reproduction—compare to existing data (assuming availability)	195,000	325,000	195,000	325,000	**Additive Study**—Pilot Costs: $630k-$806k. Baseline at pilot scale collected population, distribution, and behavior to assess direct effects. Pilot scale information will be applicable to commercial scale, but additional studies may be needed to assess system-wide effects on habitat and food supply due to operation of arrays. May also investigate energetic consequences of responses to array presence. Could be used in potential BACI-like monitoring studies, if required.
Fish	Baseline Health—Population analysis, food availability and preference, reproduction—compare to existing data (assuming availability)	195,000	325,000	195,000	325,000	**Additive Study**—Pilot Costs: $325k-$520k. Baseline at pilot scale collected population, distribution, and behavior to assess direct effects. Pilot scale information will be applicable to commercial scale, but additional studies may be needed to assess system-wide effects on habitat and food supply due to operation of arrays. May also investigate energetic consequences of responses to array presence. Could be used in potential BACI-like monitoring studies, if required.

Seabirds	Baseline Health—Population analysis, food availability and preference, reproduction—compare to existing data (assuming availability)	0	0	0	0	**Covered in Pilot—**Pilot Costs: $10k-$30k. Impacts to seabirds not expected from operation of turbines in deep water. Outside diving depths, and no surface expression. Literature review in pilot should be sufficient.
Water Quality	Baseline—Hydrodynamic modeling task would assess changes in the structure of the gulfstream due to deployment of devices at small and large commercial scales. Water quality (temperature, DO, etc.) not likley a concern in an open ocean environment with this technology	0	0	0	0	**Covered in Pilot—**Not likely a need for water quality studies beyond those assessed in hydrodynamic modeling task
Habitat	From seabed survey, development of habitat maps and potential nearshore survey	50,000	100,000	100,000	200,000	**Incremental Increase**—Increase in costs to factor in studies habitat mapping for larger project footprint. Seabed survey would provide data needed for mapping of habitat for species of concern. Deep sea corals are a habitat of special concern. As with pilot, shore-based surveys may or may not be required depending on where and how cable makes a landing.
Cultural Resources	Three phases: Inventory, testing, data recovery	0	130,000	52,000	650,000	**Incremental Increase**—Increasing the area of potential effect offshore would increase the likelihood that submerged cultural resources would be found requiring documentation or mitigation Coastal Florida is rich in submerged cultural resources. This estimate assumes that the nearshore footprint of the cable landing is the same at all project phases. If nearshore or shore-based footprint were to grow, costs would also grow.
Navigation	AIS transponder, risk assessment	0	0	13,000	39,000	(Small Commercial) **Covered in Pilot—**Navigation not expected to be much of an issue, except (perhaps) for submarine navigation. Pilot sutdy may suffice. (large Commercial) **Incremental Increase—**Significantly larger footprint than pilot and small commercial may require additional studies or data processing. If submarine navigation was a concern of the Navy, the number of cables and large devices at cruising depths could require negotiation.
Recreation	Additional assessment costs above pilot for more precision, focus groups or panel evaluations, survey based evaluations, descriptive use information study, evaluation of changes to recreational resource	50,000	100,000	50,000	100,000	**Additive Studies—**Larger project area, greater potential risk to recreational opportunities, may require more detailed and intensive studies to understand potential effect on recreational resources and mitigation strategies. Recreational focus is likely on deep water fishing as well as diving or shore recreation at cable run and landing.
Total		**1,190,000**	**2,420,000**	**1,925,000**	**4,339,000**	

Information Need	Specific Studies	Small Scale Commercial (Low Estimate, USD)	Small Scale Commercial (High Estimate, USD)	Large Scale Commercial (Low Estimate, USD)	Large Scale Commercial (High Estimate, USD)	Scaling Rules—Scaling up from pilot
Marine Mammals and Turtles	Nearfield Monitoring—blade strike, entanglement,aggregation effects, avoidance effects.	39,000	422,500	39,000	780,000	**Continuing Costs:** Monitoring at the pilot scale will have established effects at the nearfield; costs for small commercial nearfield monitoring will be lower or remain at the same level per year. At the low end of range, periodic surveys expected. At the high end, continuation of nearfield visual and acoustic monitoring (farfield monitoring is an additive study costed below under "Ecosystem Effects"). Effects of avoidance from large scale commercial array may need to be studied, leading to costs beyond those at pilot scale. Costs are per year—potentially recurring for 2-3 years at high costs, and continuing at a lower level of effort and cost for the term of the license. ***Tremendous cost uncertainty, due to lack of real-world experience with this technology at any scale.***
Fish	Nearfield Monitoring—blade strike, aggregation effects, avoidance effects.	39,000	422,500	39,000	780,000	**Continuing Costs:** Monitoring at the pilot scale will have established effects at the nearfield; costs for small commercial nearfield monitoring will be lower or remain at the same level per year. At the low end of range, periodic surveys expected. At the high end, continuation of nearfield visual and acoustic monitoring (farfield monitoring is an additive study costed below under "Ecosystem Effects"). Effects of avoidance from large scale commercial array may need to be studied, leading to costs beyond those at pilot scale. Costs are per year—potentially recurring for 2-3 years at high costs, and continuing at a lower level of effort and cost for the term of the license. ***Tremendous cost uncertainty, due to lack of real-world experience with this technology at any scale.***
Benthos	Periodic survey and sampling to determine effects	300,000	500,000	400,000	600,000	**Continuing Costs:** Monitoring at the pilot scale (if applicable) will have established effects at the nearfield; if

						monitoring was carried out at the pilot scale, costs for small commercial at the nearfield will likely be constant (won't likely be lower than at pilot scale due to regulatory importance of deep sea corals) and may also include sampling and surveys of the farfield. At the low end of range, periodic nearfiled surveys expected. At the high end, additional sampling may be required in the farfield. Costs are per year—potentially recurring for 2-3 and continuing at a lower level of effort and cost for the term of the license. ***Tremendous cost uncertainty, due to lack of real-world experience with this technology at any scale.***
Acoustic Characterization Monitoring	Sound produced by turbines	5,000	5,000	5,000	5,000	**Continuing Cost:** Assuming initial investment and deployment of monitoring technology at pilot scale, costs would be only for the recurring data collection and analysis. Costs are per year—would likely continue for life of project for the purposes of both environmental and performance monitoring.
Ecosystem Effects Marine Mammals and turtles	Assess changes to pre-installation population analysis, fitness, food availability and preference, reproduction—compare to existing data (assuming availability)	100,000	500,000	100,000	500,000	**Additive Study—**If there is regulatory concern that the scale of a project is likely to result in food chain or ecosystem effects on species of concern, or population level effects from changes in migration routes or navigation impacts from EMF, monitoring may be required to assess changes based on pre-installation baseline studies. Studies may not be required for small-scale commercial deployments. If Before After Control Impact (BACI)-type studies are required for large commercial deployments, cost could be very high and have tremendous effects on project feasibility. Costs are per year—potentially recurring for 3-5 years at high cost, and continuing at a reduced effort and cost for the term of the license. Costs may potentialy increase periodically for additional survey effort or equipment replacement. ***Tremendous cost uncertainty, due to lack of real-world experience with this technology at any scale.***
Ecosystem Effects Fish	Assess changes to pre-installation population analysis, fitness, food availability and preference, reproduction—compare to existing data (assuming availability)	150,000	750,000	150,000	750,000	**Additive Study—**If there is regulatory concern that the scale of a project is likely to result in food chain or ecosystem effects on species of concern, monitoring may be required to assess changes based on pre-installation baseline studies. Studies may not be required for small-scale commercial deployments. If Before After Control Impact (BACI)-type studies are required for large commercial deployments, cost could be very high and have tremendous effects on project feasibility. Costs are per year—potentially recurring for 3-5 years at high costs, and continuing at a reduced effort and cost for the term of the license. Costs may increase periodically (approximately every five years) for additional survey effort or equipment replacement. ***Tremendous cost uncertainty, due to lack of real-world experience with this technology at any scale.***
Total		**633,000**	**2,600,000**	**733,000**	**3,415,000**	**(Per year)**
30-year total		**9,899,000**	**19,400,000**	**10,399,000**	**22,345,000**	**(Based on 30-year monitoring cost profile illustrated in chart below)**

Commercial - Current Totals

Information Need	Specific Studies	Small Scale Commercial (Low Estimate, USD)	Small Scale Commercial (High Estimate, USD)	Large Scale Commercial (Low Estimate, USD)	Large Scale Commercial (High Estimate, USD)	Notes
Siting and Scoping		90,000	145,000	105,000	170,000	**Preliminary Permit, scoping, and lead up to DLA**
Pre-Installation Studies		1,190,000	2,420,000	1,925,000	4,339,000	**From final license agreement through baseline data collection phase**
Post-Installation		9,899,000	19,400,000	10,399,000	22,345,000	**Over the course of the 30 year license**
NEPA and Process		300,000	900,000	500,000	1,150,000	**Over the course of the FERC licensing process, Preliminary permit to FLA**
Total		**11,479,000**	**22,865,000**	**12,929,000**	**28,004,000**	**(additional costs above those incurred in pilot)**

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