PCCI
Marine and Environmental Engineering

DECOMMISSIONING COST ESTIMATION FOR THE CAPE WIND ENERGY PROJECT

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List of Abbreviations

AHT	Anchor Handling Tug
avg	average
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CFR	Code of Federal Regulations
COP	Construction and Operations Plan
CPM	Critical Path Management
CWA	Cape Wind Associates, LLC
cu	Cubic
CY	Calendar Year
D_{50}	Median Sieve Size
D/B	Derrick Barge
dia	Diameter
Demob	Demobilization
DGPS	Differential Global Positioning System
DOT	Department of Transportation
DWT	Deadweight Tons
ea	each
ESP	Electrical Service Platform
FDR	Facility Design Report
FIR	Fabrication and Installation Report
ft	foot
gal	Gallons
hp	Horsepower
hr	Hour
in	inch
J/B	Jack-up Barge
kg	kilograms
kV	kilovolt
lb	pound
m	meter
mm	millimeter
Mob	Mobilization
MMCT	Massachusetts Marine Commercial Terminal
mT	metric Tons

nm	nautical miles
N/A	Not Applicable
OCS	Outer Continental Shelf
OSV	Offshore Support Vessel
OT	Overtime
PDF	Probability Distribution Function
PERT	Program Evaluation and Review Technique
RFQ	Request for Quotation
ROV	Remotely Operated Vehicle
ST	Straight Time
T	Tons
TLR	Top Level Requirements
UW	Underwater
WBS	Work Breakdown Structure
wt	weight
WMJV	Weeks Manson A Joint Venture
WTG	Wind Turbine Generator
yd	yard

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Executive Summary

PCCI, Inc. (PCCI), with assistance from TSB Offshore, Inc. (TSB), estimated the total decommissioning cost of the Cape Wind Energy Project through a series of tasks by:

- Reviewing applicable Bureau of Ocean Energy Management (BOEM) regulations and Renewable Energy Lease Number OCS-A 0478 (the Cape Wind Lease);
- Reviewing applicable sections of the Cape Wind Construction and Operations Plan (COP), Facility Design Report (FDR), and Fabrication and Installation Report (FIR);
- Analyzing relevant factors contributing to the decommissioning cost;
- Employing a deterministic method to develop offshore decommissioning costs, using specific unit rates, task durations, equipment suites, etc.;
- Preparing a probabilistic model of the total cost for all decommissioning work.

The PCCI and TSB project personnel team reviewed the applicable BOEM regulations and the decommissioning stipulations contained in the Cape Wind Lease. We documented our understanding of the decommissioning requirements in a set of Top Level Requirements (TLR), along with the assumptions used in the subsequent analysis to estimate the decommissioning cost.

Information obtained from the applicable sections of the Cape Wind COP, FDR, and FIR, as well as previous offshore wind energy decommissioning plans and cost estimates, was used in conjunction with the TLR to develop a Work Breakdown Structure (WBS) identifying the work processes required to decommission the major project components. The WBS also identified the size, quantities and types of materials to be decommissioned, and the equipment and vessels that would be required to support the decommissioning work processes.

The major factors contributing to the decommissioning cost were the type, quantity, and day rates of equipment and vessel suites required to complete the identified work; the estimate of time to complete each work process; and the time required to transport and dispose of the quantities and types of materials requiring disposal or recycling. To analyze these factors, a decommissioning schedule was created based on information submitted to BOEM by Cape Wind Associates, LLC (CWA) for the project installation, as well as information contained in previous decommissioning cost estimates, and the experience of project personnel with reasonable decommissioning techniques using today's technology and best practices. Equipment and vessel day rates were solicited from area providers, including those with direct involvement in the planned Cape Wind Energy Project installation.

In order to estimate the decommissioning costs, each major WBS item was entered into a spreadsheet along with respective equipment and vessel quantities, cost rates, and duration from the schedule for the task processes. Fuel costs for vessel operations were added for each vessel operating day. Minimum, most likely, and maximum equipment and vessel utilization estimates were used to obtain a range of decommissioning estimates. The resulting estimates, based on current technology and day rates, are:

- Minimum estimate = $71,073,507
- Expected estimate = $103,299,968

- Maximum estimate = $125,550,261

Additionally, for informational purposes, the potential salvage value for recycled materials was estimated based on the total weight of copper, lead and steel that would be available from the decommissioned cables and structures.

- Estimated total salvage value = $22,875,920

1. BACKGROUND

The Energy Policy Act of 2005 authorizes the U.S. Department of the Interior to issue leases, easements and rights of way to allow for renewable energy development on the Outer Continental Shelf (OCS). BOEM's Office of Renewable Energy Programs oversees this process and is responsible for implementing regulatory requirements at 30 C.F.R. Part 585, "Renewable Energy and Alternate Uses of Existing Facilities on the Outer Continental Shelf." At the end of a project's life, the regulations at 30 C.F.R §§585.902-913 require the leaseholder to follow strict decommissioning protocols, including the removal of the project's facilities, structures, cables, pipelines and any other associated equipment and to clear the seafloor of all obstructions related to the project. In order to protect the United States government from financial liability if a company is unable to meet its decommissioning obligations, BOEM requires the developer to post decommissioning financial assurance prior to the installation of facilities on the OCS which will cover the estimated cost of facility decommissioning.

In June 2014, the Bureau of Safety and Environmental Enforcement (BSEE), on behalf of BOEM, issued a Request for Quotation (RFQ) for Decommissioning Cost Estimation for the Cape Wind Energy Project. The work reported herein is the result of a contract awarded to PCCI, Inc. for a successful proposal submitted in response to the RFQ. BOEM procured a contract to estimate the decommissioning cost of the Cape Wind Energy Project to inform its decision-making on the amount of decommissioning financial assurance it will require pursuant to 30 C.F.R. §585.516.

2. REVIEW OF APPLICABLE BOEM REGULATIONS AND RENEWABLE ENERGY LEASE NUMBER OCS-A 0478

2.1 Introduction

PCCI reviewed the requirements for decommissioning commercial wind energy facilities pursuant to BOEM's regulations at 30 C.F.R. Part 585 (Reference 1) and stipulations contained in Renewable Energy Lease Number OCS-A 0487 for the Cape Wind Energy Project (Reference 2).

2.2 Top Level Requirements

Top Level Requirements (TLR) were created to describe the Cape Wind Energy Project decommissioning requirements as well as the technical assumptions used in developing the decommissioning cost estimates for the project. The TLR were used in developing the decommissioning work processes summarized in Section 3 to ensure that all requirements were achieved by the planned work, and in the analyses summarized in Section 4 to ensure the decommissioning schedule met BOEM's regulatory requirements. The TLR developed for this project are included in Appendix A.

3. CAPE WIND DOCUMENTS AND OTHER REPORT REVIEWS

3.1 Reports and Confidential Business Information

After the review team members signed and returned Contractor Employee Non-Disclosure Agreements, BOEM provided a compact disc to PCCI and TSB with References (1) through (9). BOEM included applicable parts of the Cape Wind COP, FDR and FIR, as well as other available reports on decommissioning cost estimating in BOEM's possession.

The FDR and FIR contained CWA Confidential Business Information including:

- Wind turbine generator (WTG) array layouts
- Design drawings
- Details of project components and their design basis
- Scour protection arrangements and design details
- Installation method summaries and schedules

3.2 Work Breakdown Structure

PCCI reviewed all documents and used the information contained therein to develop a Work Breakdown Structure (WBS) identifying the work processes required to decommission, remove and dispose of all project facilities and components, and to conduct site survey and clearance activities as required in BOEM's regulations and specified in the Cape Wind lease. The work processes were generally the reverse of the installation tasks identified in References (3) and (7), and as described in the conceptual decommissioning plan included in Reference (3), but with the following changed assumptions:

- 101 WTGs and their associated cables were considered, rather than the original proposed project build out of 130 WTGs, since BOEM has only authorized construction of 101 WTGs at this point in time.
- Onshore facilities (e.g., upland transmission cables and substations) were not considered because their removal is not required by the Cape Wind lease or BOEM regulations.
- Similarly, only those portions of the submarine power cables that fall directly within the lease area and within BOEM's jurisdiction were considered (cables in Massachusetts State waters are excluded).
- The Massachusetts Marine Commerce Terminal (MMCT) at New Bedford, MA is used as the onshore location for receipt of the materials and the marshaling yard for disposal and recycling, rather than the Prolerized New England, Everett, MA facility proposed by CWA.
- Intra-array and export cables will be pulled up and cut into manageable lengths for storage and transport to shore, rather than being spooled onto reels.
- WTGs will be dismantled using three picks instead of six, assuming the rotor and blades can be removed in a single pick, and lowered onto the jack-up barge where the blades would be removed by a second crane for stacking on the shore transport barge, while the main crane continues to dismantle the tower.
- Disposal of rock armoring will be at a permitted offshore location where the materials can be dumped from split hull hopper barges, rather than at an onshore disposal site.

- Site clearance geophysical surveys will be conducted in an approximate 1,000-ft area around each of the 101 WTG locations, and in a 200-ft wide corridor along cable routes, followed by limited underwater video of selected targets identified during survey activities.

The WBS was used to identify the major structural project components, including their dimensions and weights, and to account for the major pieces of equipment and vessels needed to accomplish each identified decommissioning work process. The list of components and their dimensions and weights were obtained from the engineering design drawings and fabrication and installation information contained in References (4) through (6). A copy of the WBS is included as Appendix B.

4. ANALYSIS OF RELEVANT FACTORS

4.1 Introduction

Using the information obtained from the reports, the TLR, and the WBS, PCCI developed a reasonable project schedule for the offshore decommissioning tasks. The time required to complete each of the work tasks in the WBS was entered into a decommissioning schedule Gantt chart. The methodology for estimating work task durations is provided in the discussion in Section 4.2.

4.2 Decommissioning Schedule

The decommissioning schedule for the offshore tasks developed by PCCI for the Cape Wind Energy Project is shown in Appendix C. This schedule reflects the expected estimate of task durations, and includes an overall 13% contingency factor for weather downtime. The 13% contingency was selected using a summary of historical data from the Nantucket Sound Buoy on the National Oceanic and Atmospheric Administration's National Data Buoy Website (Reference 13) collected over the past five years. Thirteen percent is the yearly average occurrence for winds exceeding 25 miles per hour combined with significant wave heights exceeding 1 meter. These conditions were identified as the general controlling limits for offshore operational work in Reference (12). These limiting conditions for offshore operational work were selected based on the offshore operational experience of the Project Director for the Joint Venture companies selected for the installation of the Cape Wind Energy Project.

The 13% contingency factor is an average of the statistical values from a relatively small data set, which PCCI has selected for use as an aggressive schedule for determining average task durations. It is intended to cover items such as stand-by day rates for equipment and vessels, and partial work days.

4.2.1 Decommissioning Task Assumptions

4.2.1.1 Scour Protection Removal

The total time required for armor stone and filter material removal at each site can be broken down into four categories: stone removal, repositioning of the derrick crane barge at the removal site, relocating the derrick barge to the next removal site, and transportation and disposal of the recovered stone. The transport and disposal of the recovered stone can occur simultaneously with the dredging operation. The removal and disposal process is assumed to be a 24-hour operation, with the dredge docking once every 14 days for refueling, supplies, water and routine maintenance. This assumption is based on the U.S. Army Corp of Engineers' offshore dredge practice and standard practices in offshore construction activities.

The total quantity of scour protection, including rock armor and filter material, was estimated from the scour protection design drawings, Reference (4), to be approximately 86,500 m^3, or an average of 856 m^3 of rock armor at each turbine location.

The speed of the stone removal process is directly tied to the size of the clamshell bucket as well as the speed of the crane. The size of the clamshell assumed for this estimate is 6.1 cubic meters (8 cubic yards). Using information obtained through communications with commercial dredging operators, the estimated time required to fill and dump the clamshell is 2 to 2.5 minutes on average. The total amount of time to remove the rock armor is based on a removal rate of 2.25 minutes per clamshell bucket lift, resulting in 5.2 hours of removal time per site.

The derrick crane barge will be capable of reaching most areas around a turbine site by maneuvering within its own anchor spread. However, the anchor spread will be required to be reset once at each site in order to reach the entire area round the turbine. The total estimated time for repositioning at a given turbine site is 6-hours. It is estimated to take 8 hours for the derrick barge to retrieve its anchors, relocate to the next turbine, and deploy its anchors for the next dredging operation.

We recognize that there are multiple inefficiencies related to the dredging operation that have been ignored in this high level estimate. For example, the clamshell bucket will not be 100% full on each lift. The material that is removed may include some amount of existing seabed sediment, and 100% of the scour protection and filter stone may not be recovered. In addition, the actual size of clamshell that is used may be larger or smaller. Excavator type dredges exist that are equipped with 16 cy buckets. The operational depth of these larger dredges is limited, but one could conceivably be used on a large portion of the WTGs while the remaining sites are handled by a derrick crane barge with a clamshell. Due to the numerous factors that could increase or decrease the production rate and the overall cost, we feel it is appropriate to maintain a more generalized estimate for the scour removal operation.

The rock armor is assumed to be re-purposed or disposed of at an approved offshore location rather than at an onshore disposal site. We assume two 4,000 cubic-yard (cu-yd) split hull dump scows will be used to receive, transport and dump the armor stone. The total quantity of 86,500 cu-yd will require 29 ea full 4,000 cu-yd dump scows. Based on the estimated removal rate, and without taking weather into account, a 4,000 cu-yd dump scow can be filled in less than three days. While the location of an offshore disposal site is presently undefined, there are several active disposal sites in close proximity to the project area (Reference 14). It can be reasonably assumed that 3 days will be a sufficient amount of time for the material to be transported to a site, dumped and the barge returned to the site. The estimated removal time is provided in Table 1 below.

Table 1 – Scour Protection Removal Time Estimate

Description	**Quantity**	**Unit**
Total Volume	86475	m^3
Average per Turbine	856	m^3
Clamshell Size (Assumed)	6.1	m^3
No. of Picks per Site	140	picks
Time per Pick	2.25	min
Total Removal Time	5.2	hours
Repositioning Time at Turbine	6.0	hours
Relocation to Next Turbine	8.0	hours
Total Hours per Turbine	**19.2**	**hours**
No. Days Assuming 24-hr Shift	0.80	days/WTG
Total Days Excluding Weather	81	days
Weather Delays	13%	-
Total Days Including Weather	**92**	**days**

4.2.1.2 Cable Removal

The cable removal process includes removal of 66.7 miles of intra-array cable and 9.8 miles of dual circuit export cable. The removal focuses on only those portions of cables that fall within the lease area and BOEM's jurisdiction; therefore, the portion of the export cable route outside of the lease area is excluded from the estimate.

To determine an estimated removal rate, the estimated installation rate is used as a baseline, and then reduced based on an adjustment factor which represents the estimated increase in productivity of the removal process vs. the installation process. Reference (8), Kaiser and Snyder 2011, suggests an adjustment factor of 1.5 to 3 for intra-array cable removal, and 1 to 2 for export cable removal. Reference (8) also states that for export cables, an additional vessel is required to retrieve buried sections of cable. There is no direct statement of what has been used to define the assumed adjustment factors used by Kaiser and Snyder. However, it can be reasonably assumed that the increased adjustment factor for intra-array cables results from the assumption that the cables will not be buried.

For the Cape Wind Energy Project, both import and export cables will be buried to a depth of at least 1.8 m. It is therefore assumed that the adjustment factor range presented by Kaiser and Snyder for export cables can be applied toward both intra-array and export cables. The average adjustment factor for export cables, 1.5, has been used for estimating the required removal rate. Using an adjustment factor of 1.5 and applying it to the installation time provided in Reference (7) results in a removal rate of 0.37 miles per day. The installation time listed in Reference (7) includes an unlisted amount of weather delay time, therefore no additional weather delays have been added to the estimated removal rate. The installation rate and estimated removal rate are provided in Table 2 below.

Table 2 –Cable Removal Time Estimate

Cable Installation Rate based on Reference (7)			
	Unit	**Intra-Array**	**Export**
Length	miles	66.7	25
Installation Days (Ref 7)	days	272	102
Installation Time	mi/day	0.25	0.25
Estimated Removal Rate			
Adjustment Factor	-	1.5	1.5
Removal Rate	mi/day	0.37	0.37
Quantity of Cable	miles	66.7	9.8
Total Removal Days	days	181	27

The equipment suite required for the removal includes one derrick crane barge, one material transport barge, one tug, and one crew boat. The removal process is assumed to be a 24-hr operation, as is typical of offshore construction activities of this nature.

4.2.1.3 WTG Removal

The WTG removal process will require the use of a JB-114 Jack-up Crane Barge, two material barges working in rotation, two 2000+ hp tug boats, and one crew boat. The JB-114 is assumed to be used for the removal process. The JB-114 is a foreign flagged vessel and will not be permitted to come into a United States port due to compliance with the Merchant Marine Act of 1920 ("Jones Act"). Therefore, all material required to be transported to shore must be transported by separate barges, and work crews not residing on the JB-114 will need to be transported to and from the barge via a crew-boat.

The removal process has been assumed to require 3 lifts, as compared to the 6 lifts required for installation. Reducing the number of lifts required during the removal process in turn reduces the total number of hours required for the removal process when compared to installation. The hub and blades will first be removed in a single lift and placed on the material barge. The nacelle will be removed during the second lift, followed by the tower in the third lift. Prior to lifting the tower, the blades will be removed from the hub with the use of a secondary crane. This activity can take place while preparing for lifting the nacelle.

The installation time provided in the installation schedule in Reference (7) was used as a baseline for determining the estimated time for removal. As noted in Reference (8), the WTG removal time is driven primarily by the number of lifts required to perform the task. For decommissioning, where damage to removed components is of little consequence, we assume the number of lifts required to remove the WTG is 3, compared to the 6 required during installation. The three lifts would encompass:

(1) Removal of the hub and blades (See Figures 1 and 2)
(2) Removal of the nacelle
(3) Removal of the tower above the transition piece

Figures 1 and 2: Self-Elevating Platform JB-114

Therefore, to determine the estimated removal time, the total installation time required per WTG was divided in half, resulting in a 50% adjustment factor. The time required for the JB-114 to relocate to the next WTG site and set its legs for the next removal operation is estimated to be 8 hours. Since the repositioning of the JB-114 between WTG sites is independent of the removal operation (i.e., number of picks), the 50% adjustment factor was not applied to the repositioning time. The WTG removal time estate is shown in Table 3.

Table 3 – WTG Removal Time Estimate

				Rate per WTG				
Description	**No. of Vessel Spreads**	**# of WTGs**	**Total Calendar Days**	**Crew Days**	**Total Hours**	**Repositioning Moving Hours**	**Work Hours**	**Adjustment Factor**
WTG Installation per Ref (7) schedule (includes weather delays and 6 required lifts)	2	101	164	3.25	78	8	70	N/A
Decommissioning, (includes weather delays and assumes 3 lifts results in 50% reduction in work hours	1	101	181	1.8	43	8	35	50%

We estimate that 8 hours of transit time is required each way from the offshore site to the marshaling yard in New Bedford, MA, and that the offloading process will require two full days at port. Components for two full WTGs are assumed to be transported on a single material barge. The total estimated time required for removing two WTGs is 86 hours, leaving sufficient time for one transport barge to be sent to shore, offloaded, and returned to the site while a second material transport barge is being used for WTG component removal.

Fluid removal may be accomplished either by a smaller vessel, transiting to each WTG site, or by the JB-114 just prior to WTG removal. This will be a minor procedure in relation to the overall WTG removal process, as each WTG contains only 220 gallons of gear oil and 460 gallons of hydraulic fluid. Containers for storing the fluid can be placed on the material transport barge and taken to shore along with the main WTG components.

4.2.1.4 Transition Piece and Monopile Removal

The transition piece and monopile removal will be performed by a derrick barge with a minimum 1000-ton crane. The transition piece is grouted to the monopile and should be removed with the monopile in a single lift to avoid the time consuming operation of cutting through two layers of steel with approximately 6-inches of grout sandwiched in between. The sediment within the monopile will be removed down to 15-ft below the mud-line. The monopile will then be cut from the inside utilizing a high pressure water/grit cutting machine or similar procedure.

Each monopile is custom designed for its specific location, and the full weight of the monopiles ranges from 284 to 650-tons with lengths between 120 to 202-ft. The piles are driven to variable depths depending on engineering and site-specific conditions. During decommissioning each monopile will be cut to 15-ft below the mudline and removed, and the portion below that point will remain in the seabed. Since the COP states that the approximate monopile penetration into the seabed is 85-ft, a 70-ft section of monopole will remain in the seabed. The average weight of this remaining section is 174-T, which subtracted from the weight of the tallest monopile makes the heaviest monopile section weight approximately 476-T.

The weight of the transition piece is 186-T. The weight of the grout is estimated to be 57.4-T. The combination of the transition piece, grout, and monopile results in a maximum estimated lift of 719-tons.

Table 4 below provides a description of the estimated removal time required for each step of the operation. The removal process is assumed to be a 24-hr operation.

Table 4 – Monopile Removal Time Estimate

Description	Quantity	Unit
Remove Sediment from Bottom of Monopile & Prepare Monopile for Lifting	8	hrs
Cut Monopile	8	hrs
Lift	8	hrs
Relocate	8	hrs
Total Removal Time per WTG (Hours)	32	hrs
Total Removal Time per WTG (days)	1.33	days
Total Removal Time for 101 Monopiles	134.7	days
Assumed Weather Delays	13%	-
Total Removal Time Including Weather Delays	152	days

4.2.1.5 ESP Removal

The ESP removal process will be similar to the installation process except in reverse. Initially, ancillary steel items will be removed from the topsides, loose materials will be removed and secured, and the fluids (including 27,000 gallons of transformer oil) will be removed. The topsides will be prepped for removal via a float-under process. We have assumed this preparation can be accomplished by work crews delivered by crew boats to the platform without the need for attending vessels. A material transport barge will then be brought to the site, ballasted down and positioned underneath the topsides. The barge will then be de-ballasted allowing the topsides to rest on the barge. The topsides will then be transported to a shore-side facility, assumed to be the New Bedford material marshalling site, for offloading where it will be dismantled and recycled.

The remaining jacket structure will be lifted from the piles by the JB-114 jack-up barge and placed on a material transport barge. After removing the jacket structure, the remaining eight piles will be cut 15-ft below the mudline and removed. The estimated removal time is shown in the Table 5.

Table 5 – ESP Removal Time Estimate

Description	Quantity	Unit
Prepare topsides for removal (JB-114 not required)	5	days
JB-114 arrives, sets legs	8	hrs
Float-under operation	24	hrs
Cut jacket #1 from piles	24	hrs
Lift jacket #1	12	hrs
Remove 4 piles at jacket #1 location	4	days
Relocate JB-114 for jacket #2 lift	8	hrs
Cut jacket #2 from piles	24	hrs
Lift jacket #2	12	hrs
Remove 4 piles at jacket #1 location	4	days
Total JB-114 working time	304	hrs
Weather delays	13%	-
Total working time including weather delays	344	hrs
Total 24-hr work days required	**14.5**	**days**

4.2.1.6 Site Survey and Clearance

The site survey clearance estimates were provided by Ocean Surveys, Inc. (OSI, Reference 10). The survey program that would consist of the acquisition of multi-sensor geophysical data (multi-beam hydrography, sub-bottom profiling, magnetometer and side scan sonar imagery) in an approximate 1,000-foot area around each WTG and in a 200-ft wide corridor along cable routes, followed by limited underwater video of selected targets identified during survey activities. OSI estimated the survey would take approximately 4.5 weeks around the 101 WTGs and 1.5 weeks along the cable routes. In making these estimates, OSI assumed the following:

- Survey investigations will be performed utilizing a Differential Global Positioning System (DGPS)
- 12-hour workdays and moderate sea conditions
- Minimal fishing gear is deployed in areas to be investigated
- Daily survey production of approximately 15-17 nm
- Data processing focused on locating and inventorying features on the sea bottom and in shallow subsurface areas related to decommissioned wind facility
- Intra-array and export cable route investigations will occur under the same mobilization as WTG investigations.

Site clearance would be performed using a trawler at the location of features identified during the survey. We have assumed 10 days to accomplish seafloor trawling at the sites identified during the survey.

4.3 Equipment and Vessel Rates

Equipment, personnel and vessel day rates were solicited from northeastern marine contractors, including those involved in installation planning for the Cape Wind Energy Project. Additionally, these contractors were asked for advice on the time required to complete some of the identified tasks to confirm or modify the assumptions made by our estimating team. The following companies provided cost information for equipment, personnel or vessel rates used in our analysis:

- DonJon Marine Company, Inc.
- Jack-up Barge, B.V.
- Ocean Surveys, Inc.
- Weeks Marine

Estimates of fuel use for crew boats and tug boats were multiplied by an assumed marine diesel fuel cost of $3.50/gallon, based on the average fuel cost PCCI has incurred on recent offshore workboat charters. Day rates used as multipliers in our analysis are shown in the cost estimates contained in Appendices D through F.

4.4 Material Disposal Costs

4.4.1 Background

There are three primary methods of disposal for steel and other materials associated with dismantling WTGs and the ESP: refurbish and reuse, scrap and recycle, and dispose in designated landfills. Opportunities for refurbishing and reusing facilities in the northeast are limited due to the current lack of wind power facilities in the area. We reasonably assumed that the steel and other materials removed from the WTGs and the ESP will be transported to shore for scrapping and recycling or disposal in landfills.

Information on disposal costs is limited as there have been no offshore wind power projects constructed or decommissioned in the United States. Based on research of local scrap facilities, TSB assumed that the scrapped material will be processed out of the MMCT in New Bedford, MA and the non-recyclable materials disposed of in a nearby landfill. TSB assumed that the fiberglass reinforced epoxy resin blades of the WTGs will be cut and shredded to allow for disposal in a landfill.

4.4.2 Inventory of Decommissioned Materials

Table 6 shows the material weights for the WTGs, ESP and associated cables.

Table 6 – Decommissioned Material Inventory

Item	Qty	Weight Each (tons)	Weight Total (tons)
Blades	303	32	9,696
Nacelle Hubs (Steel = 70% estimated)	101	87	8,787
Nacelle Hubs (Copper = 30% estimated)	101	38	3,838
Towers	101	180	18,180
Transition Pieces	101	169	17,069
Monopiles (Remove 80')	101	365	36,865
Intra-Array Cable - Copper	-	-	2,002
Intra-Array Cable - Steel	-	-	464
Intra-Array Cable - Filler	-	-	2,059
Export Cable - Copper	-	-	746
Export Cable - Lead	-	-	600
Export Cable - Filler	-	-	1,466
Service Platform Topside	-	2,672	2,672
Service Platform Jackets	2	304	608
Support Piles	8	15	122
Total Blade Weight			9,696
Total Nacelle Hub Copper Weight			3,838
Total WGT Steel Weight (Includes Nacelle Hub)			80,901
Total Cable Copper Weight			2,748
Total Cable Steel Weight (Intra-Array Cable)			464
Total Cable Lead Weight (Export Cable)			600
Total Cable Filler Weight			3,525
Total Service Platform Weight			3,402
Total Weight			**105,174**

4.4.3 Cost Development

Costs were developed for the major WBS items considering the durations necessary for four tasks common to each:

- offloading barges at the marshaling area;
- trucking materials to processing locations;
- processing scrap materials for recycling;
- transport of non-recyclables to a landfill for final disposal.

TSB used historical costs developed by Schnitzer Steel Products Company in the Pacific Northwest for the equipment required to complete the onshore disposal, including costs for: crane and operator, riggers, roustabouts, tandem trucking (per load), dump truck, permit loads (per load), pickup trucks, processing fees (per ton), disposal fee (per ton), topside cutting crew, 500 bbl DOT Cargo Tanks, disposal of fluids (per bbl), and tank cleaning. The landfill disposal fee includes costs associated with site preparation, materials handling, materials offloading, materials demolition, and materials scrap processing costs. The known rate differences have been adjusted and updated where necessary. The estimates developed include all operational costs, personnel, equipment, mobilization, etc. for the time period required and normalized to a per ton basis. The historical costs we used are shown in Appendix G.

4.5 Variable Factors Used to Obtain Minimum and Maximum Estimates

As noted in the discussion in Section 2.6, the amount of time required to perform a particular task is never exactly the same from one job to the next. We have used average values based on the marine contracting experience of the PCCI Team, the Cape Wind Energy Project scheduling installation estimates contained in Reference (3), and those contained in References (8) and (9), to develop our *expected estimate* of task durations.

To obtain the *minimum estimate*, we used the lower bound of time estimates by:

- Reducing the cycle time per bucket load of scour protection removal by 30 seconds, resulting in a reduction of 3 days onsite.
- Reducing the time required for cable removal by increasing the "adjustment factor" multiplier for the speed of cable removal from 1.5 to 3 for the intra-array cables and to 2 for the export cables, resulting in a reduction of 97 days onsite (See Section 4.2.1.2 for the discussion of adjustment factor application and ranges).
- Reducing the number of days required for WGT removal to 1 WTG per day, as used in Reference (9), resulting in a reduction of 67 days onsite.
- Reducing the time required for removal of the transition piece and foundation by 45%. The 45% reduction reflects the difference between the expected and minimum foundation removal times using a lift vessel, as presented in Reference (8). This reduces the time onsite by 78 days.
- Removing one day from the ESP removal estimate.
- Halving the 13% weather contingency from the site clearance survey estimate, to 6.5%.

To obtain the *maximum estimate*, we used the higher bound of time estimates by:

- Increasing the cycle time per bucket load of scour protection removal by 30 seconds, and increasing the assumed weather impact multiplier by a factor of three to 39%, resulting in an additional 24 days onsite. Increasing the assumed weather impact multiplier by a factor of three was suggested as a more realistic and conservative approach to account for the standard deviation in average statistical values of limiting combined wind and wave conditions (Reference 12).
- Increasing the time required for cable removal by decreasing the "adjustment factor" multiplier for the speed of export cable removal from 1.5 to 1 (meaning the removal takes as long as installation estimate), resulting in an additional 13 days onsite. No change was made to the time for removal of the intra-array cables.
- Increasing the assumed WTG removal weather impact multiplier by a factor of three, resulting in an additional 42 days onsite.
- Increasing the assumed transition piece and foundation removal weather impact multiplier by a factor of three to 39%, resulting in an additional 35 days onsite.

- Increasing the number of vessels required for ESP removal by changing the removal method from an assumed float under barge de-ballasting lift to one requiring multiple cranes to lift the ESP topsides off the jackets and onto a barge.
- Increasing the assumed site clearance survey weather impact multiplier by a factor of three to 39%.

4.6 Deterministic versus Probabilistic Analysis

The cost estimating procedure used in spreadsheets can be classified as deterministic since it develops an ensemble of specific unit rates, task durations, etc., which result in a single cost figure for each case. The individual values used in assembling the total cost are the most likely values for each cost element and the resulting total is the most likely total cost. In the current context these values (costs) may also be referred to as the expected values. However, when we examine the estimating process closely we can show that there is virtually always some uncertainty in the individual values that make up the total cost. Even with experienced contractors performing familiar activities, the amount of time required to perform a particular task is never exactly the same from one job to the next. The variations in time (and cost) for particular tasks can become large, particularly when the physical conditions of the offshore facilities and weather factors are considered. When we use spreadsheets, we apply a contingency to cover these types of uncertainties, based upon our past experience. While we are correct in our estimates and contingency provisions more often than not, it is desirable to know more specifically the risk of a cost overrun. This need becomes more acute as more uncertainty enters the estimating process. Uncertainty can come from many sources such as:

- Labor problems
- Uncertainty in permit approvals
- Failure of acceptance tests
- New technology being available
- Severe weather
- Variations in contractor performance
- Variations in site conditions
- Political instability in a development area
- Inadequate specifications
- Delays in management reviews and approvals
- Mechanical breakdown and malfunctions

In the early days of the missile and space programs the government was faced with the task of estimating the time and cost requirements for projects in the face of great uncertainty. The best project management, cost estimating, and applied mathematics minds of the day were focused on the task of developing methods to deal with the problem. From this effort evolved the Program Evaluation and Review Technique (PERT), which was the forerunner of the Critical Path Management (CPM) procedures commonly used in project management today. A distinguishing feature of the early PERT procedure was its application of probabilistic methods for estimating time and cost. This involved the use of distribution functions for individual cost and time estimates, rather than a single number. It also allowed for probabilistic branches within a project, whereby completely different activities might take place based on the outcome of some event.

While the PERT procedure was shown to be appropriate for large government programs, it required massive computer resources and technical support which was generally not available in commercial applications. The probabilistic features were discarded as CPM was developed for industry use. With the development of extremely powerful desk-top computers and parallel improvement in commercially available software, it is now possible to apply probabilistic cost and schedule forecasting methods to practical problems in project management. In particular, this allows us to use all of the information and experience which we have available to provide a complete picture of cost and schedule risk in any situation where uncertainty exists. The use of probabilistic methods in this context is generally referred to as “Risk Analysis.”

A wide variety of software packages for personal computers are available to perform risk analysis, depending on the application. These range from programs which work with the commonly used MS Excel spreadsheet programs, such as Palisade Corporation's @RISK™, to add-on modules for the most popular construction cost and schedule programs, such as Welcom Software Technology's OPEN PLAN™ and Primavera Systems' PRIMAVERA PROJECT PLANNER™ (P3). TSB has evaluated most of the commercially available systems and has concluded that the @RISK™ software is the most flexible and user friendly. It uses Monte Carlo simulation techniques to arrive at the probabilistic distribution of project cost or time.

The process of developing a project model for use in @Risk™ is essentially the same as that for a conventional CPM cost/schedule control network. The project execution plan is developed in the form of a logic network which identifies the sequence and relationships between the various activities and events that make up the project. In the process of determining the relationships between individual activities and their durations, the resources (labor, derrick barges, etc.) required to execute the work are also determined. It is at this point that the probabilistic cost/schedule estimating process deviates from the deterministic approach. In the latter, a single estimate would be required for each cost or time element. In the probabilistic model, we are required to have a Probability Distribution Function (PDF) for each cost/time element that has uncertainty. In practice this means that we must determine three values for each item that can vary: 1) the minimum likely, 2) the maximum likely, and 3) the most likely (highest probability) value.

In actual project situations there is always some chance that values could occur outside the range estimated. This is handled by assuming that most of the time, e.g. 80%, the values will fall within the range, with the remainder divided evenly at the two extremes. The percentage of values which are allowed to fall outside the range can be controlled, but it is generally assumed to be ten or twenty percent. The results of the probabilistic cost estimate are discussed in Section 5.2. The probability distribution curves shown in Appendix H are based on 20% (below 10% and above 90% are excluded).

5.0 RESULTS

5.1 Deterministic Cost Estimates

PCCI used a deterministic method to develop offshore decommissioning costs, using specific unit rates, task durations, equipment suites, etc., resulting in a total cost figure for each of three cases. Appendices D through F show the spreadsheets PCCI used to estimate the expected, the minimum, and the maximum costs for decommissioning of the Cape Wind Energy Project. Included in each of these spreadsheets is a line-item cost for the related onshore disposal efforts (minimum, expected, and maximum) that was developed by TSB using their probabilistic estimating methodology.

The resulting estimates are:

- Minimum estimate = $71,073,507
- Expected estimate = $103,299,968
- Maximum estimate = $125,550,261

Figure 3 shows our level of confidence that the decommissioning costs will fall near the minimum, expected and maximum estimates. We did not feel a high level of confidence was warranted for the expected estimate given that there have been no offshore wind facilities decommissioned anywhere in the world to date.

ESTIMATE	CONFIDENCE LEVEL
Minimum	**Low**
Expected	**Moderate**
Maximum	**Moderate**

Figure 3: Cost Estimate Confidence Levels

The potential salvage/ scrap value of recycled components is not included in the above estimates. It is calculated and discussed separately for information purposes in Section 5.3.

5.2 Probabilistic Cost Estimates

A probabilistic model of the total cost for the decommissioning work was developed as discussed in Section 4.6. The cost model is based on the minimum, most likely (expected), and maximum cost of the individual cost elements from the deterministic cost estimate. These were subjected to a Monte Carlo-type simulation of the project using 10,000 iterations. The results of the probabilistic modeling are presented in Appendix H. Figure H-1 shows the Probability Distribution Function (PDF) and the Cumulative Distribution Function (CDF) for total project cost. The major results are summarized as follows:

- Absolute Minimum Cost = $84,175,718
- Mean (Expected) Cost = $101,637,257
- Absolute Maximum Cost = $118,956,058
- Median (P50) Cost = $101,691,869
- Cost with 10% chance of not being exceeded (P10) = $94,764,223
- Cost with 90% chance of not being exceeded (P90) = $108,446,266

Selection of a particular cost for use in budgeting is made based on balancing the consequences of 1) budgeted cost being exceeded, and 2) over estimating the cost and harming the project.

5.3 Salvage Value of Materials

TSP also estimated the potential salvage value for recycled project materials based on the total weight of copper, lead and steel from the decommissioned cables and structures. The potential salvage value of recycled materials was calculated using the quantities shown in Table 7 and using the following rates obtained from Rockaway Recycling (Reference 11):

- Recycle Copper (per lb) $0.85
- Recycle Steel (per lb) $0.07
- Recycle Lead (per lb) $0.55

The estimated total salvage value = $22,875,920

Table 7 – Estimated Salvage Value of Recycled Materials

Description	Total Weight (lbs)	Total Weight (t)	Total Value
Total Copper Weight (Inc. Nacelle & Cables)	13,172,000	6,586	$11,196,200
Total Steel Weight (Inc. Nacelle, Cables, Towers & Platform)	169,534,160	84,767	$11,019,720
Total Lead Weight (Inc. Cables)	1,200,000	600	$660,000
Total Value of Recycled Materials			**$22,875,920**

5.4 Quality Control

For this project PCCI implemented a practical Quality Control (QC) system known as "One over One" for quality control of its estimates. This system, which involves peer review by another engineer, is not unique and is in active use by PCCI and firms with similar "products" as ours. The idea was borrowed from Battelle Labs, where we were introduced to the concept. The key elements included:

- The Project manager ensured that all PCCI and subcontractor developed documents and other materials or items have received and passed a "One over One (1/1)" review.
- Quality 1/1 reviews were performed by the PCCI engineer who was the most knowledgeable subject matter expert independent of the initial estimating process. Independent editorial reviews were assigned as appropriate. The assigned engineers were

responsible for checking any developed documents and estimates for adequacy, accuracy, consistency, completeness and conformance with the overall requirements of the statement of work or other customer instruction.

- Recommended changes to the estimating procedure that resulted from the review were discussed with the original estimator, and if necessary referred to the Project Manager or company principal for resolution.

For this project, the estimates developed by each team member (PCCI and TSB) were also reviewed by the other team for reasonableness. Additionally, the marine construction contacts listed in Section 4.3 were periodically consulted by PCCI reviewers to check the reasonableness of construction time estimates.

BOEM was kept appraised of the estimating methodology and potential problems though a Midway Project Status Meeting, and was provided a draft of this report for review and comment. The BOEM review resulted in the re-estimation of some project elements.

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(2) BOEM Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf, Renewable Energy Lease Number OCS-A 0478. Available at http://www.boem.gov/Renewable-Energy-Program/Studies/Cape-Wind.aspx

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(13) http://www.ndbc.noaa.gov/station_page.php?station=44020

(14) http://northeastoceanviewer.org/# (search for “Ocean Disposal Sites” in the search field at top left).

APPENDIX A - Top Level Requirements for Decommissioning the Cape Wind Energy Project

Table of Contents

REFERENCES

(1) Federal Register, Volume 76, No. 201, October 18, 2011
(2) U.S. Department of the Interior Bureau of Ocean Energy Management, Regulation and Enforcement, Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf, Renewable Energy Lease Number OCS-A 0478 with Cape Wind Associates, LLC
(3) Memo from Tom Hudon, PCCI Principal Engineer, to Andrew Kruger, BOEM COR and Rebecca Kruse, BSEE CO, dated 15 August 2014, Re: Task Order No. M14PD00053 Post-Award Meeting Summary

1. INTRODUCTION

This Top Level Requirements (TLR) Document summarizes the Cape Wind Energy Project decommissioning requirements as well as the technical assumptions being used in developing decommissioning cost estimates for the project.

2. PROJECT DECOMMISSIONING REQUIREMENTS

The decommissioning requirements, and decommissioning bond requirements, are contained in BOEM's regulations at 30 C.F.R. §585.902 and the applicable portions of BOEM's Renewable Energy Lease Number OCS-A 0478. These documents were reviewed and are summarized herein.

2.1. BOEM Regulations

Subpart I 30 CFR Part 585 (Reference 1) contains the requirements for decommissioning which include:

2.1.1 General Requirements (30 C.F.R. §585.902)

Within two-years following termination of the lease:

1. Remove all facilities authorized under the Site Assessment Plan (SAP), Construction and Operations Plan (COP), or General Activities Plan (GAP), including project's facilities, cables, pipelines, and obstructions. *(NOTE: Cape Wind was not required to submit a SAP since the documents normally included in the SAP were submitted to the U.S. Army Corp of Engineers).*
2. Clear the seafloor of all obstructions created by project activities on the lease, including project easements.

Before decommissioning the facilities, the lessee must submit a decommissioning application (see 2.1.2) and receive approval from BOEM.

Following approval of the decommissioning application, the lessee must submit a decommissioning notice to BOEM at least 60-days before commencing decommissioning activities. The notice must include:

- Description of any changes to the approved removal methods and procedures in the approved decommissioning application, including changes to types of vessels and equipment to be used; and
- An updated decommissioning schedule.

Immediately halt bottom-disturbing activities within 1,000-ft of any archeological resource discovered while conducting decommissioning activities until BOEM makes an evaluation and advises how to proceed.

Provide BOEM with documentation of coordination efforts with affected States, local and tribal governments.

2.1.2 Decommissioning Application Requirements (30 C.F.R. §585.905)

Submit upon the earliest of the following:

- 2-years before the lease expiration;
- 90-days after completion of commercial activities on the lease;
- 90-days after cancellation, relinquishment, or other termination of the lease.

The decommissioning application must include:

- Identification of applicant;
- Description of facilities to be removed or proposed to be left in place;
- Proposed decommissioning schedule;
- Description of removal methods and procedures, including the types of equipment, vessels, and moorings to be used;
- Description of site clearance activities;
- Plans for transportation and disposal or salvage of the removed facilities and cables, and any required approvals;
- Description of resources, conditions and activities that could be affected;
- Results of any recent biological surveys conducted in the vicinity of the project structure(s);
- Mitigation measure to be used to protect archeological and sensitive biological features during removal activities;
- Description of measures to prevent unauthorized discharge of pollutants into the offshore waters; and
- A statement of whether divers will be used to survey the area after removal to determine the effects on marine life.

2.1.3 Facility Removal Requirements (30 C.F.R. §585.910)

All facilities must be removed to a depth of 15-ft below the mudline, unless otherwise authorized by BOEM.

Within 60-days after facility removal, the lessee must verify to BOEM that the site has been cleared.

2.1.4 Decommissioning Report Requirements (30 C.F.R. §585.912)

Within 60-days after removal of a facility or cable submit a written report to BOEM that includes:

- A summary of the removal activities;
- Description of any mitigation measures undertaken; and
- If explosives were used, a statement that certifies the types and amounts used in removing the facility were consistent with those in the decommissioning application.

2.2. Lease Number OCS-A 0478 Requirements

Decommissioning requirements are included in Section 13 of the lease, *"Removal of Property and Restoration of the Leased Area on Termination of Lease."*

2.2.3 Removal of Property and Restoration of Leased Area

All facilities, projects, cables pipelines and obstructions shall be removed and the seafloor shall be cleared of all obstructions created by the activities on the leased area, including any project easement(s) within two years following lease termination "in accordance with the Addenda and applicable regulations". *(NOTE: There are no project easements in the lease. Requirements identified in the Addenda are summarized in the following sections.)*

2.2.4 Protection of Cultural Resources

Addendum C, Section 1.V.c requires the lessee to afford the Wampanoag Tribe of Grey Head / Aquinnah and the Wampanoag Tribe of Mashpee an opportunity to monitor all bottom disturbing activities as described in that section, and to send monthly reports to BOEM regarding Tribal monitor participation.

All bottom disturbing work is to be monitored by a qualified geologist meeting the Department of the Interioor's Professional Qualifications Standards for Archeology.

Addendum C, Section 1.VI contains procedures for the unanticipated discovery of cultural resources and human remains.

2.2.5 Air Quality Mitigation and Monitoring

Addendum C, Section 3.IV requires the lessee to comply with any requirements specified by BOEM in order to meet the general conformity requirements applicable at the time of decommissioning of any facility or structure.

Addendum C, Section 3.V requires contractors operating diesel-powered equipment at the Quonset Point staging site use ultra-low sulfur diesel fuel, if requested to do so by the Rhode Island Department of Environmental Management.

2.2.6 Fisheries and Essential Fish Habitat Mitigation and Monitoring

Addendum C, Section 8.VI-VII requires the lessee to notify commercial fishers and other Outer Continental Shelf users through a local Notice to Mariners when conducting offshore survey operations employing towed geophysical gear, and regarding the timeframe and location of decommissioning activities two weeks before the start of operations, and again at least 72 hours prior to mobilization. Daily broadcasts on the appropriate marine channel are required as to decommissioning activities for the upcoming day.

2.2.7 Marine Mammals and Sea Turtles Mitigation and Monitoring

Addendum C, Section 9.I.b requires the lessee to abide by the following guidelines during decommissioning:

1. National Marine Fisheries Service (NMFS) Northeast Regional Viewing Guidelines;
2. BOEM Gulf of Mexico Notice to Lessee (NTL) No. 2007-G04 (*Note: This has since been superseded by JOINT NTL No. 2012-G01*); and
3. Marine Trash and Debris Awareness Elimination NTL No. 2007-G03 (*Note: This has since been superseded by BSEE NTL No. 2012-001*).

Addendum C, Section 9.I.c: All seismic surveying equipment is to comply with applicable equipment noise standards of the U.S. Environmental Protection Agency and have noise control devices no less effective than those provide on the original equipment.

Addendum C, Section 9.I.d: Marine mammal monitoring inside a 500-m radius exclusion zone around the seismic-survey source vessel required.

Addendum C, Section 9.I.f: A report must be provided to BOEM and NMFS within 90-days following survey activities to include a summary of the surveying and monitoring activities, and an estimate of the number of marine mammals and sea turtles that may have been taken as a result of the seismic survey activities.

Addendum C, Section 9.I.m: Prior to commencing decommissioning activities, provide BOEM with a detailed decommissioning plan. The lessor must consult with the NMFS and U.S. Fish and Wildlife Service regarding the contents of the plan before authorizing commencement of decommissioning activities.

3. TECHNICAL ASSUMPTIONS

The following technical assumptions were agreed to during the post-award kick-off meeting (Reference 3).

- No repowering occurs prior to decommissioning;
- No waivers to the Jones Act are granted;
- No inflation occurs;
- Use of present day technology without consideration of the likelihood in technological advances in decommissioning methods or vessels;
- New Bedford and other sites in Massachusetts may be considered as alternates to the Quonset, RI location for shore side decommissioning infrastructure support.
- Explosives will not be used

APPENDIX B – Work Breakdown Structure

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1.0 Project Documentation

- 1.1 Decommissioning Application
- 1.2 Decommissioning Notice
- 1.3 Decommissioning Plan
- 1.4 Decommissioning Report

Equipment common to all offshore crane barge spreads:

generator
welder
deck lighting
office van
break room van
tool/workshop van
tool/workshop van
toilet/washroom

2.0 Site Clearance

- 2.1 De-Energize Systems
  - 101 WTG's
  - 1 Ea. ESP
- 2.2 Remove Armor Stone Layer: 24-m dia. At 101 Monopile locations + 1 ESP & Filter Stone Layer: 29m dia. at 77-106 WTG's and the ESP location
  - Derrick Crane Barge w/ clamshell bucket and GPS
  - Twor 180' x 54' x 14' cargo barges (2000-t capacity)
  - Two 1400 to 2000 HP Tugs
  - Crew Boat
  - Hydrographic Surveys of armored areas
  - Monitoring by Archeologist
- 2.3 Remove Subsea Cables
  - 2.3.1 Remove33kV Intra-Array Cables (66.7 miles)
    - 3.72" dia. Cables, 10.75-lb/ft
    - 4.71" dia. Cables, 19.22-lb/ft
    - 5.26" dia. Cables, 25.7-lb/ft
  - 2.3.2 Remove 115-kV Transmission Cables
    - 4 cables x 4.9 circuit miles of 7.87" dia., 54.36-lb/ft
  - 2.3.3 Monitoring by Archeologist
  - 2.3.4 Equipment
    - Crane barge w/ mooring/ tug
    - Material barge and tug
- 2.4 Remove 101 3.6-MW WTGs
  - 2.4.1 Remove Fluids
    - 90 ga hydraulic per WTG Nacell/Hub (11,700 ga total)
    - 220 ga gear oil per WTG Nacell/Hub (28,600 ga total)
    - 370 ga hydraulic per tower (48,100 ga total)
  - 2.4.2 Main WTG Components
    - Three blades/WTG
    - Rotor dia. = 351-ft, wt = 95 tons
    - Nacelle hub height = 256-ft, wt = 125 tons
    - Tower = 195-ft to nacelle flange (top section = 75.3mT, 36,000 mm length, bottom section is 92.5mT, 23,470 mm length)
  - 2.4.3 Equipment
    - 1 Jack-up Crane Barge
    - 2 transport barges
    - 2 transport Tug Boats (1400 - 3000 hp)
    - 1 Anchor Handling Barge w tug
    - Fluid holding tanks
- 2.5 Remove 101 Transition Pieces & Monopoles
  - 2.5.1 Excavate Sediment within monopile
    - + vacuum pump
    - + barge for temporary storage of sediments
  - 2.5.2 Remove Transition Pieces. L=67-ft, wt=169-t
    - Crane barge
    - Material barge
  - 2.5.3 Cut and remove Monopiles with Transition Piece (118 to 184-ft), avg wt=324-t, Monopole - max wt =545-t, 16.4-ft dia., plate thickness 2.2" to 3.7") Transition Piece - L=67-ft, wt=169-t
    - HP water jet
  - 2.5.4 Monitoring by Archeologist
- 2.6 Remove ESP
  - 2.6.1 Remove Fluids
    - ESP - 27,000 ga cooling oil
    - ESP - Misc. Fluids
    - Holding Tanks Required
  - 2.6.2 Remove Secondary Steel Items from ESP
    - ESP Crane utilized to offload components

3.0 Transport & Disposal/Salvage

- 3.1 Port and Staging Areas
  - 3.1.1 Establish onshore material mashalling site at New Bedford Marine Term. (42 nm)
    - 150-T to 200-T crane
    - Trucks with flat bed/low-boy trailers'
    - Pick-up trucks
- 3.2 Transport Armor and Filter Stone to offshore disposal site
  - Two Transport / Hopper Barges (3 to 4)
  - Tugs
- 3.3 Transport cable sections to shore
  - material barge w tug
- 3.4 Offload and dispose or recycle cable materials
  - 3.4.1 Offloading barge at marshalling area
  - 3.4.2 Trucking to processing
  - 3.4.3 Processing materials for recycling
- 3.5 Transport fluids to shore
- 3.6 Fluid disposal
- 3.7 Disposal of WTG and Tower Materials
  - 3.7.1 Offloading barge at marshalling area
  - 3.7.2 Trucking to processing
  - 3.7.3 Processing materials for recycling
  - 3.7.4 Transport to landfill
- 3.8 Disposal of ESP Material
  - 3.8.1 Offloading barge at marshalling area
  - 3.8.2 Trucking to processing
  - 3.8.3 Processing materials for recycling

4.0 Post Removal Survey

- 4.1 Site Clearance Verification and mop-up
  - Multi-sensor survey of Site (1000-ft radius around WTGs and 200-ft wide cooridor along cable routes)
  - Trawl for debris around areas identified by survey

- 2.6.3 Remove ESP Superstructure
  - 2.6.3.1 Remove topside (est. wt 2762 Tons)
    - reverse float-over barge
  - 2.6.3.2 Remove two jackets
    - Crane Barge
    - Jacket Transport Barge 260'x80'x16' minimum
    - Two 1400 to 2000 HP Tugs
- 2.6.4 Remove Eight ESP Piles
  - Pile removal
    - Crane Barge with Vibro Hammer
    - Cargo Barge
    - Tug
  - Monitoring by Archeologist

APPENDIX C - Decommissioning Schedule: Offshore Tasks

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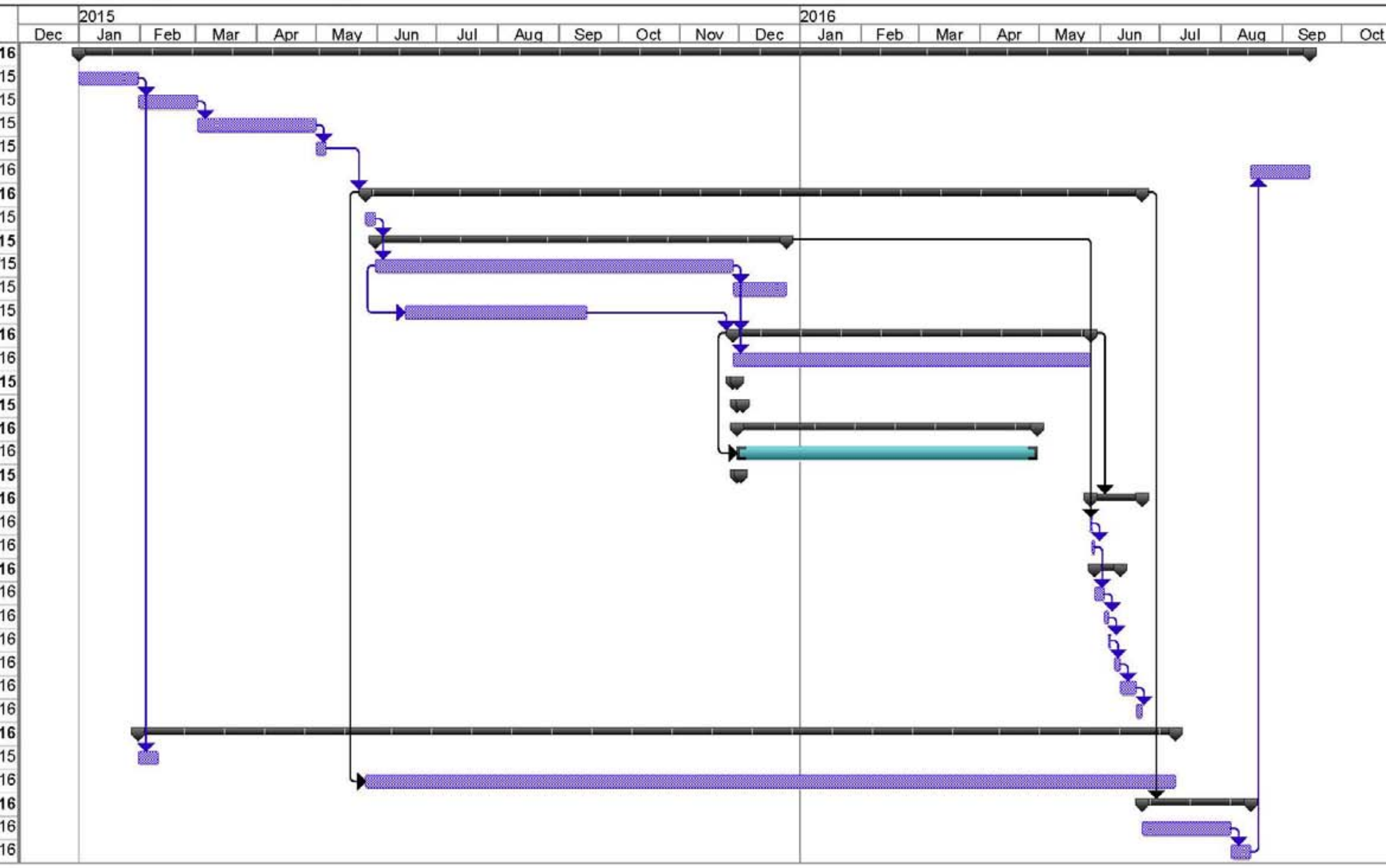
Cape Wind Decommissioning

ID	WBS	Task Name	Duration	Start	Finish
1	**1**	**Project Documentation**	**622.38 days**	**1/1/15**	**9/14/16**
2	1.3	Decommissioning Plan	30 days	1/1/15	1/31/15
3	1.1	Decommissioning Application	30 days	1/31/15	3/2/15
4	1.1	Application Review by BOEM	60 days	3/2/15	5/1/15
5	1.2	Decommissioning Notice	5 days	5/1/15	5/6/15
6	1.4	Decommissioning Reports	30 days	8/15/16	9/14/16
7	**2**	**Site Clearance**	**392.38 days**	**5/26/15**	**6/21/16**
8	2.1	De-Energize System	5 days	5/26/15	5/31/15
9	**2.3**	**Remove Subsea Cables**	**208 days**	**5/31/15**	**12/25/15**
10	2.3.1	33 kV Inter Array Cables	181 days	5/31/15	11/28/15
11	2.3.2	115 kV Transmission Lines	27 days	11/28/15	12/25/15
12	2.2	**Remove Armor Stone Layer**	**92 days**	**6/15/15**	**9/15/15**
13	**2.4**	**Remove 101 WTG's**	**181 days**	**11/28/15**	**5/27/16**
14	2.4	Remove 101 WTG's	181 days	11/28/15	5/27/16
15	**2.4**	**Remove 1 turbine**	**1.79 days**	**11/28/15**	**11/30/15**
21	**2.4**	**WTG Component Transportation**	**2.67 days**	**11/30/15**	**12/2/15**
25	**2.6**	**Remove Transistion Piece and Monopile**	**152 days**	**11/30/15**	**4/30/16**
26	2.6.1	Remove 101 ea. Transition Pieces & Monopiles	152 days	11/30/15	4/30/16
27	**2.6.2**	**Remove 1 Monopile & Transition Piece**	**1.51 days**	**11/30/15**	**12/1/15**
32	**2.7**	**Remove ESP**	**25.38 days**	**5/27/16**	**6/21/16**
33	2.7.1	Remove Oil and Lube	0.33 days	5/27/16	5/27/16
34	2.7.2	Remove Secondary Steel	1.67 days	5/27/16	5/29/16
35	**2.7.3**	**Remove Superstructure**	**12.38 days**	**5/29/16**	**6/10/16**
36	2.7.3.1	Prep Topsides for removal	5 days	5/29/16	6/3/16
37	2.7.3.1	Floatover-Removal	2 days	6/3/16	6/5/16
38	2.7.3.1	Transport Topsides to New Bedford	1 day	6/5/16	6/6/16
39	2.7.3.2	Remove 2 Jackets	3 days	6/7/16	6/10/16
40	2.7.4	Remove 8 ea. Piles	8 days	6/10/16	6/18/16
41	2.7.4	Transport Jackets/Piles	3 days	6/18/16	6/21/16
42	**3**	**Transport & Disposal / Salvage**	**525 days**	**1/31/15**	**7/9/16**
43	3.1	Establish onshore material marshalling site	10 days	1/31/15	2/10/15
44	3	Transportation to Onshore Material Site	410 days	5/26/15	7/9/16
45	**4**	**Verification of Site Clearance**	**55 days**	**6/21/16**	**8/15/16**
46	4.1	Post Removal Seabed Survey	45 days	6/21/16	8/5/16
47	4.2	Trawl net for debris recovery	10 days	8/5/16	8/15/16



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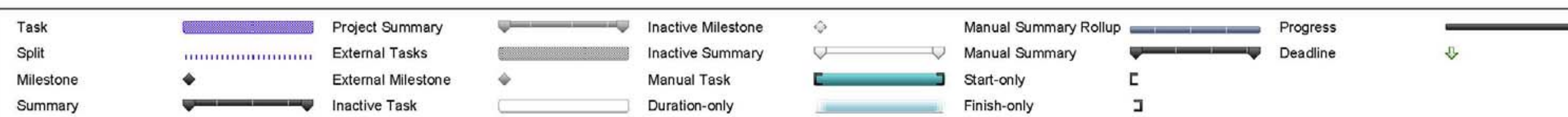

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APPENDIX D – Expected Decommissioning Cost Estimate

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Expected Decommisioning Cost Estimate											
WBS	Task Description	Equipment	Quantity	Rate	unit	Days	Extension	Fuel ga/day	Fuel (2) cost/day	Total Fuel Cost	Total
PROJECT DOCUMENTATION											
1.1	Decommissioning Plan			$1,200	ManDay	20	$24,000				
1.2	Other Documentation						NSP (1)				
Subtotal Project Documentation											**$24,000**
STONE REMOVAL											
2.1	De-Energize System										
2.2	Remove Stone Armor	Derrick Crane Barge w/8 Cy Bucket	1	$45,000	day	92	$4,140,000		$0	$0	
		4000 CY Dump Scow	2	$5,000	day	92	$920,000		$0	$0	
		Tug (2000 hp)	2	$5,163	day	92	$949,992	1,100	$7,700	$708,400	
		Crew Boat	1	$2,400	day	92	$220,800	450	$1,575	$144,900	
Subtotal Armor Stone Removal							$6,230,792			$853,300	**$7,084,092**
CABLE REMOVAL											
2.3	Subsea Cable Removal	D/B Farrell 256 (190-T)	1	$37,500	day	208	$7,800,000		$0	$0	
		Barge (180 x 54)	1	$1,133	day	208	$235,664		$0	$0	
		Tug (2000 hp)	1	$5,163	day	208	$1,073,904	1,100	$3,850	$800,800	
Subtotal Cable Removal							$9,109,568			$800,800	**$9,910,368**
WTG REMOVAL											
2.6	Remove 101 WTG's	JB-114	1	$57,150	day	181	$10,344,150		$0		
		Tug (2000 hp)	3	$5,163	day	181	$2,803,509	1,100	$11,550	$2,090,550	
		300 x 90 Barge	2	$8,803	day	181	$3,186,686		$0		
		Anchor Scow	1				$0				
	Mobilization of JB-114	JB-114	1	$57,150		32	$1,828,800				
		Tug	1	$5,163		32	$165,216	2,200	$7,700	$246,400	
Subtotal WTG Removal							$18,328,361			$2,336,950	**$20,665,311**
TRANSITION AND MONOPILE REMOVAL											
2.8	Remove Transition Piece ar	1000-T crane	1	$90,000	day	152	$13,680,000		$0	$0	
		Tug (2000 hp)	3	$5,163	day	152	$2,354,328	1,100	$11,550	$1,755,600	
		300 x 90 Barge	2	$7,500	day	152	$2,280,000				
	Mob/Demob of Crane	1000-T crane	1	$25,000	day	2	$50,000				
	Mob/Demob of Tug	Tug (2000 hp)	1	$5,163	day	2	$10,326	2,200	$7,700	$15,400	
Subtotal Transition Piece and Foundation Removal							$18,374,654			$1,771,000	**$20,145,654**
ESP REMOVAL											
2.9	Remove Superstructure	JB-114	1	$57,150	day	2	$114,300			$0	
		Tug (2000 hp)	3	$5,163	day	2	$30,978	1,100	$11,550	$23,100	
		300 x 90 Barge	1	$7,500	day	2	$15,000				
	Remove Jackets	JB-114	1	$57,150	day	4	$228,600				
		Tug (2000 hp)	2	$5,163	day	4	$41,304	1,100	$7,700	$30,800	
		300 x 90 Barge	2	$7,500	day	4	$60,000				
	Remove Piles	JB-114	1	$57,150	day	9	$514,350				
		Tug (2000 hp)	2	$5,163	day	9	$92,934	1,100	$7,700	$69,300	
		300 x 90 Barge	2	$7,500		9	$135,000				
		Crew Boat	1	$2,400	day	6	$14,400	450	$1,575	$9,450	
Subtotal ESP and Foundation Removal							$1,246,866			$132,650	**$1,379,516**
ONSHORE DISPOSAL											
See Onshore Tab											
Subtotal Onshore Disposal							$43,297,857			$0	**$43,297,857**
SITE SURVEY AND CLEARANCE											
4.1	Bottom Scan	WTG and Cable Routes	1	$768,400	LS		$768,400			$0	
4.1	Bottom Trawling	Trawler	1	$2,400	day	10	$24,000	22	$77	$770	
										$0	
Subtotal Site Survey and Clearance							$792,400			$770	**$793,170**

Notes:
(1) Not separately priced — **TOTAL:** $103,299,968
(2) Marine Diesel Cost / Gallon $3.50

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APPENDIX E - Minimum Decommissioning Cost Estimate

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Minimum Decommissioning Cost Estimate											
WBS	Task Description	Equipment	Quantity	Rate	unit	Days	Extension	Fuel ga/day	Fuel (2) cost/day	Total Fuel Cost	Total
PROJECT DOCUMENTATION											
1.1	Decommissioning Plan			$1,200	ManDay	20	$24,000				
1.2	Other Documentation						NSP (1)				
Subtotal Project Documentation											**$24,000**
STONE REMOVAL											
2.1	De-Energize System										
2.2	Remove Stone Armor	Derrick Crane Barge w/8 Cy Bucket	1	$45,000	day	89	$4,005,000		$0	$0	
		4000 CY Dump Scow	2	$5,000	day	89	$890,000		$0	$0	
		Tug (2000 hp)	2	$5,163	day	89	$919,014	1,100	$7,700	$685,300	
		Crew Boat	1	$2,400	day	89	$213,600	450	$1,575	$140,175	
Subtotal Armor Stone Removal							$6,027,614			$825,475	**$6,853,089**
CABLE REMOVAL											
2.3	Subsea Cable Removal	D/B Farrell 256 (190-T)	1	$37,500	day	111	$4,162,500		$0	$0	
		Barge (180 x 54)	1	$1,133	day	111	$125,763		$0	$0	
		Tug (2000 hp)	1	$5,163	day	111	$573,093	1,100	$3,850	$427,350	
Subtotal Cable Removal							$4,861,356			$427,350	**$5,288,706**
WTG REMOVAL											
2.6	Remove 101 WTG's	JB-114	1	$57,150	day	114	$6,522,530		$0		
		Tug (2000 hp)	3	$5,163	day	114	$1,767,760	1,100	$11,550	$1,318,202	
		300 x 90 Barge	2	$8,803	day	114	$2,009,373		$0		
		Anchor Scow	1				$0				
	Mobilization of JB-114	JB-114	1	$57,150		32	$1,828,800				
		Tug	1	$5,163		32	$165,216	2,200	$7,700	$246,400	
Subtotal WTG Removal							$12,293,678			$1,564,602	**$13,858,279**
TRANSITION AND MONOPILE REMOVAL											
2.8	Remove Transition Piece ar	1000-T crane	1	$90,000	day	74	$6,660,000		$0	$0	
		Tug (2000 hp)	3	$5,163	day	74	$1,146,186	1,100	$11,550	$854,700	
		300 x 90 Barge	2	$7,500	day	74	$1,110,000				
	Mob/Demob of Crane	1000-T crane	1	$25,000	day	2	$50,000				
	Mob/Demob of Tug	Tug (2000 hp)	1	$5,163	day	2	$10,326	2,200	$7,700	$15,400	
Subtotal Transition Piece and Foundation Removal							$8,976,512			$870,100	**$9,846,612**
ESP REMOVAL											
2.9	Remove Superstructure	JB-114	1	$57,150	day	2	$114,300			$0	
		Tug (2000 hp)	3	$5,163	day	2	$30,978	1,100	$11,550	$23,100	
		300 x 90 Barge	1	$7,500	day	2	$15,000				
	Remove Jackets	JB-114	1	$57,150	day	4	$228,600				
		Tug (2000 hp)	2	$5,163	day	4	$41,304	1,100	$7,700	$30,800	
		300 x 90 Barge	2	$7,500	day	4	$60,000				
	Remove Piles	JB-114	1	$57,150	day	8	$457,200				
		Tug (2000 hp)	2	$5,163	day	8	$82,608	1,100	$7,700	$61,600	
		300 x 90 Barge	2	$7,500		8	$120,000				
		Crew Boat	1	$2,400	day	6	$14,400	450	$1,575	$9,450	
Subtotal ESP and Foundation Removal							$1,164,390			$124,950	**$1,289,340**
ONSHORE DISPOSAL											
See Onshore Tab											
Subtotal Onshore Disposal							$33,164,511			$0	**$33,164,511**
SITE SURVEY AND CLEARANCE											
4.1	Bottom Scan	WTG and Cable Routes	1	$724,200	LS		$724,200			$0	
4.1	Bottom Trawling	Trawler	1	$2,400	day	10	$24,000	22	$77	$770	
										$0	
Subtotal Site Survey and Clearance							$748,200			$770	**$748,970**
										TOTAL:	$71,073,507

Notes:
(1) Not separately priced
(2) Marine Diesel Cost / Gallon $3.50

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APPENDIX F - Maximum Decommissioning Cost Estimate

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Maximum Decommissioning Coest Estimate											
WBS	Task Description	Equipment	Quantity	Rate	unit	Days	Extension	Fuel ga/day	Fuel (2) cost/day	Total Fuel Cost	Total
PROJECT DOCUMENTATION											
1.1	Decommissioning Plan			$1,200	ManDay	20	$24,000				
1.2	Other Documentation						NSP (1)				
Subtotal Project Documentation											**$24,000**
STONE REMOVAL											
2.1	De-Energize System										
2.2	Remove Stone Armor	Derrick Crane Barge w/8 Cy Bucket	1	$45,000	day	116	$5,220,000		$0	$0	
		4000 CY Dump Scow	2	$5,000	day	116	$1,160,000		$0	$0	
		Tug (2000 hp)	2	$5,163	day	116	$1,197,816	1,100	$7,700	$893,200	
		Crew Boat	1	$2,400	day	116	$278,400	450	$1,575	$182,700	
Subtotal Armor Stone Removal							$7,856,216			$1,075,900	**$8,932,116**
CABLE REMOVAL											
2.3	Subsea Cable Removal	D/B Farrell 256 (190-T)	1	$37,500	day	221	$8,287,500		$0	$0	
		Barge (180 x 54)	1	$1,133	day	221	$250,393		$0	$0	
		Tug (2000 hp)	1	$5,163	day	221	$1,141,023	1,100	$3,850	$850,850	
Subtotal Cable Removal							$9,678,916			$850,850	**$10,529,766**
WTG REMOVAL											
2.6	Remove 101 WTG's	JB-114	1	$57,150	day	223	$12,724,220		$0		
		Tug (2000 hp)	3	$5,163	day	223	$3,448,564	1,100	$11,550	$2,571,562	
		300 x 90 Barge	2	$8,803	day	223	$3,919,906		$0		
		Anchor Scow	1				$0				
	Mobilization of JB-114	JB-114	1	$57,150		32	$1,828,800				
		Tug	1	$5,163		32	$165,216	2,200	$7,700	$246,400	
Subtotal WTG Removal							$22,086,706			$2,817,962	**$24,904,667**
TRANSITION AND MONOPILE REMOVAL											
2.8	Remove Transition Piece ar	1000-T crane	1	$90,000	day	187	$16,830,000		$0	$0	
		Tug (2000 hp)	3	$5,163	day	187	$2,896,443	1,100	$11,550	$2,159,850	
		300 x 90 Barge	2	$7,500	day	187	$2,805,000				
	Mob/Demob of Crane	1000-T crane	1	$25,000	day	2	$50,000				
	Mob/Demob of Tug	Tug (2000 hp)	1	$5,163	day	2	$10,326	2,200	$7,700	$15,400	
Subtotal Transition Piece and Foundation Removal							$22,591,769			$2,175,250	**$24,767,019**
ESP REMOVAL											
2.9	Remove Superstructure	1000-T Crane	3	$75,000	day	2	$450,000			$0	
		Tug (2000 hp)	4	$5,163	day	2	$41,304	1,100	$15,400	$30,800	
		300 x 90 Barge	1	$7,500	day	2	$15,000				
	Remove Jackets	JB-114	1	$57,150	day	4	$228,600				
		Tug (2000 hp)	2	$5,163	day	4	$41,304	1,100	$7,700	$30,800	
		300 x 90 Barge	2	$7,500	day	4	$60,000				
	Remove Piles	JB-114	1	$57,150	day	9	$514,350				
		Tug (2000 hp)	2	$5,163	day	9	$92,934	1,100	$7,700	$69,300	
		300 x 90 Barge	2	$7,500		9	$135,000				
		Crew Boat	1	$2,400	day	6	$14,400	450	$1,575	$9,450	
	Mob/Demob of Crane	1000-T crane	2	$25,000	day	2	$100,000				
	Mob/Demob of Tug	Tug (2000 hp)	2	$5,163	day	2	$20,652	2,200	$15,400	$ 30,800.00	
Subtotal ESP and Foundation Removal							$1,713,544			$171,150	**$1,884,694**
ONSHORE DISPOSAL											
See Onshore Tab											
Subtotal Onshore Disposal							$53,538,029			$0	**$53,538,029**
SITE SURVEY AND CLEARANCE											
4.1	Bottom Scan	WTG and Cable Routes	1	$945,200	LS		$945,200			$0	
4.1	Bottom Trawling	Trawler	1	$2,400	day	10	$24,000	22	$77	$770	
										$0	
Subtotal Site Survey and Clearance							$969,200			$770	**$969,970**

Notes:
(1) Not separately priced
(2) Marine Diesel Cost / Gallon $3.50

TOTAL: $125,550,261

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APPENDIX G – Onshore Disposal Cost Summary

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Table G.1 Disposal of WTG and Tower Material

Description	Minimum Duration (Hr.)	Most Likely Duration (Hr.)	Maximum Duration (Hr.)	Minimum Cost	Most Likely Cost	Maximum Cost
Offloading barge at marshaling area	20.4	24	31.2			
Trucking to processing	6.8	8	10.4			
Processing materials for recycling	713.15	839	1090.7			
Transport to landfill	2.55	3	3.9			
Total Disposal Cost per WTG				$292,561	$379,631	$484,285
Total Disposal Cost for 101 WTG's				$29,548,662	$38,342,791	$48,912,837

Table G.2 Disposal of Electric Service Platform Material

Description	Minimum Duration (Hr.)	Most Likely Duration (Hr.)	Maximum Duration (Hr.)	Minimum Cost	Most Likely Cost	Maximum Cost
Offloading barge at marshaling area	20.4	24	31.2			
Trucking to processing	285.6	336	436.8			
Processing materials for recycling	2,891.7	3,402	4,422.6			
Total Disposal Cost for ESP & Jacket				$1,062,915	$1,463,894	$1,916,771

Table G.3 Disposal of Electrical Cable

Description	Minimum Duration (Hr.)	Most Likely Duration (Hr.)	Maximum Duration (Hr.)	Minimum Cost	Most Likely Cost	Maximum Cost
Offloading barge at marshaling area	20.4	24	31.2			
Trucking to processing	142.8	168	218.4			
Processing materials for recycling	6,236.45	7,337	9,538.1			
Total Disposal Cost for Electric Cable				$2,482,279	$3,409,896	$4,532,525

Table G.4 Disposal of Fluids

Description	Minimum Duration (Hr.)	Most Likely Duration (Hr.)	Maximum Duration (Hr.)	Minimum Cost	Most Likely Cost	Maximum Cost
Hydraulic Hub Fluid (279 barrels)	61.2	72	93.6			
Gear Oil (681 barrels)	122.4	144	187.2			
Hydraulic Tower Fluid (1,145 barrels)	183.6	216	280.8			
Total Disposal Cost for Fluids				$70,655	$81,276	$92,667

Table G.5 Total Disposal Cost for All Materials

Description	Minimum Cost	Most Likely Cost	Maximum Cost
101 - Wind Turbine Generators	$29,548,662	$38,342,791	$48,912,837
1 – Electric Service Platform & Jacket	$1,062,915	$1,463,894	$1,916,771
Electrical Cable	$2,482,279	$3,409,896	$4,532,525
Fluids	$70,655	$81,276	$92,667
Total Disposal Cost for All Materials	$33,164,511	$43,297,857	$55,454,800

Rates	**Hourly**	**Day**	**One Time**
Crane (qty 1)	$45	$1,080	
300 x 90 Barge(qty 1)	$367	$8,803	
Crane Operator (qty 2)	$100	$2,400	
Riggers (qty 2)	$63	$1,500	
Roustabouts (qty 4)	$100	$2,400	
Tandem Trucking (per load)	$500		
Dump Truck	$84	$2,016	
Permit Loads (per load)			$3,000
Pickup Trucks	$12	$288	
Processing and Disposal Fee (per ton)	$450		
Topside Cutting Crew	$500	$12,000	
500 bbl DOT Cargo Tanks	$11	$275	
Disposal of Fluids (per bbl)	$18		
Tank Cleaning	$83	$2,000	

APPENDIX H – Probabilistic Cost Graph

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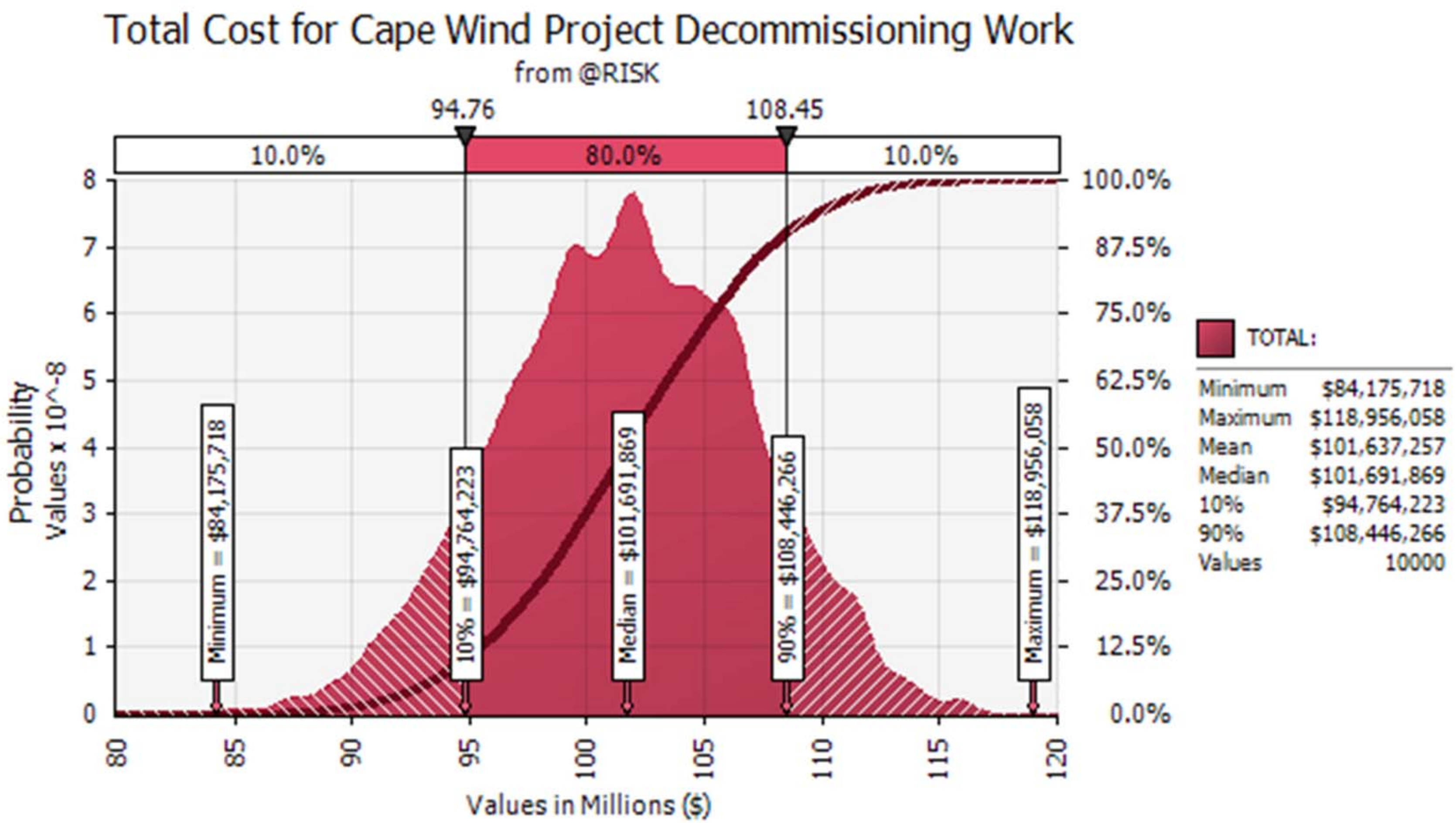

Figure H-1 Projected Distribution of Total Project Cost

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