APPENDIX M – DECOMMISSIONING COST ANALYSIS

DNV·GL

DAKOTA RANGE III WIND PROJECT

Decommissioning Cost Analysis

Apex Clean Energy Management, LLC

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List of abbreviations

Abbreviation	Meaning
BOP	Balance of Plant
COD	Commercial Operation Date
DNV GL	Garrad Hassan America, Inc.
GRP	Glass Reinforced Plastic
O&M	Operations and Maintenance
WTG	Wind Turbine Generator

EXECUTIVE SUMMARY

Apex Clean Energy Management, LLC ("Apex" or the "Sponsor") retained Garrad Hassan America, Inc. ("DNV GL") to perform a decommissioning analysis of the Dakota Range III Wind Project (the "Project") to be located in South Dakota. The study estimates the costs associated with the dismantling, removal, and salvage or disposal of the Project equipment; all costs in this study are given in 2018 U.S. dollars. Section 6 presents an estimate for costs taking into account inflation.

The Project is intended to consist of 36 Vestas V136-4.2 MW wind turbine generators (WTG) with a total rated output of 151.2 MW and associated infrastructure. Apex has indicated that the Project includes one substation, three met towers and an 8 mile long transmission line. The turbines will be mounted on 105 m tubular steel towers. The Project is anticipated to commence commercial operations in 2020. Per Apex's request, it is assumed that decommissioning of the Project will take place 30 years after the start of commercial operations [1]. This report assumes that the decommissioning process for all 36 WTGs will take place as a single process.

DNV GL assumes that there are strong parallels between wind power project construction and decommissioning programs and consequently bases the estimates for decommissioning costs on its broad experience of wind power project construction programs and the associated costs of labor, plant, and materials. The complete decommissioning cost is calculated as the sum of the cost of disassembly, removal, and disposal of the turbines and balance of plant (BOP), as may be offset by gains from salvage or resale of materials and components. It is noted that crane costs are the most dominant cost item in disassembly while transportation of the large turbine components dominates the costs of removal.

Assessments of salvage opportunities are based on the bill of quantities identified in this report. The average material weights and ratios for turbine components are derived from previous DNV GL studies, Sponsor documentation [2], and/or turbine supplier technical specification sheets. Although DNV GL assumes certain commodity prices and disposal service rates based on present day estimates, it does not forecast such future values. The salvage value is calculated as the difference between the sum of parts resale and scrap revenue, less the landfill cost of the remaining material. Two salvage/disposal scenarios are presented: Scenario 1 considers that all equipment is sold as scrap, while Scenario 2 assumes partial resale of some of the Project's major components.

The net decommissioning value is determined from the difference of 1) the sum of the disassembly and removal cost and 2) the sum of the salvage value and resale. The estimated net decommissioning gain or cost for the Project assuming no resale (Scenario 1), and with partial resale of the Project's major components (Scenario 2), are presented in Table ES-1 and Table ES-2 below. Note: values in parenthesis are negative values representing positive returns to the Project.

Table ES-1 Net decommissioning costs

	Scenario 1 – No Resale	Scenario 2 – Partial Resale
Total per WTG	$101,420	$53,000
Total for Project (36 WTGs)	$3,651,000	$1,908,000

As it is considered to be the more likely option, a detailed breakdown of Scenario 2 is shown below.

Table ES-2 Project Net decommissioning cost with partial resale (Scenario 2)

Item	Disassembly [$] (A)	Removal [$] (B)	Disposal [$] (C)	Total Costs [$] (D=A+B+C)	Salvage/Resale [$] (E)	Net [$] (D+E)
WTG	3,708,000	2,794,000	468,000	6,970,000	(7,981,000)	(1,011,000)
Collection System	499,000	145,000	13,000	657,000	(533,000)	124,000
High voltage substation	112,000	58,000	7,000	177,000	(409,000)	(232,000)
Transmission Line	984,000	55,000	-	1,039,000	(157,000)	882,000
Access roads & Crane Pads	332,000	445,000	20,000	797,000	(221,000)	576,000
Met Masts	32,000	31,000	900	63,900	(5,900)	58,000
Mobilization/Soft Costs	1,511,000	-	-	1,511,000	-	1,511,000
Project Totals	7,178,000	3,528,000	508,900	11,214,900	(9,306,900)	1,908,000
Total per WTG [$]						**53,000**
Total Project (36 WTGs) [$]						**1,908,000**

Note: negative values, those in parenthesis, are positive returns to the Project.

It is stressed that this report is based on broad assumptions regarding the Project, including the approach to the decommissioning task and the market conditions for contracting costs, scrap value, and resale options. It is recommended that the estimated costs of decommissioning be reviewed closer to the end of the operating period (e.g., 2 to 4 years prior to the end of operations). At that time, it would also be prudent to take into consideration: 1) whether Project profitability and turbine conditions justify continued operation beyond the initially assumed Project operating life; and 2) whether a "re-powering" scenario, in which case the existing turbines would be removed in the interest of constructing a more valuable project with larger, more efficient turbines, may be feasible. In the first scenario, decommissioning costs could be paid for by allocations of Project revenues in future Project years, while in the latter scenario any decommissioning costs could be transferred to the capital budget of the new project.

INTRODUCTION

Apex Clean Energy Management, LLC ("Apex" or the "Sponsor") retained Garrad Hassan America, Inc. ("DNV GL") to perform a decommissioning analysis of the portion of the Dakota Range III Wind Project (the "Project") to be located in South Dakota. The Project is intended to consist of 36 Vestas V136-4.2 MW wind turbine generators (WTG) with a total rated output of 151.2 MW, one substation, three met towers and a high voltage transmission line.

Apex has advised DNV GL that the required decommissioning tasks will include the removal of all towers, WTGs, substation, transmission line, met towers, ancillary equipment and other physical material owned by and pertaining exclusively to the Project, and restoration of the property, including the Project roads.

In compliance with section 1211.04 of the Grant County Ordinance as well as the Roberts County Ordinance No. 21 [3], the following assumptions have been applied in this report:

- Decommissioning will start soon after the end of the Project's operating life (assumed to be 30 years for purposes of this study), and all decommissioning work is performed in generally conducive weather conditions;
- Decommissioning includes removal of WTGs, electrical cabling, electrical components, roads, and any other associated facilities down to four feet below grade, as specified in the applicable ordinances, and in accordance with industry best practice. Additionally:
    - The WTG foundations will have only four feet out of its total six feet pedestal removed and the remainder of the spread footing is abandoned in place.
    - Apex has advised DNV GL that the underground portion of the collection system, approximately 26.1 miles of underground cabling, will be buried below four feet grade. Therefore, the decision on whether underground cabling will be removed will be based mainly on economic factors. Apex may ultimately elect to leave the cabling buried, which would be in compliance with the applicable ordinances. This decision may be made closer to the decommissioning date. This report assumes that the cables *will* be removed during decommissioning.
    - One Project substation with one main transformer is assumed, an 8-mile, 345 kV transmission line will be completely decommissioned.
    - Approximately 10 miles of Project roads will be decommissioned. DNV GL considers this a conservative assumption as many land owners may find such roads a benefit to their land and request to keep them.
- Crane pads are assumed to have been remediated during initial construction, but reseeding is assumed herein.

It should be noted that commodity values are volatile and difficult to predict over the study horizon.

This report also does not consider the decommissioning scenarios from legal, regulatory, or commercial perspectives other than the ones specifically mentioned in this report. DNV GL recommends these perspectives to be assessed by the Sponsor.

1 STUDY ASSUMPTIONS

DNV GL's decommissioning study methodology assumes there are strong parallels between wind power project construction and decommissioning programs. DNV GL has used an internal bottom-up decommissioning model developed from its experience in the wind industry to formulate these study results.

All costs are quoted in 2018 US dollars, and it should be noted that no specific quotes were obtained in relation to this study, although the Project's location has been considered in the modeling. The study is broken down into three sections: disassembly, removal, and salvage/disposal. Due to the uncertainty associated with the majority of cost categories assumed and modeled, DNV GL has rounded costs to the nearest $1,000, unless otherwise noted.

1.1 Crane assumptions

DNV GL has assumed that, on average, one wheeled crane will dismantle one turbine every 1.5 days (including time for crane movements from turbine to turbine, crane teardowns where necessary, and some minor weather delays). The wheeled crane is also called main crane in this report. The Project layout was analyzed for crane walking impediments to estimate crane teardown requirements. DNV GL has assumed that one wheeled crane will be necessary for this Project, instead of the more typical tracked crane, based on the Project road layout. Since each individual WTG is connected to a public road by a local road, a tracked crane would have to be unrigged for each and every single WTG, which would make the cost of the dismantling higher than using a wheeled crane. Rigging down a wheeled crane is much faster compared to a tracked crane and thus, more cost-efficient. A base crane for lower tower sections, as well as to aid in loading the components onto transport trucks, will also be required. The number of main cranes used determines the approximate time to complete the job. While a detailed analysis in this regard was not performed, the Project was assumed to require the number of cranes and teardowns presented in Table 1-1.

1.2 Initiation and mobilization

Before executing any decommissioning works, it is necessary to plan the work carefully, secure the appropriate permits and insurance, and manage the program of work and associated health and safety risks in order to ensure successful completion of the work. It is assumed that mobilization and soft costs are overhead. Soft costs, for the purposes of this study, include costs not specifically accounted for in the derivations presented later in this Report, including environmental studies, obtaining permits, environmental protection plans, hazardous material disposal, onsite administrative infrastructure and staff, utilities, off-site project management and insurance/legal services. DNV GL assumed 5% of the total disassembly and removal cost will be required for soft costs.

In addition to soft costs, DNV GL assumed that an additional 1% of the total disassembly and removal costs will be needed for contractor mobilization. DNV GL separately accounted for a lay-down yard of 10,000 m^2 to house the office trailers, staff parking and facilities for mobilization and demobilization. Table 1-1 summarizes the crane, mobilization, and soft cost assumptions used in this report, as well as the total cost estimate for such activities. As mentioned previously, it is assumed that the decommissioning, and thus the mobilization activities, for the entire project consisting of 36 WTGs, will take place as a single process.

Table 1-1 Mobilization and soft cost assumptions

Item	Quantity
Number of main cranes needed (wheeled)	1
Number of main crane tear-downs needed	36
Number of base cranes needed	1
Number of base crane tear-downs needed	0
Decommissioning contractor's lay-down yard size [m^2]	10,000
Additional mobilization as percent of total hard costs (1)	1%
Decommissioning soft costs as percent of total hard costs (2)	5%
Total Mobilization and Soft Costs	**$1,511,000**

(1) Represents the costs of contractor's mob./demob.
(2) For soft costs, it is assumed that decommissioning would be completed for the entire Project at once.
(3) Crane tear-downs refer to those between turbines and exclude removal of cranes from Project site.

1.3 Schedule

It is assumed that the decommissioning program would be 15 to 23 weeks in length. This timeline is based on the assumption that the dismantling rate of the WTGs is approximately one turbine per 1.5 workdays per crane, and that 7 to 10 workdays of mobilization and demobilization are allowed before and after turbine dismantling. While disassembly could in theory be done with slightly less care than during assembly (damage to turbines not as much of a concern), safety and resale considerations will likely dictate that disassembly be accomplished in much the same fashion as erection, although in reverse order.

It is also assumed that other works across the site such as foundation removal, underground collection systems disassembly, substation disassembly and reclaiming of roads will be done simultaneously and/or in concert with the turbine dismantling and crane progress.

2 DISASSEMBLY

The disassembly of the Project pertains to all work prior to physical transportation of the infrastructure from the site. In the case of the WTGs, it includes the dismantling and loading of the tower sections, nacelle, and blade scraps onto trucks for transport. In the case of concrete foundations and roads, it pertains to the tear down, aggregate stripping, excavation and backfilling, and all reclaiming as necessary. Reseeding of removed roads and turbine areas is included in these costs.

Although certain activities must be sequenced appropriately, based on DNV GL's knowledge of wind project construction considerations, it is assumed that many activities (e.g., turbine, collection system, and substation disassembly) may be undertaken in parallel, facilitating an efficient decommissioning process.

2.1 Turbines

Once the site is mobilized, it is assumed that the decommissioning of turbines would start immediately and sequentially. This typically entails the individual removal of the rotor assembly followed by the nacelle enclosure. The tower internals are stripped of lifts, cables, cabinets, lighting and other miscellanea and are then dismantled, section by section, down to the foundation surface.

For the Project, 36 turbines are to be removed, consisting of 4.2 MW nacelles, with three-section, 105-m steel towers, and 66.7-m blades. It is assumed that the scope of the disassembly works includes the cost of labor, machinery, and tools required to perform the tasks and the loading of the dismantled material onto transport vehicles for removal from site. The wheeled crane would be required on site for approximately 13 to 19 weeks during the turbine dismantlement activities. The base crane may be required a slightly longer period in order to assist with transport loading activities and substation dismantling.

It is also assumed that aside from the possible removal of the drive train to aid lifting, the nacelle and its contents will remain fully intact for purposes of transport. All cooling, heating, and lubrication fluids will be drained, stored, and appropriately disposed of before the nacelle is removed from site. Blades, however, will be cut into sections for easier transport to a recycling or incineration plant.

The costs presented below include the cost of a wheeled crane to handle the hub/rotor, nacelle and top tower section (or top sections, depending on base crane hired). They also include the cost of a base crane for lower tower sections, as well as to aid in loading the components onto transport trucks. The costs take into consideration the rental of special tools needed from the manufacturer.

Apex has advised that the site will be remediated to four feet below grade. It is assumed that approximately 29 m^3 of crushed concrete will result from removing each turbine's foundation pedestal to achieve these criteria. Table 2-1 summarizes the turbine disassembly costs for Project.

Table 2-1 Summary of turbine disassembly costs

Cost item	Estimate per WTG ($)
Dismantle hub and blades (3 blades per turbine)	27,000
Dismantle nacelle (drive train, generator and transformer included)	27,000
Dismantle tower sections, internals included	44,000
Remove turbine foundation (1)	5,000
Total per WTG	**103,000**
Total for Project (36 WTGs)	**3,708,000**

(1) 1.2 m (4 feet) below grade. Does NOT consider concrete tower sections (which are not expected)

DNV GL notes that the disassembly costs of WTGs are highly dependent on crane costs (which include crane plus crane crew): over 90% of the total per-WTG cost is associated with crane-related costs. DNV GL estimated this cost based on experience from various projects in North America. It is noted that crane availability may greatly influence crane costs, and that it is not possible to accurately predict crane costs given the long study horizon.

2.2 Collection system

The decommissioning of the collection system has been considered in this report. Although, the underground portion of the collection system does not need to be removed, since it will be located four feet below ground as stated in the applicable ordinances. That said, due to the relatively high value of conductors, removal and resale of the underground cables may yield a positive return to the Project. Apex has requested DNV GL to calculate this potential revenue and include it in the net decommissioning cost calculations. The decision on whether the underground cabling will ultimately be removed will be based mainly on economic factors and will be made closer to the decommissioning date.

2.2.1 Underground Collection System

According to Apex [2], the Project collection system will be composed of 26.1 miles of three-phase buried lines along with bare copper grounding cable. Underground collection system disassembly includes trenching, winding triplex with ground wire, and reclamation. The conductors would subsequently need to be re-reeled for transport.

It is assumed that the scope of the disassembly includes the cost of labor and the loading of the dismantled material onto transport vehicles for removal from site. It is assumed that the disconnection work at the terminals would be performed as part of turbine removal or substation removal. The results are reported in Table 2-3 below.

2.2.2 Overhead Collection System

In accordance with the documentation provided by Apex, which indicates that no overhead collection lines are being utilized, DNV GL did not consider any overhead lines in this decommissioning analysis.

2.3 High-voltage substation

Apex has advised that the Project will be equipped with one 345/34.5 kV, 100/133/167 MVA ONAN/ONAF/ONAF transformer at the substation location. The remaining portions of the Project's high-voltage (HV) substation is assumed to include typical equipment seen in North American for wind projects of this size, including grounding transformers, bus bars, relay switches, circuit breakers, air disconnect switches, capacitor banks, reactor banks and a control/O&M building. It is assumed that a dead-end structure will also be present.

An interconnection switchyard for the Project has not been considered in this decommissioning analysis.

It is assumed that the scope of the disassembly work includes the cost of labor and machinery required to perform the disassembly tasks, including disconnection work at the terminals, and the loading of the dismantled material onto transport vehicles for removal from site. The following table summarizes the costs to disassemble the Project's HV substation.

Table 2-2 Costs to disassemble Project substation

Item	Estimate ($)
Preparation	4,000
Dismantle HV equipment	9,000
Dismantle and prep. main transformers for shipment	6,000
Remove control/O&M building	40,000
Remove foundations	18,000
Large machinery hire	15,000
Small machinery hire	13,000
Reclaim and reseed	7,000
Total for Project (one substation)	**112,000**

2.4 Transmission line

According to Apex, the Project will use a 8-mile, 345 kV overhead transmission line. Transmission line disassembly includes pole teardown and reclaiming. The conductors would subsequently need to be re-reeled for transport.

It is assumed that the scope of the disassembly includes the cost of labor and the loading of the dismantled material onto transport vehicles for removal from site. The results are reported in Table 2-3 below.

2.5 Site access roads

In practice, it is probable that most of the roads could remain after the completion of the Project, with the exception of the dead-end access roads that lead to the turbines. However, for purposes of the study, DNV GL has assumed that the entirety of the approximately 10 miles of roads will be remediated. Based on

Sponsor information, DNV GL has additionally assumed that 36 crane pads will be reseeded during decommissioning, but that removal of concrete would have occurred during initial construction activities. The lay-down yard reclamation is accounted for in the mobilization/demobilization costs. Decommissioning of the site access roads will typically include stripping back the road surface and replacing it with topsoil in keeping with the surrounding environment. In the case of the Project, this activity also includes stripping and piling geotextile material used in the road base. The costs include reseeding with native grasses. A secondary reseeding may be required if the initial work proves inadequate.

The results are reported in Table 2-3 below. Note the cost of aggregate transport off site is captured in removal costs.

2.6 Meteorological masts

Up to three permanent 105-m meteorological masts will be installed for the Project. It is assumed that the met masts will be disassembled at an appropriate time during the decommissioning activities so as not to interfere with the other ongoing work. This typically involves the use of a base crane to dismantle the masts, section by section, down to the foundation surface. The instrumentation and booms would be either removed before the sections are laid down, or removed from the sections once on the ground.

It is assumed that the scope of the disassembly works includes the cost of labor, machinery and tools to perform the dismantling tasks, including foundation removal to appropriate below grade level, and the loading of the dismantled material onto transport vehicles for removal from site. It is also assumed that only one crane is needed for removal. The results are reported in Table 2-3 below.

2.7 Disassembly conclusion

The total estimated cost for the disassembly of the Project is summarized in Table 2-3.

Table 2-3 Summary of Project disassembly costs

Cost item	Estimate ($)
WTG	3,708,000
Collection system	499,000
HV substation	112,000
Transmission line	984,000
Access roads	332,000
Met Mast	32,000
Mobilization & soft costs	1,511,000
Total Project Disassembly Cost	**7,178,000**

3 REMOVAL FROM SITE

Removal of the Project in this study refers strictly to the transporting of the equipment from the site to the appropriate landfill, aggregate rework facility, or scrap yard. Various distances and truck sizes are applied in DNV GL's decommissioning model, depending on which Project component is being considered. Removal costs also include the costs of unloading the material once it reaches its destination. DNV GL notes that appropriate landfills and scrap yards appear to be located in the general region of the Project.

3.1 Turbines

It is assumed that the scope of the removal of the WTGs includes the cost of labor and vehicles required to transport the dismantled material to an appropriate disposal, salvage or rework facility. It is assumed that the transport distances for general waste would be within a radius of 80 miles, whereas the more complex and valuable material is assumed to be transported within a radius of 300 to 450 miles (300 miles for the tower internals and 450 miles for the main turbine and substation components). These assumptions may be somewhat conservative considering there are a number of recycling or salvage facilities near the Project site. DNV GL additionally notes the presence of rail transport in the relative vicinity which could decrease costs for removal of turbine components. While most of the main turbine components are modeled to be removed much as they were initially transported to the site during construction, the turbine blades will be sectioned to limit oversize transport.

Table 3-1 summarizes the costs for the removal of each of the turbine components from the site.

Table 3-1 Turbine removal costs

Turbine component	Estimate ($)
Blades (cut up prior to loading)	5,000
Hub (one per truck)	10,000
Nacelle	11,000
Tower sections	50,000
Internals	1,000
Crushed foundation (29 m^3)	600
Total per WTG	**77,600**
Total for Project (36 WTGs)	**2,794,000**

3.2 Collection system

3.2.1 Underground collection system

It is assumed that the scope of the removal works includes the cost of labor and vehicles required to transport the dismantled material to an appropriate salvage facility. The material will mainly include the wound reels and/or cut cables removed by trucks. The results are reported in Table 3-3 below.

3.2.2 Overhead collection system

In accordance with the documentation provided by the Sponsor, which indicates that no overhead collection lines are being utilized, DNV GL did not consider the removal of overhead lines in this decommissioning analysis.

3.3 High-voltage substation

It is assumed that the transport distances for substation foundation rubble and general waste would be within a radius of 80 miles, whereas the more complex and valuable substation material is assumed to be transported within a radius of 300 to 450 miles. It is assumed that local dump truck loads are 10 yd^3 in capacity.

The following table summarizes removal costs for the Project substation. As previously mentioned, an interconnection switchyard has not been considered in the present study.

Table 3-2 Project substation removal costs

Substation component	Estimate ($)
HV equipment	10,000
Main transformers	10,000
Control/O&M building	13,000
Dead-end structures	10,000
Crushed foundations (local transport)	9,000
Yard gravel (local transport)	6,000
Total removal costs for HV substation	**58,000**

3.4 Transmission line

It is assumed that the scope of the removal works for the overhead transmission line includes the cost of labor and vehicles required to transport the dismantled material to an appropriate salvage or rework facility. The material will include the wound reels and/or cut cables as well as the dismantled poles (70 wood poles assumed). The results are reported in Table 3-3 below.

3.5 Site access roads

For the purpose of removal calculations and at the Sponsor's request, the Project's 10 miles of roads to be removed were assumed to be 16 feet wide and approximately 1 foot deep and underlain by geotextile in line with industry best practice. While this width attempts to capture any shoulder material as well, the assumption that all roads to be removed are 16 feet wide is likely conservative with respect to the Project design and is expected to therefore cover the cost of decompaction and reclamation of any additional width required due to crane walking. Dump truck capacity is assumed to be 10 yd^3 and all load trips are assumed to be local. The results are reported in Table 3-3.

3.6 Meteorological masts

It is assumed that the scope of the removal works includes the cost of labor and vehicles required to transport the dismantled material from up to three meteorological masts to an appropriate disposal, salvage or rework facility. The results are reported in Table 3-3 below.

3.7 Removal conclusions

Table 3-3 summarizes the total anticipated costs for removing the turbines, electrical collection system, substation, roadways, and met masts from the Project site.

Table 3-3 Project removal conclusions

Item	Estimate ($)
WTG	2,794,000
Collection system	145,000
HV substations	58,000
Transmission line	55,000
Access roads	445,000
Met Mast	31,000
Total Project removal cost	**3,528,000**

Note: Three (3) masts have been used for calculating this cost.

4 SALVAGE – DISPOSAL

While it is impossible to predict the exact evolution of an industry 30 years into the future, it is not unreasonable to assume that there may exist by that time consolidated centers that will fully recycle a wind turbine given that many project "decommissionings" or "repowerings" will have been undertaken prior to that time. For example, DNV GL notes that significant attention is being placed by industry and academia alike into possible uses or methods for recycling wind turbine blades.

DNV GL notes that in this section only, gains are shown as positive and costs to the Project are shown in parentheses

While it may become easier to recycle wind turbines in the future, DNV GL performed this study assuming only the application of present day means. Following the disassembly and removal of all materials from the Project site, four potential destinations for the remediated material are typically envisaged by DNV GL when performing decommissioning studies. These scenarios may add extra cost to the decommissioning budget or offer an opportunity to reclaim some value from the project components to offset the cost of decommissioning.

1. Low-grade material such as contaminated aggregate, concrete rubble, wood, non-recyclable materials and other mixed general waste will in all likelihood be sent to landfill or incineration at cost to the Project. DNV GL notes that there is a relatively large volume of waste associated with the glass reinforced plastic (GRP) which composes most turbine blades today. It is possible that in 30 years recycling blade GRP into cement fill, roofing shingles or other useful industrial raw materials may be a net positive for the Project, or at least an offset to the cost, but no such projections have been made in the present study. Thus, blade GRP has been considered waste.
2. Medium-grade materials such as small- and medium-gauge cabling, small motors, cabinets of mixed electronics, and lighting may be sent to salvage centers to be stripped for parts and sold for re-use or re-processing. This may be done at a nominal, neutral, or negative cost (positive return) to the Project. However, this material may also be sent to landfill if an appropriate third party cannot be found. DNV GL notes that it is difficult to predict future returns of salvage for such materials due to the unpredictability of commodity prices.
3. High-grade materials such as large steel components (tower sections, bedplates, hub castings, gearboxes, and steel cables), large-gauge copper and aluminum cabling, aluminum flooring and ladders will be sent to reprocessing centers at a net neutral cost or positive return to the Project. DNV GL notes that it is difficult to predict future returns of reprocessing for such materials due to the unpredictability of commodity prices.
4. Reusable components that are deemed to be undamaged, functional and have not fulfilled their design life could be sold back to the manufacturer or its supply chain for a modest second-hand price for refurbishment. Some electrical infrastructure equipment as well as recently replaced turbine components could fall into this category.

Applying a conservative approach, DNV GL only considered items 1, 3, and 4 in this study. No resale gains were assumed for item 2, only scrap/disposal value. Furthermore, item 4 was limited only to certain main components within a conservative age range.

4.1 Pricing assumptions

The following salvage assessment is based on DNV GL's decommissioning model which estimates bill of quantities, typical material weights, and mass and volume values for turbine components derived from the manufacturer's technical specifications or from DNV GL experience. The DNV GL model uses commodity prices and disposal service rates as inputs.

For the Project's decommissioning study, the following scrap commodity prices are assumed:

- Steel and cast iron: $270/ton
- Copper: $5,500/ton
- Aluminum: $1,414/ton

Weights are in metric tons. It should be noted that the commodity price of metals is volatile and thus, assuming present day values will hold true is highly uncertain. The assumed prices are based on DNV GL's analysis of USGS historical scrap metal cost statistics [4].

Because landfill costs are expected to keep rising, DNV GL used a different cost variable for the incineration, recycling, or disposal of GRP. Although it is possible that in 30 years technology will be available to extract the fibers from the epoxy laminate for high-grade industrial reuse at a net benefit, DNV GL assumed a net cost to incinerate or low-grade recycle the GRP as a separate cost to landfill. The following landfill costs are assumed:

- GRP disposal (incineration or recycling): \$100/m^3
- Class 2 landfill, Industrial/toxic waste: \$75/m^3
- Class 3 landfill, General waste: \$35/m^3

4.2 Turbines

4.2.1 Salvage and disposal

There should be considerable opportunity to reclaim scrap value from the turbines from the copper in the low voltage cabling, transformer and generator; steel from the tower, hub, drive train and bedplate; and aluminum from the tower internals. The blades and nacelle housing are made from GRP and would have to be disposed of.

The following table summarizes the salvage revenues and disposal costs per each turbine. Component weights have been estimated by DNV GL, and/or obtained directly from manufacturer's documentation.

Table 4-1 Turbine salvage and disposal values

Component	Estimate ($)
Blades	(8,500)
Hub + blade steel	8,500
Nacelle/hub GRP	(3,500)
Nacelle bedplate	17,000
Main shaft	3,000
Gearbox	8,000
Generator	18,000
Tower steel sections	92,000
Internals	22,000
Turbine transformer	7,000
Crushed foundation	(1,000)
Net total per WTG	**163,000**
Net total for Project (36 WTGs)	**5,868,000**

Note: Negative values (those in parenthesis) are costs to the Project which represent disposal. Positive values are salvage-associated revenue.

4.2.2 Partial resale of major components

DNV GL considers that at the end of the Project's assumed 30-year operating life, many of the components of the turbines will still be serviceable and have positive value in the secondary parts market. DNV GL considers that the towers and nacelle shells would still be sold as scrap as well as the rest of the major components that were not resold.

While wind turbines are structurally designed to meet a fatigue life of 20 years plus some margin, DNV GL expects a significant number of failures during the Project's operating life involving the major components such as gearboxes and generators. DNV GL continually tracks and models the various failure rates for each of the main components across all major wind turbine model types and has, for the purposes of this study, modeled failure rate assumptions for the Project for the assumed 30-year life. DNV GL considers that a number of other considerations apply to the actual potential for the turbines to economically operate past their 20-year design life, but notes that such discussion is outside the scope of this report.

It is assumed that other North American wind power projects with Vestas wind turbines (either owned by the Sponsor or not) will be arriving or will have arrived at their 20-year design life at the time of decommissioning of the Project, and some will have chosen to operate beyond it. Therefore, a secondary parts market may be assumed to exist that would demand some of the major components being decommissioned from the Project. Using a conservative approach and with the exception of the transformer, major components that are five years or younger (i.e., replaced or refurbished during operational years 25 through 30) are considered candidates for resale. Only the gearbox, generator, blades, pitch system, main yaw system, hydraulic unit, power converter, main bearing, and transformer are considered. The transformer is assumed to have a higher design life and so, half of the Project's 36 turbine transformers are considered candidates for resale.

Table 4-2 summarizes the turbine partial resale valuations estimated for the Project. The calculations account for the lost scrap opportunities.

Table 4-2 WTG component resale valuations

Component	Qty. to Resale [$] (1)	Assumed Resale Value [$] (2)	Scrap Loss [$] (3)
Gearbox	6	634,000	48,000
Generator	6	328,000	108,000
Blades	2	182,000	(17,000)
Pitch bearing	4	50,000	-
Power converter	8	84,000	-
Main bearing	4	218,000	-
Transformer	18	414,000	126,000
Gross Resale Total [$]		**1,910,000**	
Minus Loss of Scrap [$]			**(265,000)**
Net Resale Total [$]			**1,645,000**

(1) Component assumed to be resold based on DNV GL engineering judgment.
(2) Represents aggregate resale value of all components eligible for resale.
(3) Partial resale of turbine components means scrap opportunities need to be subtracted from previous calculations; this is taken into account in this column, and therefore the net resale value of turbine components includes this loss of scrap.

4.3 Collection system

4.3.1 Underground collection system

The underground three-phase conductor and ground cabling reels from the Project will likely be sold for scrap. Based on Project information, DNV GL has estimated a total of approximately 78 miles of conductor (3 phases) along with 26.1 miles of bare copper ground wire. The salvage - disposal results are reported in Table 4-3 below.

4.3.2 Overhead collection system

In accordance with the documentation provided by the Sponsor, which indicates that no overhead collection lines are being utilized, DNV GL did not consider the salvage value of overhead lines in this decommissioning analysis.

4.4 High-voltage substation

There should be opportunity to reclaim metal scrap value from substation electrical equipment. Equipment such as bus work, circuit breakers, grounding transformers, and main transformers contain a significant amount of conductive material such as copper and aluminum. Dead-end and other steel structures contain a significant amount of steel. The substation yards also contain aggregate fill that could be sold. Rubble from the foundation demolition and all other materials would be sent to landfill at cost. The scrap value of the substation is presented in Table 4-3 below.

DNV GL considers that there is a resale market for substation transformers. Therefore, the transformer could be sold as operational second-hand equipment instead of being scrapped. This scenario has been taken into account in Section 5.

4.5 Transmission line

The three-phase conductor cable can be sold for scrap and the steel poles from the overhead line could potentially be resold to an electric utility as second hand parts. Based on Project drawings and specifications, DNV GL has estimated a total of 70 wood transmission poles and approximately 8 miles of total conductor (3 phases). The salvage – disposal results are presented in Table 4-3.

4.6 Site access roads

For the purpose of removal and salvage calculations and at the Sponsor's request, the Project's 10 miles of roads to be removed were assumed to be 16 feet wide and 0.3 m (~1 foot) deep and underlain by geotextile, in line with Project drawings.

The salvage – disposal results are presented in Table 4-3.

4.7 Meteorological masts

Although it is possible that the three met masts could be dismantled, resold and reused at a different location, a 30-year old mast may have limited reinstallation value (although it could very well be a candidate to remain installed onsite in a repowering scenario). For the purpose of conservatism in this study, DNV GL assumes a dismantling and removal scenario with the intent of scrapping the met towers.

The salvage – disposal results are presented in Table 4-3.

4.8 Salvage – disposal conclusions

Table 4-3 summarizes the opportunities from the salvage / disposal analysis. Please note that this table does not incorporate the turbine major component resale scenario presented in Table 4-2.

Table 4-3 Salvage/disposal value (without resale of turbine components)

Item	Disposal ($)	Salvage ($)
WTG	(468,000)	6,336,000
Collection System	(13,000)	533,000
HV Substation	(7,000)	311,000
Transmission Line	-	157,000
Access Roads	(20,000)	221,000
Met Masts	(900)	5,900
Total Project Salvage Return	**(508,900)**	**7,563,900**

Note: The value presented does not include the resale returns of turbine components; negative values, those in parenthesis, are costs to the Project.

5 NET DECOMMISSIONING COST

The estimated net decommissioning cost for the Project is calculated by subtracting the total salvage value from the total of the disassembly and removal costs. This report presents two net decommissioning cost breakdowns: Scenario 1 assumes no resale of Project components, and Scenario 2 assumes the partial resale of major turbine components noted in Section 4.2.2 and the substation's main power transformer.

5.1 Net decommissioning cost – no resale

Table 5-1 summarizes the Project's net decommissioning costs assuming no resale of any Project components other than for scrap value (Scenario 1).

Table 5-1 Project Net decommissioning costs – no resale (Scenario 1)

Item	Disassembly [$] (A)	Removal [$] (B)	Disposal [$] (C)	Total Costs [$] (D=A+B+C)	Salvage [$] (E)	Net [$] (D+E)
WTG	3,708,000	2,794,000	468,000	6,970,000	(6,336,000)	634,000
Collection System	499,000	145,000	13,000	657,000	(533,000)	124,000
HV Substation	112,000	58,000	7,000	177,000	(311,000)	(134,000)
Transmission Line	984,000	55,000	-	1,039,000	(157,000)	882,000
Access Roads & Crane Pads	332,000	445,000	20,000	797,000	(221,000)	576,000
Met Masts	32,000	31,000	900	63,900	(5,900)	58,000
Mobilization/Soft Costs	1,511,000	-	-	1,511,000	-	1,511,000
Project Totals	7,178,000	3,528,000	508,900	11,214,900	(7,563,900)	3,651,000
Total per WTG [$]						**101,420**
Total for Project (36 WTGs) [$]						**3,651,000**

Note: negative values, those in parenthesis, are positive returns to the Project.

5.2 Net Decommissioning Cost – Partial Resale of Selected Components

Table 5-2 summarizes the Project's net decommissioning costs for Scenario 2, which includes some plausible and conservative parts resale assumptions.

Table 5-2 Project Net decommissioning costs – partial resale of selected components (Scenario 2)

Item	Disassembly [$] (A)	Removal [$] (B)	Disposal [$] (C)	Total Costs [$] (D=A+B+C)	Salvage/Resale [$] (E)	Net [$] (D+E)
WTG	3,708,000	2,794,000	468,000	6,970,000	(7,981,000)	(1,011,000)
Collection System	499,000	145,000	13,000	657,000	(533,000)	124,000
High voltage substation	112,000	58,000	7,000	177,000	(409,000)	(232,000)
Transmission Line	984,000	55,000	-	1,039,000	(157,000)	882,000
Access roads & Crane Pads	333,000	445,000	20,000	797,000	(221,000)	576,000
Met Masts	32,000	31,000	900	63,900	(5,900)	58,000
Mobilization/Soft Costs	1,511,000	-	-	1,511,000	-	1,511,000
Project Totals	7,178,000	3,528,000	508,900	11,214,900	(9,306,900)	1,908,000
Total per WTG [$]						**53,000**
Total Project (36 WTGs) [$]						**1,908,000**

Note: negative values, those in parenthesis, are positive returns to the Project.

5.3 Future recommendations

It is stressed that this report is based on broad assumptions regarding the Project including the approach to the decommissioning task, the market conditions for contracting costs, and scrap value and resale options. DNV GL recommends that the estimated costs of decommissioning be reviewed closer to the end of the operating period (e.g., 2 to 4 years prior to the end of operations) when better visibility on these factors would be possible. Also at this time, the value of decommissioning could be reviewed against potential extended operational revenue. At the same time it would also be prudent to consider a "re-powering" scenario, in which case the existing turbines would be removed in the interest of constructing a more valuable project with larger, more efficient turbines. Any cost to remove the old turbines would be incurred as construction costs of the new wind power project.

6 DECOMMISSIONING COSTS ESTIMATE FOR 2050

While it is impossible to predict the exact evolution of an industry 30 years into the future as well as the time value of money, DNV GL has at the request of Apex, estimated the inflated decommissioning costs of the project using an annual inflation rate 2% as agreed with Apex [5].

Results incorporating the inflation rate are presented in Table 6-1.

Table 6-1 Project Net decommissioning costs including 2% annual inflation rate

	Scenario 1 – No Resale	Scenario 2 – Partial Resale
Total per WTG 2018 USD	$101,420	$53,000
Total for Project 2018 USD	$3,651,000	$1,908,000
Total per WTG 2050 USD	$183,710	$96,000
Total for Project 2050 USD	$6,613,280	$3,456,080

7 REFERENCES

[1] Email from B. Gunderson, Apex Clean Energy to K.Kallevig-Childers, DNV GL providing Project assumptions, 24 April 2018.

[2] Emails from B. Gunderson, Apex Clean Energy to D. Pardo, DNV GL providing infrastructure assumptions, 1 to 11 May 2018.

[3] Email from B. Gunderson, Apex Clean Energy to K. Kallevig-Childers, DNV GL with clarifications, 30 May 2018.

[4] USGS web site: http://minerals.usgs.gov/minerals/pubs/commodity/

[5] Email from B. Gunderson, Apex Clean Energy to D. Pardo, DNV GL, 21 Jun 2018.

APPENDIX A – CUSTOMER PROVIDED INPUTS

1000	**Special requirements**	
1001	Decommissioning requirements applicable to the Project	Roberts and Grant counties Ordinances
1100	**Project Basics**	
1101	Wind Power Plant Name	Dakota Range III
1102	Construction Status	County Permitting
1103	General Location	45.267343, -97.096762
1104	No. Wind Turbines	36
1105	Make and Model of Wind Turbine	Vestas V136 4.2 MW
1106	Hub Height	105 m
1107	Project Capacity	151.2 MW
1108	Project Design Life (civil, turbine, electrical and financial)	30 years
1109	Decommissioning to Occur After Which Project Year	2050
1110	No. of Substations to Remove	1
1111	No. of main project transformers	1
1112	No. of O&M buildings to Remove	1
1113	Length of Underground Collection System to Remove	26.1 miles
1114	Length of Overhead Collection System to Remove	0 miles
1115	Length of Transmission Line to Remove	8 miles
1116	Length of Project Access Roads to Reclaim	10 miles
1117	No. of Meteorological Towers to Remove	3
1118	Average Height of Met Towers	105 m
1119	Met tower type	Self-support
1120	Depth of removal	4 feet
1200	**Additional Information**	
1201	COD date	2020
1202	Estimated Annual P50 Production Capacity Factor	Confidential
1203	Main step-up transformer voltage	345/34.5 kV/kV
1204	Main step-up transformer rating	167 MVA
1205	No. of Transmission Line Steel Poles	0
1206	No. of Transmission Line Wood Poles	70
1207	Project Layout file name	DAT_Layout.kmz
1208	Number of tower sections per Wind Turbine	6
1209	Site plan (incl. Electrical layout)	DAT_Layout.kmz

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Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas and energy industries. We also provide certification services to customers across a wide range of industries. Combining leading technical and operational expertise, risk methodology and in-depth industry knowledge, we empower our customers' decisions and actions with trust and confidence. We continuously invest in research and collaborative innovation to provide customers and society with operational and technological foresight. Operating in more than 100 countries, our professionals are dedicated to helping customers make the world safer, smarter and greener.