**BEFORE THE PUBLIC UTILITIES COMMISSION**
**OF THE STATE OF SOUTH DAKOTA**

**IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT FOR A WIND ENERGY FACILITY IN BON HOMME, CHARLES MIX, AND HUTCHINSON COUNTIES, SOUTH DAKOTA, FOR PREVAILING WIND PARK ENERGY FACILITY**

**SD PUC DOCKET EL 18-026**

PRE-FILED SUPPLEMENTAL DIRECT TESTIMONY OF DANIEL PARDO
ON BEHALF OF PREVAILING WIND PARK, LLC

August 10, 2018

## I. INTRODUCTION AND QUALIFICATIONS

**Q. Please state your name, employer, and business address.**

A. My name is Daniel Pardo, and I work for DNV GL, with a business address of 333 SW 5th Ave, Suite 400, Portland, Oregon 97204. I work at our office location with an address of 4100 rue Molson, suite 100, Montreal, H1Y 3N1, Canada.

**Q. Briefly describe your educational and professional background.**

A. I have a Master of Science in Wind Energy from Danmarks Tekniske Universitet and a Bachelors of Engineering in Mechanical Engineering from the Universidad de Los Andes. I have 13 years of practical experience in renewables. In my current position, I provide technical advice on renewable energy projects to developers on topics such as feasibility studies, technology selection, and decommissioning assessments. A copy of my statement of qualifications is attached as Exhibit 1.

## II. OVERVIEW

**Q. Please describe your familiarity with the Prevailing Wind Park Project ("Project")?**

A. DNV GL prepared the Decommissioning Cost Analysis attached as Exhibit 2 to my testimony.

**Q. What is the purpose of your Supplemental Direct Testimony?**

A. The purpose of my Supplemental Direct Testimony is to provide information regarding estimated decommissioning costs.

**Q. What exhibits are attached to your Supplemental Direct Testimony?**

A. The following exhibits are attached to my Supplemental Direct Testimony:

- Exhibit 1: Statement of Qualifications.
- Exhibit 2: Decommissioning Cost Analysis.

## III. DECOMMISSIONING COST ESTIMATE

**Q. Could you provide DNV GL's per turbine decommissioning cost estimate identified in the Decommissioning Cost Analysis, and explain the basis for that estimate?**

A. Yes. DNV GL´s decommissioning cost analysis for the Project includes the disassembly, removal, and disposal of wind turbines and other associated Project infrastructure. The results are presented for two scenarios: one where partial resale of turbine major components occurs and another scenario where it does not. For the partial resale scenario, DNV GL estimates the decommissioning cost to be $13,790 per turbine. For the scenario without partial resale, the decommissioning cost is estimated to be $51,540 per turbine.

The DNV GL decommissioning cost analysis thoroughly explains the methodology for its decommissioning cost conclusions. Additionally, the results presented in DNV GL´s cost analysis study use conservative assumptions.

**Q. Could you discuss the accuracy of the decommissioning cost estimate provided in your report?**

A. The report contains DNV GL's most accurate estimate based on our engineering judgement, market knowledge and Project-specific information. Our decommissioning cost analysis is based on conservative assumptions. Further, DNV GL participates in the project financing for approximately 75 percent of all wind projects financed throughout North America. This extensive experience with financing of wind projects provides DNV GL with a comprehensive understanding of the processes and costs associated with construction, which are very similar to those involved in decommissioning.

**Q. Please explain the assumptions used in the cost analysis.**

A. As noted above, the results presented in DNV GL's cost analysis study use conservative assumptions. Some of these assumptions are: all access roads will be decommissioned, use of a conservative distance from the Project to recycling/salvage facilities, and a width of 16 feet for all access roads. For the partial resale scenario, conservative assumptions have also been made. These assumptions include: only major components that are five years or younger can be sold (at a fraction of the original price), and medium-grade materials, such as small motors and medium-gauge cabling, would not be resold. Thus, DNV GL's analysis provides a conservative decommissioning cost estimate based on a specified and appropriate methodology.

**Q. Could you explain the role of partial resale and salvage value in your per turbine decommissioning cost estimate for the Project?**

A. Yes. The study assumes that some of the major components can be sold after they have been decommissioned. The resale value of these components constitutes potential income that would offset the costs of decommissioning. The study also assumes that some material can be sold as scrap and, thus, the salvage value would also offset a portion of the decommissioning costs.

**Q. For what point in time is the cost estimate calculated? In other words, when is it assumed that the decommissioning costs for the Project would be incurred relative to when the Project becomes operational?**

A. For the analysis, decommissioning is anticipated to start soon after the end of the Project's operating life (assumed to be 30 years for purposes of this study). However, the costs are calculated in 2018 dollars.

## IV. CONCLUSION

**Q. Does this conclude your Supplemental Direct Testimony?**

A. Yes.

Dated this 10th day of August, 2018.

Daniel Pardo

## Daniel Pardo

### Senior Project Manager, Engineering

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**Summary**


Daniel Pardo holds a Master of Science degree in Wind Energy from DTU and has 13 years of practical experience in renewables. He was the Mexico Country Manager in Energy Advisory business for 7 years leading a team of wind and solar specialists who provided support to developers, banks, investors, and lenders for Mexico, Central América, Cuba, and Dominican Republic. He previously worked in the project development team of a renewable energy world leading utility for projects in Europe, Asia, and LATAM.

In his current position with DNV GL, Mr. Pardo is part of the Owner's Engineering team, providing technical advice on renewable energy projects to developers in topics such feasibility studies, LCOE, technology selection, turbine RFQs and RFPs, turbine bid evaluations, technology benchmarking, CAPEX and OPEX estimates, and decommissioning assessments.


**Academic qualifications**

M.S. Wind Energy, Danmarks Tekniske Universitet, 2004

B.Eng. Mechanical Engineering, Universidad de Los Andes, 2001

| Languages | Reading level | Writing level | Speaking level |
|---|---|---|---|
| **Spanish** | Native | Native | Native |
| **English** | Advanced | Advanced | Advanced |
| **French** | Beginner | Beginner | Intermediate |
| **Danish** | Beginner | Beginner | Intermediate |

**Career profile**

<u>DNV GL – Energy, Advisory Americas (formerly GL Garrad Hassan)</u>

Senior Project Manager, Engineering, 2016-present

- Serves as part of the Owner's Engineering team, providing technical advice on renewable energy projects to project developers in topics such as feasibility studies, LCOE, technology selection, turbine RFQs and RFPs, turbine bid evaluations, technology benchmarking, CAPEX and OPEX estimates, decommissioning assessments.

Mexico Country Manager, 2009-2016

- Lead a team of wind and solar specialists who provided support to developers, banks, investors, and lenders for Mexico, Central América, Cuba, and Dominican Republic.

<u>Iberdrola Renewables</u>

Wind Energy Analyst, 2004-2009

- Responsible for execution, coordination, and delivery of wind energy studies (wind potential and suitability) of onshore wind turbines in approximately 10 European countries for nearly 5000 MW
- Utilized detailed technical knowledge and skills in anemometry, wind flow, computational models, Geographic Information Systems (GIS), and maps

- Participated in the development of methodologies and unification of criteria for technical wind studies with international companies of Iberdrola Renewables

Risø National Laboratory

Research Assistant, Blade Modelling, 2004

- Performed modelling of wind turbine blades by means of finite element analyses: buckling, non-linear models, parametric studies of imperfections, etc.

**Publications and presentations**

D. Pardo Tovar, Finite Element Analysis of the Cross-section of Wind Turbine Blades; A Comparison between Shell and 2D-Solid Models, Wind Engineering, vol. 29, no. 1 (2005)

I. Antoniou, T. Pedersen, D. Pardo, Site Calibration: Wind speed regression versus wind speed ratio, The Science of making Torque from Wind, DUWind, Delft University of Technology, ISBN 90-76468-10-9 (19-21 April 2004)

I. Antoniou, T. Pedersen, C. Chekuri, D. Pardo, Site Calibration Analysis: Høvsøre Test Site, Risø National Laboratory internal report: Risø-I-2018 (July 2004)

DNV·GL

**PREVAILING WIND PARK, LLC**

# Decommissioning Cost Analysis

**sPower Development Company, LLC**

**Document No.**: 10096813-HOU-R-01
**Issue:** D**, Status:** DRAFT
**Date:** 10 August 2018

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| Prepared by: | Verified by: | Approved by: |
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| D | 10 August 2018 | Removal depth update | D. Pardo | K. Kallevig-Childers | K. Kallevig-Childers |

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## List of abbreviations

| **Abbreviation** | **Meaning** |
|---|---|
| BOP | Balance of Plant |
| COD | Commercial Operation Date |
| DNV GL | DNV KEMA Renewables, Inc. |
| GRP | Glass Reinforced Plastic |
| O&M | Operations and Maintenance |
| WTG | Wind Turbine Generator |

# EXECUTIVE SUMMARY

sPower Development Company, LLC ("sPower" or the "Sponsor") retained DNV KEMA Renewables, Inc. ("DNV GL") to perform a decommissioning analysis for Prevailing Wind Park, LLC of the Prevailing Wind Park Energy Facility (the "Project") to be located in Bon Homme, Charles Mix and Hutchison counties, 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 and do not account for inflation.

The Project is spread across Bon Homme, Charles Mix and Hutchison counties, South Dakota, approximately 38 miles northwest of the city of Yankton. sPower has indicated that the Project is intended to consist of 57 GE 3.8-137 wind turbine generators (WTG) with a total rated output of 216.6 MW; one project substation; one Operations and Maintenance building; a 115 kV transmission line; and four met towers as well as associated infrastructure. The turbines will be mounted on 110 meter (m) tubular steel towers. The Project is anticipated to commence commercial operations in 2019. Per sPower's request, it is assumed that decommissioning of the Project will take place 30 years after the start of commercial operations [1].

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 mass and volume ratios for turbine components are derived from previous DNV GL studies, Sponsor documentation, 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 on the next page. 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** | $51,540 | $13,790 |
| **Total for Project (57 WTGs)** | $2,938,000 | $786,000 |

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 | 5,187,000 | 4,423,000 | 855,000 | 10,465,000 | (11,462,000) | (997,000) |
| Collection System | 1,033,000 | 349,000 | 31,000 | 1,413,000 | (1,324,000) | 89,000 |
| High voltage substation | 261,000 | 73,000 | 14,000 | 348,000 | (453,000) | (105,000) |
| Transmission Line | - | - | - | - | - | - |
| Access roads & Crane Pads | 550,000 | 619,000 | 34,000 | 1,203,000 | (369,000) | 834,000 |
| Met Masts | 37,000 | 6,000 | 1,400 | 44,400 | (8,400) | 36,000 |
| Mobilization/Soft Costs | 929,000 | - | - | 929,000 | - | 929,000 |
| *Project Totals* | 7,997,000 | 5,470,000 | 935,400 | 14,402,400 | (13,616,400) | 786,000 |
| **Total per WTG [$]** | | | | | | **13,790** |
| **Total Project (57 WTGs) [$]** | | | | | | **786,000** |

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

sPower Development Company, LLC ("sPower" or the "Sponsor") retained DNV KEMA Renewables, Inc. ("DNV GL") to perform a decommissioning analysis for Prevailing Wind Park, LLC of the Prevailing Wind Park Energy Facility (the "Project") to be located in Bon Homme, Charles Mix and Hutchison counties, South Dakota. The Project is intended to consist of 57 GE 3.8-137 WTGs on 110 m towers with a total rated output of 216.6 MW and associated infrastructure.

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

This report makes the following key assumptions:

- 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; and
- Decommissioning includes removal of WTGs, electrical cabling, electrical components, roads, and any other associated facilities down to 4 feet below grade from the natural surface of the property except for collector cables as stated below.

  Additionally:

  - The WTG foundations will have only 4 feet of the pedestals and concrete transformer pads removed and the remainder of the spread footing, which will be below this 4 feet grade, will be abandoned in place.
  - sPower has advised DNV GL that the underground portion of the collection system, approximately 64.8 miles of underground cabling, will be buried below 4 feet grade [1]. This report assumes that the cables *will* be removed during decommissioning.
  - Approximately 16.9 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.
- At the Sponsor's request, no transmission line has been included in this assessment.

This report does not consider the time value of money; the results should therefore be adjusted to represent the inflated costs at the time of decommissioning (e.g., annual escalation). It should also 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 a legal or commercial perspective, which should 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 General assumptions

DNV GL has assumed that, on average, one 700 or 800-ton tracked crane will dismantle one turbine every 1.5 days (including time for crane movements from turbine to turbine and some minor weather delays). The Project layout provided by the Sponsor which included crane paths was analyzed for crane walking impediments to estimate crane teardown requirements. Two base cranes 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.

### 1.1.1 Bon Homme County Requirements

DNV GL considered the Bon Homme County requirements for decommissioning [3], which were provided by sPower. The requirements relevant to this analysis include the following:

> *(d) Decommissioning Requirements. Decommissioning and site restoration includes dismantling and removal of all towers, turbine generators, transformers, overhead and underground cables, foundations, buildings and ancillary equipment to a depth of forty-two (42) inches; and removal of surface road material and restoration of the roads and turbine sites to substantially the same physical condition that existed immediately before construction of the LWES. To the extent possible, the site must be restored and reclaimed to the topography and topsoil quality that existed just prior to the beginning of the construction of the commercial wind energy conversion facility or wind turbine. Disturbed earth must be graded and reseeded, unless the landowner requests in writing that the access roads or other land surface areas be retained.*

According to sPower, there are no decommissioning requirements in Charles Mix or Hutchinson Counties.

## 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 accounted for a lay-down yard of 48,311 $m^2$ to house the office trailers, staff parking and facilities for mobilization and demobilization based on information provided by the Sponsor [1]. 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.

**Table 1-1 Mobilization and soft cost assumptions**

| Item | Quantity |
|---|---|
| Number of main cranes needed (wheeled) | 1 |
| Number of main crane tear-downs needed | 1 |
| Number of base cranes needed | 2 |
| Number of base crane tear-downs needed | 1 |
| Decommissioning contractor's lay-down yard size [$m^2$] | 48,311 |
| 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** | **$929,000** |

(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.

## 1.3 Schedule

It is assumed that the decommissioning program would be 17 to 20 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 9 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 is 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, 57 turbines are to be removed, consisting of 3.8 MW nacelles, with five-section, 110-m steel towers, and 67.2-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 bigger crane would be required on site for approximately 12 to 15 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.

sPower has advised that the site will be remediated to 4 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 this criterion. 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) | 22,000 |
| Dismantle nacelle (drive train and generator included) | 22,000 |
| Dismantle tower sections, internals included | 36,000 |
| Dismantle pad-mounted transformer | 4,000 |
| Remove turbine foundation (1) | 7,000 |
| **Total per WTG** | **91,000** |
| **Total for Project (57 WTGs)** | **5,187,000** |

(1) 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 80% 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, per the Bon Homme County requirements and as requested by the Customer. Due to the relatively high value of conductors, removal and resale of the underground cables may yield a positive return to the Project. sPower has requested DNV GL to calculate this potential revenue and include it in the net decommissioning cost calculations. Therefore, it was assumed that all underground cabling will be removed and trenches restored.

### 2.2.1 Underground Collection System

According to sPower, the Project collection system will be composed of 64.8 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 sPower, 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

The Sponsor has advised that the Project will be equipped with one 34.5/115 kV, 225 MVA transformer located at the project substation. The remaining portion of the Project high-voltage (HV) substation is assumed to include typical equipment seen in North American wind power project substations for projects of this size, including grounding transformers, bus bars, relay switches, circuit breakers, air disconnect switches, capacitor banks, reactor banks and a control building. It is assumed that a dead-end structure will also be present.

The interconnection switchyard for the Project has not been considered in the 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 high voltage substations.

**Table 2-2 Costs to disassemble Project substation**

| Item | Estimate ($) |
|---|---|
| Preparation | 8,000 |
| Dismantle HV equipment | 25,000 |
| Dismantle and prep. main transformer for shipment (each) | 17,000 |
| Remove control/O&M building | 115,000 |
| Remove foundations | 52,000 |
| Large machinery hire | 15,000 |
| Small machinery hire | 13,000 |
| Reclaim and reseed | 16,000 |
| **Total** | **261,000** |

## 2.4 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 16.9 miles of roads will be remediated. Based on Sponsor information, DNV GL has additionally assumed that 57 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.

## 2.5 Meteorological masts

Four permanent 110-m meteorological (met) masts are to be installed at 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 mast, 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.

## 2.6 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 | 5,187,000 |
| Collection system | 1,033,000 |
| HV substation | 261,000 |
| Transmission line | - |
| Access roads | 550,000 |
| Met Masts | 37,000 |
| Mobilization & soft costs | 929,000 |
| **Total Project Disassembly Cost** | **7,997,000** |

# 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 km (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[1]. 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 | 10,000 |
| Tower sections | 50,000 |
| Internals | 1,000 |
| Transformer | 1,000 |
| Crushed foundation (29 $m^3$) | 600 |
| **Total per WTG** | **77,600** |
| **Total for Project (57 WTGs)** | **4,423,000** |

[1] DNV GL identified more than four in the Sioux Falls city area.

## 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, 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 foundation rubble and 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 km. It is assumed that local dump truck loads are 12 $yd^3$ in capacity.

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

**Table 3-2 Project substation removal costs**

| Substation component | Estimate ($) |
|---|---|
| HV equipment | 10,000 |
| Main transformer(s) | 10,000 |
| Control/O&M building(s) | 31,000 |
| Dead-end structures | 10,000 |
| Crushed foundations (local transport) | 8,000 |
| Yard gravel (local transport) | 4,000 |
| **Total removal costs for HV substation(s)** | **73,000** |

## 3.4 Site access roads

For the purpose of removal calculations and at the Sponsor’s request, the Project’s 16.9 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 12 $yd^3$ and all load trips are assumed to be local. The results are reported in Table 3-3.

## 3.5 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 the four meteorological masts to an appropriate disposal, salvage or rework facility. The results are reported in Table 3-3 below.

## 3.6 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 | 4,423,000 |
| Collection system | 349,000 |
| HV substation | 73,000 |
| Transmission line | - |
| Access roads | 619,000 |
| Met Masts | 6,000 |
| **Total Project removal cost** | **5,470,000** |

# 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 in this plan.
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 a 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 were considered. 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 ratios 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 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 | (10,000) |
| Hub + blade steel | 8,500 |
| Nacelle/hub GRP | (3,500) |
| Nacelle bedplate | 17,000 |
| Main shaft | 2,000 |
| Gearbox | 7,000 |
| Generator | 24,000 |
| Tower steel sections | 76,000 |
| Internals | 18,000 |
| Turbine transformer | 12,500 |
| Crushed foundation | (1,000) |
| **Net total per WTG** | **151,000** |
| **Net total for Project (57 WTGs)** | **8,607,000** |

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 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 GE 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 57 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 | 579,000 | 42,000 |
| Generator | 15 | 765,000 | 360,000 |
| Blades | 2 | 184,000 | (20,000) |
| Pitch bearing | 12 | 135,000 | - |
| Power converter | 21 | 200,000 | - |
| Main bearing | 9 | 288,000 | - |
| Transformer | 28 | 581,000 | 350,000 |
| **Gross Resale Total [$]** | | **2,732,000** | |
| **Minus Loss of Scrap [$]** | | | **(732,000)** |
| **Net Resale Total [$]** | | | **2,000,000** |

(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 194 miles of conductor (3 phases) along with 64.8 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, 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 electrical equipment. Yard 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 yard also contains aggregate fill that would 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.

DNV GL considers that there is a resale market for the substation transformer. 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 Site access roads

For the purpose of removal and salvage calculations and at the Sponsor's request, the Project's 16.9 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.

## 4.6 Meteorological masts

Although it is possible that the met masts could be dismantled, resold and reused at a different location, a 30-year old mast has very limited reinstallation value. 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 below.

## 4.7 Salvage – disposal conclusions

The following table 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 | (855,000) | 9,462,000 |
| Collection System | (31,000) | 1,324,000 |
| HV Substation | (14,000) | 301,000 |
| Transmission Line | - | - |
| Access Roads | (34,000) | 369,000 |
| Met Masts | (1,400) | 8,400 |
| **Total Project Salvage Return** | **(935,400)** | **11,464,400** |

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 | 5,187,000 | 4,423,000 | 855,000 | 10,465,000 | (9,462,000) | 1,003,000 |
| Collection System | 1,033,000 | 349,000 | 31,000 | 1,413,000 | (1,324,000) | 89,000 |
| HV Substation | 261,000 | 73,000 | 14,000 | 348,000 | (301,000) | 47,000 |
| Transmission Line | - | - | - | - | - | - |
| Access Roads & Crane Pads | 550,000 | 619,000 | 34,000 | 1,203,000 | (369,000) | 834,000 |
| Met Masts | 37,000 | 6,000 | 1,400 | 44,400 | (8,400) | 36,000 |
| Mobilization/Soft Costs | 929,000 | - | - | 929,000 | - | 929,000 |
| *Project Totals* | 7,997,000 | 5,470,000 | 935,400 | 14,402,400 | (11,464,400) | 2,938,000 |
| **Total per WTG [$]** | | | | | | **51,540** |
| **Total for Project (57 WTGs) [$]** | | | | | | **2,938,000** |

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 | 5,187,000 | 4,423,000 | 855,000 | 10,465,000 | (11,462,000) | (997,000) |
| Collection System | 1,033,000 | 349,000 | 31,000 | 1,413,000 | (1,324,000) | 89,000 |
| High voltage substation | 261,000 | 73,000 | 14,000 | 348,000 | (453,000) | (105,000) |
| Transmission Line | - | - | - | - | - | - |
| Access roads & Crane Pads | 550,000 | 619,000 | 34,000 | 1,203,000 | (369,000) | 834,000 |
| Met Masts | 37,000 | 6,000 | 1,400 | 44,400 | (8,400) | 36,000 |
| Mobilization/Soft Costs | 929,000 | - | - | 929,000 | - | 929,000 |
| *Project Totals* | 7,997,000 | 5,470,000 | 935,400 | 14,402,400 | (13,616,400) | 786,000 |
| **Total per WTG [$]** | | | | | | **13,790** |
| **Total Project (57 WTGs) [$]** | | | | | | **786,000** |

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 REFERENCES

[1] Email from B. Canty, sPower, to K.Kallevig-Childers, DNV GL, providing Project assumptions, 7 June 2018.

[2] Email from B. Canty, sPower to D. Pardo, DNV GL regarding project infrastructure, 20 June 2018.

[3] Email from B. Canty, sPower, to K. Kallevig-Childers, DNV GL, providing Bon Homme County decommissioning requirements, 15 May 2018.

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

# APPENDIX A – CUSTOMER PROVIDED INPUTS

| | | |
|---|---|---|
| **1000** | **Special requirements** | |
| 1001 | Decommissioning requirements applicable to the Project | Bon Homme County Requirements |
| **1100** | **Project Basics** | |
| 1101 | Wind Power Plant Name | Prevailing Wind Park Energy Facility |
| 1102 | Construction Status | ntp 4th quarter 2018 |
| 1103 | General Location | South Dakota |
| 1104 | No. Wind Turbines | 57 |
| 1105 | Make and Model of Wind Turbine | GE 3.8-137 3.8 MW |
| 1106 | Hub Height | 110 m |
| 1107 | Project Capacity | 216.6 MW |
| 1108 | Project Design Life (civil, turbine, electrical and financial) | 30 years |
| 1109 | Decommissioning to Occur After Which Project Year | 30 |
| 1110 | No. of Substations to Remove | 1 |
| 1111 | No. of main project transformers | 1 |
| 1112 | No. of control/O&M buildings to Remove | 1 |
| 1113 | Length of Underground Collection System to Remove | 104.3 km |
| 1114 | Length of Overhead Collection System to Remove | 0 |
| 1115 | Length of Transmission Line to Remove | 0 |
| 1116 | Length of Project Access Roads to Reclaim | 27.1 km |
| 1117 | No. of Meteorological Towers to Remove | 4 |
| 1118 | Average Height of Met Towers | 110 m |
| 1119 | Met tower type | Self-support |
| 1120 | Depth of removal | 4 feet |
| **1200** | **Additional Information** | |
| 1201 | COD date | 2019 |
| 1202 | Estimated Annual P50 Production Capacity Factor | Confidential |
| 1203 | Main step-up transformer voltage | 34.5kV/115kV |
| 1204 | Main step-up transformer rating | 225 MVA |
| 1205 | No. of Transmission Line Steel Poles | N/A |
| 1206 | No. of Transmission Line Wood Poles | N/A |
| 1207 | Project Layout file name | Prevailing_Winds_LTE_v180425_For_DNV.kmz |
| 1208 | Number of tower sections per Wind Turbine | 5 |
| 1209 | Site plan (incl. Electrical layout) | Prevailing_Winds_LTE_v180425_For_DNV.kmz |
| 1210 | Construction schedule | Not provided |
| 1211 | As built or issued for construction (IFC) drawings (civil & electrical) | Not provided |
| 1212 | Contracts in place or existing quotes/price | Not provided |

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