SAND2013-10227P

MUIR DATA SYSTEMS, INC.

# Wind Industry Segments & CMMS Value Propositions

## Muir Data Systems / Wind Energy Technology
## Sandia National Laboratories

**James Parle, Jonathan Gibson, Chad Reese**

**11/12/2013**



# Contents

Background ..... 3
1.0 Executive Summary ..... 4
2.0 Introduction ..... 8
3.0 CMMS Overview ..... 9
3.1 Wind Industry Work Order Information Flow Survey ..... 9
3.2 Wind CMMS ..... 10
3.3 Switching Costs ..... 11
3.4 Oil & Gas CMMS ..... 12
4.0 Segments Overview ..... 18
4.1 Independent Service Providers ..... 18
4.2 Owner Operators ..... 20
4.3 Original Equipment Manufacturers ..... 24
5.0 CMMS Value Proposition ..... 29
5.1 ISP CMMS Value Propositions ..... 30
5.2 OO CMMS Value Propositions ..... 31
5.2 OEM CMMS Value Propositions ..... 32
6.0 Conclusion ..... 34

## Figures

Figure 1: Survey Work Order Detailed Summary ..... 9
Figure 2: Wind CMMS Overview ..... 10
Figure 3: CMMS Enabled Transition from Reactive to Predictive Maintenance ..... 11
Figure 4: Rodgers Diffusion of Innovation Curve ..... 12
Figure 5: Siemens Oil & Gas Product Overview ..... 14
Figure 6: Siemens Oil & Gas Summary of Benefits ..... 14
Figure 7: TabWare Mobile ..... 16
Figure 8: TabWare Maintenance Analytics Dashboard ..... 16
Figure 9: Distribution of ISP Services ..... 19
Figure 10: O&M Costs per MW over Time by Region ..... 21
Figure 11: O&M Costs Based on Plant Commission Year ..... 21
Figure 12: Top 20 Global OOs as of 2012 ..... 22
Figure 13: Additional Services Offered by OOs ..... 22
Figure 14: 2008 - 2012 Top 7 Global OEM Market Share ..... 25
Figure 15: US OEM Market Share ..... 25
Figure 16: Proposed Offshore Wind Projects ..... 27
Figure 17: CMMS Benefits Based on Survey Data ..... 29
Figure 18: Example Financial CMMS Value Propositions ..... 30

## Tables

Table 1: Industries That Use CMMS ..... 13
Table 2: Aberdeen Group Best-in-Class Maintenance Management Comparison ..... 15
Table 3: Summary of ISP Findings ..... 20
Table 4: Summary of OO Findings ..... 23
Table 5: Top Ten Manufacturers by Global Commissioned Capacity in 2012 ..... 24
Table 6: Forecasted US Annual Wind Capacity Additions (MW) ..... 26
Table 7: 2012 Annual and Cumulative Capacity Summary ..... 26
Table 8: Summary of OEM Findings ..... 28
Table 9: ISP CMMS Value Propositions Summary ..... 31
Table 10: OO CMMS Value Propositions Summary ..... 32
Table 11: OEM CMMS Value Propositions Summary ..... 33

## Background

Through a wide variety of activities and interactions, Sandia National Laboratories has observed limited adoption of electronic work orders in the wind industry. To explore the value of electronic work orders in various segments of the wind industry, the Continuous Reliability Enhancement for Wind (CREW) team at Sandia commissioned Muir Data Systems to identify and summarize the segments of the wind industry and to identify the value propositions each segment would experience from a Computerized Maintenance Management System (CMMS) that handles electronic work orders. This report summarizes those ideas, including an overview of CMMS, and is one of the steps in driving a culture change toward the electronic collection of accurate work order data and the development of a "full data picture" for the wind industry.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# 1.0 Executive Summary

In the wind industry, management of turbine maintenance typically incorporates a mix of analog and digital solutions that can be unwieldy and inefficient. Computerized Maintenance Management Systems (CMMS) have the potential to considerably streamline the existing work order information processes in the wind industry.

This paper focuses on four key points:

1) What is CMMS and how has it been used in other industries to reduce maintenance costs?
2) What are the characteristics of the three primary industry segments (Independent Service Providers - ISPs, Owner Operators - OOs, and Original Equipment Manufacturers - OEMs)?
3) What is the value proposition of CMMS for the different company and employee types?
4) What can be done to make CMMS adoption in the wind industry a priority?

A series of summarizing text and tables that address these four topics follow.

Oil and gas has many similar O&M challenges as the wind industry Research indicates that other industries have benefited from having CMMS readily available and the wind industry will likely be no different.

**Table 1: Industries That Use CMMS**

| | | | |
|---|---|---|---|
| Food & Beverage | Industrial Manufacturing | Mining | Chemical Manufacturing |
| Facilities Maintenance | Automotive | Federal, State, & Local Government | Electricity Generation |
| Water & Wastewater | Forest Products | Amusement Parks | Ports |
| Wholesale & Retail | Hospitals | Aviation | Data Centers |
| Sports Arenas | Telecommunications | Schools & Universities | Oil & Gas |

ISPs tend to be smaller privately held companies that focus on a mix of long term operations and maintenance (O&M) contracts in addition to specialty O&M work. The specialty side of ISPs really separates them from other organization types because the companies often have extensive knowledge within a specific subsystem domain. ISPs tend to have less advanced work order systems than larger wind organizations such as OOs and OEMs.

**Table 2: Summary of ISP Findings**

| **Metric** | **Value** | **Notes** |
|---|---|---|
| Typical Number of Employees | 25 – 300 | Based on data and industry experience |
| Average Number of Employees | 160 | Limited employee data available (primary research) |

| | | |
|---|---|---|
| Average Number of Locations | 6 | A few outliers had a significant number of locations |
| Median Number of Locations | 3 | More accurate than average given few large outlier ISPs |
| International Locations | 44% | All ISPs had US locations |
| Wind Industry Only ISPs | 60% | A number of ISPs are part of a parent company that services other sectors |
| ISPs using CMMS | 12% | Limited adoption of advanced maintenance technology |

OOs represent the financial "hub" of the wind industry and the twenty-five biggest OOs in the world manage about a quarter of the world's wind energy. On average O&M costs make up 20% - 25% of the total levelized cost of wind turbine ownership and this is the number that CMMS seeks to reduce. The key to broad adoption is to develop CMMS offerings that fulfill the needs of the highly varied OO market while being accessible at a sensible price point.

**Table 3: Summary of OO Findings**

| Metric | Value | Notes |
|---|---|---|
| Cost per MW Installed | $2M | Typical for current wind technology |
| Power Purchase Agreement (PPA) Duration | 15 – 25 years | Standard is 20 years |
| Typical O&M Turbine Costs | 20% - 25% | Average levelized cost of ownership (depends on age, region, parts availability, etc.) |
| New O&M Turbine Costs | 15% | Turbines recently out of warranty |
| End of Life O&M Turbine Costs | 35% | Turbines approaching dismantling or repower |
| Top 25 OOs Average Number of Plants | 82 | The sum of the plants owned by the top 25 OOs is ~27% of the world's wind energy |
| Top 25 OOs Average Capacity per Plant | 52 MW | Size of typical wind plant owned by OOs |
| Top 6 OOs MW Managed for each Employee | 7.5 MW / Employee | Includes all staff associated with wind side of business |
| Estimated OOs Worldwide | 2,100+ | Large diffuse market of OOs |
| Additional OO Company Functions Average | 3.5 | Additional functions included product development, public utilities, asset servicers, energy traders, transmission, and energy storage |

OEMs are typically large multinational corporations that specialize in manufacturing wind turbines. Industry factors such as the Production Tax Credit (PTC), a vast number of wind turbines coming out of warranty, and increased competition from Chinese manufacturers have increased the emphasis on extended warranty and O&M service contracts. The offshore wind market is emerging in the US, and it is unclear which manufacturers are going to be the leaders. CMMS has the potential to reduce maintenance warranty costs, improve research and development of new wind turbine designs, and will likely be an important part of off-shore wind and its intrinsically difficult O&M challenges.

**Table 4: Summary of OEM Findings**

| Metric | Value | Notes |
|---|---|---|
| Top OEMs 2012 | GE/Vestas | Tied for first place with 11.8% of global installed capacity |
| Top 7 OEMs Global Market Share Reduction 2008 - 2012 | 72% to 60% | Top 7 OEMs have seen a reduction in annual sales as a result of increased competition |
| Top 10 OEMs 2012 Global Market Share | 70% | 7 out of 10 turbines were sold by the top 10 OEMs, which include four Chinese companies |
| 2012 New US Wind Capacity | 13,131 MW | Biggest year for wind in US ever, surpassed all other types of new installed capacity (cumulative capacity ~60 GW) |
| US OEM increase 2005 – 2012 | 4 to 11+ | There are now eleven or more OEMs selling turbines |
| OEM Change in Emphasis | O&M | OEMs are placing greater value on extended warranty and O&M service contracts |
| Average Capacity Forecast 2013, 2014, 2015 | 3,380, 8,160, 4,625 (MW) | Production Tax Credit (PTC) leading to reduction in 2013 forecasted new capacity |

Value propositions are the value that a customer believes can be obtainable from a product or service, and is the baseline reason why a customer buys a product or service from a seller. Value propositions can apply to individual employees, parts of the company, entire organizations, customer accounts, and/or the products or services offered.

Table 5: ISP CMMS Value Propositions Summary

| Employee | Primary | Secondary | Tertiary |
|---|---|---|---|
| Technician | Increased employee field and office/hotel work efficiency | Trouble-free workplace communication | Proper physical risk management |
| Manager | Streamlined human resource management | Better employee accountability | Data driven maintenance/ repair decision making |
| Executive | Superior customer satisfaction | Enhanced financial accountability | Competitive advantage over other ISPs and OEMs |

Table 6: OO CMMS Value Propositions Summary

| Employee | Primary | Secondary | Tertiary |
|---|---|---|---|
| Technician | Higher work order fidelity | Precise time management | Appropriate compensation distribution |
| Manager | Improved maintenance forecasting | Upgraded inventory management | Increasingly accurate job performance evaluation |
| Executive | Better return on investment | Accurate regulatory compliance | More detailed financial accountability |

Table 7: OEM CMMS Value Propositions Summary

| Employee | Primary | Secondary | Tertiary |
|---|---|---|---|
| Technician | Confident real-time decisions | Insightful resource allocation | Improved job satisfaction |
| Manager | Higher office productivity | Improved accountability | Greater customer transparency |
| Executive | Informed product improvement | Substantiated marketing messaging | Predictable financial forecasting |

CMMS has proven its value in a variety of industries outside of wind for the past thirty years. Analysis suggests that all segments of the wind industry stand to gain from adoption of CMMS. In order to truly actualize the value propositions discussed, it will be essential that the industry put forth a concerted effort towards moving to digital CMMS in a manner that minimizes switching costs and recognizes the unique ways in which CMMS can be tailored to wind.

## 2.0 Introduction

In the roughly thirty years since their introduction, Computerized Maintenance Management Systems (CMMS) have proven useful tools for maintenance teams working in a variety of industries. For these teams, and indeed the rest of the value chain of which they are a part, the benefits of CMMS have been far-reaching. These benefits underlie the "value proposition" of CMMS – the perceived advantages that users receive from the system at the individual and/or company level. It is the value proposition that determines whether an individual company, or even an industry as a whole, is likely to adopt a CMMS.

This paper investigates the value proposition of CMMS in the wind industry. Although some wind companies have incorporated CMMS, historically the wind industry has been slow to adopt these platforms. Many of the current industries that use CMMS are more mature and often operate in more accessible locations than wind plants, making adoption of CMMS notably easier. Modern mobile technology, Cloud-based servers, and wireless connectivity, however, are beginning to bridge this gap, making CMMS useful even given the constraints of the wind industry. These advancements come at an opportune time, as the wind industry is growing rapidly and a large number of wind turbines are coming out of warranty, making properly managed O&M a new priority. At this pivotal point, it is important to evaluate the unique benefits CMMS has to offer specifically to wind.

The wind industry is divided into three primary segments, which include Independent Service Providers (ISPs), Owner Operators (OOs), and Original Equipment Manufacturers (OEMs), and each segment stands to benefit from CMMS in different ways. This paper examines the value proposition of CMMS to the primary segments, and the employees who work within each segment, with a focus on technicians, managers, and executives.

The first step to understanding the complete value chain that CMMS can provide to the wind industry is to define the type of companies typically found within each segment. Research was done to compile detailed information regarding companies that represent a cross section of the wind industry. Using this data, the value proposition of CMMS specific to each of three employee types is explained for each company type. An emphasis is placed on how CMMS specifically developed for the wind industry can help minimize switching costs while solving many of the historical limitations that have led to poor CMMS adoption in the wind industry.

The information presented here shows that CMMS can add value throughout the work order information flow. A better understanding of this potential should encourage greater adoption of CMMS in the wind industry.

In summary, this paper focuses on four key points:

1) What is CMMS and how has it been used in other industries to reduce maintenance costs?
2) What are the characteristics of the three primary industry segments (ISPs, OOs, OEMs)?
3) What is the value proposition of CMMS for the different company and employee types?
4) What can be done to make CMMS adoption in the wind industry a priority?

## 3.0 CMMS Overview

CMMS is the acronym used to describe maintenance management software platforms that handle a variety of maintenance related functions. These may include scheduling, work order management, inventory, budgeting, reporting, and other functions ranging from basic to highly complex. Currently, wind industry maintenance management typically uses a mix of analog and digital solutions which can be unwieldy and inefficient.

### 3.1 Wind Industry Work Order Information Flow Survey

Based on previous industry survey work performed by Muir Data Systems in the recently published publically available document titled "Wind Industry Work Order Information Flow Survey," the typical work order information flow in the wind industry was found to be as follows:[1]

> "The average work order information flow starts with a paper form which contains "Moderately Accurate" data being transcribed by the office into a "Somewhat Digital" hand-off to other office systems. The now "Digital" work order is stored on a server in a manner that is often not searchable and then reports, which typically take 30 minutes to create, are generated using templates in Excel. These reports are "Sometimes" used to help inform future maintenance decisions and the industry is "Moderately Satisfied" with this maintenance management scenario."

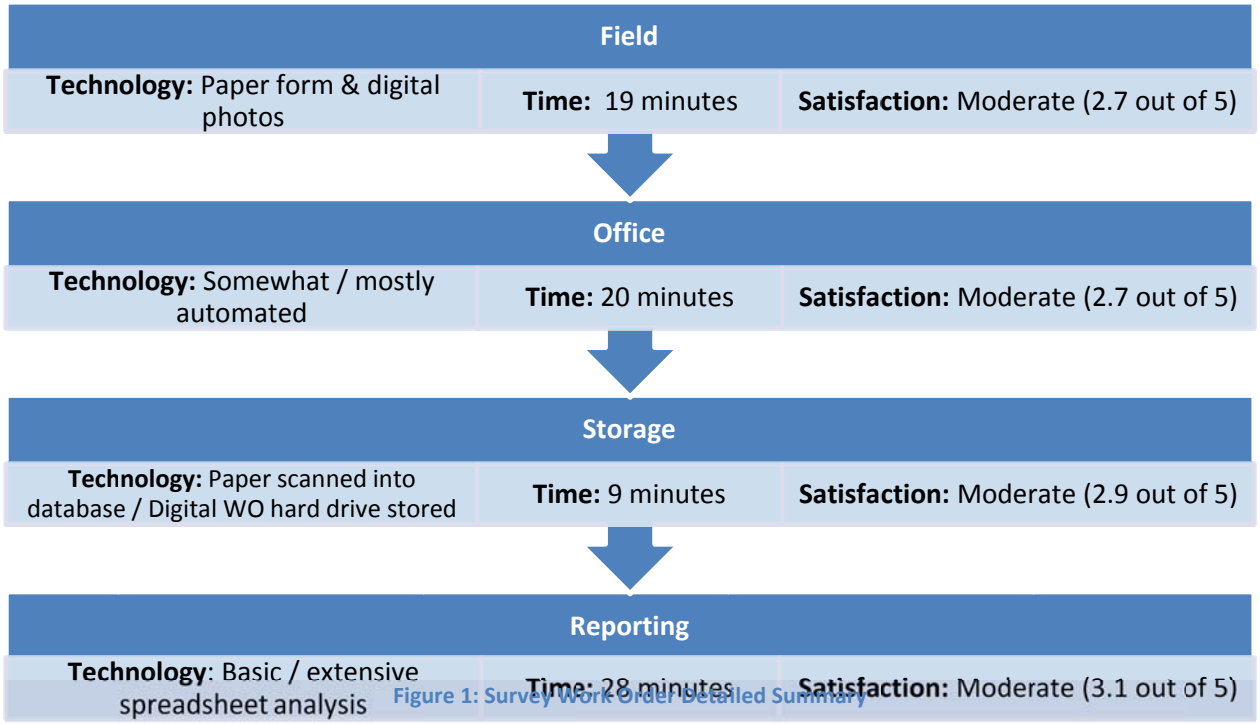



Figure 1: Survey Work Order Detailed Summary

[1] Wind Industry Work Order Information Flow Survey. Muir Data Systems, November 2013.

A more detailed summary of the work order information flow as determined by the Muir Data Systems Industry Survey is presented in Figure 1. The figure provides a graphical representation of the survey results regarding technology, time, and satisfaction for each of the four steps of a simplified work order information flow process. The average current work order management approach leaves some room for improvement.

The wind industry as a whole is relatively new. As a result of the rapid growth of the wind industry, properly managing O&M is becoming increasingly challenging. As the installed base continues to grow and the number of aging wind turbines coming out of warranty increases from its already all-time high, this challenge only increases. OOs are now making decisions regarding how best to manage the O&M of assets that have a twenty year life expectancy.

Correctly implemented CMMS can provide a level of maintenance management transparency and peace of mind that has not historically been available. By making the transition not only to CMMS, but CMMS developed directly for the wind industry, the work order information flow has the potential to be less time consuming, have higher accuracy, improve customer satisfaction, quickly generate actionable reports, and reduce total cost of ownership while enhancing uptime. It is possible that the demanding nature of wind maintenance management can largely be addressed with a modern dedicated software solution.

## 3.2 Wind CMMS

One of the key attributes of a high performing CMMS in the wind industry is that it is designed to be digital throughout the entire information flow (Figure 2). Being entirely digital enables a velocity of actionable information not previously available in most wind maintenance organizations. In order to make this possible, work orders have to be completed using a mobile electronic device such as a tablet or smartphone in the field, and the data synced to a server where it can be quickly accessed by the office. Pertinent information can then be automatically handed off to other digital systems such as inventory management, finance, Supervisory Control and Data Acquisition (SCADA) data software packages, and Enterprise Resource Planning (ERP).

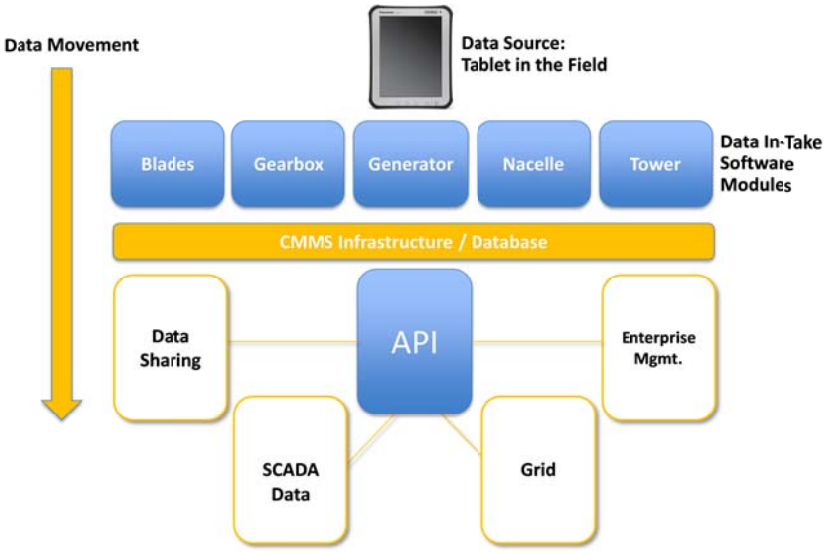



Figure 2: Wind CMMS Overview

The two most sensitive parts of a wind CMMS are how data is recorded in the field and how quickly actionable reports can be generated. The field interface needs to be built specifically for wind technicians who have little time to fill out detailed paperwork, digital or otherwise. The data in-take interface needs to be smart and task specific to the point that high quality field data can be recorded in equal or less time than what is required to complete a paper form.

The digital interface also has the benefit of being easily able to incorporate data quality checks where data that appears to be outside of regular bounds can be flagged and double checked before leaving the wind turbine. Furthermore, technicians could have access to relevant and up-to-date digital instruction manuals, technical schematics, and past work orders to assist in real-time trouble shooting in the field.

Similarly, the reporting interface must be easy enough to use for any potential employee in a wind company with little to no previous instruction. A wind specific CMMS also has the potential to incorporate proprietary algorithms that synthesize a breadth of work order data into a focused report that requires little additional interpretation before being actionable.

Digitization also affords the potential to add CMMS data to SCADA data, and more recently, data from specialized sensors such as Condition Monitoring Systems to enable increasingly data driven maintenance decisions. By making historical work order data more accessible, maintenance decisions are less dependent on technician "tribal knowledge." The technician's intuitive sense of maintenance situations can be extremely useful, but relying purely on "tribal knowledge" can become problematic in an industry that tends towards high employee turnover.

## 3.3 Switching Costs

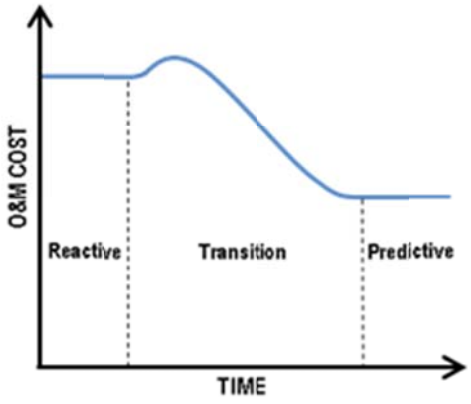



Figure 3: CMMS Enabled Transition from Reactive to Predictive Maintenance

The introduction of a new CMMS to an established wind organization can initially be challenging. As suggested by Figure 3, there is often a temporary increase in cost during the transition to the new system. A small portion of this cost is associated with signing up for the new software solution with the vast majority resulting from a disruption of business as usual.

Evaluating and changing well established work order management systems while simultaneously being open for business can be chaotic. Wind CMMS as opposed to generic CMMS offerings will likely reduce switching costs while also providing a better long term fit to wind O&M organizations.

Transparency of process is essential for the successful implementation of CMMS. In order for the new system to take root, the entire organization must clearly understand how day-to-day activities are going to change. Upper management must champion the effort by clarifying expectations of the transition

while emphasizing the long term benefits of CMMS despite the near term pitfalls of introducing the new system. Persevering through this transition can yield reduced O&M costs, increasingly predictive maintenance, and improved employee satisfaction. Not all companies will succeed with their initial effort to implement a CMMS, however in the long run these digital tools will more than likely become the norm and be required to remain competitive.

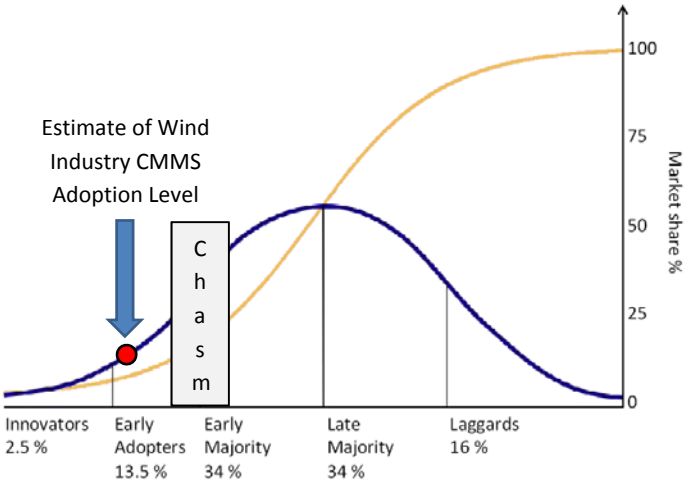



**Figure 4: Rodgers Diffusion of Innovation Curve**
Source: http://en.wikipedia.org/wiki/Everett_Rogers

Preliminary industry research suggests that many wind O&M organizations are making the transition to digital work orders, are in the process of starting to transition, or are investigating potentially updating their incumbent systems to be more digital. Many of the companies that are generally unaware of the benefits of digital work orders are overwhelmed with day-to-day work and have not had the time to figure out how to get started with researching CMMS. For an industry that tends to keep extremely busy, it is a daunting task to spend time on a project like CMMS that solves long term problems, but does not help complete the work that is currently underway.

The wind industry is estimated to be in the start of the "Early Adopters" phase of CMMS implementation on the classic technology adoption curve (Figure 4). There is still a reasonable way to go until the "Early Majority" is utilizing CMMS. This includes crossing the famed "Chasm" between "Early Adopters" and the "Early Majority" which was highlighted in a popular book titled "Crossing the Chasm" by Geoffrey Moore. The "Chasm" is a well-known gate keeper of broad disruptive technology adoption and it is expected that CMMS will have to pass through this phase in order to impact the greater wind industry.

The wind industry tends to be conservative and hence CMMS adoption is likely to take time to gain momentum industry wide. A wind specific CMMS can help minimize risk by reducing switching costs and as a result make CMMS more likely to navigate the chasm towards wide adoption. Other more mature utility industries such as oil and gas have already made the shift towards CMMS with encouraging results.

## 3.4 Oil & Gas CMMS

The first CMMS solutions started to gain traction nearly thirty years ago and were limited to large companies who had access to mainframe computers. CMMS installs have been dominated by IBM Maximo and SAP which made up greater than one third of installations between 1990 and 2010.[2] Other companies have followed suite and there are now a breadth of CMMS solutions available for different

[2] CMMS Best Practices Study Report. Reliability Web, Thomas & O'Hanlon. July, 2011.

industry types. Many CMMS offerings are designed to be generic and are subsequently lightly tuned for a specific industry. **Error! Reference source not found.** outlines which industries have typically capitalized on the benefits of CMMS.

**Table 1: Industries That Use CMMS**

| | | | |
|---|---|---|---|
| Food & Beverage | Industrial Manufacturing | Mining | Chemical Manufacturing |
| Facilities Maintenance | Automotive | Federal, State, & Local Government | Electricity Generation |
| Water & Wastewater | Forest Products | Amusement Parks | Ports |
| Wholesale & Retail | Hospitals | Aviation | Data Centers |
| Sports Arenas | Telecommunications | Schools & Universities | Oil & Gas |

Based on the long list of industries presented in **Error! Reference source not found.**, it becomes clear that the benefits of CMMS are significant enough to have overcome the barriers to implementation in most established industries outside of wind energy. A closer examination of the oil and gas industry will clarify how CMMS has helped this capital-investment-heavy industry minimize costs.

Oil and gas has similar challenges in terms of O&M as the wind industry. Oil and gas systems are often remote, mechanically complex, require significant maintenance, exposed to severe environmental conditions, operate on slim margins, and have a long list of compliance issues.

Oil and gas can be thought of as being broken into three different stages which include: exploration, production, and refining. Exploration involves mobile assets that complicate tracking, and production and refining have extremely high costs associated with downtime. O&M in the oil and gas industry must be very carefully monitored because if there is a failure, the consequences to employee safety and the environment can be significant.

Siemens offers a CMMS product specifically for the oil and gas industry. The oil and gas product is introduced by Siemens using the following language:[3]

> "There is probably no industry in the world where flawless and reliable performance is as important as it is in the case of oil & gas. A large part of the economy is directly dependent on it, and if delivery contracts are not fulfilled, contract penalties for oil & gas companies are severe. In case there is an oil & gas related accident, the human, economic and ecological repercussions quickly become catastrophic.
>
> In short: Failure is not an option and a state-of-the-art maintenance solution is needed to optimize asset utilization and ensure flawless operations."

[3] Siemens CMMS for Oil & Gas. https://www.cee.siemens.com/web/at/en/csb/CVC/products/Operation-Support-Systems/CMMS_Oil_Gas/Pages/CMMS_Oil_Gas.aspx, October 2013.

The key point is that in an industry such as oil and gas, where the stakes are very high, CMMS has been found to be a helpful tool. Wind has a number of similar challenges to oil and gas and CMMS will more than likely result in a similar improvement in maintenance management efficiency.

The Siemens oil and gas software product (Figure 5) offers many of the standard functions found in a CMMS, but also includes the "Mobile agent" which is a tablet based application that ensures all maintenance activities that require physical on-site labor are completed "efficiently and effectively." The "Mobile agent" has the ability to work offline when there is no wireless connectivity and then sync back to the web database when an Internet connection is available. Clearly industries that require field work have benefited from having a digital interface readily available to technicians and other field based staff. This supports the value of a similar tablet solution being used for wind CMMS.

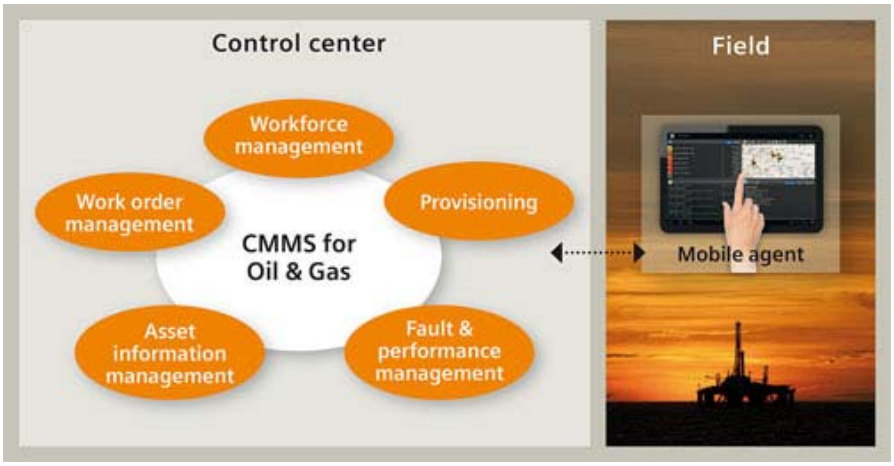



**Figure 5: Siemens Oil & Gas Product Overview**
Source: https://www.cee.siemens.com/web/at/en/csb/CVC/products/Operation-Support-Systems/CMMS_Oil_Gas/Pages/CMMS_Oil_Gas.aspx

The Siemens CMMS solution has been specifically built for the oil and gas industry. The software is designed to quickly add new assets while keeping in context the physical properties of the asset. These assets include: rigs, pipelines, movable equipment such as mud pumps, and IT assets such as servers, cables, and power grids. Additionally, the software is designed to integrate with oil and gas SCADA and provide a "state-of-the-art" fault and performance management of all sensor data.

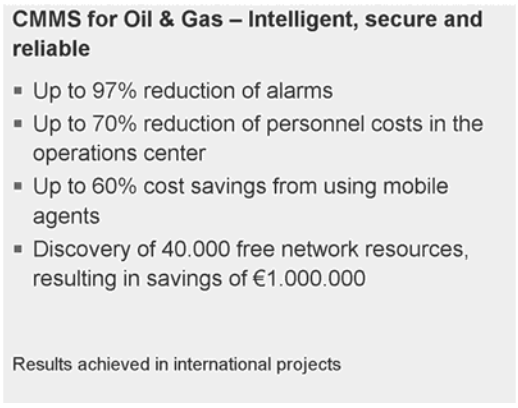



**Figure 6: Siemens Oil & Gas Summary of Benefits**
Source: https://www.cee.siemens.com/web/at/en/csb/CVC/products/Operation-Support-Systems/CMMS_Oil_Gas/Pages/CMMS_Oil_Gas.aspx

A summary of the system's benefits are presented in Figure 6. The savings Siemens suggests are impressive, but it should be noted that this is marketing material. That said, even if the results were half as spectacular as Siemens suggests in reality, the value proposition could still be favorable. Further research into the front lines usage of the Siemens oil and gas CMMS could shed light on the typical performance found by most customers as opposed to the marketing driven case presented.

Assetpoint offers a maintenance management product called TabWare which provides an oil and gas specific Enterprise Asset Management System (EAM). CMMS versus EAM is an ongoing discussion in the maintenance management industry. EAM is an up and coming term for maintenance management software that adds additional functionality beyond the typical CMMS baseline. The additional functionality includes items such as predictive maintenance, root cause analysis, financial cost analysis, technical document management, etc. Basic CMMS functionality is often limited to completing and managing work orders with the goal of competently getting the work done. EAM in most cases adds more downstream domain specific data processing functionality that is used to make more informed decisions.

TabWare includes much of the oil and gas functionality offered by Siemens and in many ways is a direct competitor of Siemens. In terms of expected outcomes, TabWare only gives a few high level benefits such as "Maximized asset performance," "Reduced unplanned downtime," "Reduced overtime," etc. More quantified benefits are hard to come by and the main source of more detailed information is a report titled "The Role of Software in Asset Performance Management" authored by the Aberdeen Group.[4] TabWare chose to use a third party such as the Aberdeen Group to help validate the value of CMMS. In a way, Tabware's approach is indirectly saying "you don't have to take our word for it" with regards to the system's value.

Table 2: Aberdeen Group Best-in-Class Maintenance Management Comparison

| | Best-in-Class | Average | Laggards |
|---|---|---|---|
| Knowledge | Asset performance data is collected in real time | | |
| | 43% | 27% | 18% |
| | Centralized knowledge warehouse to store asset performance data from different plants | | |
| | 30% | 21% | 21% |
| | On-demand asset lifecycle information easily accessible by maintenance and production employees | | |
| | 30% | 27% | 20% |
| Technology | Enterprise Asset Management (EAM) | | |
| | 72% | 57% | 40% |
| | EAM with Performance Management and Analytics | | |
| | 28% | 17% | 17% |
| Performance | Failure data is used to perform root cause analysis to understand the impact and the probability of failures | | |
| | 61% | 38% | 25% |

Source: Aberdeen Group, October 2010

The Aberdeen report makes no mention of Assetpoint or Tabware, but does lay out a more detailed case for "best-in-class" maintenance management performance based on an industry survey completed by 117 respondents. The Aberdeen Group states, "The purpose of this study is to highlight the vision and strategies of companies that are able to successfully optimize operations and maintenance processes with zero tolerance towards safety incidents."

The report takes a holistic view of what "best-in-class" companies are doing to achieve success. The high level findings are presented in **Error! Not a valid bookmark self-reference.** with the conclusions pointing out that the best companies utilize maintenance technology to the fullest with a particular

[4] The Role of Software in Asset Performance Management. Aberdeen Group, October 2010

emphasis on CMMS/EAM, analytics, and mobile technologies. One key metric was that 72% of "Best-in-class" companies had successfully implemented a CMMS/EAM which further supports the benefits of the EAM that TabWare sells.

TabWare supports mobile electronic devices (**Error! Reference source not found.**) and an analytics dashboard (**Error! Reference source not found.**) as part of its oil and gas EAM package. TabWare also goes on to clarify the tieback of EAM, analytics, and mobile technologies to more informed decision making through better data and higher velocity of actionable information. There are few reasons why these same trends should not remain true for an industry such as wind that has a notable amount of overlap with the O&M issues frequently encountered in oil and gas.

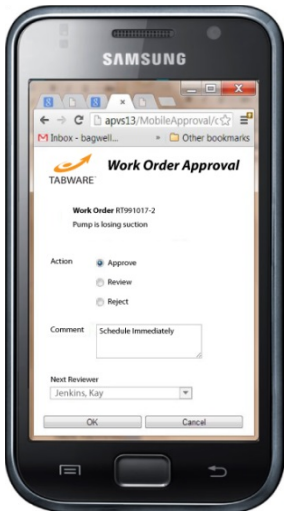



**Figure 7: TabWare Mobile**
Source: http://www.assetpoint.com/products-eam-work-order-management-module.htm


**Figure 8: TabWare Maintenance Analytics Dashboard**
Source: http://www.assetpoint.com/products-eam-analytics.htm

The justification for a CMMS is compelling. Similar approaches have been taken in other industries such as oil and gas and the results have been promising. Throughout the research process there was no information found indicating that other industries that have successfully implemented CMMS are now reverting back to an analog or hybrid of analog and digital maintenance management approach. The general consensus in other industries outside of wind is that "your mileage may vary" regarding the details of the benefits, but in general the return on investment on CMMS merits working through the switching costs.

The wind industry could benefit most from an EAM, however a well thought out, purpose built CMMS would be a great start in an industry that is generally behind in maintenance management technology. Mobile solutions are gaining popularity in other industries and with the remote aspects of wind generation, mobile is likely to be a key part of broad adoption. The long term goal for the wind industry is a full featured EAM that is reasonably priced such that the wind industry can reduce its total cost of ownership and become increasingly cost competitive.

# 4.0 Segments Overview

The segments portion of the paper delves into the three primary company types typically involved with O&M in the wind industry. Primary Internet research was performed in order to better understand the background of the top twenty-five ISPs, twenty-five OOs, and ten OEMs. The companies that were selected were intended to be best of class within each segment type and represent a "reasonable" cross section of the greater wind industry. The investigation was limited to metrics that the three company types made publically available. Later sections of the document will examine the value proposition of CMMS to the company segments presented below.

## 4.1 Independent Service Providers

ISPs are typically privately held companies that employ a dedicated maintenance team, most often between twenty-five and three hundred employees. Research indicates that the twenty-five ISPs evaluated had (when data available) an average of 160 employees, at an average of six different locations, with 44% of companies having one or more international locations. It should be noted that the larger ISPs had a much greater number of locations which significantly increased the average. If the median (middle value of the dataset) is used instead of the average, the number of locations drops to only three locations.

A number of ISPs are part of a larger parent company that serves other industries beyond wind. It was found that 60% of all of ISPs only worked in the wind industry, with the remaining companies also offering services in industries such as mining, maritime, oil and gas, and other renewable energy sectors such as hydroelectric. The ISP industry is particularly dynamic and a few of the companies that were independent have been recently acquired by companies outside of wind and even companies within the wind industry. In some cases, large OOs have purchased ISPs to become their permanent in-house maintenance providers. Purchasing an ISP may be faster and cheaper than developing a high-functioning maintenance team from scratch.

The work that ISPs perform is often a mix of long term O&M contracts as well as specialty O&M services. At one extreme, an ISP may be part of an O&M contract where the company maintains the same wind plant for a decade, and at the other, a specialty ISP team might work on a single turbine for an afternoon and then never work on that same turbine again. Some ISPs do both long-term contractual O&M and specialty O&M, but ISP companies tend to vary greatly with respect to the distribution of the types of contracts they seek. This is often a balance of the type of work requested by customers and the technical strengths of the company. That said there are a limited number of firms that only perform one specific type of specialty O&M work and aim to be a "best-of-breed" through this specialization.

Specialty ISP firms are often on call after a specific maintenance issues arises. For example, if a gearbox unexpectedly fails or there has recently been severe weather resulting in hail and lighting blade damage, a specialty ISP team may be flown in within 24 hours or in some cases even less time. The ability to do "fire drill" quick response for specific types of inspections and repairs sets some ISPs apart. Not all specialty ISP work is done by a rapid response team, but it is one of the distinctions that separate specialty ISP work from routine long-term O&M contractual work.

Customers of ISPs are mainly OOs and OEMs, but there is also some outsourcing performed from one ISP to another ISP. Some ISPs perform very specialized work that is outsourced by other ISPs who do not have the subsystem domain expertise. Specialties typically include inspections and/or repairs of major

components such as gearboxes, generators, blades, and control systems to name a few. A previous survey performed by Muir Data Systems concluded the following outsourcing data:[5]

1) ISP Outsourcing: 14%
2) OEM Outsourcing: 34%
3) OO Outsourcing: 56%

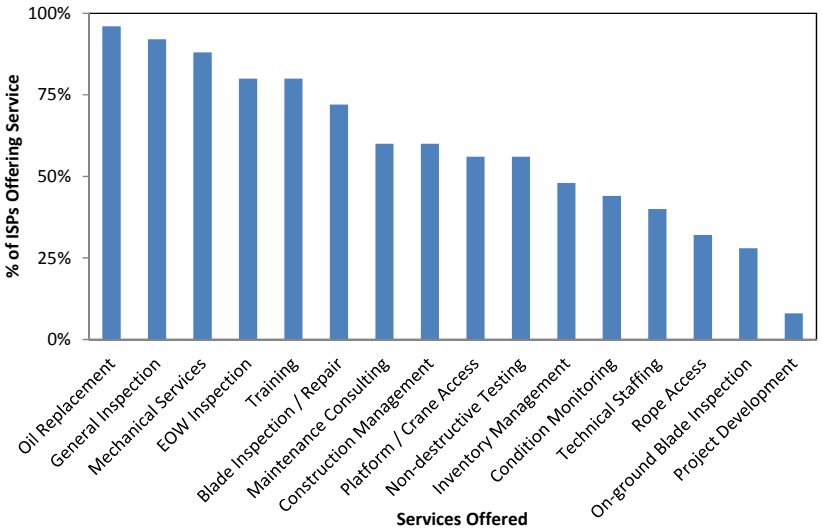



Figure 9: Distribution of ISP Services

The percentages imply that ISPs are most often the companies to whom the work is being outsourced, and the main outsourcing done by ISPs is to other ISPs who specialize in specific types of inspection or repair. OEMs outsource about one third of their warranty and extended service and warranty work to ISPs. About 45% of wind turbine maintenance is performed in-house by OOs and the rest is outsourced to ISPs and/or OEMs. Despite there being no connection between the organizations surveyed, the sum total of the outsourcing percentages equals 104%. There is no direct reason that the outsourcing sum total should equal approximately 100%, but it does hint that the data set may be somewhat representative of the greater wind industry.

ISPs typically offer about 9 of 16 industry standard services (Figure 9). The top 3 most-widely offered services are "Oil Replacement," "General Inspection," and "Mechanical Services,' which typically include gearbox repair, generator repair, and torque testing. The three services listed above are offered by more than 85% of the twenty-five ISPs researched.

The following seven services were offered by between 50% and 85% of the twenty-five ISPs researched: "End of Warranty Inspection," various forms of "Training," "Blade Inspection & Repair," "Consulting" (including creation of wind energy O&M best practices & procedures), "Construction Management," "Platform and/or Crane Access Solutions," and "Non-destructive Testing and/or other Testing Services." The six services least-offered, which were provided by fewer than 50% of the ISPs researched, were: "Inventory Management," "Condition Monitoring," "Technical Staffing," "Rope Access," "On-Ground Blade Inspection," and "Project Development Services."

Interestingly, only 12% of ISPs where found to use some form of CMMS, which suggests that the vast majority of ISPs are most likely using paper work orders in the field and office. There is the possibility, however, that more ISPs are using CMMS but do not make the information publically available and as a result it was not found during the research process.

For specialty ISP work, customer reports are directly part of the company's revenue stream. In the case of an OO or OEM who hires a specialty ISP, the only deliverable that confirms the work was completed correctly is a detailed work summary report. By using a CMMS that has a mobile component in the field, ISPs may provide a more accurate, faster, and overall improved report delivery experience to customers. CMMS has the potential to improve the reports that directly pay the bills for specialty ISPs.

[5] Wind Industry Work Order Information Flow Survey. Muir Data Systems, November 2013.

In the case of long term contractual O&M, ISPs using a CMMS may be able to make better recommendations to their customers for how to best minimize costs while maximizing uptime. Without reliable work order data and an efficient way to manage work orders, making the transition to increasingly predictive maintenance becomes daunting. In the not too distant future, it is expected that ISPs will not only be defined by the services the company provides, and the quality of service, but also by how effective the organization is at supporting the customer's growing thirst for asset data.

A summary of the findings from the ISP segment section is presented in **Error! Reference source not found.**. The key points are that ISPs are generally smaller, privately held companies that perform a mix of long-term contractual maintenance in conjunction with specialized services such as inspection and repair of gearbox, blades, etc. ISPs tend to have less advanced information flow systems than larger wind organizations such as OOs and OEMs, despite the importance of accurate report generation, especially in the case of specialty ISP contracts.

**Table 3: Summary of ISP Findings**

| Metric | Value | Notes |
|---|---|---|
| Typical Number of Employees | 25 – 300 | Based on data and industry experience |
| Average Number of Employees | 160 | Limited employee data available (primary research) |
| Average Number of Locations | 6 | A few outliers had a significant number of locations |
| Median Number of Locations | 3 | More accurate than average given few large outlier ISPs |
| International Locations | 44% | All ISPs had US locations |
| Wind Industry Only ISPs | 60% | Many ISPs are part of a parent company that services other sectors |
| ISPs using CMMS | 12% | Limited adoption of advanced maintenance technology |

## 4.2 Owner Operators

Wind plants have an expected 20+ year operational life and the OOs are the organizations that have the ultimate responsibility for the return on the investment. Often OOs are part of large, well established parent corporations or are themselves relatively large and stable. With wind turbines costing approximately $2M per MW installed, many OOs have multiple billions of dollars invested in the company's wind energy portfolio.[6]

OOs have a lot at stake and represent the financial "hub" of the wind industry. In many cases OOs will finance wind projects. In order to justify the financial risk exposure, a long term Power Purchase

[6] 2012 Wind Energy Technologies Market Report. DOE, Wiser & Bolinger. August, 2013.

Agreement (PPA) is signed well before the wind turbines are installed. In the case of outside investors, the 15 – 25 year PPA is used as a bargaining chip for obtaining the required project financing.

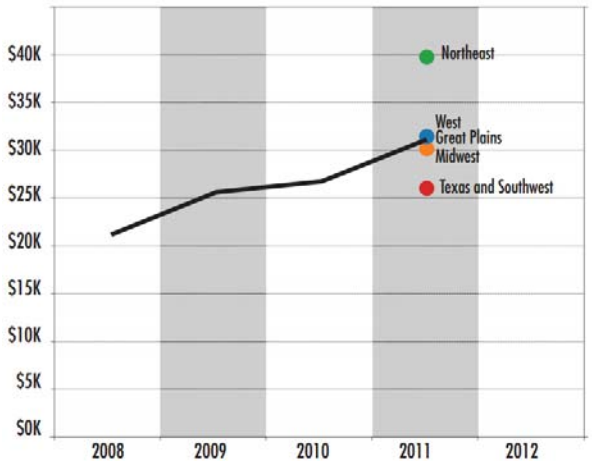
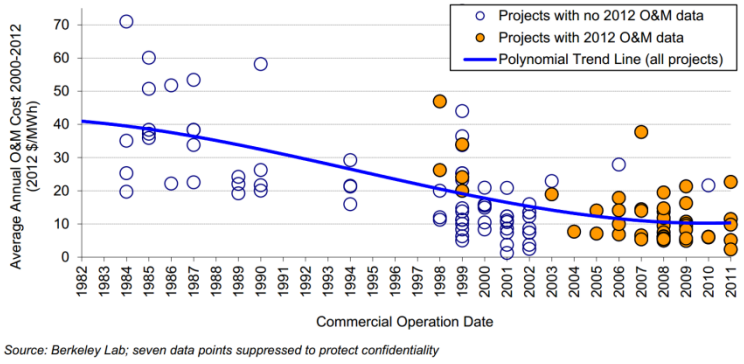



**Figure 10: O&M Costs per MW over Time by Region**
Source: http://www.glgarradhassan.com/assets/downloads/The_Real_Truth_About_Wind_Farm_O_and_M_Costs.pdf

O&M is one of the largest and most difficult to forecast of ongoing wind plant costs. Other typical recurring costs include insurance, grid power, administration, land usage, and a small amount of miscellaneous, all of which tend to be more predictable.

On average O&M costs tend to make up 20% - 25% of the total levelized cost of wind turbine ownership.[7] Most often, O&M costs are lower in the beginning when the wind turbines are recently out of warranty and are experiencing few unscheduled maintenance events. However, as the turbines age, the frequency of expensive unscheduled maintenance events such as gearbox issues increases and O&M costs trend upward accordingly. O&M of recently out of warranty wind turbines typically accounts for 15% of the total levelized cost of ownership, with wind turbines towards the end of the expected 20 year life expectancy costing as much as or in some cases exceeding 35% the levelized cost of ownership.

This trend of an aging wind turbine fleet can be seen in the more than 8 GW of O&M data from GL Garrad Hassan presented in Figure 10. The study included O&M costs associated with scheduled and unscheduled maintenance as well as balance-of-plant (BOP). Looking at the data, it becomes increasingly clear that the age and location of the wind turbines in the data set are significant drivers of the cost of O&M. Poor weather, difficult access, parts availability, and smaller more distributed plants were cited for the Northeast's increased in O&M prices.




*Source: Berkeley Lab; seven data points suppressed to protect confidentiality*

**Figure 11: O&M Costs Based on Plant Commission Year**

No mention was made in the research about the impact of the make and model of the wind turbine with regard to longevity and O&M cost. This is not atypical in the wind industry, where an effort is often made not to point fingers at specific makes and models of wind turbines as being more or less reliable. This data is controversial by nature, but it would be helpful to the wind industry to have access to Consumer Reports high level data sets when selecting wind turbines for future plants.

In general the O&M cost of recently installed wind turbines compares favorably with the cost of older wind turbines when first installed (Figure 11). These reductions in O&M cost come in part from more robust designs, better sensor monitoring, and increased O&M efficiency. The jury is still out on how

[7] Wind: Getting O&M Under Control. Renewable Energy Focus, Rajgor. June, 2012.

exactly new wind turbine models are going to age relative to the smaller less complex wind systems installed a decade ago. The big question is if the initial O&M costs are lower than the older systems, will the O&M costs stay lower for the entire life of the wind turbine?

It should be noted that the primary difference between Figure 10 and Figure 11 is that Figure 10 represents the O&M costs of a fixed group of 8 GW of aging wind turbines while Figure 11 presents the average O&M based on the year the wind plant was commissioned. These two figures suggest that O&M cost increase as a plant ages, but overall newly installed wind plants are trending towards initially less expensive O&M.

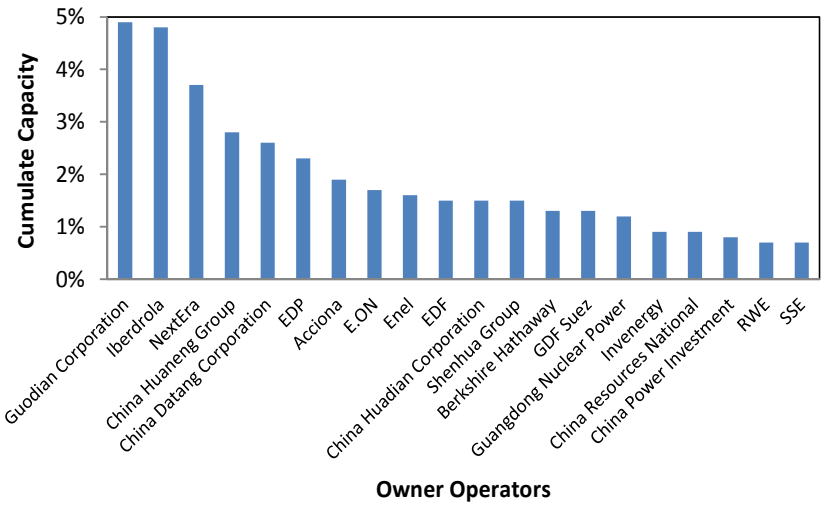



Figure 12: Top 20 Global OOs as of 2012

Looking at the more detailed OO industry trends, the largest twenty-five OOs operate an average of 82 wind plants with an average capacity of 52 MW per location. The top six OOs manage over 42,000 MW (~15% of worldwide capacity) with an average 919 employees in wind related activities. That equates to about 7.5 MW of capacity under management per employee. The entire top twenty-five OOs managed 27% of the world's wind energy capacity.

At the top of the wind industry the biggest OOs dominate the world's wind energy production, however there is a long tail of much smaller companies (Figure 12).[8] According to the wind turbine and wind farm database at thewindpower.net, there are over 2,100 OOs globally.[9] More than likely there are even more OOs than those specifically listed in the database. This, and the large distribution in company sizes, suggests that there are a significant number of O&M management strategies that are in place. In order for a wind CMMS product to gain traction in this diffuse marketplace, it must be flexible in functionality and price structure.

Nearly all of the reviewed twenty-five OOs operate in at least three other capacities such as project developers, public utilities, asset servicers (similar to ISPs), or energy trading companies

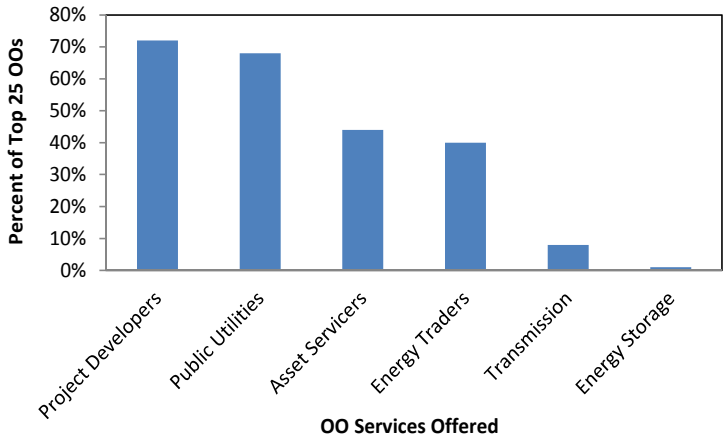



Figure 13: Additional Services Offered by OOs

[8] 2012 Top 20 Wind Asset Owners. Bloomberg New Energy Finance. April, 2013.
[9] Operators Database, http://www.thewindpower.net/actors_operators_en.php. The Wind Power. October, 2013.

(Figure 13). OOs were found to pursue a range between two and six, with an average of three and a half, other activities beyond simply owning wind turbines.

The variety of other activities performed by OOs illustrates the complexity of the typical top twenty-five OO organization. OOs are often oversimplified by outsiders who think of them simply as wind turbine owners who outsource most tasks. Having access to the large amount of digital work order data provided by a CMMS enables a complex OO to be able to share this data into other wind oriented functions within the company. For example, having access to extensive searchable standard formatted historical work order records would enable past projects to better inform future plant analysis performed by the project development portion of the company.

A summary of the findings from the OO segment section is presented in Table 4**Error! Reference source not found.**. The assets that OOs manage are expensive and are designed to function through two decades of operation. The O&M costs associated with a wind turbine vary significantly based on age and region of installation and must be properly managed to ensure proper return on investment. The twenty-five biggest OOs in the world manage about a quarter of the world's wind energy. These organizations have extensive corporate resources that extend beyond simple turbine ownership. There is a much larger number of drastically smaller OOs, however, who have much more limited resources, but many of the same challenges as the larger companies. The key is to develop CMMS offerings that fulfill the needs of the highly varied OO market while being accessible at a sensible price point.

**Table 4: Summary of OO Findings**

| Metric | Value | Notes |
|---|---|---|
| Cost per MW Installed | $2M | Typical for current wind technology |
| Power Purchase Agreement (PPA) Duration | 15 – 25 years | Standard is 20 years |
| Typical O&M Turbine Costs | 20% - 25% | Average levelized cost of ownership (depends on age, region, parts availability, etc.) |
| New O&M Turbine Costs | 15% | Turbines recently out of warranty |
| End of Life O&M Turbine Costs | 35% | Turbines approaching dismantling or repower |
| Top 25 OOs Average Number of Plants | 82 | The sum of the plants owned by the top 25 OOs is ~27% of the world's wind energy |
| Top 25 OOs Average Capacity per Plant | 52 MW | Size of typical wind plant owned by OOs |
| Top 6 OOs MW Managed for each Employee | 7.5 MW / Employee | Includes all staff associated with wind side portion of business |
| Estimated OOs Worldwide | 2,100+ | Large diffuse market of OOs |

| | | |
|---|---|---|
| Additional OO Company Functions Average | 3.5 | Additional functions included product development, public utilities, asset servicers, energy traders, transmission, and energy storage |

## 4.3 Original Equipment Manufacturers

OEMs tend to be large multinational corporations that specialize in manufacturing wind turbines primarily for purchase by OOs. Manufacturing utility scale wind turbines is a capital intensive process and OEMs are often placed in difficult financial situations as economic and political forces rapidly change the demand for new wind turbines. Despite these challenges, existing OEMs continue to aggressively bid for their share of the industry, and new OEMs are beginning to crowd the market - many of them from China.

The 2012 top ten global wind turbine manufacturers ranked by newly commissioned capacity are presented in Table 5.[10] These ten OEMs produce a combined 80 different turbine models with nameplate capacities varying from 0.6 MW to large off shore 8 MW machines.

**Table 5: Top Ten Manufacturers by Global Commissioned Capacity in 2012**

| Manufacturer | Country | 2012 Global Market Share |
|---|---|---|
| GE | US | 11.8% |
| Vestas | Denmark | 11.8% |
| Siemens | Denmark | 11.0% |
| Enercon | Germany | 7.2% |
| Suzlon/Repower | India | 6.6% |
| Gamesa | Spain | 6.4% |
| Goldwind | China | 6.0% |
| Guodian United Power | China | 3.5% |
| Sinovel | China | 2.7% |
| Sewind | China | 2.3% |

[10] 2012 Top 10 Wind Turbine Manufacturers by Commissioned Capacity. Bloomberg New Energy Finance. April, 2013.

The top tier OEMs such as Vestas, GE, and Enercon are still leading the pack, but the bottom half of the top ten manufacturers has been changing significantly in recent years. For example, in 2008 Acciona and Nordex were within the top ten, but by 2009 were primarily replaced by Chinese OEMs and have not been able to reclaim a position within the ranks.

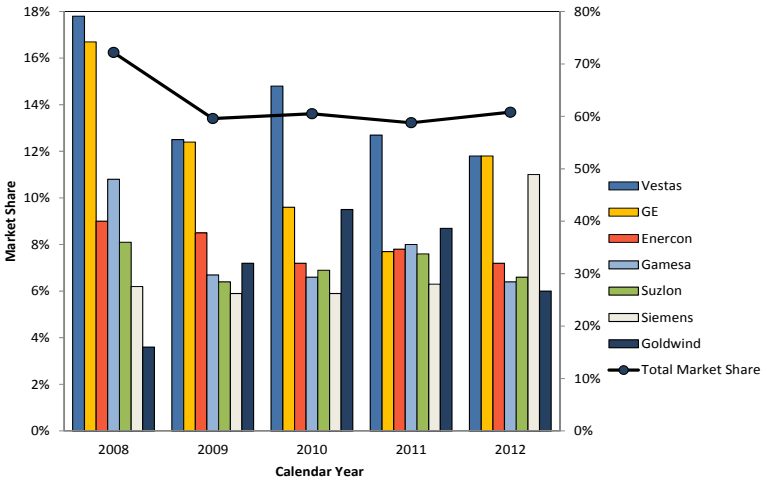
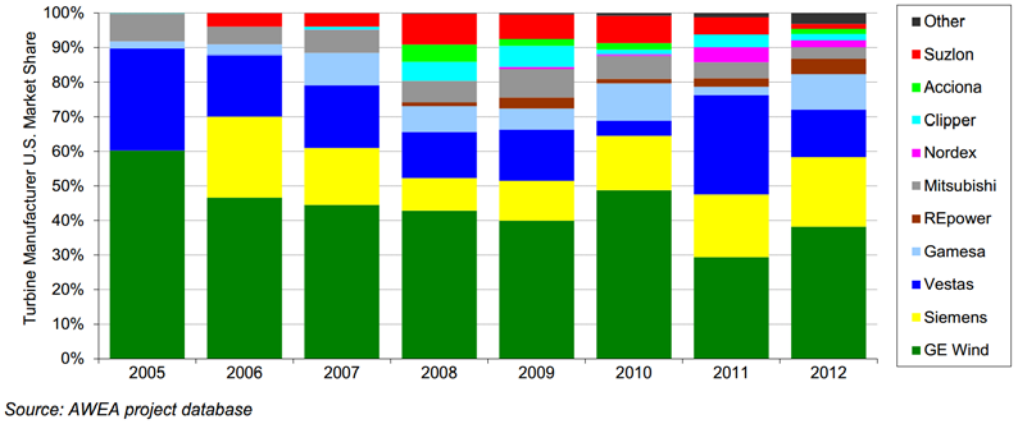



Figure 14: 2008 - 2012 Top 7 Global OEM Market Share
Source: US International Trade Commission, BTM Consult, Cleantech Investor, Bloomberg

There are seven OEMs that have been on the list of top ten manufacturers of new installed capacity from 2008 to 2012. Figure 14 summarizes the market share of these seven OEMs for each of those five years. A "Total Market Share" line is presented in black which represents the total percentage of turbines sold each year by all seven OEMs.

Relative to 2008, the seven OEMs saw a reduction in market share from 72% to an average of 60% for the next four years. Across all four years from 2009 to 2012 all of the reduction in the seven OEMs' share of the market was due to Chinese OEMs with the exception of REpower in 2009 just before the company was acquired by Suzlon. As a whole, the top ten OEMs captured 70% of the market share of new turbines in 2012.




Source: AWEA project database

Figure 15: US OEM Market Share

All of the previous data looked at OEMs from the perspective of global market share. US wind capacity makes up about 20% of worldwide capacity and similar trends can be seen within the US wind market where there has been a growth of OEMs beyond the historically dominant OEMs. In 2005, there were four OEMs represented, and by 2012 this number had jumped to ten plus an unknown number of OEMs within the "Other" category. The simplest way to see this is that the number of colors on Figure 15 generally increases from left to right implying a more competitive marketplace with more variety of wind turbine types being installed within the US. The more competitive nature of the wind market has led to an increased emphasis on extended warranty plans offered by OEMs.

OEMs have been mainly focused on selling wind turbines to make a profit. This model has been shifting as the wind industry's increasingly competitive landscape generally leads to reduced sales margin.

Additionally the uncertainty within the US surrounding the Production Tax Credit (PTC) has made for a volatile product demand curve.

Table 6: Forecasted US Annual Wind Capacity Additions (MW)

| Source | 2013 | 2014 | 2015 |
|---|---|---|---|
| Bloomberg NEF (2013a, 2013c) | 2,800 | 8,000 | 3,200 |
| IHS EER (2013) | 2,000 | 6,000 | 7,300 |
| Navigant (2013) | 5,000 | 9,000 | 3,500 |
| MAKE Consulting (2013) | 3,500 | 7,700 | 4,500 |
| EIA (2013b) | 3,600 | 10,100 | N/A |

The PTC has existed since 1992 to encourage renewable energy development by paying out 2.3 cents per kilowatt hour in incentives. The PTC has been double edged in the sense that the tax credit does make wind energy more financially appealing, but each of the three times that the tax credit has expired, it has sent the wind industry into a temporary tailspin. 2012 was no different as the PTC was approved significantly later than normal as a result of getting caught up in the "Fiscal Cliff" package. Even though the PTC was eventually approved, just the hint that it might lapse led to reductions in many of the new installations forecasts relative to the boom year of 2012 where 13,131 MW of new capacity was installed (Table 6 vs. Table 7).

The average of the five sources in Figure 6 is 3,380 MW for 2013, 8,160 MW for 2014, and 4,625 MW for 2015. The average projections for 2013 represent nearly a 75% reduction in new installed capacity relative to the boom year of 2012. OEMs reacted to the delay in signing the PTC by throttling back manufacturing. Even once the PTC was reinstated it took months to recover and the market is still recuperating.

This scenario in conjunction with a large number of wind turbines coming out of warranty has led to OEMs taking the O&M service side of the wind energy business much more seriously. Every one of the top ten OEMs offers extended warranty and service packages with many offering a hierarchy of permutations depending on the level of coverage desired by the OO.

Some companies are even surpassing extended warranty and service packages and offering "full-wrap" contracts that may include design, engineering, procurement, construction, and full maintenance coverage in addition to the capital costs of the wind turbines rolled into a single contract. OEMs are tending to offer more service options at increasingly competitive prices in order to secure a higher number of long term extended warranty and service contracts. To some degree, the market dynamics are pushing OEMs to behave like ink jet printer manufacturers. The printers (wind turbines) are sold at lower margins to enable the recurring revenue associated with ink cartridge sales (extended warranty, service packages, parts sales, etc.).

Table 7: 2012 Annual and Cumulative Capacity Summary

| Annual Capacity (2012, MW) | | Cumulative Capacity (end of 2012, MW) | |
|---|---|---|---|
| **United States** | **13,131** | China | 75,372 |
| China | 12,960 | **United States** | **60,005** |
| Germany | 2,415 | Germany | 31,467 |
| India | 2,336 | Spain | 22,462 |
| United Kingdom | 1,958 | India | 18,602 |
| Italy | 1,272 | United Kingdom | 9,113 |
| Spain | 1,112 | Italy | 7,998 |
| Brazil | 1,077 | France | 7,593 |
| Canada | 936 | Canada | 6,214 |
| Romania | 923 | Portugal | 4,363 |
| *Rest of World* | 6,838 | *Rest of World* | 42,368 |
| **TOTAL** | **44,958** | **TOTAL** | **285,558** |

*Source: Navigant; AWEA project database for U.S. capacity*

Despite these changes in the market, the US has been installing a

significant number of wind turbines. These new installations have been good for the economy as well as a step in the right direction for meeting long term state level Renewable Portfolio Standards (RPS). Thirty states have signed variations of the RPS and in conjunction with the federal PTC, are two levers that have, with some success, helped move the wind industry forward. Additionally, wind technology has continued to mature and overall costs are tending to decrease.

As a result, in 2012 the US broke the 60 GW mark for total installed capacity, second only to China. The US led the way for new installed capacity worldwide and in 2012 installed an incredible 22% of the country's total capacity (Table 7).

In terms of job creation, it was found that 92% of all new capacity came from OEMs that currently manufacture or have announced nacelle assembly manufacturing in the US. The domestic parts content of US installed wind turbines has increased from 25% in 2005 to 67% in 2012. There are over 559 manufacturing facilities and at least ten research and development centers that provide wind related jobs in the US.[11] The wind industry is one of the few industries that are currently increasing the amount of domestic manufacturing jobs.

Moving forward, the potential for offshore wind in the US represents an exciting opportunity for continued industry growth (Figure 16). Offshore wind resources are sizeable and much of the population lives in close proximity to the coasts which ensures steady demand for electricity. This could represent the next wind industry gold rush, if the cost of offshore technologies continues to come down, and proper legislation is put in place to facilitate wide US adoption. Many European OEMs have experience with offshore wind turbine product development and it will be interesting to see which companies lead the charge in the potentially massive US offshore wind market.

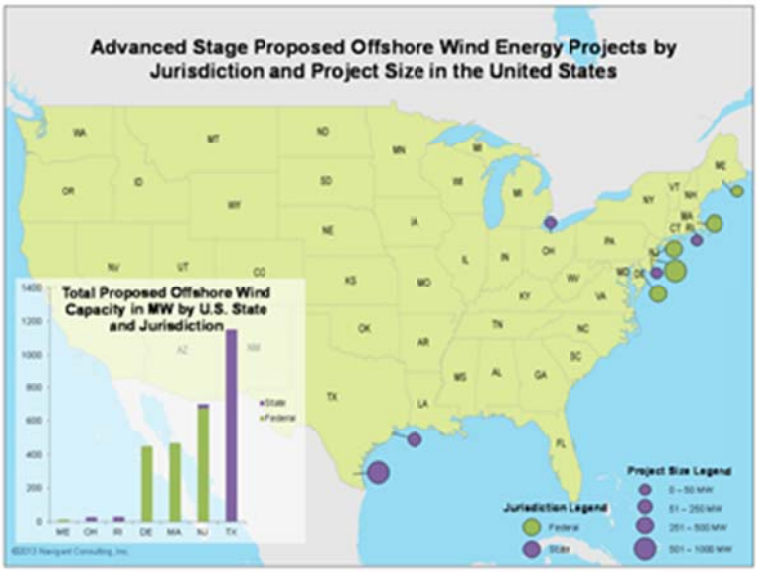



**Figure 16: Proposed Offshore Wind Projects**
Source: http://www1.eere.energy.gov/wind/pdfs/ 2012_wind_technologies_market_report.pdf

Off-shore wind installations represent a significant opportunity for CMMS. The value of data driven maintenance management is crucial given the high cost associated with off-shore installations. When a helicopter or boat is required to access a wind plant, maximizing O&M data availability using a CMMS is likely to become the standard.

A summary of the findings from the OEM segment section is presented in Table 8**Error! Reference source not found.**. As the wind industry continues to grow and mature, the OEM landscape is changing. A few years ago the global wind markets were dominated by a few top tier manufacturers. This has not completely changed, but there are indications that wind turbines built in the China are becoming increasingly popular. Similar behavior has

[11] US Wind Energy Industry Manufacturing & Supply Chain. AWEA. July, 2013.

been seen within the US, and the variety of OEMs installing turbines in the US has increased significantly in recent years.

Industry factors such as the PTC, a vast number of wind turbines coming out of warranty, and increased competition have led OEMs to place emphasis on extended warranty and O&M service contracts. These contracts enable recurring revenue that is not directly susceptible to the changing market behavior of new wind turbine sales. Despite these industry changes, the US had a boom year in 2012 and set precedents for successful wind energy implementation.

Many of the wind turbine components are built domestically providing a steady increase in jobs that is good for the US economy. The offshore wind market represents a wild card in the US for OEMs and it is unclear which manufacturers are going to be the trailblazers. There is little question that the coastal US is a hotbed of electricity demand and wind resources, both of which make for a highly valuable emerging market for OEMs.

**Table 8: Summary of OEM Findings**

| Metric | Value | Notes |
|---|---|---|
| Top OEMs 2012 | GE/Vestas | Tied for first place with 11.8% of global installed capacity |
| Top 7 OEMs Global Market Share Reduction 2008 - 2012 | 72% to 60% | Top 7 OEMs have seen a reduction in annual sales as a result of increased competition |
| Top 10 OEMs 2012 Global Market Share | 70% | 7 out of 10 turbines were sold by the top 10 OEMs, which include four Chinese companies |
| 2012 New US Wind Capacity | 13,131 MW | Biggest year for wind in US ever, surpassed all other types of new installed capacity (cumulative capacity ~60 GW) |
| US OEM increase 2005 – 2012 | 4 to 11+ | There are now eleven or more OEMs selling turbines |
| OEM Change in Emphasis | O&M | OEMs are placing greater value on extended warranty and O&M service contracts |
| Average Capacity Forecast 2013, 2014, 2015 | 3,380, 8,160, 4,625 (MW) | Production Tax Credit (PTC) leading to reduction in 2013 forecasted new capacity |

# 5.0 CMMS Value Proposition

For each of the three previous industry segments investigated in sections 4.1 through 4.3 (ISPs, OOs, OEMs) the value proposition of CMMS will be presented. The value propositions of CMMS will be broken down by the three segments as well as three employee types which include technicians, managers, and executives. The objective is to develop multiple value positions for each company and employee type in order to better understand how to encourage greater adoption of CMMS in the wind industry.

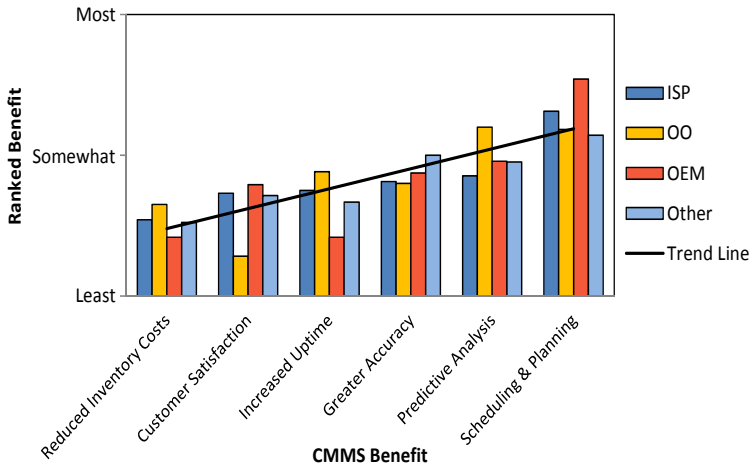



Figure 17: CMMS Benefits Based on Survey Data

This is intended to be a preliminary effort to make an educated first pass at the value propositions of CMMS to the wind industry. The assumptions, value propositions, and conclusions drawn should all be revisited as more data on this subject becomes available as a result of CMMS becoming more widely adopted in the wind industry.

Currently there is information available on the general benefits of CMMS for other industries, but little for wind. The goal here is to combine the understanding of the wind industry, general CMMS, and data gathered from the Muir Data Systems work order survey to inform the proposed value propositions.[12] The CMMS benefits ranking in Figure 17 is one of the plots from the survey data that was used to help inform the CMMS value propositions tables that follow.

The generic CMMS typically implemented in wind organizations is often not hugely different from one company to the next; however the perceived benefits of the system and associated work order data are likely to vary more substantively. There is some overlap between organization type and its perception of the value of CMMS, but the objective of this work is to better understand the subtle differences in the value propositions specifically applied to wind organizations.

What exactly is a value proposition? Value propositions can be thought of as the value that a customer believes can be obtainable from a particular product or service. The perceived value of a product by a customer is always subjective and is informed by experience using the product or service, the individual's position within the product's value chain, the software company's reputation, marketing material, competing products, etc.

The entire deal between company and customer comes unhinged without the fundamental belief that the product is capable of meeting or exceeding the customer's expected performance. In simple terms,

[12] Wind Industry Work Order Information Flow Survey. Muir Data Systems, November 2013.

value propositions are the baseline reasons why a customer buys a product or service from a seller. Example financial oriented value propositions are shown in Figure 18 for generic CMMS.[13]

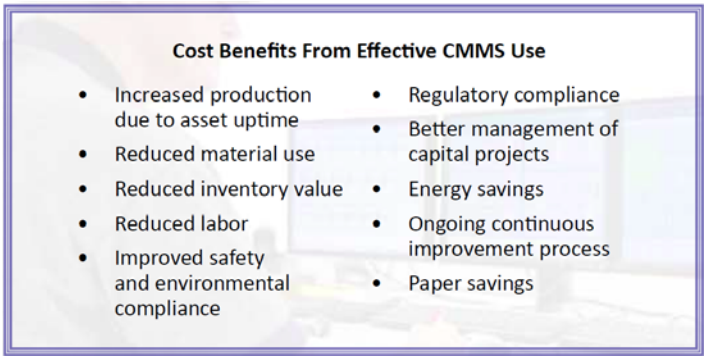


Figure 18: Example Financial CMMS Value Propositions

Value propositions can apply to individual employees, parts of the company, entire organizations, customer accounts, and/or the products or services offered. Once the value propositions for a specific product or service have been confirmed through customer feedback, the information can be used as an anchor for the seller's organization.

For example, a list of repeatable customer value propositions might function as a road map for business development, marketing material, and pricing. Properly identified value propositions allow sellers to quickly place themselves in the position of their customers. This mental exercise enables sensible day-to-day internal company decisions that tend to be well aligned with customer's ideals.

Understanding and applying value propositions to decision making is a non-trivial task. In general it is easier to understand a customer's perception of a physical product. A data driven system like a CMMS is partially invisible and its benefits often originate from improved data flow (velocity), different types of data being brought together (variety), and magnitude of data available (volume). CMMS value propositions, therefore, are inclined to be especially challenging to pin down. Below we will investigate the value propositions specific to each segment of the wind industry.

## 5.1 ISP CMMS Value Propositions

Table 9 summarizes the value propositions of ISPs for each of the three employee types. Technicians who work for ISPs often travel in order to perform specialty O&M work and in some cases even for routine O&M contracts. Some specialty O&M work requires rope, platform, crane, or in some situations confined space access for which proper safety checklists must be completed. CMMS enables the technicians to reduce the amount of time spent completing reports after a long day in the field. This is especially important when the documentation for specialty O&M work takes from fifteen minutes to as much as eight hours (based on interviews) for a complex uptower repair.

Technicians generally have an aversion to paperwork and CMMS reduces their "homework" by enabling nearly all of the reports to be completed in the field using a mobile electronic device. It is crucial that ISP technicians do an effective job of filling out the reports because these documents are often delivered directly to customers. Unlike the other company types, ISPs in many cases will only get paid after all of the reports have been submitted for customer review and as a result, proper work order documentation is directly linked to the company's bottom line.

[13] CMMS Best Practices Study Report. Reliability Web, Thomas & O'Hanlon. July, 2011.

A digital work order system also allows technicians and managers to communicate much more easily with regard to project dispatch, progress, and completion. ISPs often have maintenance teams that function in a variety of capacities and a number of locations throughout the country. The connectivity associated with CMMS affords managers a nearly real-time perspective on technicians' progress while being able to review past work orders and make recommendations to the technicians on how to best proceed with an inspection or repair in the field.

Customer satisfaction is especially important for ISPs. OOs and OEMs are most often the customers of ISPs and for short term contracts switching costs are relatively low to change to another ISP. Decisions must be made to keep total costs down in an attempt to outbid competitors while providing an overall positive customer experience. Being that CMMS is not currently widespread among ISPs, having an established digital work order system in place is often seen as a competitive advantage. ISPs generally perceive that a purpose built CMMS will save time in the field and office, while providing a superior customer experience.

**Table 9: ISP CMMS Value Propositions Summary**

| Employee | Primary | Secondary | Tertiary |
|---|---|---|---|
| Technician | Increased employee field and office/hotel work efficiency | Trouble-free workplace communication | Proper physical risk management |
| Manager | Streamlined human resource management | Better employee accountability | Data driven maintenance/ repair decision making |
| Executive | Superior customer satisfaction | Enhanced financial accountability | Competitive advantage over other ISPs and OEMs |

## 5.2 OO CMMS Value Propositions

Table 10 summarizes the value propositions of OOs for each of the three employee types. In some instances OOs choose to take over the maintenance themselves after the OEM's warranty expires. Technicians who work in-house for OOs often maintain the same wind plant on a routine basis. OO technicians are interested in reducing unscheduled maintenance events that disrupt their work routine.

In addition to the manager's intuition, CMMS can also provide employee data with regards to employee performance and help inform who deserves a raise or promotion and why. Managers who implement a CMMS would have access to some degree of key performance indicators for their staff. Some technicians will see the system as "big brother is watching" and others will see it as an opportunity to quantify how hard they work with real world data while avoiding office politics.

Mobile electronic devices used in the field enable technicians to in-take more accurate work order data. By going straight to a digital work order, the office transcription phase is eliminated and the work order data tends to be more accurate. Furthermore, the software running on the mobile electronics device can run error checks while in the field to ensure all data is within normal parameters before returning to

the office. The more accurate work order records can be used to carefully monitor inventory as well as help inform predictive maintenance analysis. OOs tend to be the most conservative about the long term value of the wind plant and digital work order will enable better decision making at all levels within the organization.

Executives are interested in using digital work order data metrics to clarify to stakeholders that the plant is being managed in a financially responsible manner with a long term plan to maximize return on investment. Regulatory compliance is an important part of plant ownership and executives must ensure that regulations are not violated in order minimize fines and ensure maximum wind turbine uptime.

**Table 10: OO CMMS Value Propositions Summary**

| Employee | Primary | Secondary | Tertiary |
|---|---|---|---|
| Technician | Higher work order fidelity | Precise time management | Appropriate compensation distribution |
| Manager | Improved maintenance forecasting | Upgraded inventory management | Increasingly accurate job performance evaluation |
| Executive | Better return on investment | Accurate regulatory compliance | More detailed financial accountability |

## 5.2 OEM CMMS Value Propositions

Table 11 summarizes the value propositions of OEMs for each of the three employee types. Technicians who work for OEMs may work on a specific plant for the duration of the warranty period which is typically two to five years. In the case of an extended warranty an OEM could be involved for a longer period of time, but some of the extended coverage plans do not exceed ten years in total length.

Technicians who work for OEMs are often trying to reduce costs by being able to make real-time decisions that keep in mind resource usage. There is almost always a “cat and mouse game” between OEM and OO, and the technician has to walk a fine line between taking reasonable care of the wind turbine while keeping in mind that the warranty period will be ending in only a few short years. Technician satisfaction is improved by having access to more data as a result of the CMMS being in place. The CMMS helps shed some light on how the technician should best navigate this precarious balance between the demands of the OEMs versus the OOs.

Managers process large numbers of work orders for all the wind turbines that are still under warranty. Office efficiency is paramount for hedging against increased warranty costs. Understanding how to curtail surprise expenditures during the warranty period is advantageous to OEMs. CMMS makes it possible to spend less time processing work orders while having greater accountability and potentially increased customer transparency. Some OOs are negotiating for access to work order records during the warranty period and CMMS makes this hand-off of information drastically easier.

OEMs are interested in research and development and how to improve future products. The data gathered by a CMMS during the warranty period can be used by an OEM to help inform where the

research and development team should best expend their effort to improve the most failure prone and expensive components of a given wind system. The additional purview provided by digital work order data can also be used to advise and substantiate a marketing message that would otherwise not be justified.

**Table 11: OEM CMMS Value Propositions Summary**

| Employee | Primary | Secondary | Tertiary |
|---|---|---|---|
| Technician | Confident real-time decisions | Insightful resource allocation | Improved job satisfaction |
| Manager | Higher office productivity | Improved accountability | Greater customer transparency |
| Executive | Informed product improvement | Substantiated marketing messaging | Predictable financial forecasting |

## 6.0 Conclusion

Wind specific CMMS has the potential to improve how wind turbine O&M is performed. CMMS in other industries has a proven track record, providing cost savings in addition to a host of other trickle down benefits that help make organizations more competitive. The oil and gas industries, in particular, have a number of parallel challenges to those that arise in the wind industry, such as harsh environmental conditions, remote locations, a high priority given to uptime, and potentially dangerous working conditions to name a few. CMMS has become standard in the oil and gas industries and it is expected that the same will eventually be true of the wind industry.

Wind CMMS should be a purpose-built system that is dedicated to overcoming the O&M management issues of the wind industry. CMMS for wind places an emphasis on a technician interface so that field data in-take is especially easy to navigate and can be completed in equal or less time than the industry standard paper form. Additionally, wind CMMS places a premium on making work order data driven reports quickly available to anyone within the company regardless of technological skill level. These two elements, 1) the ability to quickly take in accurate digital data in the field, and 2) the ability to generate informative industry specific reports with little time or skill required, enables wind CMMS to encourage greater adoption of predictive maintenance practices.

Because CMMS makes work order data digital, technicians will have historical work order data at their fingertips in addition to the "tribal knowledge" they already have. In an industry that tends to have a high employee turnover rate, relying on "tribal knowledge" can be particularly problematic when an experienced employee leaves the company. Wind CMMS can help reduce the time to get new employees up to speed by giving them access to past work order data.

The three segments were found to have notability different company properties. ISPs tend to be smaller companies that focus on a mix of long term O&M contracts in addition to specialty O&M work such as blades and gearbox repair. The specialty side of ISPs really separates them from other organization types because the company often has extensive knowledge within a specific subsystem domain. Also the specialty work can tend to be highly distributed throughout the country and an ISP can be a very dynamic place to work as they are often on-call as specific O&M emergencies arise.

OOs are the financial "hub" of the wind industry and are often in the business for the long haul, being that wind turbines have an expected life of 20+ years. The OO market is dominated by a few large multinational conglomerates; however there are over 2,100 OOs worldwide. From 20% - 25% of the total levelized cost of wind turbine ownership is the result of O&M costs, and it is the goal of OOs not only to reduce the magnitude of these costs, but also to reduce their volatility. Low, predictable O&M costs are highly favorable to OOs. O&M costs tend to vary based on region, access, part availability, and distribution of wind plants.

In order to manufacture large industrial systems like wind turbines, OEMs have had to invest a substantial amount of capital into manufacturing facilities. As a result of the large infrastructure investments, OEMs tend to have a difficult financial challenge as the demand for new wind turbines

changes. Increased competition from China, the variability of the PTC in the US, and many wind turbines coming out of warranty have all contributed to a reevaluation of OEMs' baseline business model. As a result, OEMs are placing a higher priority on extended warranty and O&M service packages to help combat dwindling wind turbine sales margins. The offshore market in the US represents a new potential market for OEMs to compete in, and it is unclear who will be the success story for offshore installations.

In many cases wind CMMS has the potential to help maintenance organizations overcome some of the challenges they face. The value of CMMS varies based on the specific organization type, but in general such systems offer a strong case for adoption assuming the switching costs can be properly managed.

For ISPs, CMMS has the potential to address the problems associated with having maintenance teams functioning remotely around the country. Digital work order systems can ensure that safety checklists are properly filled out, especially when crane, platform, rope, or confined space work is required. ISPs currently see CMMS as a competitive advantage as many of the companies do not have a comprehensive maintenance management system in place.

Many OOs currently do not have access to work order information accurate enough to truly optimize the total cost of ownership of their assets. Using CMMS, OOs will be able to much better track their assets by reducing labor, inventory, and downtime expenditures to name a few. OOs will be able to step towards increasingly data driven decision making through the use of digital work orders.

OEMs would like to use CMMS to reduce costs during the warranty period. CMMS gives OEMs a greater amount of accountability regarding the warranty work performed in the "cat and mouse game" that tends to exist between OEMs and OOs. Furthermore, OEMs will be able to feed the resulting work order data back into their research and development groups to be able to help inform the development future increasingly more reliable wind turbine designs.

CMMS has proven its value in a number of industries for the past thirty years. The analysis presented here has demonstrated that all segments of the wind industry stand to gain from the widespread adoption of CMMS. In order to truly actualize the value propositions discussed, it will be essential that the industry put forth a concerted effort towards moving to digital maintenance management systems in a manner that minimizes switching costs and recognizes the unique ways in which CMMS can be tailored to wind.