Meeting And Taking Advantage Of The Market Challenges For The Future Of Wind Power

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***Abstract*—It is expected that the use of wind power will increase significantly as the cost of traditional grid-based electrical energy increases, or as availability due to grid overload decreases. Add to this are the increasing concerns over the environmental impact of the production and use of fossil derived power. Clearly the use of renewables in the form of both wind and solar is a potential addition and in some cases a substitute. Still, most consumers fear the addition of wind power to the power-generation system because of preconceptions of high initial cost, lack of cost benefits due to power density and reliability, un-addressed environmental concerns, or simply a general lack of understanding of the technology. However, most of these concerns can be solved through the appropriate sizing of the power-generating unit based on location and purpose, which is often excluded from the public discussion, or by using turbines as power-offset mechanisms instead of as a sole-source system. This is particularly true for the small to mid-sized wind turbine systems.**

The use of these lower power systems for remote locations and third world applications will continue to grow, maybe exponentially, as these systems become more cost effective, autonomous, and transparent. The wind turbine portion of the energy market should not be taken lightly, even with all of the current and historical problems associated with its introduction into the market place. The placement and sizing of any new technology is often difficult but for wind turbine technology and because of its growth and offset potential the benefits may well outweigh the problems, for at least some of the applications. On a more global scale, everything that is used to improve and make wind power more transparent and financially viable to the consumer will have instant appeal for remote, unattended applications. It will also provide safety and health related advantages in addition to the democratization through power-enabled communications of the under-represented regions of the globe.

I. INTRODUCTION

Wind power has been around for centuries, originally used to drive sailing ships, power gristmills, and for pumping water. While these uses continue even today in remote regions of the world, all of them have their limitations related to total energy captured and efficiency versus the cost to install and maintain these systems. The primary issue with wind is, as it has always been, its intermittency. The irregularities and intensity of the wind are related to geographic location, the season, and the weather; all of which are directly linked to the Sun's solar activity and the Earth's relative position, both for the axis tilt and the rotational position.

The temperature changes from night to day create regional energy imbalances that are regulated through the movement of air and other weather associated phenomenon. Even with a lack of predictability, wind is very much an available and renewable commodity. Because of the magnitude of the energy present in the wind and its relative inexpensive cost, it cannot be ignored for its potential to supplement our current and future energy needs. Also, in a growing number of situations, it could replace some of our current and future energy requirements.

It is the intermittent and unpredictable nature of the wind, which creates most of the problems in using this resource to offset, replace and/or supplement, our current electrical power needs. To understand this from a power generation perspective the two terms that are most used to define power generation are the availability factor and the capacity factor. The availability factor relates to what percentage of the time a power generation device is available to generate and provide power. Alternative energy systems like solar and wind are touted to reach a 95–98% [1] availability factor, as they require very little maintenance or downtime.

This is why an additional factor must also be introduced to assess total potential power generation, the capacity factor. The capacity factor is the measure of the percentage of actual power produced divided by the maximum amount of power that could have been produced over a specific period of time. Again, conventional power plants can have a very high capacity factor if they are used as base load plants. Downtime and maintenance issues affect this factor, which for conventional coal burning or nuclear plants is on average (yearly) 12.5% [1].

Similar industries comparable to wind turbine manufacturing within the U.S. include solar panel manufacturing, electrical equipment manufacturing, and aircraft, engine, and parts manufacturing [2]. Of these, solar energy is the other more prominent source of renewable energy. While many renewable energy systems are attractive because of high availability, the source of their energy is often cyclic and unpredictable and thus their capacity factor can be less than economical. For example solar panels generate primarily during the day light hours and with varying amounts of retrievable power based on sun angle, solar panel angle, etc.

In the case of wind energy, the wind speed varies cyclically from day to day and hour-to-hour with somewhat reliable peaks in the late evening and early morning. So while these “free” energy sources are attractive, their performance characteristics and capacity factors need to be considered during the design and implementation process and more particularly during the cost to benefit analysis.

Often, the actual cost of the system and installation plus service and maintenance expenses directly affect the true potential profitability of these systems, where in some cases the return on investment may never be realized. For example in some larger wind farm applications it is the need to offset peak requirements and overages that drive the acceptability of these systems where profitability is not necessarily the highest considered requirement. In other cases the lack of grid power for remote locations may easily force profitability to be of a lesser concern to just having some access to power. Even for these situations, it is in the location, material, and design attributes of these wind systems where many of the future advances will be made to capture even greater quantities of this readily available, though un-predictable, natural resource. All of this work, of course, will need an eye to the continual improvement in sustainability and performance efficiency for these systems. Even considering the inherent problems with wind energy capture, the viable uses for wind energy for our current and ever increasing energy needs are visible and manifest.

Continued research and development, like performance modeling and testing of vertical axis wind turbines at West Virginia University [3]-[7], is aiming to improve performance of these systems through a systematic research and development based approach. Additionally, initial research recommending airfoil selection [8] and structural considerations [9], as well as small and large scale experimental testing [10]-[11], has cleared a way for future designs, improvements, and advances. This work like similar efforts at institutions around the globe will help to increase the availability and profitability of future wind turbine technologies.

II. The Current US Electrical Grid

The current electrical energy distribution system, at least in the US, is referred to as a grid where the general public believes that the system is contiguous and uninterrupted. While there are some consistent elements in that understanding the reality is that the grid is discretely operated and controlled within a number of sectors. While these sectors work together to route and re-direct capacity, the magnitude of these excess capabilities is relatively small. In other words, the local power grid is designed to handle their direct customer base with some small amount of reserve to handle the coldest days of winter and hottest days of summer. These individual power companies are all profit centers and are responsible to produce power as inexpensively and as reliability as possible. For the most part, except during crises, they do their job routinely and with few interruptions.

Their capacity is dependent on resource availability, both energy and money, and the capacity of the transmission system, plus the willingness of the governing agencies and the voting public to allow their future expansion [12]-[13]. While it is true that a properly sized and operated power plant has reserve capacity, most of that excess capacity is normally used for maintenance and for those few days where overloads are anticipated. They only maintain this minimal excess capacity because of the enormous expense both in capital and personnel of keeping it available [14]. One of their largest current concerns is not in having excess capacity but in having it idle with no load because of irregularities in customer load demand or, for wind turbine supplemented systems, excess and/or intermittent wind power production.

If wind capture is sufficient to off-set at least a small percentage of the current base power plant production, it has the potential to increase the idling of on-line generators that must be kept spun-up to anticipate changing wind conditions. Couple this with the need to enlarge transmission capacity with the placement of any appreciably sized wind farm, particularly if it is remote from the base plant, and the inexpensive wind capture system becomes less cost effective, at least for the immediate future and under the current-use doctrine.

Because of these concerns some power companies co-locate their wind farms on-site around conventional power plants, thus reducing the additional transmission costs and allowing for more responsiveness during changing wind conditions and consumer needs. While this is more commonly used in other countries, particularly in Europe and the Far East, the reality is that intermittency is still a major concern for them, as well as for similar cases in the US where most power plant locations do not lend themselves to wind turbine farm placements.

III. The US Wind Power Situation

Generator capacity is the maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, adjusted for ambient conditions [15]. In 2012, wind power became the largest source of new generation capacity added to the US electrical grid. Wind power contributed roughly 43% of all US generation capacity additions, overtaking natural gas-fired generation as the leading source of new capacity [16].

The wind turbine manufacturing industry is largely driven by investment tax credits and other government incentives that encourage energy producers to establish wind farms in the US [2]. The largest contributor to this effort, in recent years, has been the federal production tax credit (PTC), which granted wind power-generating companies a tax credit of 2.3 cents per kW of energy produced [2].

Though wind turbine manufacturing, wind power production, and industry revenue have all fluctuated drastically over the past five years, the trends have looked more positive in recent years with a peak expected around 2015 year. According to the Energy Information Administration (EIA) in 2014 wind generation capacity increased to total 65,643 MW of energy and is expected to increase to 75,594 MW by the end of 2015 [2]. Furthermore, the effects of the expected wind generation increase allowed industry revenue to shoot up by 117.5% reaching $14.2 billion in revenues [2].

It should be understood, though, that this increase was primarily made possible through continued assistance from government agencies such as the PTC, which offered subsidies to wind turbine-manufacturing enterprises. Unfortunately, these contracts were set to expire at the end of 2014. It is because of this that newer projections show a decline in wind turbine manufacturing demand and revenue. For example, the ISBISWorld forecasts that, due to the ending PTC arrangement, the wind turbine manufacturing industry will plummet with an annual growth of roughly -23.2% in the years following 2015, and continuing until the end of 2020 [2].

Even with all of this said, wind is the next best bet to partially off-set the world's growing energy requirements for the next few decades, and thus these drawbacks will need to be addressed, though some already have. While the problems and their solutions are very complex, it all comes down to two immediate considerations, intermittency and capacity offset. Consider these two as independent but interconnected issues as will be discussed further in this document. Also, note that these issues as applied to the range of wind energy capture opportunities, including: small, low capacity wind energy capture for residential and small business applications; mid-range, mid-scale local grid, for communities and larger businesses; large, high capacity wind for direct regional grid applications, large wind farms. Also, note that while this discussion fits nicely with a well-developed power supply system, these concepts can easily dovetail into remote or under developed power system applications.

The evolution of wind energy in the U.S. has prominently focused around the large-scale wind turbine industry. Instinctively it was assumed the heightened size -economy of scale- applied to the wind industry, like for most other energy sources, would allow for increased forgiveness within the infrastructure responsible for gathering and storing the available energy. Over time, though, this has been reevaluated and the wind turbine industry has grown to become defined by its several subdivisions of rated capacities, of which three predominant categories have emerged. Fig. 1 highlights this breakdown of the wind turbine market products and services in Mega-Watts for 2015 [2]. This study will examine the small (0.1MW or lower), mid (0.1 to 1 MW), and large (1 MW or greater) size capacity wind turbines.

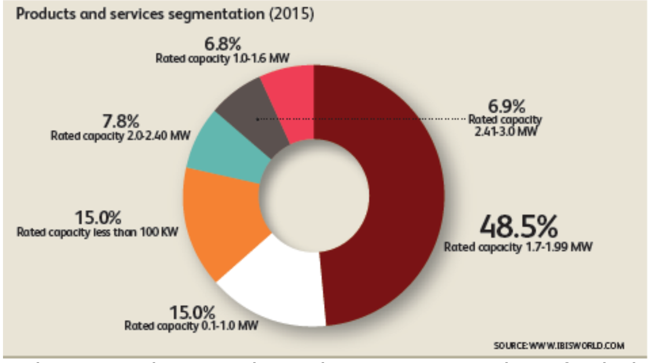

Fig. 1: Products and Services Segmentation of Wind Turbine Industry in 2015 [2].

IV. Small, Low Capacity Wind Turbine Systems

Most lower capacity wind capture systems are designed currently to provide local power and are not normally connected to the local grid distribution supply in the dwelling or business structure. The majority of these systems are of such a small capacity, and lacking sophistication and complexity that they are installed and employed to power auxiliary devices, such as outdoor lighting, pumps, etc. This sector has also shown strong ties to agriculture.

Small wind turbines are normally customer-sited, primarily used to provide supplemental power for residences, farms and small businesses. Approximately 18.4 MW of small wind turbines (100 kW and smaller) were sold in the US in 2012, with 86% manufactured by US companies [16]. These figures show a 3% decline in annual sales (in terms of capacity) relative to 2011, which is further exaggerated when compared to the peak sales year of 2010 [16].

The largest 2012 markets for these small turbines were located in Nevada, Iowa, Minnesota, Alaska, and New York [16]. The average installation cost of the US small wind turbines in 2012 was reported at $6,960/kW (a 15% increase from 2011) [16]. A variety of state incentive programs have historically driven sales in this sector, plus wind turbines of 100 kW or smaller are eligible for an uncapped 30% federal investment tax credit (ITC) through 2016 [16].

Newer systems are available that can be connected to the local bus (often called grid connected) which also include the power conditioning and circuitry to integrate these energy sources into the local grid network. Some of these are even sophisticated enough to permit net metering, but come with the additional cost of an appreciable increase in up-front purchase price, installation cost, and complexity, notwithstanding the cost and availability of maintenance and service.

The promise implied with the advent of wind usage for the individual consumer is that the low range wind user would be able to off-set their entire energy usage and even sell power back to the local grid during times when their electrical production exceeds their household usage, subject to wind conditions. While the smart grid components are being developed and produced, an increasing numbers of governing bodies have put laws and incentives on the books to allow for this capability. The reality is that the additional start-up costs coupled with longer payback periods currently make this less than attractive but for a very small portion of the population, or those who are willing to take a significant financial loss in the spirit of being "environmentally green." It should be noted that the cost and complexity of some of these smaller systems placed improperly in locales with limited wind availability could even have a negative environmental consequence exceeding the expected return in value.

It is worth noting that there are very few complete, mass-produced wind turbine systems available for the consumer to purchase and have installed capable of returning excess power to the local grid. There are even fewer that would make this cost effective even if the local grid could handle the extra, intermittent, and less critically conditioned power [17]. Add to this the intermittency and availability of the wind, in addition to the needs for a local storage and additional conditioning medium to smooth out the power levels produced by these larger than necessary low capacity units, and the costs could escalate for the local grid system, which in turn could cause elevated costs to all of the local users.

These additional expenses will prove a less than effective justification for increasing the size of the individual, consumer owned wind turbine system past their currents off-set needs. In fact, it may be shown that for consumers on a grid, the amount of cost-effective power that would allow the system to be transparent to the owner is only a small percentage of their current maximum usage. Similar in fact to the percentages that large wind farms would have over a base plant capacity to be economically viable.

To address the issue of the storage medium is the key even at this end of the power scale, if you want to produce more power than you can consume over any one-time period. Otherwise you are faced with excess capacity that will not help to shorten the payback period, which has now increased through sizing, to allow for the larger capacity. Additionally, these larger systems are also more complex and require a more sophisticated operations and maintenance plans, which most consumers are not interested in addressing. Electrical power while a necessity is also a convenience. The average user has very little interest in what it takes to deliver power to the switch that is flipped in his home and even less interest in having a part to play in supplying that power for his use.

This would imply that there is only limited potential at the low end of the wind generating scale; which is the farthest from the truth. The use of wind power must be differentiated into two categories: sole use or offset use. The sole use applications for wind power are predominately for applications where it is the only or most expedient choice, such as applications in sailing, pumping water, or other mechanical processes, or in locations not supported by a local grid. There are numerous agricultural opportunities that employ wind turbines to nullify the expenses of stringing electric wire and because the power is used intermittently, for example pumping water into a cistern, or for crop irrigation.

The second category, offset, presents more interesting opportunities. If the consumer sizes wind turbines to simply offset some of the current usage, then the initial costs can come down significantly and the time-to-payback is reduced enormously. For instance, in this offset scenario, there is no need for peak storage or grid metering requirements. Additionally, these systems are smaller and easier to install and maintain.

One such system incorporates a viscous controller instead of a generator controller. In this system the viscous controller maximizes the capture efficiency of the wind turbine, as similarly performed by the standard electrical controller, but instead of generating power it produces heat. This heat can then be transferred into the customer's hot water system, which serves to not only off-set the power requirements but it also acts as a storage medium during peak wind conditions.

It might be assumed that only offsetting a portion of the 15-25% of the current household energy requirements (the amount of energy require for domestic or small business hot water [18] usage, for example) is not worth the trouble. The reality is, however, that energy prices are going to continue to rise and with the increased demand, short-term shortages may increase in frequency. Multiplying this smaller, more economical offset amount by even a fraction of the 117.5 Million homes [19] and 21 Million small businesses [20] available for wind capture in the US, and the contribution becomes significant. These projected capture areas include land plots with two or more acres of space. [21] This total will effectively extend existing generating capacity for years to come and reduce or delay the inevitable increased cost per kilowatt.

What is needed is a low cost and easy to install wind turbine system sized to offset a portion of the consumers' current power usage. It also needs to be maintenance-free and effectively bulletproof so the average consumer can self-install, or consigned installers can provide it. These systems do not require the expenses or the service attention of the standard generator based systems and even less concern on the part of the consumer. Based on a market survey the sizes could range from 0-10 kW for the individual dwelling and up to 100 kW for small businesses. [21] In all cases, the sizing should be less that the on-going individual, hot water systems and priced to provide payback in a period of less than 2-4 years.

For the low capacity wind applications, the individual consumer capacity offset within the grid is handled because the product is sized to never exceed the consumer's current usage. With respect to wind intermittency, when the wind blows the consumer saves money and gains a payback for their investment. When it doesn't blow, everything remains the same as before, totally transparent to the user and the power grid.

A. *Low Capacity Market Opportunity*

The market has seen a growing number of small wind turbine entrees, designed as one-size-fits-all, with little anticipation of the needs of the consumer or their ability to install the unit with the required interface to their existing wiring infra-structure. The market needs a well-designed series of sized units with the marketing and training required for their proper selection and installation. These units should be provided as an offset to the customer's normal electricity usage and be maintenance free or designed to provide the buyer or a central service provider with the needed information to affect the needed maintenance and repairs. All of this, of course, geared to the non-technical consumer to make the whole process as transparent as possible; much like satellite TV.

The technology should be rigorously designed for ease of use and safety. The global patent art is deep in this area, although most of it has expired, but there are ample areas to refine and perfect patent coverage. There is significant art to be developed for the different potential applications and how the turbines are used and/or their generating source and delivered product for those interested in investing in this area of renewable energy.

Additionally, several lift enhancement technologies, and mechanical and electrical conversion technologies will need to be considered for this range of sizes, although at this point there are plenty of turbine blade designs and the support equipment for both vertical and horizontal axis turbines that can be utilized as the market penetration is expanded.

Growth in this sector of the wind energy market will encourage further advanced turbine blade designs and the resulting needed support equipment. There is even a current interest in small portable units for recreational and emergency needs, including military and humanitarian uses. It should be noted that a well-designed and inexpensively produced series of turbines would have global appeal as well, particularly in non-grid supported regions of the globe.

V. Mid-Sized, Local Grid Wind Turbine Systems

Mid-sized, or mid-scale, wind turbines (100 to 1000 kW) are estimated to generate 15% of the total industry revenue [2]. They account for such a small percentage of industry revenue due to their limited product availability in the US [2]. The National Renewable Energy Laboratory says that the lack of successful adoption of wind power in the US is, in part, due to the lack of mid-scale wind turbine market availability [2]. The IBISWorld study estimates that "this product segment will decline as US manufacturers reduce or eliminate production of these mid-scale wind Turbines" [2].

The mid-range wind applications are similar to the previous illustration, but with several caveats. Several communities and large business concerns are installing or considering the installation of mid-scale wind turbines. Most of these are in the 100-1000 kW size range. With few exceptions, these applications are used to off-set current usage with some applications looking to sell limited amounts of power back to the grid; when the wind is at its peak during off usage periods. Note that as the price per kilowatt continues to increase there will be an increased interest from communities and larger commercial concerns to reduce their energy costs through wind, and other renewable resources. As these needs and interests grow the wind intermittency problem will become more pronounced, creating the same problems, albeit on a smaller scale, as with the conventional power generation systems with storage and cost versus size issues.

Mid-sized wind systems can consist of a single unit or multiple units of varying sizes to accommodate the financial limitations of the community and/or business. These systems may also be sized to fit the local terrain and adjacent structures. Most likely these units will be tied together and maintained by a common service provider. The size of these units will continually grow as the warranted life of these systems increases. Also, as these systems grow in sophistication the use of a variety of advanced technologies will come on line to make them more capture efficient and more reliable, to help shorten their payback period.

It is clear, also, that these mid-sized units will continue to be used by manufacturers as prototype testing and demonstration units for the even larger turbine systems. This will become particularly true as new and uniquely shaped configurations are developed to solve the anticipated materials problems with the current horizontal axis turbines, which have mechanical design, strength, and fatigue limitations. Furthermore, blade and system failures are much easier to absorb financially for the 500 kW units than for units an order of magnitude larger. For the same cost of a large commercial system several of the mid-sized units can be placed and life-tested prior to making the enormous commitment to the art and the related sub-systems that have yet to be tested and validated for the larger designs.

A. *Mid-Range Market Opportunity*

The mid-range wind sector is open for additional penetration. Little attention has been given to this market sector, which includes units too large to put on your house and too small to make a dent in the generating needs of the regional power producers. While there will be smaller numbers of these purchased in contrast to the low capacity wind market, their larger potential for reliable grid off-set will make them attractive to communities and larger sized businesses and manufactures. Like their smaller cousins, these systems will need to be easy to install and maintain either with home grown staff and/or under a locally supported maintenance agreement. This size affords the platforms for consumer testing and an efficient and cost effective methodology for large-scale future developments, especially in size and system complexity.

It is the belief that future larger wind systems will include more alternatives than the current most predominately used horizontal axis systems. Unless there are some truly significant advances in mechanical design and materials, the current systems will reach a size/capacity constraint in the very near future. It is within the mid-range designs that will provide for the inexpensive testing and system integration for these future larger systems.

Add to this consideration for platform testing the environmental issues and the current noise levels, both of which are mitigated by several newer design concepts including vertical axis turbines, and the design future for wind turbines becomes a lot rosier. In all cases, and the examples above, these design requirements will best be determined fielding the mid-range, or smaller, configurations described here.

More importantly, these mid-sized systems can be made inexpensively and with an insurable life expectancy that will provide an adequate return on investment. While several of these mid-sized systems on a local grid could cause some of the same idling problems that are caused by the larger wind farms, it is clear that most of these mid-sized systems would be more judiciously placed to minimize intermittency and most likely as an off-set of the current usage levels.

It should also be noted that there is growing interest in these mid-sized units in non-grid or intermittent power regions as a stopgap measure to insure at least enough power for health, safety and communication considerations.

VI. High Capacity Wind Turbine Systems (Wind Farms)

Large-scale wind turbines exceed 100 kW in size. In 2012 the US wind power market reached a record 13.131 MW of new capacity added, bringing the cumulative total to approximately 60,000 MW [16]. This translates into a $25 billion (2012) USD invested in wind power project installation in 2012, and a cumulative investment total of $122 billion since the 1980's [16]. Furthermore a 90% increase in wind power installations was found between the years of 2011 and 2012, with the cumulative wind power capacity growing 28% [16]. The cost and difficulty of putting in large capacity wind farms is similar to constructing other major utility installations. Land purchases, zoning, and environmental impact, not to mention easements and rights of domain all complicate the larger systems and delay their implementation. Additionally, the problem with these farms is the need to capture as much wind as possible per acre to justify the initial expense. Add to this is the cost for transmission and grid acceptance, which is further exacerbated by the unpredictable nature of the wind, and the introduction of a major wind farm is a multi-year if not multi-decade development proposition.

Unlike the previous examples, a wind farm large enough to be cost effective [22] also results in an energy potential that could adversely affect the local power grid power plant, particularly during intermittent wind conditions, requiring the idling of excess capacity and/or producing power fluctuations in the grid supply [23].

All of these problems can be mitigated, at least somewhat, by incorporating storage devices to help average out the peaks and valleys in captured energy caused by wind intermittency. Some of the current solutions are chemical storage, pump-storage, and large-scale flywheels, with even more proposals being developed in our global research labs. These additional technologies add to the complexity of the system, but are expected to reduce the long-term payback period, even with the higher start-up costs.

These additions help to alleviate the intermittency problem, but it further exacerbates the capacity offset problem. To be cost effective requires wind farms and turbines to be larger and more energy efficient. Also, for wind farms, land is money and the co-location of turbines to maximize the extraction efficiency is a major consideration. The situation is also helped if the serviceable units are online when the wind is available and operational under most of the sites' environmental conditions. This involves using the turbines over a larger wind speed range and in temperature extremes that are often less than desirable, such as stormy and icing conditions.

Current large turbines are being considered to include de-icing technology that is normally used on aircraft. Vertical axis designs are also being re-considered that can operate over a larger wind range where some of the proprietary technology are being developed commercially and in many of our university research centers.

A. *High Capacity Market Opportunities*

It is evident that any alternate design will have trouble in competing with the currently fielded horizontal axis wind turbines. They have a large development lead, but even with that margin it has become clear that those designs will not advance in size much more than is currently available, at least not at a reasonable cost. Additionally, the newer configurations, some vertical axis, offer a larger variety of lift and control advancements that will outrun these older less efficient systems even without considering the greater speed and environmental range advantages of these newer designs. The reduced blade turbulence and shedding blade tip vortices, and thus noise levels, lower wildlife damage and esthetically more pleasing appearance will eventually deepen that market penetration. This, coupled with lower transportation and construction costs and even lower maintenance costs, augmented by the ability to co-locate turbines closer to each other will ultimately prove their long-term viability, and profitability.

VII. Summary

There is a lot of activity in the marketplace regarding the use of wind energy. It is being supported at growing global levels by almost all governing agencies [24]. Several governmental programs subsidize its development at unprecedented levels and over a range of applications unseen in most all programs of its type. Add to this the recent language and funding by many world leaders, re-enforced by on-going research and development programs, and the confidence that these incentives provide, will continue and most likely increase in size and scope.

The general attitude of the buying public is to consider taking another hard look at using renewables as a way to participate in these incentives, save some energy dollars, and contribute to the national and global energy needs. At the low capacity level, it is also a feel-good way to contribute plus it presents bragging rights to neighbors as well. At the upper end, the utilities are faced with the growing problem of making more with less, decreasing the carbon footprint, and planning for that next great power outage. At the yearly growth rate in energy consumption, the current power capacity will be outstripped in the very near future and putting more conventional capacity on-line is a long-term and publicly scrutinized process. Current large-scale producers have no choice but to add to the build-up in wind energy, especially while the government and the public are encouraging and supporting the effort.

A. *Combined Market Opportunity*

This document proposes three opportunity levels that, with the correct and timely funding, could lead to a series of business opportunities and a general payback to the public and the environment. A significant array of patent art has been identified and/or prosecuted that will provide an advantage to these future investments, both domestically and globally. The timing is right, and the consumer environment is ripe for a well-designed and executed product development, and marketing and distribution plan. The critical elements of the R&D efforts are in place and ready to be employed, and with a good business development and leadership team a market-responsive product line can be quickly designed and fielded for commercial use.

Each of these development opportunities are stand-alone capable. Each has its own art and design requirements. Each, also, has their own market and customer base and with each there is the need to create the business plan that will work with the market sector and the purchaser. For example, at the low-end there is the direct purchase model where the profit is realized from the direct sale. There is additional potential in monitoring the performance and remotely providing service. This feature, or service, also makes the product even more transparent and allows for up-sale sizing for those locations where appropriate.

For the mid-scale region the business model could be direct purchase, lease purchase or direct lease, again with remote monitoring to enhance maintenance and to have the statistical data to take advantage of tax incentives and possibly to help with policy considerations. This also provides the test bed for enhanced lift efficiency, and thus increased capture capacity, for introduction into larger turbine power applications.

At the large-scale wind portion of the market the business model would be to sell or lease to the large producers or to become one of those producers. The key here is to introduce larger and more capable units than can be produced with the current designs, and to stay ahead of the intellectual property development for the support systems that will make wind power even more advantageous and profitable. Note that most of these larger designs and the peripheral support systems can be created from scratch but the most economical method will most likely come from building the advanced technology into the mid-sized units, in mass, for field testing opportunities.

The market is ready and the need is acute. The public is ready and willing to participate in the process. The art is under-developed and with the mood of the government, and the needs of the environment, the ability to get assistance and support has never been better. We, as a society, just need to get behind the necessity.

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IX. Author Biographies

Andrew D. Lowery has received degrees of Doctor of Philosophy in Engineering (2012), Masters of Science in Mechanical Engineering (2006) and dual Bachelors of Science degrees in Computer and Electrical Engineering (2004) from the College of Engineering and Mineral Resources at West Virginia University (WVU). Currently, he is a Visiting Scholar and Adjunct Assistant Professor in the Mechanical and Aerospace Engineering department at WVU and a Research Assistant at the Center for Industrial Research Applications at WVU where his research focuses primarily in the areas of control systems and systems engineering. Dr. Lowery has been associated with various projects funded by federal agencies (including DoD, DoE, and DARPA) while also having multiple opportunities to teach engineering students at the undergraduate level.

During his educational career he has participated in research in the areas of design and controls, electromagnetics, and engineering education, resulting in peer reviewed publications, including nine conference proceedings and two journal or bound papers. Dr. Lowery is a member of the Institute for Electrical and Electronics Engineers (IEEE), Society of Automotive Engineers (SAE), and Sigma Xi, The Scientific Research Society.

Allison M. Arnold received her Bachelor of Science degree in Civil Engineering from West Virginia University (WVU), Morgantown, West Virginia, USA in May 2014. She is currently pursuing a Master's of Science in Mechanical engineering while working with the Center for Industrial Research Applications (CIRA) at West Virginia University on various developing technologies.

During her undergraduate career, Allison has upheld several vital positions within various student organizations, including Engineers without Borders (EWB), American Society of Civil Engineers (ASCE), Society of Women Engineers (SWE), the academic honor societies Alpha Lambda Delta (ALD) and Golden Key, as well as Chi Epsilon, the national Civil Engineering honor society. Her work experiences include a variety of vocations that have taught her a diverse array of skills.

James E. Smith received his Bachelor of Science and Master of Science degrees in Aerospace Engineering and Doctor of Philosophy degree in Mechanical Engineering from West Virginia University (WVU), Morgantown, West Virginia, USA in 1972, 1974, and 1984, respectively. He is currently the Director of the Center for Industrial Research Applications (CIRA) at West Virginia University, where he is also the Innovation Coordinator and Professor in the Mechanical and Aerospace Engineering (MAE) Department. He has taught at the University since 1976, before which he was a Research Engineer for the Department of Energy (DOE). He was the 2009 SAE International President and Chairman of the Board of Directors, which afforded the opportunity to travel to the innovation centers of the world.

During his 40-plus-year scientific career, he has been the principal and/or co-principal investigator for various projects funded by federal agencies (Tank-Automotive Armaments Command (TACOM), Department of Defense (DOD), HEW, Department of Transportation (DOT), US Navy, Defense Advanced Research Projects Agency (DARPA), and Department of Energy (DOE)), international corporations, and numerous US corporations. The work in these projects has resulted in the publication of over 250 referred technical papers and articles. This work has resulted in the granting of 34 United States Patents and numerous foreign patents on mechanical and energy-related devices.

Dr. Smith is a member of American Institute of Aeronautics and Astronautics (AIAA), Society of Automotive Engineers (FSAE) International, American Society of Mechanical Engineers (FASME), International Society for Computers and Applications (ISCA), American Society for Engineering Education (ASEE), and the Institution of Mechanical Engineers (FIMechE).