Report on
Wind Energy for Small Communities

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INUIT TAPIRIIT KANATAMI

Prepared for Inuit Tapiriit Kanatami
by John F. Maissan
Leading Edge Projects Inc.
30 Tay St., Whitehorse Yukon
Y1A 4M6 Canada
P (867) 668-3535 F (867) 668-3533
E john@leprojects.com

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EXECUTIVE SUMMARY

Under a range of realistic conditions wind energy projects can be economically viable in the north at oil prices in the order of $US60 per barrel. The main requirements for economic viability for the initial “leader” wind-diesel projects include: locations with economies of scale, availability of local equipment, availability of local technical human resources, access to reasonable transportation, committed community, committed project proponent, and a wind resource of 6.5 m/s or higher at turbine hub height (depending on local diesel plant fuel cost). These first projects are likely to cost $5,000 to $7,000 per installed kW if done well with good quality equipment. Wind resource data from towers at least 30 meters high with anemometers at 3 levels collected over a period of at least one year (preferably 2 or more) located on potential project sites is required for credible feasibility analyses.

The technology of cold weather wind turbines in the 50 kW to 300 kW range and the available wind-diesel integration technology is ready for planned installation in the north. There have been some advances in wind turbines recently, some good quality European wind turbines on the market, and a new model by a US manufacturer about to enter the market. For some wind turbines tall guyed towers are still lacking. Wind-diesel integration technology has been maturing in other countries and is available and applicable. This equipment is available in both sophisticated prepackaged modules or in less costly formats.

While both the wind turbines and the wind-diesel equipment has been improving, further improvements and cost reductions, will, in part, be dependant on the installation of projects to increase the sales volumes for the suppliers. New Leader projects will also provide their owners an opportunity to work with equipment suppliers to overcome any difficulties encountered. For the suppliers there is a window of opportunity opening up because the higher oil prices and the net metering opportunities are increasing the market for this equipment.

It is recommended that leader projects be carefully and thoroughly planned and that they be kept technically simple to start with, either low or medium penetration. Proponents will require adequate financial and human resources to overcome any difficulties encountered and to keep the projects operating. Because wind technology is relatively new and unfamiliar to most people, the provision of training for operating and maintenance staff is very important, and time will be required to gain experience. Following the success of leader projects, and based on the knowledge and experience gained in them; the same proponents could install projects in smaller more isolated communities.

Financial planning to maximize the use of available government support programs and to maximize project revenues is also important. Corporate ownership structure options need to be examined. As a minimum a very good working relationship with the diesel plant owners is required.

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1.0 Background

Leading Edge Projects Inc. (Leading Edge) was retained by Inuit Tapiriit Kanatami (ITK) to prepare a paper on wind energy for small northern communities to assist their community leaders in the realistic assessment of the feasibility of wind power (among other energy options) in their diesel dependant remote communities. Leading Edge researched available materials related to wind energy development in arctic and sub-arctic communities, consulted with various wind power developers in Canada and Alaska, consulted with a wind resource assessment specialist experienced in the north, and consulted with various wind turbine and wind-diesel integration equipment manufacturers in preparing this report.

Energy conservation per se is not discussed in this report on wind energy for small communities, but the author wishes to point out that wind energy projects should not take the place of energy conservation. Energy conservation (which includes energy efficiency) is typically the cheapest form of new electrical energy and electrical capacity "supply" (or the equivalent reduction of diesel requirement if you prefer), and the cheapest way to reduce energy bills. Wind energy can be a cost effective option to reduce diesel generation requirements in the appropriate circumstances as discussed in this report.

The purpose of this report is to assist Inuit organizations and communities in their assessment of wind energy as a one potential renewable energy option for the replacement of diesel generated electrical energy. All other renewable energy sources should be considered either for electrical energy generation or for space heating energy. The optimum and most cost effective community energy solution is likely to consist of more than one of these renewable energy options. This report is not intended to promote wind energy to the exclusion of these other renewable energy sources.

Readers should also become aware, as they study this report, that wind energy (like most other renewable energies) is capital intensive rather than labour intensive. This means, in practical terms, that there will not be much ongoing work created except briefly during the construction period. In large projects in southern Canada a rule of thumb that is sometimes quoted is that there is one construction job for every MW of wind farm capacity and one operating job for every 10 MW of capacity. The jobs created will be somewhat higher in small projects. The principal direct economic benefit of a renewable energy project would be the flow of interest from the money invested in the project to the party that put up the money to build it. The more money a community puts into a wind project, the greater the benefit to the community. There may also be some benefit to the local government owned power utility in the form of reduced operating cost, but with rate subsidy programs in place this is not likely to translate into lower power bills to the community's retail customers.

2.0 Wind Resource Assessment

The wind resource available within reasonable distance of any community will be one of the key factors determining the economic viability of any wind-diesel project. When examining diesel served communities for the potential to host wind power projects to displace diesel power generation, it is therefore one of the factors that must be carefully researched.

Since the energy content of the wind is proportional to the cube of the wind speed, even small increases in the wind speed a wind turbine is exposed to can make a noticeable improvement in project economics, or vice versa. The wind speed distribution can have a similar although less pronounced effect. It is thus of critical importance that accurate wind resource information on the actual site for a possible wind farm be available. Airport wind speed data and wind atlas data can be used as a preliminary screening tool to rule out communities with an obviously inadequate wind resource and to identify communities which may have an adequate wind resource, but any final community selection should be based on good quality wind resource data.

This also principle also applies to the selection of the specific wind farm site near a community that is a candidate for a wind project. In some instances there are geographic and topographic variations that can be used to advantage in selecting a site. A location on a hill or a ridge can make a significant difference in the wind resource which the wind turbines would harness. These local topographic and geographic differences cannot be picked up by the Canadian Wind Atlas calculation programs, so significant differences between Wind Atlas predictions and actual site data, positive or negative, may be encountered. Similarly data from an airport located either in a flat valley or on top of a higher ridge could lead to overly pessimistic or optimistic assumptions.

A January 2005 report by Terriplan Consultants of Yellowknife said: *"Wind energy has been measured in only 15 NWT communities so far. Most of these measurements come from airport-related weather equipment and may not represent the ideal wind energy sites in the community. More detailed assessment work is required to determine if grid-connected small wind systems could provide cost-competitive electricity in diesel-electric communities."* It is not known whether this is also the case in Nunavik, Nunavut, or Nunatsiavut, but it confirms the importance of good wind resource assessment at the appropriate sites.

The author's experience in wind monitoring (mostly in treed areas) also indicates that lower level (e.g. at 10 meters) wind speed data, at airports or elsewhere, can lead to significant underestimation of the actual wind speed at 30 meters or higher.

Appendix A consists of a table of Northwest Territories, Nunavut, Nunavik, and 2 Yukon communities (not all Inuit communities) displaying wind data (and some other data) from various sources. This table will give the reader an idea of the wind resources across the north. A number of the communities, especially those along coasts, appear to have significant wind resources. The source of this data will need to be considered, and if it is based on airport or Canadian wind atlas information, it should only be used as a screening tool. Communities with wind speeds in excess of 6 m/s (meters per second) annual average can be screened in and communities with wind speeds of less than 5 m/s can be screened out for consideration of wind projects in the short term. Communities with wind speeds of between 5 and 6 m/s could be screened in if taking advantage of the local topography might yield a significant increase in wind speed for a turbine to harvest. The communities passing this screening test would then be the focus of further work.

In the author's view it is vitally important that wind monitoring using up to date methods and procedures be conducted at candidate wind project sites. The minimum height of a monitoring tower should be 30 meters, and anemometers should be located at a minimum of 3 different heights (for example at 10, 20, and 30 meters). Without this information a credible assessment of the viability of a potential project is not possible.

3.0 Wind Power Technology Review

On a global basis smaller scale wind power generation technology, in particular the wind turbines themselves, is relatively mature. However, the bulk of the market at present is in moderate to warm climate applications and the cold climates of the north (or far south) bring their own special requirements to wind turbines and their towers. The special cold weather requirements are less well developed in the smaller turbines and towers, and there is considerably less choice on the market for these products.

Overall the much more sophisticated electronic / digital technology that has made wind-diesel integration possible will require different operating, trouble shooting, and maintenance skills than the comparatively simpler and better known diesel plant technology in use today. Training programs for the operating and maintenance staff is thus important for the success of wind-diesel projects.

There are many wind-diesel systems working around the world, including a report of 8 high penetration wind-diesel systems in Australia. There are several wind-diesel projects in Scandinavia, several in Alaska, but only a very few in Canada. The number of failures of wind turbines in Canada's north has resulted in a justifiable concern about the viability of these systems. However, when the circumstances of the failures are considered (one lightning related failure, one due to lack of maintenance, and one due to human error), and the improvements made to these turbines over the past 7 to 10 years, there is no reason to conclude that these machines are not ready for the Arctic.

Those directly involved in wind-diesel project operations contacted by the author consistently stated that the wind power technology was ready for the north, however all did allow that there was still a need for the technology to mature further. A view expressed regularly was that in order for the technology to mature, in particular the cold climate aspects of the technology, more wind turbines would need to be installed and operated in the north. Improvements would come with time and experience.

3.1 Wind Turbines

Wind turbine technology in the 50 to 300 kW size range, and for cold climate applications in particular, had, until very recently, undergone very little modernization over a period of 15 to 20 years. This was likely due to the limited sales in this market segment. Fortunately this trend has been reversed recently with both Entegrity Wind Systems Inc. and Atlantic Orient Canada Inc.

spending time and effort overcoming the well known problems in their machines (controls, yaw dampening, and tip brakes included). Those who successfully deploy these machines consider the fundamental components of the machine (generator and gearbox) to be robust and have put considerable effort of their own into the turbine controls and maintenance / modification of their weaknesses. Further improvements are coming from the manufacturers.

An established USA manufacturer, Bergey WindPower, has recently entered the field and is about to start selling its new XL.50 (70 kW peak output) direct drive, permanent magnet generator wind turbine. According to Bergey's website it will be available with a range of guyed towers. However, it is not yet known whether there will be a cold weather version available right away. Wind Energy Solutions (WES) of the Netherlands, a successor to Lagerwey, has recently re-entered the Canadian market with the WES 18 (80 kW) and the WES 30 (250 kW).

The advent of net metering across much of the USA and Canada will increase the market for this size range of turbine. It expected that this increase in sales volume will allow manufacturers to further improve their turbines and potentially reduce prices.

Enercon (a German manufacturer) has a 330 kW turbine, the E33, which is probably the highest quality turbine in this category. It is a direct drive unit with tubular tower heights of 43 and 49 meters. There are three of these units operating in the Antarctic (Mawson Research Station). Its main disadvantages are the need for a significant concrete foundation and the need for a substantial crane for its installation. Up to now the cold weather operation has been limited to -30°C.

Northern Power Systems have sold their first run of 10 NorthWind 100 wind turbines. It too is expensive and comes with a tubular tower (and the need for a substantial concrete foundation), but it is designed to operate in temperatures down to -40°C.

Fuhrlander of Germany, through its agent Lorax Energy Systems, LLC of Rhode Island USA, manufactures and sells turbines of 100 and 250 kW (as well as a 30kW unit). They have a cold weather design package that the literature says will allow them to operate down to -40°C. These turbines also have tubular towers and thus a need for substantial foundations as well as a crane for installation.

Bergey WindPower has been indicating that they will soon be marketing their new direct drive XL.50 wind turbine. It will be available in two different rotor diameter options and a peak output of 70 kW. Tower heights of 28 meters to 82 meters (reportedly guyed towers) are to be available. At this time it is not known if a cold temperature version suitable for the arctic will be available.

WES Canada (office in Smithville, Ontario) has two turbines of interest. The WES 18 (80 kW) available with a 40 meter guyed tower, and the WES 30 (250 kW) which uses a 50 meter tubular tower. Company officials are concerned about the failures that have occurred in NWT in the past and have said that without a guarantee of professional maintenance they would not sell turbines into northern Canada.

One general trend in the wind industry that could benefit the north too is the development of wind turbines more suited to lower wind speeds. These turbines have a greater swept area than what has been the norm per unit of capacity. A relevant example is the new Bergey XL.50 for which both 14 and 16 meter rotor diameters are available. Existing turbines such as the Entegrity EW15 and Atlantic Orient's AOC 15/50 equipped with a larger rotor diameter would generate more energy in moderate wind speeds.

Present potential suppliers of turbines suitable for the small communities of the north are:

Atlantic Orient Canada Inc., AOC 15/50, 60 kW
Enercon GmbH, E33, 330 kW
Entegrity Wind Systems Inc., EW15, 60 kW
Fuhrlander / Lorax Energy Systems LLC, FL100, 100kW; and FL250, 250 kW
Northern Power Systems, NorthWind 100, 100 kW
Wind Energy Solutions Canada, WES 18, 80 kW; and WES 30, 250 kW

There are several larger communities in the north with adequately large electrical needs that would probably benefit from the cost effectiveness of wind turbines in the 250kW to 1000kW range, should the wind resource be adequate for economical wind power generation. In recent years manufacturers have been discontinuing turbines in this size range as the market moves to larger and larger turbines. There are only a few models between 330 kW and 1000 kW left that the author is aware of (Enercon E48 810 kW; Fuhrlander FL600 600 kW; and Mitsubishi MWT600 600 kW). These are not discussed further in this report but if they are to be considered for projects their low temperature operation limits and the crane requirements for their installation will need to be considered.

3.2 Wind Turbine Towers

Tower designs can be a significant portion of the cost of northern wind projects. Free standing tubular towers usually require a substantial concrete foundation. Concrete in isolated communities is expensive and, in some Alaskan communities at least, aggregate has to be barged in (seasonally) which further adds to costs. Free standing towers most often also, but not always, require a crane for their installation. Crane mobilization and demobilization presents both logistical and cost challenges. Guyed tubular (or lattice) towers, such as those developed by wind turbine manufacturer Vergnet of France (and more recently WES and Bergey), result in reduced foundation and anchor loadings and are thus cheaper to install. Guyed towers are not yet available from turbine suppliers such as Atlantic Orient Canada, Entegrity Wind Systems, and Northern Power Systems, but are available from WES Canada and are reportedly to be available for the Bergey XL.50 turbine. Lattice towers are less desirable in locations where icing is a problem as they provide a great deal more surface area onto which the ice can adhere.

Another tower aspect that is of significant importance is the height. Since the capital costs of building roads and power lines in remote northern communities is expensive, it is generally not practical to go far from these communities to take advantage of local topography to develop the best wind site. As a consequence the only alternative for increasing the wind resource which the turbine is harvesting is to put it on a taller tower. While taller towers cost more than shorter towers, the percentage increase in energy capture is usually in excess of the percentage increase in project cost. Bluntly speaking it is cost effective. However, the turbine manufacturers that have the smaller turbines suitable for the north have not yet designed such towers; mostly they still have 25 and 30 meter towers. The exceptions are the Enercon E33 330 kW, the Fuhrlander FL250 250 kW, and the WES turbines which have towers between 40 and 50 meters available. In a location with a modest 6 m/s wind resource at 30 meters, a 50 meter tower would increase the energy output of a turbine by about 20% over a 25 meter tower (wind shear coefficient of 0.16).

Taller, guyed towers can be designed (Vergnet of France and WES have done so) – it is simply a case of vendors needing customers for them to justify designing and building them.

3.3 Wind-Diesel Integration

Key components of wind-diesel integration include (depending on a whether low, medium, or high penetration system is installed) some or all of the following: controllers for the wind turbines, an overall master controller for the wind plant, modern digital governors for the diesel plant if not already so equipped, a modern controller for the diesel plant if not already so equipped (ideally one that combines the control of the diesel plant and the control of the wind plant into one), a dump load boiler or equivalent, a low load diesel, and a synchronous condenser. Other components may also be required or desirable.

The wind-diesel integration equipment is less weather dependant than wind turbines as this equipment is normally housed in a heated building such as the diesel plant, or in temperature controlled enclosures. In practical terms this means that the development and maturation of this technology anywhere in the world is applicable anywhere else. The north can thus benefit from the development work done elsewhere. This is readily apparent in the relative maturity of the wind-diesel integration equipment from The Powercorp Group of Australia. Australia has many isolated regions, much like northern Canada, except that their climate is hot. Powercorp wind-diesel equipment is available in North America through its subsidiary, Powercorp Alaska, LLC, located in Anchorage, Alaska.

Another company with relatively mature wind-diesel integration equipment is Northern Power Systems (NPS) of Vermont USA. They have been in the wind-diesel and alternative energy business for many years. This company has also designed and built for the north a 100 kW direct drive wind turbine, the NorthWind 100. It can operate in temperatures down to -40°C. Ten of these wind turbines are now deployed, or about to be deployed, in Alaska. These machines tend to be expensive and require a crane for installation. Foundations for free standing towers can also be expensive, see comments under foundations and civil works.

Frontier Power Systems (FPS) of Prince Edward Island (PEI) also has a wind-diesel integration system, one that is more economical that those of Powercorp and NPS. This system is based on FPS's principal Carl Brothers' experience in wind diesel integration work at the Atlantic Wind Test Site, and in cooperation with the wind-diesel test bed work done at IREQ (Hydro Quebec's research group) in Varennes. The FPS system has been installed in their own wind-diesel project in Ramea (on an island off Newfoundland). This system can be replicated for other projects but FPS does indicate that their system, while lower in cost, may not be as mature as Powercorp's or NPS's systems.

Modern digital governors for the diesel generators will be required to ensure that the diesel generators respond quickly as the wind fluctuates. This is necessary since the output of wind turbines will change quickly with changes in the wind (gustiness). Without fast acting governors there will be fluctuations in the frequency and / or voltage of the power system.

The overall diesel plant control needs to accommodate the control of the wind turbines either directly if the power plant controller has the capacity to do so (or if a new one that can do this is installed), or by interfacing with the wind plant controller. Digital governors and plant controllers are existing mature technology. However any given diesel plant may require modernizing to accommodate a wind plant.

Low load diesels, those with the ability to operate effectively at a very low percentage of their rated capacity, may be required if the existing diesels in the plant are not capable of doing so. These may be purchased as a complete package such as provided by Powercorp, or may be purchased directly from manufacturers and installed as any other unit in the diesel plant fleet. Some modern diesels are capable of carrying a load that is a relatively low percentage of their rated capacity. Low load diesel technology is available but is relatively new and any given diesel plant may or may not be equipped with these units.

Boilers equipped with a large number of small capacity heating elements or the ability to vary the power input, are often used as a means of leveling out the fluctuations of wind power. A fast acting controller will add or drop heating elements (or otherwise vary the load on larger heating elements) as the power output from the wind plant increases or decreases. In projects with a substantial wind penetration level, a specified minimum capacity kept on at all times can help smooth the effect of a turbine trip. Boilers and their heating elements are standard off-the-shelf technology. The Controllers are also fairly standard electronic pieces of equipment, but their programming and speed of action are aspects that will require special attention. Details will vary from project to project. Dump loads, such as electric air heaters, will function in the same manner as a boiler (which is essentially a dump load too) but these may or may not be situated so that the dumped energy can be recovered. The purpose of a boiler is to capture and make use of the energy that would otherwise be wasted.

If a diesel plant is to be shut down to allow a wind power plant to serve the entire electrical load (high penetration system), the grid frequency needs to be maintained by a device such as a synchronous condenser. Synchronous condensers have been around for a long time and are quite "standard" although typically designed for each specific application. They do consume power in their operation, power which would be produced by the wind plant and which will then not be available to displace diesel fuel. A generator can be decoupled from its diesel engine (with the use of a clutch) to serve as a synchronous condenser.

An energy storage device such as a battery bank (or a spinning flywheel) will also be required in a high penetration system. The energy storage device is typically designed to serve the electrical load while allowing the diesel plant time to start up and pick up the load if the wind suddenly drops off, or if a wind turbine shuts down, or if the power line from the wind plant trips off. It can also absorb significant fluctuations in the output of the wind plant that do not involve trips. Energy storage devices tend to be relatively expensive and they consume power (wind power). Battery banks with their charging systems and inverters to store and draw out the power are standard common and mature technology. Other energy storage devices such as Powercorp's PowerStore™ flywheel storage system, represents newer, less mature technology. It is also more expensive technology than batteries at present, but it does have a significant capacity and some advantages.

When a wind plant is providing all of a community's electrical energy requirements and the diesel plant is shut down, it will need to be kept in a state of readiness for restarting at any time. This means that the building will need to be kept at a reasonable temperature and that the individual engines will need to be kept hot and ready to start and pick up load within minutes. In diesel power plants the heat from the engines (including from their block cooling and exhaust systems) is typically used to keep the building warm and any non-operating engines on hot standby. With the diesel plant shut down this heat will need to be provided by a boiler system that uses either wind energy or is oil fired or a combination of the two. This technology is common, known, and "off-the-shelf", however it does represent a capital and operating cost to the wind project because it would not otherwise be needed.

Appendix B contains some literature on wind diesel integration systems produced by Powercorp of Australia. This is not to indicate that the author promotes Powercorp's products over other suppliers, it just indicates that Powercorp has some well written and presented information bout this type of equipment.

A factor that should be considered in the challenge of maintaining a steady voltage and frequency to retail customers in the course of integrating wind and diesel, is the number of wind turbines in a wind project. Each wind turbine will produce a fluctuating power output as the wind fluctuates. In a multi-turbine installation these fluctuations occur at slightly different times in each turbine so the combined power output will be "smoother" than from any single turbine. A rule of thumb is that a wind project should have a minimum of three turbines (preferably 5). The power flow from a project consisting of a single large wind turbine (especially in a high penetration project) would be more challenging for a control system to smooth out than a project consisting of 3 or more turbines.

3.4 Wind Penetration Levels

The level of diesel energy displacement by wind energy is called the wind penetration level. Penetration levels are typically simply categorized into low, medium, and high. Low penetration is the displacement of up to about 10% of the diesel energy by wind, and would usually be accomplished in a small community by connecting one (or more) wind turbines, the "wind plant", to the system. The wind plant would need to be small enough so that the diesel plant can continue to operate as it previously would have. The only difference is that the diesel plant will "see" a slightly lower electrical load. The low penetration option requires a minimum amount of wind-diesel integration equipment. The diesel governors need to be able to respond to the fluctuating output from the wind plant, but aside from that only the physical connection and electrical protection are needed. The wind plant will have its own controller which is a normal part of a wind turbine package. The disadvantage of the low penetration approach is that the cost per kW of installed wind capacity may be high because there would be no economies of scale in the size of the project. Operations and maintenance (O&M) costs per kWh of energy produced will be higher for the same reason while the savings on diesel fuel are limited.

In medium penetration wind projects the installed wind capacity will be such that there will be more wind power than the diesel plant can accommodate at windy times. This occurs when the available wind power would reduce the diesel plant loading below the minimum allowable level on the smallest available diesel generator. When this situation happens the excess wind energy will need to be dumped. Overall diesel fuel displacement can be up to 25%. The equipment required to achieve medium penetration includes a dump load, a dump load controller, and a more sophisticated diesel plant controller, or an overall diesel and wind plant controller, to accommodate the higher level of wind energy and its fluctuations. A low load diesel may also enhance the achievable penetration level. Advantages of a medium level of penetration include a greater economy of scale in the purchase and installation of the wind plant capacity (a larger turbine or a greater number of smaller turbines), reduced O&M costs per kWh for the same reason, and a greater diesel saving.

A high penetration wind project would typically displace from 25% to 40% of the diesel energy and possibly as much as 50% in a wind rich region. In practical terms this requires the diesel plant to be entirely shut down at windy times, but maintained in a state of hot standby so it can start very quickly again as needed. A high penetration project requires the greatest amount of integration equipment and the most sophisticated equipment. There will be an excess of wind energy at windy times and for the project economics to be optimized, the excess wind energy will need to serve a useful function – such as space heating. In addition to the equipment described in the medium penetration case, required equipment includes a diesel plant heating and engine hot standby system, an energy storage system, a frequency regulation system such as a synchronous condenser, a boiler or other useful dump load system, and a sophisticated overall power system controller that regulates all of the equipment listed, and maintains power quality and reliability to the community.

The advantage of a high penetration system is that it provides the greatest economy of scale in the purchase and installation of the wind plant (size and number of turbines) and the greatest level of fuel saving. Wind energy O&M costs would be minimized for the same reason. The disadvantages are that the amount and sophistication of the equipment needed can drive up the capital cost significantly (especially for small projects) and the power requirements for this equipment detracts from the diesel displacement. The smooth operation of this equipment and its maintenance will be a challenge until the operating and maintenance staff becomes very familiar with them. There is also a requirement for power for the operation of the integration equipment which must be supplied by the wind plant, directly or indirectly. This power requirement is sometimes called parasitic load or station service load.

3.5 Anti-Icing Technology

There are some locations in which the icing of wind turbines, which can cause a reduction in power output, is a significant concern. The icing is due either to the proximity of open water under cold conditions, or extended extreme cold weather and ice fog, or because of the high relative altitude at which the turbines are to be located (to access a good wind resource). There are some effective mitigation measures available. For turbines that require wind instruments (anemometers and wind vanes) for their control, heated instruments are readily available and are proven, mature technology. There is also a blade coating available (StaClean™) that has a low adhesion surface for ice and the black coloured version absorbs solar energy (when available) to assist in blade de-icing. This coating has been shown to be effective in the north. Again this is an "off-the-shelf" product, and can be applied by qualified painting contractors.

Where the icing is severe and the "passive" mitigation features described above are not adequate the only option is a blade heating system. Blade heating systems have never been produced in any quantity, and until one supplier came to the author's attention recently (located in Finland), there had been no known commercial suppliers. There is a second potential supplier, located in the US, but this supplier still needs a significant customer to help bring the product to market. There are custom designed blade heating systems in operation in Finland, Sweden, and in Yukon. While this technology cannot be considered "off-the-shelf" at this time there is at least the appearance of light at the end of the tunnel on this matter. The cost and overall economic benefit of such a system would need to be demonstrated in actual performance in the north.

3.6 Suppliers of Wind-Diesel Integration Systems

There are a several wind-diesel integration system equipment manufacturers. Those known to the author include Powercorp, Northern Power Systems, Frontier Power Systems, Enercon, Sustainable Automation, PitchWind, and Wind Energy Solutions. There are probably others.

3.7 Wind Turbine Manufacturers Promote Wind-Diesel Systems

There are several wind turbine manufacturers who supply wind diesel systems or who promote their turbines for wind-diesel systems. Those with wind diesel systems include Enercon, Northern Power Systems, PitchWind (not sure if they make products suitable for the north), and Wind Energy Solutions (the author has no detailed technical information on their products at the time of writing). Those that promote their products for use in wind-diesel systems include Entegrity Wind Systems Inc., Atlantic Orient Canada Inc., Fuhrlander, and Vergnet (does not have suitable products for cold climates at present).

4.0 Foundations and Civil Works

The foundations for wind turbines can be a significant cost component of a wind project. In particular there are locations where there is ice rich permafrost in silt that is at risk of degradation due to global warming (this is the case in a number of Alaskan coastal communities). This makes the foundation design particularly tricky and expensive. A complicating factor can be the lack of a supply of aggregate (gravel or crushed stone), as is the case in some areas of Alaska. Where aggregate needs to be barged in it will be expensive and add significantly to the cost of foundation and road construction. These factors favour the use of guyed towers for which foundations and anchors are less demanding. Unfortunately the environmental regulations (bird impact concerns) in Alaska are such that guyed towers are not an option there at present. This leaves Canada alone to develop these towers as they are not yet available for the cold weather turbines on the market.

The further development of helical screw pile anchoring systems (such as the AB Chance helical screw type of anchors) would reduce the installed costs for the turbine towers now available and the guyed towers that we hope will be designed soon.

The ideal location for wind turbines in isolated communities is on bedrock where standard rock anchoring systems, which are cost effective, can be used. In these locations it is unlikely that aggregate supply would be a problem.

The cost of power line construction for wind turbines located some distance from a community will generally follow the cost trend for wind turbine foundations. In ice rich unstable permafrost the costs will be high, and in dry and rocky locations the costs will be substantially lower.

Other civil works, including buildings and their foundations, will follow similar cost patterns.

5.0 Present Cost Experience

A review of the historical capital costs (adjusted to present value by adjusting for inflation) for the installation of wind projects indicates a wide range has been experienced. In Northwest Territories (NWT), before the formation of Nunavut, the NWT Power Corporation (NTPC) costs for various projects have ranged from about $4,500 per installed kW to over $8,000 per installed kW. Granted there were special circumstances driving up the capital cost in most of these projects of one or two wind turbines, however, the costs are significant.

Yukon Energy's experience with two grid connected turbines, one in 1993 and one in 2000, are (inflation adjusted) costs of over $5,000 per kW to about $3,400 per kW. In this case there were significant requirements for power line reconstruction, road upgrading, and custom anti-icing (blade heating systems) included.

The author's examination of a potential project in a road accessible small diesel served community (125 to 250 kW load, average about 175 kW) suggested that costs could range from

$5,000 per kW to about $9,000 per kW depending on the number of turbines involved and the level of wind penetration in the configuration. Costs would be higher for communities without road access. The author admits to a bias of being quite conservative in cost estimating – estimating higher rather than lower.

A very interesting result of the author's examination of this potential wind project (wind speed 6.0 m/s at 30 meters) was that the medium penetration option yielded the lowest cost wind energy. The high penetration option was high in cost because of the significant amount of additional equipment required compared to the low or medium penetration options, and the amount of power consumed by this equipment. The author estimated that both the low penetration (one EW15 turbine) and the high penetration (five EW15 turbines) projects would displace diesel power at $0.55 per kWh whereas the medium penetration project (three EW 15 turbines) was projected to displace diesel at $0.44 per kWh. It was calculated that increasing the wind turbine tower height from 25 to 50 meters would reduce the cost of energy in the medium penetration case to about $0.34 per kWh. The lesson from this analysis is that it may not be cost effective in small communities to go to high penetration systems because of the high fixed costs of the wind-diesel integration equipment required. Smaller simpler projects may be more cost effective.

The most recent (anecdotal) information from the wind-diesel projects using 60 and 100 kW turbines in smaller remote communities in Alaska, seems to be indicating capital costs in the order of $CDN10,000 per kW. These coastal communities suffer from unstable permafrost and a lack of aggregate. Most also have outdated diesel plant controls so a major diesel plant upgrade is typically required and completed as part of the project.

Presentations by Hydro Quebec staff to the International Conference on Wind Energy in Remote Regions in October 2005 described two wind-diesel projects planned by the utility. One will be on Iles de la Madeleine where a 300 kW first phase of a wind-diesel project will be installed in 2007 at a cost of about $8,300 per kW. The second project is a 1,300 kW high penetration (no storage) wind-diesel project planned for Inukjuak for 2008 at an estimated cost of $7,600 per kW.

Since the cost of the wind turbine purchase is a significant portion of these costs, it is important to realize that the price per unit of capacity decreases with an increase in size. For example Fuhrlander has a series of turbines priced as follows (landed in Eastern North America): the 30 kW costs about $5,300 per kW; the 100 kW about $4,000 per kW; the 250kW about $2,200 per kW, and the 1000 kW about $1,600 per kW. The smaller Fuhrlander machines are expensive compared to other turbines (the Entegrity 60 kW costs about $2,100 per kW), but this presents an idea of the relationship between size and cost. Generally speaking then, the larger the turbines used in a project the lower the installed cost per kW of capacity will be. However there are factors that favour the use of smaller machines too – the smoothness of power flow (see section 3.3) and the potential to install them with locally available equipment.

A 2004 presentation on Hydro Quebec's prospects for wind-diesel projects indicated that for 7 of the 14 Nunavik communities examined, high penetration no storage wind-diesel projects would be economic (these would have positive net present values). Since 2004 fuel prices have increased substantially. Hydro Quebec's discount rate was 5.2%, substantially lower than the 8% used by the author in the preparation of the economic analyses that form part of this report.

The history on maintenance costs also indicates a wide spread in cost experience. Most of the projects by NTPC failed or required an enormous level of technical intervention by NTPC. If the costs were to be fully accounted for on a per kWh basis the figures would be astronomical. Yukon Energy recently indicated in a public utilities board hearing that their O&M costs for wind power were in the order of $0.08 per kWh.

The information available from Alaska indicates that the maintenance costs would probably range from about $CDN0.05 per kWh in smaller projects to less than $CDN0.01 per kWh in a larger wind farm applications. No information on the allocation of operating costs other than maintenance was available.

In the author's view it would be realistic to expect O&M costs to be in the order of $0.05 to $0.10 in somewhat larger projects and probably more like $0.10 to $0.15 in smaller projects. The project ownership structure will have a bearing on this cost as a small independent power producer with one wind project is likely to have higher overhead costs than a larger organization or the utility that already owns the diesel plant in the community.

6.0 Recommendations from Project Developers

There are a number of recommendations and comments that were received from project developers in Canada and Alaska. Included are the following (paraphrased):

Wind-diesel technology is past being experimental and ready for sequenced installation starting with "demonstration" projects. A prudent approach would see the bugs worked out and experience gained in larger communities before projects are replicated in smaller and more remote communities. These first projects must be large enough to have some economies of scale in the wind installation, have access to a reasonable amount of construction equipment, and access to some level of technical support. A suitable wind resource, one that can be expected to yield a capacity factor of at least 25% in a wind plant, is also a necessity. The community must be committed to the project.

For a jurisdiction or a utility to start into wind energy, they should begin with a "pioneer" project. This pioneer project should have economies of scale (larger project size), access to local equipment, access to technical staff, and above all have a core project staff that is committed to the success of the project. There will be much to learn (significant training required), experience to gain, and there will be difficulties to overcome. Once this pioneer project is up and running successfully, other smaller and more isolated projects can be planned and installed using the experience gained in the first project and replicating the first project as much as possible.

It would be wise to start projects as low or, at most, medium penetration projects if at all possible and to increase the penetration level when experience and comfort in the wind turbines and wind-diesel system permit. High penetration projects are much more sophisticated and are thus much more difficult to deal with, especially with inexperienced operating and technical staff.

There must be a high level of commitment to a wind project in any community where a project is constructed. Without this community commitment there will be problems and the project will either be less successful than it can be or will be a failure.

Stay with consistent equipment technology and equipment suppliers as much as possible so that projects can use similar architecture and the knowledge and experience gained by staff is transferable.

The geographical grouping of projects (including locating subsequent projects near pioneer projects) can help keep cost down, and provide nearby expertise and support when needed.

Ideally install wind projects at the same time as diesel plants are being upgraded (controls at least) so that the controls for the diesel plant and the wind plant are compatible. Modern digital governors for the diesels are a requirement for a wind project to interface successfully with the diesel plant. Wind plants will not work properly with older diesel governors and plant controls.

The required civil works for a wind project can be very tricky and very expensive. Geotechnical investigations and design / preparations need to be started well ahead of time. Innovative solutions may be required. Overall project timing from start to finish can easily be 3 years in an isolated community.

There would be a great cost and practical advantage to having wind turbine towers that are guyed and designed to be easily winched up and down. Guyed towers are not presently allowed in Alaska. As a consequence recent Alaskan wind projects required the use of a crane, and could only be done cost effectively in conjunction with other community projects that also needed a crane. There is thus a vulnerability to future major maintenance that requires a crane.

Tubular towers provide more comfortable maintenance access and are less risky for staff than lattice towers.

At present AVEC looks for sites with a class 4 wind resource (6.5 to 7.0 m/s at 30 meters above ground level) or better for their potential projects.

There is a need for cost competitive wind turbines in the 100 to 300 kW size range. Enercon has a 330kW turbine but up to now has not been prepared to sell its products into the USA, due to patent dispute issues, but this should not be a problem in Canada. It was said that Enercon may make an E20 100 kW turbine available again.

Alaska expects costs to be in the order of $CDN10,000 per kW for high penetration projects in the near term and come down to about $CDN6,500 per kW in the longer term. Accepting a higher risk of outages, and somewhat greater permissible voltage and frequency excursions on the power system would likely allow capital costs to be reduced further by reducing equipment costs.

For project success the best wind project ownership arrangement is to have the diesel plant owner also own the wind plant. There has been some experience with an independent power producer (IPP) owning a wind plant and this has resulted in some conflicts between the wind and diesel plant owners and less wind penetration and less diesel savings than would have been possible with the same owner. There must be a very high level of cooperation between the wind plant and diesel plant owners / operators as a minimum.

7.0 Project site selection criteria

The author believes that the following criteria should be used for the selection of the “leader” wind projects (or “demonstration”, or “pioneer” projects if you prefer) to position them for success. They are listed in the author’s view of the order of importance with the most important first.

1. A project proponent with the financial and human resources to make the project work, and the determination and financial incentive to overcome difficulties to make it successful;
2. A community committed to the wind project (local champions) and of adequate size to provide an opportunity for some economies of scale;
3. Good transportation access;
4. Good access to technical support;
5. Reasonable wind resource; and
6. Reasonable geotechnical conditions.

Once the leader project is up and running well, and local staff have been trained and are comfortable with the wind-diesel project, subsequent projects can be selected based on the following criteria, again in order of the author’s view of importance.

1. Community commitment;
2. The ability to replicate the leader project;
3. Good wind resource;
4. Reasonable access to technical support; and
5. Reasonable transportation access.

8.0 Simplified Economic Analyses for Small Communities

The examination of the economic status of potential wind projects was based on calculating the effect of a range of values for key variables. This means that the determination of economic viability requires looking at a multi-dimensional picture. For simplicity’s sake some less important variables, or variables that could be determined or predicted with relative ease, were fixed. These include the fuel efficiency of diesel plants, the energy recovery of wind turbines at different wind speeds, implicitly the wind speed distribution (Rayleigh distribution), turbine availability, and wind plant losses (non-diesel displacing theoretically recovered energy). This permitted the effect of key variables to be presented in a series of tables. The key variables include project capital cost, project operating cost, wind speed, and the cost of fuel to the diesel plant. Appendix C presents the spreadsheets used in these calculations.

The values used for the less important variables are as follows. It was assumed that a wind project would consist of three AOC or Entegrity wind turbines representing an installed capacity of 180 kW. The theoretical energy recovery in kWh is based on the manufacturer's curves which in turn are based on standard temperature and pressure, and a Rayleigh wind speed distribution. No adjustments to these figures were made for the purpose of the economic calculations. A turbine availability of 95% was used, perhaps optimistic based on history, but this should be achievable in a good project. Wind system losses (non-diesel displacing energy) were assumed to be 10% on the basis that the project would be low to medium penetration. While the energy efficiency of diesel-electric plants varies depending on several factors, a plant efficiency of 3.50 kWh per liter was used as a base case. A table showing how the cost of diesel energy varies with diesel plant efficiency and the cost of fuel is provided so that the reader can see the relationships. The capital cost was amortized over 20 years with annual mortgage style payments at an interest rate of about 8% (20 annual payments of 10% of the initial capital cost).

The key variables presented in each spreadsheet are the capital cost of the project (on a per kW of capacity basis), the wind speed (from 5.0 to 9.0 m/s), and the cost of diesel fuel. A series of three spreadsheets presents the cases of three different levels of annual operating costs, $5,000 per turbine (low), $10,000 per turbine (medium), and $15,000 per turbine (high). As the terms imply, the author believes that an annual operating cost of $10,000 per turbine in a three turbine project should be considered reasonable. With respect to capital costs, however, it is much more difficult to make a definitive pronouncement. Recent experience in Alaska and Hydro Quebec's plans indicate that a well executed project is likely to cost between $5,000 and $10,000 per kW in an isolated community. In the author's opinion a cost in the range of $4,000 and $7,000 should be achievable in a carefully chosen and tightly run project. Based on the experience of the leader project it should be possible to reduce the cost of subsequent projects.

The present cost of fuel in most northern communities was not available to the author. Using world crude oil prices over a number of years and various data sets that were available, the cost of diesel fuel with crude oil valued at about $60US per barrel was estimated. The cost of diesel fuel in the more accessible communities (accessed by barge) is likely in the range of $0.80 to $1.00 per liter. This means that the cost of diesel generated energy is in the range of about $0.23 per kWh to $0.29 per kWh. In the least accessible communities the cost is likely in the range of $1.00 to $1.25 per liter or about $0.29 to $0.35 per kWh. In the community of Old Crow in Yukon which is accessible only by air, the cost of fuel has recently been running in excess of $1.40 per liter, however the author is not sure that there are many communities in this category in northern Canada. In the analyses performed by the author it seemed that an increase in the price of crude oil in $US per barrel resulted in approximately the same increase in cents per liter in diesel fuel. The ratio of increase in Old Crow was slightly higher. Whether this rough relationship would continue to hold for further significant increases in the cost of oil is not known.

The spreadsheets indicate that under a number of realistic values of key variables wind projects in the north would be economically viable. At a capital cost of $5,000 per kW and a medium operating cost, a wind speed of about 7.5 m/s in a more accessible community would result in an economic project at present fuel costs. For a less accessible project location with higher fuel costs a wind speed of about 6.5 m/s would suffice to create an economic project at present fuel costs. If the capital costs were to increase to $6,000 per kW the required wind speeds would be about 8.0 m/s and 7.0 m/s respectively for the more and less accessible communities.

The need for a reasonable wind resource for leader projects to be economic and the need to manage capital costs is evident, but the information clearly indicates that economic projects are within reach. While the sensitivity to interest rates was not calculated they do have a significant impact on project economics. A reduction from the 8% used in the analyses to 5% is equivalent to a reduction in capital costs from $5,000 per kW to $4,000 per kW. This is obviously also a variable to be taken seriously in project planning.

An increase in turbine hub height from 25 to 50 meters can increase the harvested wind speed from 6.0 m/s to about 6.7 m/s (wind shear coefficient of 0.16) and increase the energy capture by about 20%. The benefit of the availability of taller towers for wind turbines in remote communities is thus very significant.

If the federal government were to implement a WPPI type of program for remote, isolated communities that provided a cost incentive of about $0.10 per kWh (proportional to WPPI for wind farms in the south), the threshold wind speed for economic project viability would drop by about 1 m/s, again very significant. Support for projects by the territorial governments or their utilities would, of course, have similar benefits.

The author would like to note that projects that are poorly done or that use unreliable equipment in an effort to save capital costs are likely to produce expensive energy. Projects that use reliable equipment, or projects that have proponents with the financial resources to make the available equipment reliable, are much more likely to be economically viable, regardless of capital cost.

9.0 Kotzebue, a model to follow

The failures in wind projects in Northwest Territories and Nunavut have lead some people to believe that wind-diesel projects can cannot be done successfully in Canada’s north. A review of these failures may lead to the conclusion that one of the main reasons for these failures was the wind turbines themselves. However, there are significant other contributing factors that need to be noted. The decisions on where the wind projects were to be located was influenced in part by politics rather than good planning and resulted in project locations that were less than ideal for leader projects. It is also the author’s impression that NTPC was encouraged to do these wind projects and was less than totally committed to them so that when they ran into serious difficulty it was easier to walk away from them. The author is of the opinion that wind-diesel projects can be done successfully if done with care and planning, and a determination to succeed. If the advice of the experienced operating staff and professionals quoted above is followed and put together we have, in essence, the successful Kotzebue Alaska wind-diesel project as a model to follow. Since 1997 they have been operating successfully (and at a maintenance cost of no more than $0.01 per kWh) the exact same wind turbines that failed in NWT.

Kotzebue, a community of about 4,000 people, is located north of the Arctic Circle on Alaska's west coast on tundra and permafrost. It serves as a local hub community to 10 other communities. It has a diesel plant with 11 MW of installed capacity. It started wind energy efforts with a small low penetration project and, as experience was gained, it expanded its wind farm in stages. The experience gained here is now being used to assist in the design and installation (and maintenance) of wind projects in the surrounding smaller communities of Wales, Selawik, Toksook Bay, and others.

In putting together their wind-diesel project and its expansions, Kotzebue Electric Association (KEA) made full use of various state and federal support programs to help reduce costs and mitigate risks. KEA first ventured into wind energy in 1997 with the installation of 3 AOC 15/50 wind turbines (these have a capacity of about 60 kW). In 1999 7 more AOC wind turbines were installed, in 2002 a NorthWind 100 was installed, and in 2004 another 2 AOC turbines were installed. This year, 2006, another 3 Entegrity EW 15 turbines (a new name for the AOC 15/50 from a new owner) are set to be installed.

KEA's determination to make the project successful is reflected in the positive operational experience with the AOC wind turbine. This turbine and its controls had a number of challenges and AOC was, it seemed, in continuous financial difficulty, could not make timely product deliveries, and product support was also a problem. KEA persevered and has developed considerable expertise in the operation and maintenance of these turbines. Their maintenance costs are in the order of $0.01 per kWh, an exceptional achievement!

Appendix D contains information on the Kotzebue project in the form of two presentations (2002 and 2004), as well as presentations on wind-diesel projects in Wales and Selawik (2004). A copy of a story that appeared in the Juneau Empire on November 13, 2005 is also included. KEA has a considerable amount of information on their wind project available on their website (see References).

In the author's opinion the KEA wind-diesel project is an excellent example to follow: start with a simple project in a larger community that has some economies of scale, equipment, and expertise, and grow from there as experience is gained and problems overcome. With a core of experience and expertise built up, these resources can then be used to establish projects in smaller communities.

10.0 Starting a Wind Energy Program

When consideration is given to the development of a wind energy program the first step is the need for the developer to decide whether an individual community project is to be developed or a regional multi-community program is to be undertaken. This decision affects the focus of a project and will influence the size and type of turbines and ancillary equipment that is purchased. It is the author's view that a regional program approach is more desirable in the long run than an individual community by community project approach. A regional program is more likely to result in successful projects in more communities because successive projects will be constructed based on the collective experience and expertise of the previous projects. A regional program will also result in standardization of equipment and therefore economies of scale in the purchase of equipment, common spare parts inventories, and the sharing of technical support personnel. The Kotzebue Alaska example is a good one upon which to model a regional program. This includes the staged progression from a simple low penetration project to a higher penetration project involving not just the smaller turbines for small communities but also the larger turbines more suited to the largest communities.

The author’s view of the prioritized factors to be considered in the selection of a first or “leader” project location (as the start of a regional program) is provided in section 7.0. It is recommended that the project follow the Kotzebue example by commencing as a smaller low penetration project. It is suggested that the wind turbines chosen for the project be a smaller wind turbine suitable as the standard wind turbine for the smaller communities. This is likely to be a turbine of about 60 kW to 80 kW. Ideally the selected model will have a guyed, winch-up tower of 30 to 40 meters (or higher). For the larger communities a larger standard size turbine is likely to be chosen from the 250 kW to 800 kW size range. These turbines will have tubular towers of 40 to 50 meters and require a crane for their installation.

In making the selection of the standard wind turbines the low temperature limit to which they can operate will be an important consideration. Based on the author’s knowledge of wind energy available at different temperatures in the far north, there is a significant amount of wind energy available between the temperatures of -30ºC and -35ºC, and still some recoverable energy between the temperatures of -35ºC and -40ºC. The AOC, Entegrity, and WES turbines operate or have all operated in the far north in the past, and achieving operating limits of about -40ºC with these turbines may not be a problem. For the larger turbines this is likely to be more of a problem as most “cold weather package” options for these turbines only allow operation down to -30ºC. Enercon and Mitsubishi turbines are designed to operate only to -30ºC and to survive temperatures down to -40ºC. Based on the author’s discussions with both of these manufacturer’s representatives, there may be a willingness to modify the design to accommodate lower temperature operation and survival. Fuhrlander literature indicates operation down to -40ºC but similar wording from other manufacturers has meant only that they can survive at temperatures down to -40ºC but they shut down when the temperature reaches -30ºC, so careful discussion with the manufacturers is required prior to making final commitments.

Financial planning for a program is an important part of the program preparation. In order to maximize the viability of the leader project all available financial support programs should be considered. Programs may be able to provide financial support during all phases of a project: for feasibility work, for staff training, for economic development, for testing and R&D, etc. There may also be production incentive programs in place that can be taken advantage of, including the CanWEA proposed ReCWIP which might be able to provide a support of $0.10 per kWh or more, and green attribute (green energy or green tags) sales. As many as possible should also be used on subsequent projects.

There are climate change MOUs in place between Canada and Nunavut, and between Canada and Newfoundland and Labrador that refer specifically to emissions reductions; to alternative and renewable energy development; to the development, demonstration and deployment of technologies addressing climate change; and to economic development and job creation related to climate change. The Canadian and territorial / provincial governments can and should support well planned wind energy projects through these MOUs.

Renewable energy projects receive favourable tax treatment, so as part of the financial planning there should be an analysis of the advantages and disadvantages of various corporate ownership structures (assuming that there are options available to the project / program proponent). The corporate liability exposure may also be a factor in determining the most desirable ownership structure.

As the first projects are executed full advantage should be taken of these to maximize the long term benefits to the communities and regions by acquiring construction and installation equipment that can be left in the communities for future projects. Similarly, local people should be trained for both construction and operation of the projects. In the longer term these community based people can use these skills for other projects and activities.

11.0 Roles of Territorial Governments and their Power Utilities

Given the nature of northern Canada, it would be desirable and advantageous for the three territorial governments (also the Quebec and Newfoundland and Labrador Provincial governments and related Nunavik and Nunatsiavut agencies) and their utilities to get together to develop a single consolidated (pan northern) approach to implement or to encourage the implementation of carefully planned and staged wind development in the north. Coordination could spread the costs and risks associated with the leader projects of larger wind development programs. The previous section identifies MOUs that are in place through which the territorial and provincial governments can and should support well planned wind energy projects.

The territorial governments and their wholly owned electric utilities and energy corporations could share in the development of a tall guyed tower for smaller wind turbines. The development of more cost effective foundations and anchors for permafrost is another item that can be worked on. Equipment suppliers too can and should be part of the mix, they must stand behind their equipment to ensure it performs up to specification and they must be committed to overcoming the difficulties if it does not.

12.0 Role of Federal Government

The federal government can provide very valuable support in several ways. First is to provide, through NRCan, a wind energy support program equivalent to the WPPI for the south. The CanWEA proposed ReCWIP, for example (see Appendix E), would make an enormous difference to the number of northern communities in which wind-diesel projects can be economic. The federal government can also consider providing some capital financial support for leader projects (financing or financing guarantees) through ReCWIP or separately. Indirectly, the CanWEA proposed Small Wind Energy Incentive Program (SWEIP – see Appendix E) to provide purchase incentives for wind turbines for the grid connected net metering market can also benefit the north. SWEIP would increase the market for the size of turbines of interest to the north thus leading to better quality products at competitive prices.

Both NRCan and the Department of Environment are signatories to the climate change MOUs in place with Nunavut and Newfoundland and Labrador through which appropriate renewable energy development can and should also be supported. Wind energy projects should have a notable place among other renewable energy projects.

Second, NRCan can increase their level of R&D financial support available to manufacturers to help them refine their existing products and to develop new products beneficial to the north. A 50 meter guyed tower for turbines of 50 to 60 kW (such as the Entegrity and AOC turbines) is one good example.

Third, INAC can be encouraged to ensure that their programs support and encourage the development of wind projects.

Fourth, federal and territorial government departments typically pay very high power rates in the north and they can insist on procuring renewable energy wherever possible so that the subsidies that they are effectively paying are channeled into renewable energy forms, including wind.

Leader projects should aim for installed costs of $CDN5,000 per kW or better, and the longer range target should be to install projects at $3,500 per kW.

13.0 Conclusions

Wind-diesel equipment is ready for installation in the north. This equipment cannot be expected to “mature” further and come down in cost without the installation of projects to increase the sales volumes. Further project installation experience will result in the development of innovative approaches to improving product performance and to reducing costs in subsequent installations.

Deployment of wind energy in the north still needs to proceed on a carefully planned and staged sequence starting with “leader” projects and branching out from there. Initial projects are likely to cost $5,000 or more per kW of installed capacity and, depending on other factors, could be economically viable in wind regimes as low as 6.5 m/s annual average. The Kotzebue Alaska wind-diesel project is a very good example to follow in the design of leader projects.

There is a need for good quality wind resource assessment at potential wind project locations in many communities in the north. Only airport and wind atlas information is presently available for many communities and these are only adequate for the screening of potential wind project sites. Airport and wind atlas data are not adequate to conduct the accurate wind project economic analyses on which wind project decisions must be based. Monitoring should consist of towers of at least 30 meters in height and have anemometers located at three elevations (for example at 10, 20, and 30 meters) to determine the wind shear. These towers should be located at actual potential wind turbine installation sites or be representative of such sites. They should not be located at sites of convenience where neither wind turbine installation nor correlation to a potential wind project site is possible.

The list of communities with potential to host a leader project site based on the suggested screening factors should be highest on the priority list for wind monitoring work if suitable data does not already exist. Other potential subsequent community wind project locations should be next on the list.

Government programs in support of wind energy in the north can make a substantial difference to the viability and expansion of wind-diesel systems in the arctic. There are a number of government programs currently in place, including climate change MOUs, which can and should support well planned wind energy projects. Other programs can provide support for the training requirements of wind energy projects and the job creation that they would provide.

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APPENDIX A

Excel table of communities in the north

Arctic Community Wind Resource Compilation

Wind Data From Various Sources as Indicated

Community	Service Provider	Fuel Source	Residential Customers (cents/kWh)	General Service Customers (cents/kWh)	Latitude	Longitude	Wind speed m/s 30 m AGL	50 m AGL	50m / 30m	Wind direction	Possible wind project location	Alternatives
Northwest Territories												
Aklavik	NTPC	Diesel	57.34	54.51	68.22	135	5.3	5.7	1.08	Strong NW	in town	
Colville Lake	NTPC	Diesel	266.6	237.36	67.04	126.085	6	6.3	1.05	SE	in town	hill 200 m higher 12 km to SE
Deline	NTPC	Diesel	57.86	53.27	65.188	123.41	5.9	6.2	1.05	E and NW	in town	hill 150 m high at 7 km NE
Dettah	NTPC	Hydro	19.84	25.44								
Dory Point / Kakisa	Northland	Hydro	26.4	26.54/21.72								
Fort Good Hope	NTPC	Diesel	63.98	55.2	66.24	128.66	5.4	5.7	1.06		by river 2 km SW of town	
Fort Liard	NTPC	Diesel	40.04	33.65	60.236	123.48	3.8	4.5	1.18	NE and SW	in town	hill 100 m higher 9 km E by road
Fort McPherson	NTPC	Diesel	52.85	46.07	67.44	134.87	3	3.3	1.10		in town	
Fort Providence	Northland	Hydro	24.16	22.66/18.84								
Fort Resolution	NTPC	Hydro	14.05	11.7								
Fort Simpson	NTPC	Diesel	36.8	29.91	61.845	121.34	3.5	4.1	1.17	NW, SE, SW	2.5 km SE of town	
Fort Smith	NTPC	Hydro	12.13	8.71								
Hay River	Northland	Hydro	12.98	11.08/8.23								
Holman	NTPC	Diesel	72.39	65.84	70.742	117.713	7.4	7.9	1.07	strong ESE	On ridge 1.2 km east of powerline	
Inuvik	NTPC	Natural Gas	38.72	32.21	68.363	133.725	4.4	4.8	1.09			
Jean Marie River	NTPC	Diesel	84.58	123.22	61.529	120.64	3.1	3.6	1.16		in town	
Lutsel K'e	NTPC	Diesel	62.06	56.68	62.409	110.722	5.2	5.8	1.12	E	on hill 60m above lake	
Nahanni Butte	NTPC	Diesel	95.73	130.2	61.087	123.385	3.2	3.7	1.16	NE and SW	on hill 1390 m ASL 4.3 km N of town	
Norman Wells	Imperial/NTPC	Natural Gas	30.84	26.83	65.34	126.61	5.8	6.2	1.07	SE, smaller NW	on hill 9 km NE of town 950 m above town	
Paulatuk	NTPC	Diesel	94.32	87.69	69.332	124.026	6		0.00	S and W	2.3 km E of town where present tower	Closer to town by reservoir, near power line
Rae-Edzo	NTPC	Hydro	19.84	25.44								
Rae Lakes	NTPC	Diesel	82.7	101.6	64.114	117.355	6.1	6.5	1.07	SE, smaller NW		
Sachs Harbour	NTPC	Diesel	97.75	89.52	71.987	125.412	5.5	5.8	1.05	E to S and N	5 km W of town	125 m ASL hill 7.5 km E
Trout Lake	Northland	Diesel	52.15	46.56/36.36	60.442	121.242	5.5	5.8	1.05	SW, lesser NE		
Tsiighetchic	NTPC	Diesel	99.29	86.73	67.44	133.74	4.6	5	1.09	SW and SE	in town	
Tuktoyaktuk	NTPC	Diesel	61.61	53.84	69.401	133.036	5.3	5.7	1.08	E, SW	4 km S of town	
Tulita	NTPC	Diesel	80.32	77.31	64.901	125.579	5.3	5.7	1.08	E,NW	in town	
Wekweti	Northland	Diesel	53.38	48.43/40.33	64.18	114.18	6.1	6.5	1.07	SE	in town	
Wha Ti	NTPC	Diesel	76.82	70.87	63.16	117.21	6	6.4	1.07	SE, NW	3.6 km NE of town	
Wrigley	NTPC	Diesel	78.04	84.9	63.227	123.337	3.3	3.9	1.18	Strong SE, NW	on hill 4.5 km NE of town 350 m above town	Wrigley measured is 2.8m/s at 10 mAGL where WEST show 2.1
Yellowknife	Northland	Hydro/Diesel	14.94	12.38								

Note: NWT wind speed data at 30 and 50 meters from Canadian Wind Atlas

Arctic Community Wind Resource Compilation

Wind Data From Various Sources as Indicated

Community	Service Provider	Fuel Source	Residential Customers (cents/kWh)	General Service Customers (cents/kWh)	Latitude	Longitude	Wind speed m/s 30 m AGL	50 m AGL	50m / 30m	Wind direction	Possible wind project location	Alternatives
Nunavik												
Akulivik	Hydro Quebec	Diesel			60.9	78	8.5				Peak load 450kW	
Aupaluk	Hydro Quebec	Diesel			59.4	69.6	7.5				Peak load 225 kW	
Inukjuak	Hydro Quebec	Diesel			58.8	77.9	8				Peak load 1600kW	
Ivujivik	Hydro Quebec	Diesel			62.5	77.9	7.5				Peak load 325kW	
Kangiqsualujjuaq	Hydro Quebec	Diesel			58.9	66	8				Peak load 700 kW	
Kangiqsujuaq	Hydro Quebec	Diesel			61.7	71.9	9				Peak load 500kW	
Kangirsuk	Hydro Quebec	Diesel			60.1	70	8				Peak load 600kW	
Kuujjuaq	Hydro Quebec	Diesel			58.1	58.5	5.5				Peak load 2800kW	
Kuujjuarapik	Hydro Quebec	Diesel			55.4	77.5	7.5				Peak load 1700kW	
Puvirnituk	Hydro Quebec	Diesel			60.1	77.2	6.5				Peak load 1400kW	
Quaqtaq	Hydro Quebec	Diesel			61.1	69.6	6.5				Peak load 325kW	
Salluit	Hydro Quebec	Diesel			62.3	75.7	7.5				Peak load 1000kW	
Tasiujaq	Hydro Quebec	Diesel			58.8	70	7.5				Peak load 275kW	
Umijuaq	Hydro Quebec	Diesel			56.6	76.5	11				Peak load 450kW	
Notes to Nunavik data												
1	**All data from October 2004 presentation to CanWEA conference**											
2	**All data interpolated from presentation graphs**											
3	**Green shaded communities indicated positive NPV for high penetration no storage wind-diesel projects at Hydro Quebec's 5.2% discount rate**											

Arctic Community Wind Resource Compilation

Wind Data From Various Sources as Indicated

	Service	Fuel	Residential	General Service								
Community	Provider	Source	Customers	Customers			Wind speed m/s		50m	Wind direction	Possible wind project location	Alternatives
			(cents/kWh)	(cents/kWh)	Latitude	Longitude	30 m AGL	50 m AGL	30m			
Nunavut												
Arctic Bay		Diesel			73.0529	85.1603	5.6	6.0			400 m hills within 6 km	
Arviat		Diesel			61.0987	94.0449	7.3	7.8				
Baker lake		Diesel			64.3306	-96.0468	5.9	6.3			100 m hills in the area	
Broughton Island		Diesel			67.5295	64.0145	6.1	6.5			500 m hill 10 km east, road access, and com tower	
Cambridge Bay		Diesel			69.1501	105.0837	6.7	7.2			30 m relief	
Cape Dorset		Diesel			64.2295	76.5471	6.3	6.7			3 km south	
Chesterfield Inlet		Diesel			63.3374	90.7651	7.5	8.0			30 relief	
Clyde River		Diesel			70.4753	68.494	7.5	8.0			480 m hill 6 km south	
Coral Harbour		Diesel			64.1641	83.1591	5	5.4			60 m relief in the area	
Gjoa Haven		Diesel			68.6473	95.8729	4.7	5.0			30 m relief	
Grise Fiord		Diesel			76.4589	82.7476	5.6	6.0			900 m hill 7 km Northeast	
Hall Beach		Diesel			68.8222	81.3134	5.3	5.7			Flat	
Igloolik		Diesel			69.4018	81.8542	4.6	4.9			Flat	
Iqaluit		Diesel			63.7837	68.5278	5.7	6.1			3 km east	
Kimmirut		Diesel			62.8425	69.8978	6	6.4				
Kugluktuk		Diesel			67.8212	115.1075	6.5	7.0			40 m relief	
Pangnirtung		Diesel			66.1106	65.7196	4.9	5.2			600 m hill 5 km east	
Pelly Bay		Diesel			68.5619	89.7618	6.6	7.1			240 m hills in the area	
Pond Inlet		Diesel			72.692	77.8104	4.5	4.8			Flat	
Rankin Inlet		Diesel			62.8345	92.1406	7.3	7.8			30 relief	
Repulse Bay		Diesel			66.5573	86.131	6.2	6.6			60 m relief in the area	
Resolute		Diesel			74.69	94.8806	6	6.4			180 m hills within 5 km	
Taloyoak		Diesel			69.5314	93.46	5.7	6.1				
Whale Cove		Diesel			62.1863	92.6157	7.7	8.2				
Note: Nunavut wind speed data at 30 and 50 meters from Canadian Wind Atlas												
Yukon												
Destruction Bay	YECL	Diesel	12.36	12.36	61.25	138.75	5.99				Measured data, 2 km NW of Destruction Bay	
Old Crow	YECL	Diesel	25.77	25.77	67.57	139.78	>6.50				On Crow Mountain 6 km from village and 540 m higher, data unpublished but reportedly better than Haeckel Hill in Whitehorse	Wind speed at village 540 m lower only about 3.8 m/s
Note: Yukon power rates are runout rates only (set in 1997) and do not include fuel surcharges												

APPENDIX B

Powercorp wind-diesel equipment

For information on Powercorp's wind-diesel equipment please visit their web site www.pcorp.com.au .

APPENDIX C

Details of economic analyses

Three turbine project per kWh costs as a function of wind speeds and costs											
		m/s >	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
		kWh >	179,550	237,006	301,644	365,256	427,073	487,350	549,167	597,645	650,228
Capital cost per kW	**Total Ann cost low**		**Cost per kWh below**								
$3,000	$69,000		$0.384	$0.291	$0.229	$0.189	$0.162	$0.142	$0.126	$0.115	$0.106
$3,500	$78,000		$0.434	$0.329	$0.259	$0.214	$0.183	$0.160	$0.142	$0.131	$0.120
$4,000	$87,000		$0.485	$0.367	$0.288	$0.238	$0.204	$0.179	$0.158	$0.146	$0.134
$4,500	$96,000		$0.535	$0.405	$0.318	$0.263	$0.225	$0.197	$0.175	$0.161	$0.148
$5,000	$105,000		$0.585	$0.443	$0.348	$0.287	$0.246	$0.215	$0.191	$0.176	$0.161
$5,500	$114,000		$0.635	$0.481	$0.378	$0.312	$0.267	$0.234	$0.208	$0.191	$0.175
$6,000	$123,000		$0.685	$0.519	$0.408	$0.337	$0.288	$0.252	$0.224	$0.206	$0.189
$6,500	$132,000		$0.735	$0.557	$0.438	$0.361	$0.309	$0.271	$0.240	$0.221	$0.203
$7,000	$141,000		$0.785	$0.595	$0.467	$0.386	$0.330	$0.289	$0.257	$0.236	$0.217
$7,500	$150,000		$0.835	$0.633	$0.497	$0.411	$0.351	$0.308	$0.273	$0.251	$0.231
$8,000	$159,000		$0.886	$0.671	$0.527	$0.435	$0.372	$0.326	$0.290	$0.266	$0.245
$8,500	$168,000		$0.936	$0.709	$0.557	$0.460	$0.393	$0.345	$0.306	$0.281	$0.258
$9,000	$177,000		$0.986	$0.747	$0.587	$0.485	$0.414	$0.363	$0.322	$0.296	$0.272
$9,500	$186,000		$1.036	$0.785	$0.617	$0.509	$0.436	$0.382	$0.339	$0.311	$0.286
$10,000	$195,000		$1.086	$0.823	$0.646	$0.534	$0.457	$0.400	$0.355	$0.326	$0.300
	(yellow)	=	Viable at fuel cost of $0.60 per liter and diesel effieicncy of 3.5 kWh per liter								
	(grey)	=	Viable at fuel cost of $0.80 per liter and diesel effieicncy of 3.5 kWh per liter								
	(blue)	=	Viable at fuel cost of $1.00 per liter and diesel effieicncy of 3.5 kWh per liter								
	(green)	=	Viable at fuel cost of $1.25 per liter and diesel effieicncy of 3.5 kWh per liter								
	(orange)	=	Viable at fuel cost of $1.50 per liter and diesel effieicncy of 3.5 kWh per liter								
	(pink)	=	Viable at fuel cost of $2.00 per liter and diesel effieicncy of 3.5 kWh per liter								

Three turbine project per kWh costs as a function of wind speeds and costs

		m/s >	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
		kWh >	179,550	237,006	301,644	365,256	427,073	487,350	549,167	597,645	650,228
Capital cost per kW	**Total Ann cost med**		**Cost per kWh below**								
$3,000	$84,000		$0.468	$0.354	$0.278	$0.230	$0.197	$0.172	$0.153	$0.141	$0.129
$3,500	$93,000		$0.518	$0.392	$0.308	$0.255	$0.218	$0.191	$0.169	$0.156	$0.143
$4,000	$102,000		$0.568	$0.430	$0.338	$0.279	$0.239	$0.209	$0.186	$0.171	$0.157
$4,500	$111,000		$0.618	$0.468	$0.368	$0.304	$0.260	$0.228	$0.202	$0.186	$0.171
$5,000	$120,000		$0.668	$0.506	$0.398	$0.329	$0.281	$0.246	$0.219	$0.201	$0.185
$5,500	$129,000		$0.718	$0.544	$0.428	$0.353	$0.302	$0.265	$0.235	$0.216	$0.198
$6,000	$138,000		$0.769	$0.582	$0.457	$0.378	$0.323	$0.283	$0.251	$0.231	$0.212
$6,500	$147,000		$0.819	$0.620	$0.487	$0.402	$0.344	$0.302	$0.268	$0.246	$0.226
$7,000	$156,000		$0.869	$0.658	$0.517	$0.427	$0.365	$0.320	$0.284	$0.261	$0.240
$7,500	$165,000		$0.919	$0.696	$0.547	$0.452	$0.386	$0.339	$0.300	$0.276	$0.254
$8,000	$174,000		$0.969	$0.734	$0.577	$0.476	$0.407	$0.357	$0.317	$0.291	$0.268
$8,500	$183,000		$1.019	$0.772	$0.607	$0.501	$0.428	$0.376	$0.333	$0.306	$0.281
$9,000	$192,000		$1.069	$0.810	$0.637	$0.526	$0.450	$0.394	$0.350	$0.321	$0.295
$9,500	$201,000		$1.119	$0.848	$0.666	$0.550	$0.471	$0.412	$0.366	$0.336	$0.309
$10,000	$210,000		$1.170	$0.886	$0.696	$0.575	$0.492	$0.431	$0.382	$0.351	$0.323

	=	Viable at fuel cost of $0.60 per liter and diesel effieicncy of 3.5 kWh per liter
	=	Viable at fuel cost of $0.80 per liter and diesel effieicncy of 3.5 kWh per liter
	=	Viable at fuel cost of $1.00 per liter and diesel effieicncy of 3.5 kWh per liter
	=	Viable at fuel cost of $1.25 per liter and diesel effieicncy of 3.5 kWh per liter
	=	Viable at fuel cost of $1.50 per liter and diesel effieicncy of 3.5 kWh per liter
	=	Viable at fuel cost of $2.00 per liter and diesel effieicncy of 3.5 kWh per liter

Three turbine project per kWh costs as a function of wind speeds and costs											
		m/s >	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
		kWh >	179,550	237,006	301,644	365,256	427,073	487,350	549,167	597,645	650,228
Capital cost per kW	**Total Ann cost high**		**Cost per kWh below**								
$3,000	$99,000		$0.551	$0.418	$0.328	$0.271	$0.232	$0.203	$0.180	$0.166	$0.152
$3,500	$108,000		$0.602	$0.456	$0.358	$0.296	$0.253	$0.222	$0.197	$0.181	$0.166
$4,000	$117,000		$0.652	$0.494	$0.388	$0.320	$0.274	$0.240	$0.213	$0.196	$0.180
$4,500	$126,000		$0.702	$0.532	$0.418	$0.345	$0.295	$0.259	$0.229	$0.211	$0.194
$5,000	$135,000		$0.752	$0.570	$0.448	$0.370	$0.316	$0.277	$0.246	$0.226	$0.208
$5,500	$144,000		$0.802	$0.608	$0.477	$0.394	$0.337	$0.295	$0.262	$0.241	$0.221
$6,000	$153,000		$0.852	$0.646	$0.507	$0.419	$0.358	$0.314	$0.279	$0.256	$0.235
$6,500	$162,000		$0.902	$0.684	$0.537	$0.444	$0.379	$0.332	$0.295	$0.271	$0.249
$7,000	$171,000		$0.952	$0.722	$0.567	$0.468	$0.400	$0.351	$0.311	$0.286	$0.263
$7,500	$180,000		$1.003	$0.759	$0.597	$0.493	$0.421	$0.369	$0.328	$0.301	$0.277
$8,000	$189,000		$1.053	$0.797	$0.627	$0.517	$0.443	$0.388	$0.344	$0.316	$0.291
$8,500	$198,000		$1.103	$0.835	$0.656	$0.542	$0.464	$0.406	$0.361	$0.331	$0.305
$9,000	$207,000		$1.153	$0.873	$0.686	$0.567	$0.485	$0.425	$0.377	$0.346	$0.318
$9,500	$216,000		$1.203	$0.911	$0.716	$0.591	$0.506	$0.443	$0.393	$0.361	$0.332
$10,000	$225,000		$1.253	$0.949	$0.746	$0.616	$0.527	$0.462	$0.410	$0.376	$0.346
	(yellow)	=	Viable at fuel cost of $0.60 per liter and diesel effieicncy of 3.5 kWh per liter								
	(grey)	=	Viable at fuel cost of $0.80 per liter and diesel effieicncy of 3.5 kWh per liter								
	(blue)	=	Viable at fuel cost of $1.00 per liter and diesel effieicncy of 3.5 kWh per liter								
	(green)	=	Viable at fuel cost of $1.25 per liter and diesel effieicncy of 3.5 kWh per liter								
	(orange)	=	Viable at fuel cost of $1.50 per liter and diesel effieicncy of 3.5 kWh per liter								
	(pink)	=	Viable at fuel cost of $2.00 per liter and diesel effieicncy of 3.5 kWh per liter								

Three turbine project annual costs as a function of capital and operating costs

Capital cost per kW	kW capacity	Total capital	Annual mortgage cost @8% 20 yrs	Low ann operating cost	Med ann operating cost	High ann operating cost	Total Ann cost low	Total Ann cost med	Total Ann cost high
$3,000	180	$540,000	$54,000	$15,000	$30,000	$45,000	$69,000	$84,000	$99,000
$3,500	180	$630,000	$63,000	$15,000	$30,000	$45,000	$78,000	$93,000	$108,000
$4,000	180	$720,000	$72,000	$15,000	$30,000	$45,000	$87,000	$102,000	$117,000
$4,500	180	$810,000	$81,000	$15,000	$30,000	$45,000	$96,000	$111,000	$126,000
$5,000	180	$900,000	$90,000	$15,000	$30,000	$45,000	$105,000	$120,000	$135,000
$5,500	180	$990,000	$99,000	$15,000	$30,000	$45,000	$114,000	$129,000	$144,000
$6,000	180	$1,080,000	$108,000	$15,000	$30,000	$45,000	$123,000	$138,000	$153,000
$6,500	180	$1,170,000	$117,000	$15,000	$30,000	$45,000	$132,000	$147,000	$162,000
$7,000	180	$1,260,000	$126,000	$15,000	$30,000	$45,000	$141,000	$156,000	$171,000
$7,500	180	$1,350,000	$135,000	$15,000	$30,000	$45,000	$150,000	$165,000	$180,000
$8,000	180	$1,440,000	$144,000	$15,000	$30,000	$45,000	$159,000	$174,000	$189,000
$8,500	180	$1,530,000	$153,000	$15,000	$30,000	$45,000	$168,000	$183,000	$198,000
$9,000	180	$1,620,000	$162,000	$15,000	$30,000	$45,000	$177,000	$192,000	$207,000
$9,500	180	$1,710,000	$171,000	$15,000	$30,000	$45,000	$186,000	$201,000	$216,000
$10,000	180	$1,800,000	$180,000	$15,000	$30,000	$45,000	$195,000	$210,000	$225,000

Diesel energy cost per kWh as function of fuel cost					
	Diesel plant efficiency >	**3.25 kWh per liter**	**3.50 kWh per liter**	**3.75 kWh per liter**	**4.00 kWh per liter**
Fuel cost per liter		**Energy cost per kWh below**			
$0.60		$0.185	$0.171	$0.160	$0.150
$0.80		$0.246	$0.229	$0.213	$0.200
$1.00		$0.308	$0.286	$0.267	$0.250
$1.25		$0.385	$0.357	$0.333	$0.313
$1.50		$0.462	$0.429	$0.400	$0.375
$1.75		$0.538	$0.500	$0.467	$0.438
$2.00		$0.615	$0.571	$0.533	$0.500

Entegrity EW 15 and AOC 15/50 annual power production					
Wind Speed m/s	**Theoretical kWh**	**kWh @ 95% availability**	**10% for all losses**	**kWh diesel displaced**	**Three turbines kWh diesel displaced**
5.0	70,000	66,500	6,650	59,850	179,550
5.5	92,400	87,780	8,778	79,002	237,006
6.0	117,600	111,720	11,172	100,548	301,644
6.5	142,400	135,280	13,528	121,752	365,256
7.0	166,500	158,175	15,818	142,358	427,073
7.5	190,000	180,500	18,050	162,450	487,350
8.0	214,100	203,395	20,340	183,056	549,167
8.5	233,000	221,350	22,135	199,215	597,645
9.0	253,500	240,825	24,083	216,743	650,228

APPENDIX D

Information on Kotzebue Electric Association's wind-diesel project

Please refer to the following documents. The first four are conference presentations that can be obtained through a web site, and the fifth is attached here. The web site is: www.eere.energy.gov/windandhydro/windpoweringamerica/calendar_past_events.asp.

1. Reeve, Brad; **"Kotzebue Electric Association Wind Projects"**, Wind Powering America: Wind Diesel 2002 Workshop Proceedings, Anchorage, Alaska, September 2002

2. Reeve, Brad; **"Kotzebue Wind Farm Operational Experiences"**, Wind Powering America: Wind Diesel 2004 Proceedings, Anchorage, Alaska, September 2004

3. Drouilhet, Steve, **"Overview of the High Penetration Wind-Diesel System in Wales, Alaska"**, Wind Powering America: Wind Diesel, September 2004

4. Drouilhet, Steve, **"Overview of the Medium Penetration Wind-Diesel System in Selawik, Alaska"**, Wind Powering America: Wind Diesel 2004 Proceedings, September 2004

5. Juneau Empire (newspaper), **"Villages turning to wind energy"**, November 13, 2005

Juneau Empire – November 13, 2005

Villages turning to wind energy

KOTZEBUE - Arctic winds blow steady and untrammeled across the flat, hoarfrosted tundra at the tip of this spindly peninsula in northwest Alaska.

These conditions are ideal for spinning the tapering white blades of the 13 turbines at Alaska's oldest utility wind farm, a technology more village leaders throughout the state are considering as wholesale diesel oil prices rise to $6 a gallon in some of the state's most remote and impoverished communities.

Lori Beaver knows the wind farm turbines are making a difference in her electricity bill, although she isn't sure exactly how much.

"I'm grateful for it and I'm hoping they put more up," the Kotzebue resident said.

The 8-year-old wind farm just outside town currently saves about $190,000 a year in electricity costs to the 3,000 residents of Kotzebue, an Inupiat Eskimo community 26 miles north of the Arctic Circle. The co-op utility passes on all savings to customers, after basic costs, said Brad Reeve, general manager of the Kotzebue Electric Association.

Nearly all of Alaska's more than 200 remote communities rely on expensive diesel for electricity and heat. As costs rise, wind farms are slowly spreading to villages in Alaska, a state with the largest total area of premium wind power in the nation, according to state and federal energy statistics.

Wind partially powers a handful of villages, including St. Paul, Wales, Pilot Point, Port Heiden and Selawik. All are in western Alaska, a region with relatively reliable winds.

Two more communities on the western coast, Toksook Bay and Kasigluk, are working on their first turbines.

"By using wind generators, hopefully we can pay less on our lighting bills," said David Tim, chairman of the Nunakauyak Traditional Council in Toksook Bay.

Another 20 villages are borrowing equipment from the state to monitor their winds and gauge whether building turbines would be worthwhile, according to Peter Crimp, project manager for the Alaska Energy Authority.

Good wind resources don't cover the entire state. About 70-90 of more than 300 communities could reduce their energy costs by using wind power, Reeve said.

Kotzebue's 66-kilowatt turbines are small, standing about 80 feet high, with blades spanning 25 feet. Kotzebue Electric plans to add four more turbines next year to the farm's 140 acres. One kilowatt is enough to power 10 100-watt light bulbs

Wind power contributes a tiny percentage of the state's overall electricity sources, generating 3.7 of the state's 5,640 megawatt hours each year. Hydroelectric power makes up most of Alaska's alternative energy use, which totals about 30 percent.

But wind power is displacing over 300,000 gallons of diesel fuel barged annually to the 130,000 residents of rural Alaska, Crimp said.

The state put about $670,000 into wind power projects this year, supplementing about $1.5 million in federal funding.

The expansion of wind energy in Alaska is part of a national trend, wind experts say. The roughly 2,500 megawatts of wind energy installed across the nation in 2005 is by far an all-time high for the industry, said Christine Real de Azua, spokeswoman for the American Wind Energy Association, an industry advocacy group based in Washington D.C.

Higher fuel prices and reinstatement of wind energy production tax credits in this year's energy bill signed by President Bush are among the reasons for the increase, Real de Azua said.

She said wind energy costs now rival natural gas, and some utilities are starting to pass those savings along to consumers.

"What was once at a premium price, the economics are changing," she said.

Alaska's frigid weather and the remoteness of its communities create extra costs and complications for villages trying to set up a wind farm.

Turbines require small heaters and special steel to resist cracking in freezing conditions.

Large building projects in tundra communities are limited to winter, when the land is frozen solid, to protect its delicate padding of lichens, mosses, and shrubs.

"If we came in spring and drove heavy equipment across we'd leave a trench there that might not disappear for a hundred years," Reeve said.

The shortage of winter daylight cuts back on construction time even further.

"After the (vernal) equinox in March, that's when we can really get going," Reeve said.

Wind turbines require large cement foundations for anchors. But destroying the strip of vegetation that protects the underlying permafrost could cause enough melting to create a lake, Reeve said.

To combat heat and sunlight, the Kotzebue wind farm uses expensive refrigerated pilings and pipes with freezeback capability in the turbines' foundations. Workers backfill any holes with a gravel and water mix that becomes part of permafrost.

Icing is not a big problem in the dry cold of Kotzebue, Reeve said, but has caused severe damage to turbines in damper areas.

APPENDIX E

CanWEA proposed ReCWIP and SWEIP programs

Canadian Wind Energy Association
Association Canadienne de l'Énergie Éolienne

REMOTE COMMUNITY WIND INCENTIVE PROGRAM (RECWIP)

Summary

Wind energy is an underutilised resource in Canada's remote communities. Despite the high cost of electricity and the proven technical capability of wind (and wind-diesel) to provide power in these circumstances, there are surprisingly few wind or wind-diesel installations in either large or small isolated communities.

In its original design, the federal government's 1,000 MW Wind Power Production Incentive (WPPI) sought to overcome this gap by making the 1 cent/kWh incentive available for wind turbines of any size in Canada's remote communities (elsewhere WPPI was restricted only to large utility-grade turbines). Although WPPI successfully spurred wind development in grid-connected parts of Canada, the program was not successful in remote communities. This is because the WPPI incentive does not adequately reflect the relatively higher costs of wind generation facilities in isolated areas of Canada. Relative to projects in grid-connected parts of Canada, projects in isolated areas incur much higher costs in terms of transportation, installation, operations and maintenance. The costs are further inflated for more remote regions; a community with only seasonal access will have higher costs than a remote community with a small grid, which in turn has higher costs than a southern grid-connected community. As a result, no remote community project has used WPPI funds to date.

CanWEA believes that Canada's remote communities represent a significant social, economic and environmental opportunity for wind and wind-diesel development. CanWEA is recommending that the federal government establish a Remote Community Wind Incentive Program (ReCWIP) that provides different levels of production incentive to the three broad categories of remote community:

- *Small grids, large communities and industrial facilities = $0.03 per kWh*
- *Remote communities that are year-round accessible (by road or by water) = $0.10 per kWh*
- *Remote communities that are accessible only by air, or seasonally by water or winter road = $0.15 per kWh*

The program would cost $5.4 million per year for 10 years and result in the installation of 65 MW of wind capacity in remote communities. These turbines would produce approximately 112 GWh of energy per year, representing roughly 10% of electricity demand in remote communities. The program would assist remote communities in diversifying their energy supply and stabilising electricity prices. It would also spur Canadian manufacturing of turbines in the 20 kW to 100 kW range where Canada already has a manufacturing niche.

220 Laurier Avenue, Suite 320, Ottawa, Ontario, K1P 5Z9
Phone: 1-800-922-6932 or (613) 234-8716
Fax: 613-234-5642 www.canwea.ca info@canwea.ca

1. OVERVIEW

The federal government's Wind Power Production Incentive (WPPI) has been effective in promoting large scale development of wind power in the populated areas of Canada served by power grids. There are, however, vast areas of Canada, primarily but not exclusively in the north, that are served only by small regional grids or local diesel generating plants. In these cases the cost of energy to the local residents and industry is generally higher than in grid served areas (in some cases many times the cost in grid served areas).

CanWEA believes that wind energy developments in these parts of Canada deserve the same relative support as that provided through WPPI to grid served areas of Canada. For this reason, CanWEA is recommending that the federal government establish a **Remote Community Wind Incentive Program (ReCWIP)** for these communities. The level of support should reflect the relatively higher prices for isolated wind installations described below.

2. RATIONALE

There are several factors that drive up the cost of wind developments in isolated areas. The main factors are discussed below.

Few wind turbines needed

The electrical loads in isolated communities are typically modest to small. This means that remote community wind project developers are unable to benefit from the same economies of scale as their "southern" large wind farm counterparts. This drives up the cost of the development both in terms of capital equipment and installation.

Smaller wind turbines needed

The appropriate size of wind turbines for small communities is generally much smaller than present day "standard" commercial machines. With a limited market, relatively few manufacturers now make turbines under 300 kW rated capacity. The machines therefore cost more on a unit capacity basis, driving up the capital costs of any development. A further complicating factor is that with very limited sales, the manufacturers of small machines cannot afford to invest in the same manufacturing and R&D improvements as their large wind counterparts. It is worth noting that half of the world's 10 to 12 manufacturers of machines in the 20 kW to 100 kW size range are Canadian. In other words, stimulation of this market would have substantial benefits for industrial development of this segment.

Limited wind resources

In the grid connected portions of Canada developers look for sites that have a good wind regime and are located near to transmission lines. In most cases, these sites are not near concentrated population centres In remote communities, developers often have to locate their projects close to the community to avoid the high cost of the power line extensions. The development must therefore make use of the wind resource that is available close to the community. The result is that instead of being able to expect a capacity factor of 30% or more as is the case in southern Canada, a capacity factor of about 20% is often the best that may be expected. This has the effect of raising the installation's produced power price.

Lack of local equipment and cost of transportation

Wind turbine installation requires the use of cranes and other heavy machinery. In the more remote parts of Canada this equipment can be hard to find, and expensive to transport – particularly for communities with only seasonal access. For the same reason, the costs of transportation for the turbines themselves are often much higher than in grid-connected parts of Canada. These factor have a significant impact on electricity production costs.

Climatic challenges

Many parts of northern and other isolated areas of Canada have unique climactic challenges. The most obvious is the generally lower temperatures that the wind generation equipment needs to endure. Low temperatures, besides requiring special materials and lubricants, make construction and maintenance difficult and thus more costly. Permafrost is present throughout much of the north, and construction in these areas requires specialized equipment and precautions, also capital cost drivers.

A further climactic complicating factor in some locations is icing. Some locations are exposed to icing that will degrade the output of wind turbines. This can be a problem in humid areas and on higher altitude sites (such as Haeckel Hill near Whitehorse). The result is that either there are significant energy losses or there are additional capital costs incurred in the provision of measures to mitigate the effects or both, driving up the cost per kWh of energy produced.

Equipment / technology

In small communities served by diesel generation, a high penetration wind-diesel system is needed to achieve a reasonable measure of diesel savings and to reach a reasonable size in a wind energy development. Switching between and integrating these two power sources while maintaining reasonable levels of power quality and reliability for customers requires sophisticated equipment, and this integration equipment is not yet off-the-shelf technology. This results in relatively higher equipment costs.

High relative operating costs

Large wind farms in grid connected areas of Canada are serviced and operated by full time specialized service and operating personnel. In remote areas the servicing is typically done by one or a few individuals who perform many other tasks in the community. They are not trained wind service experts. As well the time required to service a small wind turbine is not much shorter than that required for a very large wind turbine. If specialized service or operational attention is needed, the technicians often have to travel a great distance. All of these factors add up to a much higher operating and maintenance (O & M) cost for wind farms in remote areas than in grid served areas.

3. Program Design

The factors described above all serve, in varying degrees, to drive up the unit cost of wind energy in remote communities. Although the federal Wind Power Production Incentive (WPPI) is technically available for these communities, uptake has been very slow (in fact, non-existent). This is due in large part to the fact that the WPPI incentive of 1 cent/kWh does not adequately reflect the relatively higher costs described above. In order to provide a level of support equivalent to the Wind Power Production Incentive (WPPI) CanWEA is recommending that the federal government establish a Remote Community Wind Incentive Program (ReCWIP).

The design elements of this program are described below.

3.1 Program Target

The actual magnitude of the costs described above varies from one community to another, depending on its degree of isolation and resource availability. CanWEA therefore recommends that the Remote Community Wind Incentive Program (ReCWIP) be split into three categories to reflect the "remoteness" and therefore relatively higher costs of construction, installation and O&M. The three categories are as follows:

- **Category 1.** Includes large communities and those with small grids (e.g. Whitehorse and Yellowknife), as well as industrial facilities in remote areas (e.g. the Diavik and Ekati diamond mines).
- **Category 2.** Includes remote communities that are year-round accessible either by road or by water (e.g. Destruction Bay and Burwash Landing)
- **Category 3.** Remote communities that are accessible only by air, or seasonally by water or winter road (e.g. Old Crow).

3.2 Incentive Level

Exhibit 1 provides an overview of the context for both WPPI supported communities (those tied to the national grid) and ReCWIP-supported communities. For each, the table provides a relative indication of costs and the corresponding incentive proposed for each.

220 Laurier Avenue, Suite 320, Ottawa, Ontario, K1P 5Z9
Phone: 1-800-922-6932 or (613) 234-8716
Fax: 613-234-5642 www.canwea.ca info@canwea.ca

Exhibit 1
Recommended Incentive Level for Remote Communities

	Target for WPPI	Target for ReCWIP		
	Communities Connected to National Grid	**Category 1 Small Grids**	**Category 2 Year-Round Accessible**	**Category 3 Seasonally Accessible**
Type of Community	All areas with access to the main national grid.	Small grids or larger communities, generally in road accessible areas of remote Canada	Remote communities that are road or year-round water accessible	Remote communities that are accessible only by air, or seasonally by water or winter road
Capital costs	Reported to be in the order of $1,500 per kW of installed capacity	Typically about $3,000 per kW of installed capacity (based on Yukon Energy Haeckel Hill experience)	In the order of $6,000+ per kW, higher for high penetration systems (based on feasibility work for Destruction Bay / Burwash Landing)	In the order of $6,000 to $15,000 per kW for high penetration systems (based on Old Crow feasibility work)
Capacity factors achievable	Capacity Factors are 30% or higher (annual average wind speeds of 7+ m/s are considered threshold of feasibility)	20%+ may be reasonable (Yukon Energy experience 21% in best ever years for the Bonus machine, the Vestas machine has not yet achieved 20%), annual average wind speed is 6 to 6.5 m/s	Best possible about 20% (based on wind regime at Destruction Bay which approaches 6 m/s annual average and manufacturer's power curves)	Up to 20%, but this will vary with the wind resource (based on Old Crow which also has severe icing)
O & M costs	In the order of $0.005 per kWh	In the order of $0.02 to $0.05 per kWh (Yukon Energy's experience is in the top end of this range	In the order of $0.05 to $0.10 per kWh (based of feasibility work in Yukon)	$0.10 to $0.15 per kWh (based on Old Crow feasibility work)
Recommended Incentive Level	**$0.01 per kWh (existing)**	**$0.03 per kWh (proposed)**	**$0.10 per kWh (proposed)**	**$0.15 per kWh (proposed)**

It is useful to note that, as a percentage of utility costs, the proposed ReCWIP incentives are similar to those provided under WPPI. For example, WPPI at 0.01 $/kWh represents approximately 15% of current power pool costs (between 0.6 to 0.07 $/kWh). Similarly, ReCIP at 0.15 $/kWh is approximately 15% of current wind-diesel costs (between 0.20 to 0.90 $/kWh) in remote communities with seasonal access. The proposed ReCWIP incentive levels are therefore proportional to WPPI.

3.3 Program Costs and Impacts

Exhibits 2 and 3 provide an indication of ReCWIP program costs and impacts both annually and over the program's lifetime.

The program would cost $5.4 million per year over 10 years (total budget of $54 million) and result in the installation of 65 MW of wind capacity in remote communities. These turbines would produce approximately 112 GWh of energy per year, representing roughly 10% of electricity in remote communities.

By providing long-term financial support via the production incentive's annual payments, ReCWIP will help to ensure the continued long-term operation of supported projects. Experience has demonstrated that "one off" pilot projects are often short-lived because the impetus to maintain operations decreases after the installation is up and running. With a guaranteed 10 year cash flow from ReCWIP, developers will be given a strong incentive to ensure long-term operation with adequate training and maintenance.

The program would yield a variety of important benefits. For example, it would:

- Assist remote communities in diversifying their energy supply and stabilising electricity prices.
- Develop Canada's industrial capacity by spurring Canadian manufacturing of turbines in the 20 kW to 100 kW range, an area where Canada already has a manufacturing niche (note that almost half of the world's manufacturers of systems in this size range are Canadian).
- Help build capacity in First Nations communities for the installation and operation of wind turbines.
- Develop Canadian expertise in wind and wind-diesel systems for remote applications both in Canada and overseas (notably for rural electrification in developing countries).
- Reduce GHG emissions by 89 kilotonnes CO_2e per year, equivalent to removing over 17,000 cars from the road.[1]

[1] Total energy use in remote communities is conservatively estimated at 1200 GWh per year. Assume that wind is backing out diesel generation at 0.8 kg CO_2e per kWh

Exhibit 2
Anticipated ReCWIP Projects and Annual Impacts

	Project Details					Annual Costs and Impacts		
	Target number of projects	Capacity per project (MW)	Total Capacity (MW)	Capacity Factor	Incentive Level ($/kWh)	Annual Output (MWh)	Annual ReCWIP Payments	Annual GHG Emission Reductions (CO_2e/yr)
Category 1 - Small Grids	5	10	50	20%	0.03	87,600	2,628,000	70,080
Category 2 - Year-Round Accessible	20	0.5	10	20%	0.10	17,520	1,752,000	14,016
Category 3 - Seasonally Accessible	10	0.5	5	15%	0.15	6,570	985,500	5,256
Totals	**35**		**65 MW**			**111,690**	**$5,365,500**	**89,352**

Exhibit 3
ReCWIP Costs and Impacts Over Program Lifetime (10 Years)

	ReCWIP payments over 10 Years	GHG Emission Reductions over 10 years (kt CO_2e)	Electricity Output over 10 years (MWh)
Category 1 - Small Grids	26,280,000	700,800	876,000
Category 2 - Year-Round Accessible	17,520,000	140,160	175,200
Category 3 - Seasonally Accessible	9,855,000	52,560	65,700
Totals	**53,655,000**	**893,520**	**1,116,900**

Canadian Wind Energy Association
Association Canadienne de l'Énergie Éolienne

SMALL WIND ENERGY INCENTIVE PROGRAM (SWEIP)

Synopsis: *The Canadian Wind Energy Association (CanWEA) is recommending that the government establish a three year pilot Small Wind Energy Incentive Program (SWEIP) in the next federal budget. This pilot program would provide a 40% purchase rebate (up to $100,000) for the purchase of small wind turbines for on-grid residential, commercial and institutional applications. The program would provide a 50% rebate for installations on commercial farms.*

With annual funding of $10 million, CanWEA estimates that over 670 turbines (including 370 turbines larger than 1 kW) would be installed per year of the pilot program. The federal government's contribution would:

- *Leverage an investment of $22 million per year, three-quarters of which would be invested in the 10 kW to 100 kW range, increasing annual sales of these turbines from roughly 10 units to over 120. This would have a direct benefit for Canadian manufacturers who represent almost half of the world's suppliers of turbines in this size range. SWEIP would therefore help establish Canada as a worldwide leader in supplying these turbines for both the domestic and international market. SWEIP would also significantly increase sales of turbines in the 1 kW to 10 kW range, directly benefiting Canada's existing network of 130 small wind retailers and installers.*
- *Reduce GHG emissions by over 11 kilotonnes CO_2e per year, the equivalent of removing over 2,200 cars from the road. SWEIP would therefore be a valuable contributor to Canada's Kyoto commitments, and an effective, high-visibility way for Canadian individuals, businesses, farmers and institutions to participate in the One Tonne Challenge.*
- *Result in the installation of 6 MW of turbines producing 14 Gigawatt hours of clean energy per year, thereby contributing to Canadian energy security and grid stability.*

If so desired SWEIP could be extended to support other renewable distributed generation technologies such as solar photovoltaic (PV). Note that SWEIP is intended to complement a separate CanWEA proposal aimed at promoting small wind in remote communities (called the "Remote Communities Wind Incentive Program, or ReCWIP).

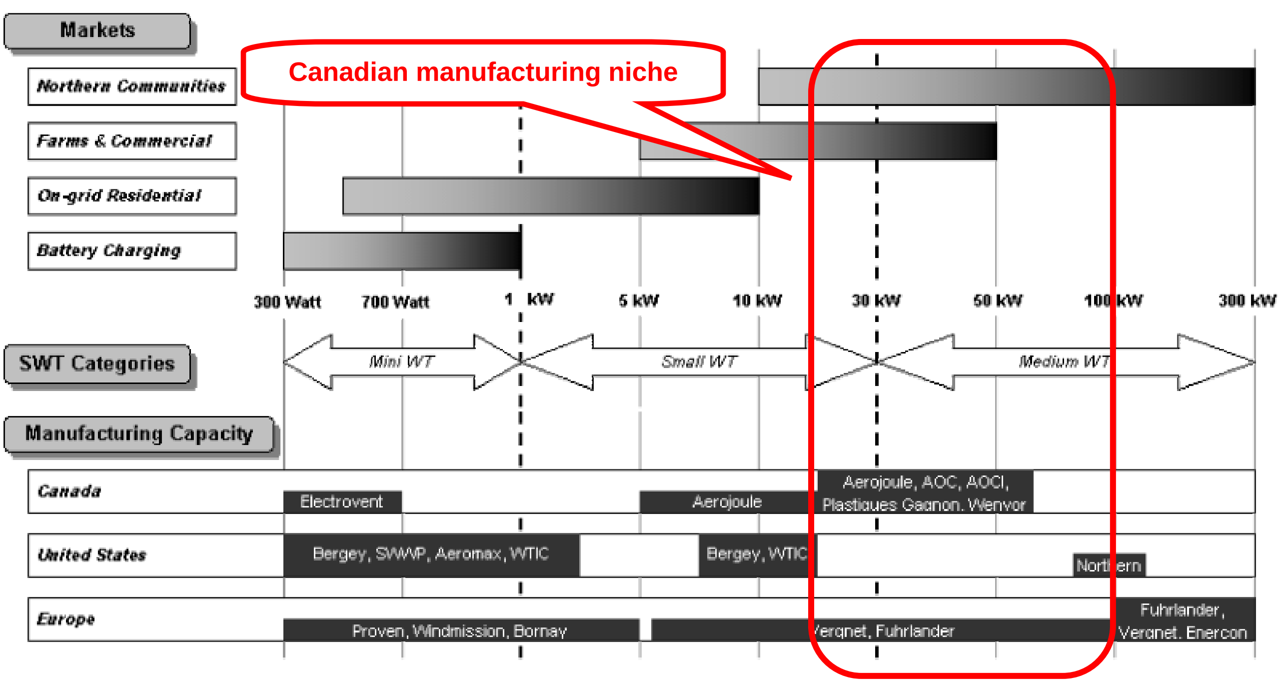
220 Laurier Avenue, Suite 320, Ottawa, Ontario, K1P 5Z9
Phone: 1-800-922-6932 or (613) 234-8716
Fax: 613-234-5642 www.canwea.ca info@canwea.ca

Overview

In recent years the Canadian wind industry has grown significantly to an installed base of 590 MW (as of September 2005) consisting almost exclusively of large, utility-scale wind turbines. The market for small wind systems (those with a rated capacity of 300 kW or less) has not enjoyed the same growth. A 2005 study by Marbek Resource Consultants for Natural Resources Canada revealed that only 600 to 800 small wind turbines are sold in Canada each year.[1] Of these, an estimated 95% are "mini turbines" of 1 kW or less that are most often used in stand-alone, battery charging applications. The report indicated that only 35 to 45 units larger than 1 kW are sold every year in Canada.

At the same time there is a very strong demand for systems up to 10 kW for on-grid residential and small commercial applications, and larger 10 kW to 300 kW units for farms and large commercial businesses. As an indication, CanWEA receives between 1,000 to 1,500 inquiries every year from Canadians seeking to purchase small wind systems. The Marbek report also noted that almost half of all manufacturers worldwide of systems in the 20 kW to 100 kW range worldwide are Canadian. Exhibit 1, extracted from the report, provides an overview of current markets (demand) and manufacturers (supply) for small wind. The exhibit clearly indicates that any efforts to promote the farm, commercial/institutional and northern community markets will likely be of direct benefit to Canadian manufacturers.

Exhibit 1
Small Wind Markets and Manufacturers



[1] *"Survey of Small (300 W to 300 KW) Wind Turbine Market in Canada"*. Marbek Resource Consultants Limited, prepared for the Wind Energy R&D Program of the CANMET Energy Technology Centre-Ottawa (CETC), Energy Technology and Programs Sector, Department of Natural Resources, Government of Canada, Ottawa, Ontario, 2005.

It is useful to note the experience of the U.S., where many states currently offer rebates ranging up to 70% on small wind systems. Examples include:

- **California's** Emerging Renewable Energy Program (ERP) offers $118 million of rebates for the purchase of small scale renewable energy systems including small wind. The program offers $2.50/W installed for systems up to 7.5 kW, then $1.50/W up to 30 kW. Since 1998, the program has assisted in the installation of almost 300 small wind turbines with a total capacity of 1.6 MW
- In **New Jersey**, systems under 10 kW receive a $5/Watt rebate, to decrease over time as more energy systems are added. Rebates are available up to 60% of system costs.
- **New York** provides rebates for installers that are then passed through to generator-owners as a discount. The rebates are linearly scaled from 50% for all parties, 60% for farms and 70% for schools with curriculum linked to wind energy.
- In **Iowa**, small wind under 10 kW is eligible for 10% of the state's renewable energy funds ($1.8 million per year from 1997 to 1999), while larger systems (> 10 kW) are eligible for 20% of the funds.
- **Minnesota's** Agricultural Improvement Loan Program provides up to 45% of loan principal (up to $100,000) for up to 10 years for farm-based small wind systems.

These initiatives, combined with enabling legislation (e.g. net metering is allowed in 40 states) and widespread education efforts have led to significant market resurgence. The American Wind Energy Association estimates that over 13,200 small wind systems are sold every year in the U.S., the vast majority of which are under 10 kW rated capacity.

Rationale

CanWEA believes that small wind represents a very significant opportunity for Canada in a number of areas:

- **Industrial development.** As indicated above, almost half of all manufacturers worldwide of systems in the 20 kW to 100 kW range worldwide are Canadian. Machines in this size range are well-suited to farms, cooperatives and commercial businesses where they can provide on-site electricity at competitive prices (roughly 15 or 16 cents/kWh with proper siting). They are also well-suited to developing country markets for village electrification and grid extension projects. A strengthening of the domestic demand for these turbines will help Canada gain a dominant position for both domestic and international applications (note that U.S. manufacturers have developed a niche primarily in the sub-10 kW size range).
- **Action on climate change.** Canadians are increasingly interested in how they can act to reduce their reliance on grid electricity, and reduce their greenhouse gas (GHG) emissions. Small wind turbines represent one of the most efficient, low-cost options for distributed generation, and as they are emissions-free, they can help Canadians achieve part of their

"One Tonne Challenge". However, at present the residential-size units (those under 10 kW) represent a high up-front cost that acts as a significant disincentive.

- **Increased energy security through distributed generation.** Increasingly, Canadian provinces are introducing legislation that encourages distributed generation and the use of home- and business-based renewable energy. Four provinces (B.C., Ontario, Quebec and Nova Scotia) have introduced net metering legislation that allows owners to "run their meters backwards". Ontario and PEI have introduced pilot "Advanced Renewable Tariffs" that will pay a fixed price for electricity from renewable energy sources. Such "enabling legislation" lays the groundwork for distributed generation, thus helping the provinces to increase their energy security and meet a growing demand for electricity.

CanWEA believes that three critical elements must be in place to capitalise on this opportunity:

- **Education.** This includes the information and tools that Canadians need to make informed decisions on whether or not small wind is right for them. Examples include websites, feasibility calculators and guidebooks.
- **Legislation.** This includes the enabling legislation that allows small wind to be easily installed and connected to the grid. Examples include net metering and municipal zoning bylaws.
- **Incentives.** This includes fiscal instruments that place a value on the social, economic and environmental attributes of small wind. Examples include rebates, production incentives and tax incentives.

Canada has so far made progress on only two of these three elements:

In terms of **education**, CanWEA, with the support of Natural Resources Canada, recently launched a new small wind website that provides information on the technology, and tools that allow users to determine whether or not small wind is right for them.

In terms of **legislation**, as noted above an increasing number of jurisdictions have either implemented, or are in the process of implementing net metering. For example, the Ontario government announced on October 25, 2005 new net metering legislation that allows for installation of systems up to 500 kW.

In terms of **incentives**, none currently exist in Canada (apart from an Ontario sales tax rebate).

Program Design

The Marbek report identified first cost as <u>the</u> major barrier in promoting small wind, and CanWEA therefore recommends that the federal government establish a pilot Small Wind Energy Incentive Program (SWEIP), providing rebates for the purchase of grid-connected small wind systems for residential, business and farm applications.

CanWEA recommends that SWEIP be established with the following design elements:

- **Target markets.** The Marbek report assessed various potential markets and prioritised them according to criteria such as potential market size, opportunity to access market, benefits for Canadian manufacturing and potential GHG reduction benefits. CanWEA recommends that SWEIP target the top markets identified in the Marbek report – namely farms & commercial, institutional and on-grid residential. Note that CanWEA is recommending that the northern and remote community market be addressed through a separate program called the Remote Communities Wind Incentive Program (or "ReCWIP" – this has been submitted as a separate proposal).
- **Incentive Level.** In its pilot phase, CanWEA recommends that SWEIP provide a direct purchase rebate of 40% for systems installed in residential, commercial, institutional and industrial applications, and 50% for systems installed on commercial farms. Note that the rebate, up to a maximum of $100,000, should be applied to the installed capital cost, including the turbine and auxiliary equipment (inverters, batteries, controllers etc.). This level of incentive would be roughly equivalent to that provided in California; one of the most successful programs in the U.S. At the end of the three year pilot program it is expected that the market will have sufficient momentum to justify a reduction in the SWEIP incentive levels (for example to 25% for homes, commercial and businesses, and 40% for commercial farms).
- **Funding.** CanWEA recommends that the government initiate SWEIP as a pilot program, providing an average of $10 million per year in incentives for a period of three years. At that point the program would be reviewed, and if deemed successful, be provided with longer-term funding. As noted above, the federal government may also choose at that time to reduce the incentive level.
- **Allocations.** CanWEA recommends that SWEIP allocate funding proportions for certain key markets, including commercial farms (50% of funding).
- **Eligible Technologies.** CanWEA recommends that the incentive apply to all CSA or UL approved wind turbines under 300 kW. Note that if desired, the SWEIP program could be extended to other renewable distributed generation technologies such as solar photovoltaic (PV). For the residential sector it is recommended that eligibility be limited to installations where the turbine displaces grid electricity or stand-alone power (e.g. diesel generation sets).
- **Verification.** It is recommended that the installations be subject to the same verification procedure as that applied under the Renewable Energy Deployment Initiative (REDI).
- **Environmental Impacts.** It is recommended that the installation of all turbines 10 kW and over be subject to a streamlined environmental assessment process. The procedure may be similar to that applied to Parks Canada's recent installation of a 10 kW turbine at the Cavendish Campground in the municipality of Cavendish, Prince Edward Island (CEAR reference number 04-01-2174).

Anticipated Cost and Impacts

Exhibits 2 and 3 provide an overview of anticipated SWEIP program costs and impacts. With annual funding of $10 million, CanWEA estimates that the SWEIP program would:

- **Leverage an investment of 2:1.** The federal government's contribution of $10 million per year would leverage a total investment of over $22 million per year, assisting in the installation of over 670 turbines (over half of which would be larger than 1 kW).
- **Develop Canadian manufacturing capacity.** Three-quarters of SWEIP funding would be invested in turbines in the 10 kW to 100 kW range, increasing annual sales of these turbines from roughly 10 units to over 120. This would have a direct benefit for Canadian manufacturers who represent almost half of the world's supplier of turbines in this size range.
- **Boost existing small wind retail network.** SWEIP would significantly increase sales of turbines in the 1 kW to 10 kW range, from an estimated 40 units per year to over 250. This would directly benefit all sectors (particularly residential) and strengthen Canada's existing network of 130 small wind retailers and installers.
- **Increase clean energy production.** Altogether the installed turbines would have an installed capacity of over 6 MW, and would produce 14 Gigawatt hours of clean energy per year. This is equivalent to the output of a 2 MW thermal plant operating at 80% capacity factor. The installed turbines would also contribute to increased grid stability through distributed generation.
- **Reduce emissions of GHGs and smog-related pollutants.** Altogether the turbines would reduce GHG emissions by almost 14 kilotonnes CO_2 equivalent per year, the equivalent of removing over 2,200 cars from the road per year. SWEIP would be a valuable contributor to Canada's Kyoto commitments, and an effective, high-visibility way for Canadians to participate in the One Tonne Challenge.

Exhibit 2
Estimated Annual Impact of the SWEIP Program

Small Wind Turbine Size Range	Units sold per year			Annual Impacts		
	Residences, Commercial, Institutional, Government	Commercial Farms	**Total**	Installed capacity (kW per year)	Energy Output (MWh / yr) *	Emission Reductions (t CO2e / yr) **
Mini (up to 1 kW)	300	-	300	300	400	300
Small (1 kW to 10 kW)	150	100	250	700	1,300	1,000
Medium 1 (25 kW)	40	40	80	2,000	4,400	3,500
Medium 2 (75 kW)	20	20	40	3,000	7,900	6,300
TOTAL	**510**	**160**	**670**	**6,000**	**14,000**	**11,100**

Notes: * - Assume different capacity factors for different size ranges: 20% for units under 10 kW, 25% for units under 50 kW and 30% for units above 50 kW. See Appendix A for details.

** - Assuming a marginal emission rate of 0.8 kg CO_2e/kWh (based on figures provided for 2004 for Environment Canada's PERRL program

Exhibit 3
Estimated Annual Costs of the SWEIP Program

Small Wind Turbine Size Range	Total Installed Cost of turbines each year of SWEIP	Portion of Cost Covered by SWEIP		
		Residences, Commercial, Institutional, Government	Commercial Farms	**Total Incentive Provided per Year through SWEIP**
Mini (up to 1 kW)	$1,730,000	$690,000	-	$690,000
Small (1 kW to 10 kW)	$4,270,000	$1,010,000	$870,000	$1,880,000
Medium 1 (25 kW)	$6,600,000	$1,320,000	$1,650,000	$2,970,000
Medium 2 (75 kW)	$9,900,000	$1,980,000	$2,480,000	$4,460,000
TOTAL	**$22,500,000**	**$5,000,000**	**$5,000,000**	**$10,000,000**

220 Laurier Avenue, Suite 320, Ottawa, Ontario, K1P 5Z9
Phone: 1-800-922-6932 or (613) 234-8716
Fax: 613-234-5642 www.canwea.ca info@canwea.ca

APPENDIX A – DETAILED PROGRAM CALCULATIONS

A. Program Design

	Turbine Characteristics			Number sold per year			SWEIP Incentive Level (%)	
	Installed cost per kW	Average Size of Turbine (kW)	Capacity Factor	Category 1 (Homes etc.)	Category 2 (Farms)	Installed Capacity (kW)	Category 1 (Homes etc.)	Category 2 (Farms)
Mini (up to 1 kW)	6400	0.9	15%	300	-	270	40%	50%
Small (1 kW to 10 kW)	5760	3	20%	146	101	741	40%	50%
Medium 1 (25 kW)	3300	25	25%	40	40	2000	40%	50%
Medium 2 (75 kW)	3300	75	30%	20	20	3000	40%	50%
TOTAL				**506**	**161**	**6,011**		

B. Financial

	Total Installed Cost ($ per year)		Portion Paid by SWEIP ($ per year)		
	Category 1 (Homes etc.)	Category 2 (Farms)	Category 1 (Homes etc.)	Category 2 (Farms)	TOTAL SWEIP INCENTIVE
Mini (up to 1 kW)	$ 1,728,000	$ -	$ 691,200	$ -	$ 691,200
Small (1 kW to 10 kW)	$ 2,522,880	$ 1,745,280	$ 1,009,152	$ 872,640	$ 1,881,792
Medium 1 (25 kW)	$ 3,300,000	$ 3,300,000	$ 1,320,000	$ 1,650,000	$ 2,970,000
Medium 2 (75 kW)	$ 4,950,000	$ 4,950,000	$ 1,980,000	$ 2,475,000	$ 4,455,000
TOTAL	**$ 12,500,880**	**$ 9,995,280**	**$ 5,000,352**	**$ 4,997,640**	**$ 9,997,992**

C. Impacts

	Energy Output (MWh/yr)		Emission Reductions (t CO2e / yr)		
	Category 1 (Homes etc.)	Category 2 (Farms)	Category 1 (Homes etc.)	Category 2 (Farms)	TOTAL SWEIP INCENTIVE
Mini (up to 1 kW)	355	-	284	-	284
Small (1 kW to 10 kW)	767	531	614	425	1,039
Medium 1 (25 kW)	2,190	2,190	1,752	1,752	3,504
Medium 2 (75 kW)	3,942	3,942	3,154	3,154	6,307
TOTAL	**7,254**	**6,663**	**5,803**	**5,330**	**11,134**

D. Table for Report - Rounded Figures

	Number sold per year			Impacts		
	Residences, Commercial, Institutional, Government	Commercial Farms	Total	Total Capacity (kW)	Energy Output (MWh / yr)	Emission Reductions (t CO2e / yr)
Mini (up to 1 kW)	300	-	300	300	400	300
Small (1 kW to 10 kW)	150	100	250	700	1,300	1,000
Medium 1 (25 kW)	40	40	80	2,000	4,400	3,500
Medium 2 (75 kW)	20	20	40	3,000	7,900	6,300
TOTAL	**510**	**160**	**670**	**6,000**	**14,000**	**11,100**

	Total Installed Cost	Portion Paid by SWEIP ($ per year)		
		Residences, Commercial, Institutional, Government	Commercial Farms	SWEIP Rebate
Mini (up to 1 kW)	$1,730,000	$690,000	$0	$690,000
Small (1 kW to 10 kW)	$4,270,000	$1,010,000	$870,000	$1,880,000
Medium 1 (25 kW)	$6,600,000	$1,320,000	$1,650,000	$2,970,000
Medium 2 (75 kW)	$9,900,000	$1,980,000	$2,480,000	$4,460,000
TOTAL	**$22,500,000**	**$5,000,000**	**$5,000,000**	**$10,000,000**