University of Montreal

An Economic Analysis of Wind Energy Production in the Remote Areas of Quebec

by

Daniel Sarafidis

Department of Economics

Faculty of Arts and Sciences

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SUMMARY

The study evaluates the economic feasibility of placing wind machines in the remote areas of Quebec. These locations are powered today by expensive diesel units because the transmission line costs are too high for these locations to be connected to the Hydro-Quebec grid. The study evaluates the feasibility by :

(i) calculating the energy generated from each wind machine for each location in Quebec from a computer simulation.

(ii) specifying the regional constraints (load factor, capacity factor, etc...).

(iii) defining from what was given by the manufacturer the revenues and costs to be included in an economic evaluation.

(iv) addressing the additional benefits and costs (shadow price of goods, environmental constraints, increase in security of energy supply, etc..) to be considered in an economic analysis.

(v) calculating the economic feasibility of each machine, in each region.

(iv) giving recommendations from the results.

With the high wind speeds and the high cost of supplying energy to these locations, wind energy production will be found to be an ideal addition to the energy supply in four locations. The study is not considered a '<u>cost-benefit study</u> ' but a '<u>cost-effectiveness study</u>'.

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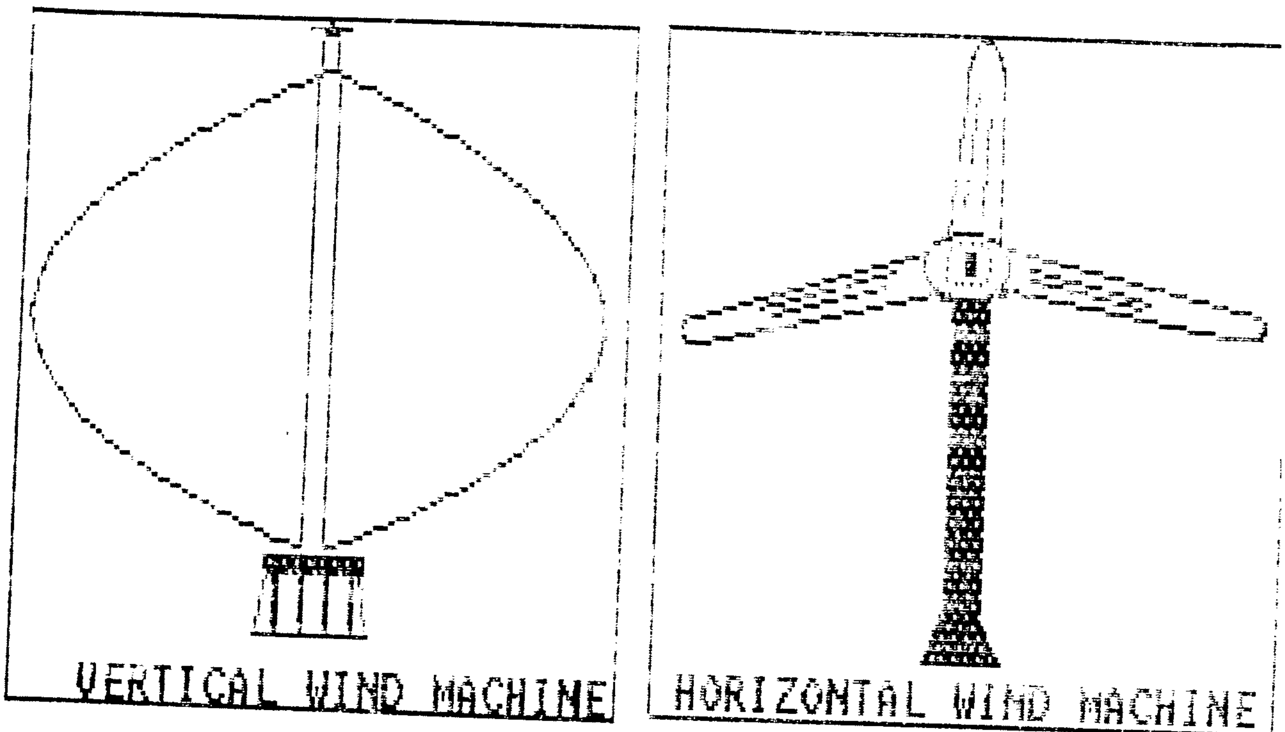
INTRODUCTION : AN OVERVIEW OF WIND ENERGY

The first windmill was built in Asia around 1100 AD. It has only been in the last two decades, with the substantial increase in the price of oil, that wind energy has been researched and developed seriously as an energy source.

The recent evolution of wind energy can be classified into three periods (Chappel, M.S., 1986). In the first period (1976-1981) there were large government programs which developed large machines. The results turned out to be disappointing and costly. In the second period (1982-1985) research and development turned to smaller size wind machines. With government tax incentives, wind energy production had become a good investment. In the third phase (1986-) there was research and development of larger productive wind machines. The loss of the tax incentives, along with lower world oil contributed to a lower commercial success of wind energy production.

The Canadian Wind Energy Program began with research on vertical axis wind energy machines. The vertical axis wind machine was introduced to Canada by the National Aeronautical Establishment. These wind machines have their blades positioned on a vertical position similar to an upside down egg beater **(see figure 1)**.

Figure 1



The vertical rotor wind machine was selected instead of the traditional horizontal rotor machine because (Chappel, M.S., 1986):

(i) same performance of both wind machines.

(ii) increased reliability of vertical rotor machines because of their aerodynamic design.

(iii) large vertical wind machines give the opportunity of placing the generator on land which is not possible for horizontal rotor wind machines.

The National Research Council started research and development on the vertical axis wind machine in early 1970. Due to the oil embargo of 1973, there was additional research on wind energy to increase self-sufficiency in energy supply. The high prices of oil in 1979 brought about addition research on Canadian wind energy machines. The Canadian Research Council and the Council for Energy Research and Development were put in charge of wind energy research and development. It was in 1984 when wind energy machines of 500 kw were being put into place for commercial use that it was decided that the Council for Energy Research and Development and the National Research Council would no longer be funded for wind energy research and development. In 1985 the Ministry of Energy, Mines and Resources was put in charge of the Canadian Wind Energy Program. It's mandate was to continue research on wind energy, eliminate direct subsidies to manufacturers, and initiate research and information exchange between wind energy manufacturers.

There has been some wind energy investment in the province of Quebec. A 224 kw vertical axis wind machine was installed on the Magdalen Island by the National Research Council and Hydro-Quebec. There was also one installed in Varennes and La Fonderie Quebec. In 1981 the National Research Council and Hydro-Quebec decided to jointly study the possibility of developing the largest vertical wind energy machine in the world with a wind spand of 4000 $meters^2$. In 1986 because of the unexpected lower world oil prices, the closing of the National Research Council's wind energy program, and the loss of tax incentives for the wind energy industry, the 4 MW Aeolus project was sold to Shawinigan Consulting Experts.

There were mainly four reasons (Grub, M.J., 1990, p.525-542) why wind energy was not considered as a viable energy source:

(i) wind machines were too costly considering their energy production output.

(ii) technology was not reliable.

(iii) variability of the wind and energy output posed a problem.

(iv) after considering the location constraint the energy resource was severely limited.

The facts today point to the contrary. The costs of wind machines fell significantly and performance improved as a result of many years of research and a better understanding of wind turbine dynamics. With the initiating stage of wind energy research and production behind the technology has become more reliable. There are many wind machines today operating at 90% to 95% availability (actual\anticipated energy output). This is possible today because the parts that needed to be replaced during operation can now be quickly replaced because the complexity of the wind machine has been reduced. Concerns arising from the variability of the energy production are not valid. Previous experience and most studies have shown that economic penalties become significant if wind production exceeds 20% and become prohibitive at about 40% of all the base load energy supply on large electrical grid operations because energy storage becomes necessary and increases the overall cost of production. The location constraint is also not considered valid. There is a great physical potential for wind energy production in Canada because the locations where wind speeds are high have high costs of energy production.

Deployment of wind energy machines today is hampered by the subsidies to other energy technologies like nuclear and the lack of information of its investment value.

ACKNOWLEDGMENT

I would like to thank M. Fernand Martin for all his help with this paper. I would also like to thank him for his teaching and guidance while I attended the University of Montreal which gave me the necessary skill and ability to write such a paper.

LIST OF ABBREVIATIONS AND DEFINITIONS

acre : 4 046.873 square meters.

db(a) : Noise measurement scale (decibel).

ft : foot.

k : Kelvin (temperature measurement) .

kpa : kilopascals (pressure measurement).

sek : Swedish currency (krona).

kg : kilogram

kw : 1 000 watts of power .

kwh : 1 000 watts of power in 1 hour.

m : meter.

m/s : meter per second.

mw : 1 000 000 watts of power.

mwh : 1 000 000 watts of power in 1 hour.

rpm : revolutions per minute

W : a watt is a continuous power of one joule for one second (0.1019 kgm/s) (Fremy, D., 1990).

A. WIND ENERGY SPECIFICS

1. Area of study

The area which was first under consideration was the whole province of Quebec. Wind speeds and other environmental data was obtained from Environment Canada (Atmospheric Environment Service, 1982) for 52 locations throughout the province.

2. Overview of the wind machines

There are many types of wind machines to choose from. Two Canadian wind machines were chosen for this study: The 4 MW Aeolus and the Daf Indal 500 KW Vertical Axis Wind Machines (Desrochers, G. 1983).

COMPARATIVE DATA OF THE WIND ENERGY GENERATORS

	DAF INDAL	EOLE
Swept area (m^2)	595	4000
Type	Vertical Axis	Vertical Axis
Speed (rpm)	45	14.25
No. of blades	2	2
Equator height (m)	21.3	55
Generator	Induction	Synch.
Speed (rpm)	1200	-
Rating (kw)	500	4000 (4 MW)
Cut-in-wind speed (m/s)	6.8	4.11
Cut-out-wind-speed (m/s)	24	26.82

Energy production curves are turbine power outputs relative to wind speeds. The curves are valid for standardized temperature and pressure of 288.15° K and 101.325 kpa respectively. The power curves are shown below (Desrochers, G. 1983) and on the next page **(see figure 2)**.

DAF-INDAL POWER CURVE (500 KW)

Wind m/s	Electric Power KW
6.8	0
8.0	35
10.0	105
12.0	200
14.0	270
16.0	370
18.0	480
20.0	540
22.0	565
24.0	580

EOLE POWER CURVE (4 MW)

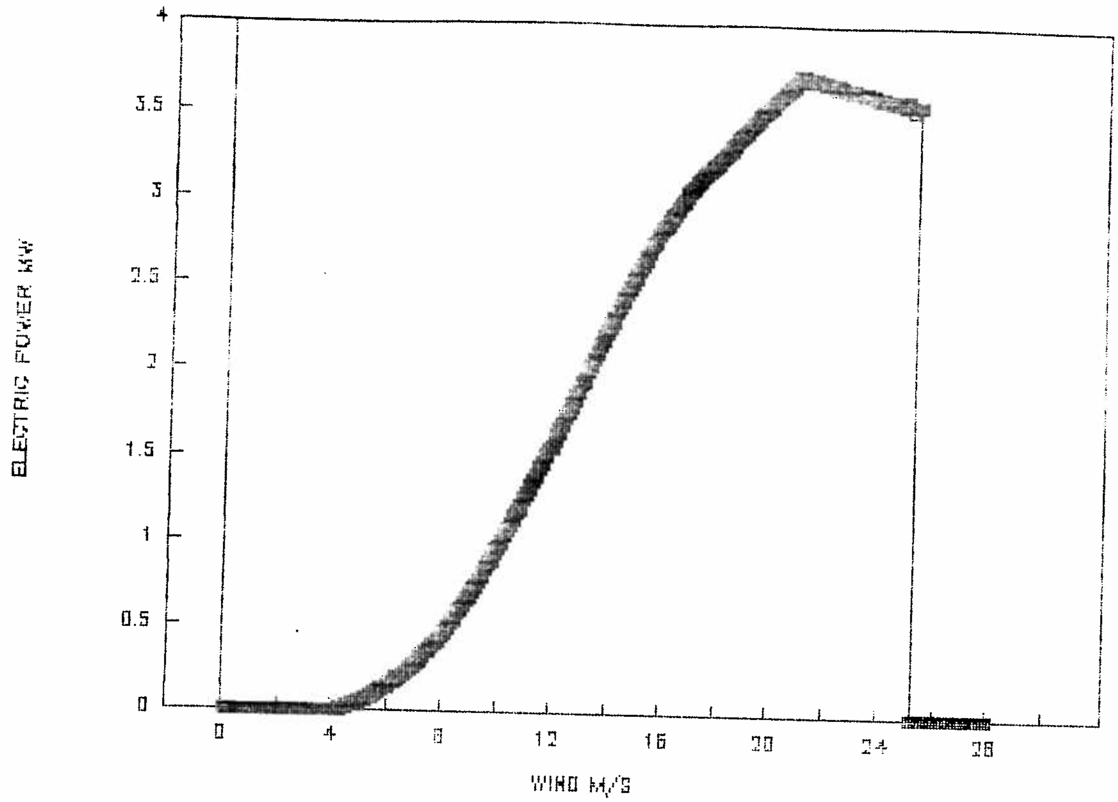
Wind m/s	Electric Power MW
4.110	0.0000
5.406	0.0855
6.701	0.2277
7.995	0.4450
9.290	0.7531
10.584	1.1277
11.879	1.5428
13.173	1.9770
14.468	2.4099
15.762	2.8002
17.057	3.0861
18.351	3.3047
19.645	3.5229
20.940	3.7134
22.234	3.6674
23.529	3.6111
24.823	3.5565
26.118	3.4853
26.820	3.4422

3. Computerized energy production output

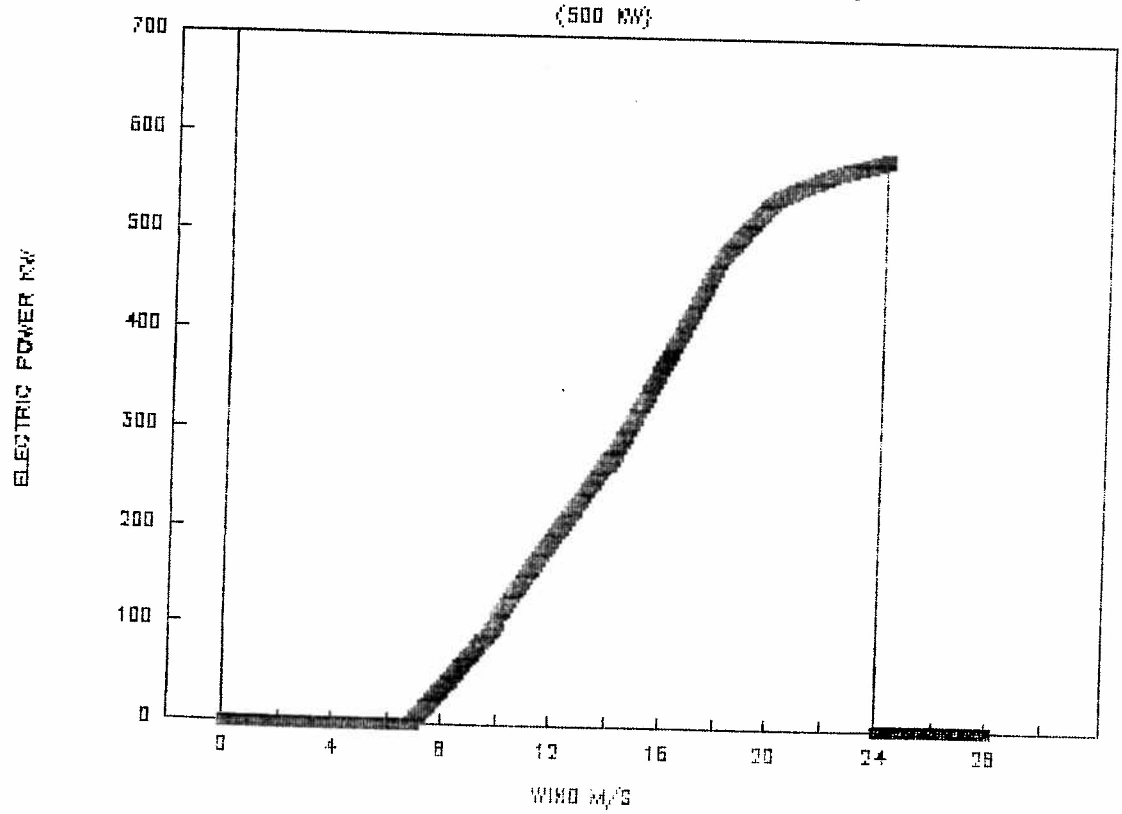
To evaluate the feasibility of installing a wind machine the energy output for each specific location must be calculated. The higher the wind speeds in a region the more energy production there is. There are three ways of estimating annual energy outputs from

Figure 2

EOLE TURBINE EFFICIENCY POWER (4MW)



DAF INDAL TURBINE EFFICIENCY, POWER
(500 KW)



wind machines (Desrochers, G. 1983). The most accurate estimate is with wind speed values for each hour or minute of the year. A second, less accurate approach uses wind speed frequency distribution data. An even less accurate measurement which requires only the average annual wind speed in a location uses a statistical wind frequency distribution such as the Rayleigh distribution. In this study the second method (wind frequency distribution) will be used. The wind energy analysis was done using a computer program developed for the region of Quebec and with some additional programming adjustments could be used for any other location. The program which was developed by myself throughout 1991 was later verified by a qualified engineer. There were about 31 000 input data for the computer simulation for such things as wind velocity, frequency of the wind, monthly temperature, monthly atmospheric pressure, height adjustment factors, ice downgrading, wind turbine efficiency, topographical constraints, start-stop, wake effects, electrical losses, availability losses, etc.. . All factors thought possible in a wind energy analysis were taken into consideration except possible hazards from ocean salt formation. The computer simulation and the wind-energy output can be seen in the appendix 5 and appendix 6 respectively. Calculation of the performance requires :

i) turbine power curves at sea level vs wind velocity
ii) wind frequency vs wind velocity for one year
iii) wind shear exponent for height adjustment
iv) average densities for the site elevation
v) availability constraints of the wind machine

The computer simulation accepts the power curves for both wind machines. The generated wind speeds, denoted w_{ref}, were adjusted for height, air pressure, temperature, and terrain.

Adjustment for height and terrain:

$$\mathbf{w = w_{ref} \; X \; (h/h_{ref})^{alpha}}$$

w = wind speed at equator height (m/s)
h = equator height
$\mathbf{h_{ref}}$ = the height from the initial wind data (m/s)
alpha = the wind shear factor adjustment for height (takes into account the terrain type).
$\mathbf{w_{ref}}$ = wind speed from the initial wind data (m/s)

Adjustment for temperature and pressure:

$$\mathbf{rho = rho_0 \; X \; (p/p_0) \; x \; (t_0/t)}$$

rho = corrected air density
$\mathbf{rho_0}$ = air density at temp t_0 (K) and pressure p_0 (kpa)
$\mathbf{t_0}$ = average monthly temperature (K)
$\mathbf{p_0}$ = average monthly pressure (kpa)
p = average month pressure (kpa) given for the location analazed
t = average month temperature (K) given for the location analyzed

The power curves were used to generate the energy output of the vertical axis wind turbines for each corrected wind velocity interval. Then adjustments for startup/shutdowns, electricity losses, vertical axis wind turbine availability, and icing were also taken into account.

4. Overview of results, compatibility, and procedure

Wind power is given by the following equation:

POWER = Air Density X $(\text{Velocity})^3/2$

Power = W/m^2

Air Density = kg/m^3

Velocity = m/s

It is not financially viable to install a wind machine with an average annual wind speed under 5 m/s. Looking at figure 2, at 5 meters/second there is very little amount of energy output because of the start-up wind speed the machines require to operate and because of the wind turbine prodution output. Regions with average annual wind speed significantly below 5 meters/second definitely do not produce enough energy to justify their costs and are therefore excluded from any further analysis. The uncorrected annual wind speed, and energy output (for those with an annual wind speed > 5m/s) for the Daf Indal and Aeolus machine for all locations is given in appendix 1. **For presentation purposes the Blanc-Sablon case will be used throughout the paper as a case model.**

Blanc-Sablon

	Average annual wind speed(m/s) uncorrected	ENERGY OUTPUT IN MWH
DAF INDAL:	6.98	548.4732
AEOLUS:	6.98	14072.4229

Regions retained for economic evaluation are situated in the remote areas of Quebec : area around the entrance of the Gulf of St. Lawrence, and the northern part of Quebec. For a wind machine to be installed in a location, it must be compatible with the energy demand of that location. The installed power for locations which have diesel as a source of energy production in 1990 is given in appendix 2 (Hydro-Quebec, 1990, 164-208).

Location	Installed Power (kw)	Production (mwh/yr)
Blanc-Sablon	10 400	24 349

The installation of one wind machine in each location is considered. The objective of the analysis is to see if the implimentation of one wind machine in each location is economically viable. If installing one wind machine is not feasible then installing more than one will certainly not be feasible (no economies of scale in production). If the installation is feasible for one wind machine, only then can it be feasible to install more if the energy demands of the location permit. When wind machines supply a higher percentage of the energy output in a location the higher the overall cost per wind machine and the lower the return on investment. This is mainly due to the fact that with a higher percentage of the total energy supply from the wind machine, the variability of the wind and energy production increase cost because high cost energy storage (battery) becomes necessary. Another reason is that with a higher percentage of the total energy supply coming from a wind machine, the chance of overproduction and energy waste increases. Given that the energy demand follows the same monthly distribution as the wind (energy production from the wind machine), and that the wind machine plays a backup role on the energy output in all regions, the energy produced from the wind machine is assumed to be completely consumed (after taking into account for start-up, availability at 95%, etc..). Since the diesel can safeguard for any energy disruptions from the wind machine, no energy storage (battery) is required.

B. ECONOMIC EVALUATION

1. Method of evaluation

To decide which energy option to use, comparable information on the system is necessary. There are three ways to compare energy options (Benis, and De Angelis, 1990) :

(i) Generic comparisons : is a comparison of alternatives as a general plant additions to the utility.

(ii) Energy supply comparison: is a comparison with an ideal utility (the addition of an energy source to a theoretical utility).

(iii) Utility Specific Comparisons : evaluate for a specific utility a specific energy supply addition.

Generic comparisons are quite limited. Limitations of generic comparisons are :

i) the treatment of transmission line costs

ii) accounting for daily and seasonal variations in the value of electricity

iii) variation in construction time.

iv) location is not considered

Utilities who have access to transmission lines, have locations of considerable distance who's cost can determine the merit of the specific energy supply. Location may raise transmission costs and increase fuel delivery charges in which generic estimates do not take into account. This is why in this study the utility specific comparisons will be used.

There are two common ways of expressing the cost of energy to a utility (Mc. Nabb, C., 1984, p.32-43); marginal capital cost, and marginal production cost. Marginal capacity which is unique to each system is defined as the cost of increasing capacity by one more kw. Marginal production cost which changes with the season, and days, as more expensive energy sources are used to cover peak demands is the cost of producing the next kwh of energy. Operation, maintenance and fuel charges are used to estimate this cost. All forms of energy must serve as either a :

(i) contribution to the base capacity
(ii) reduction on the use of base or peaking capacity
(iii) a blend of both (i) and (ii)

If the energy supply displaces fuel only and doesn't serve as an increase in capacity, marginal production costs must be used. Since it is impossible to predict the exact wind distribution in a location wind machines are not given any capacity credit at all. Wind machines cannot be considered to supply a pre-determined amount of power on a reliable basis. Wind machines have not been given credit for capacity by utilities from other provinces. In this paper the wind machine will reduce the required energy production of the diesel units during the windy periods. The wind machine will be cost effective if the supply price of wind energy is competitive with the cost of operation, maintenance, and fuel charges of the diesel units. This is the method that will be used in this paper.

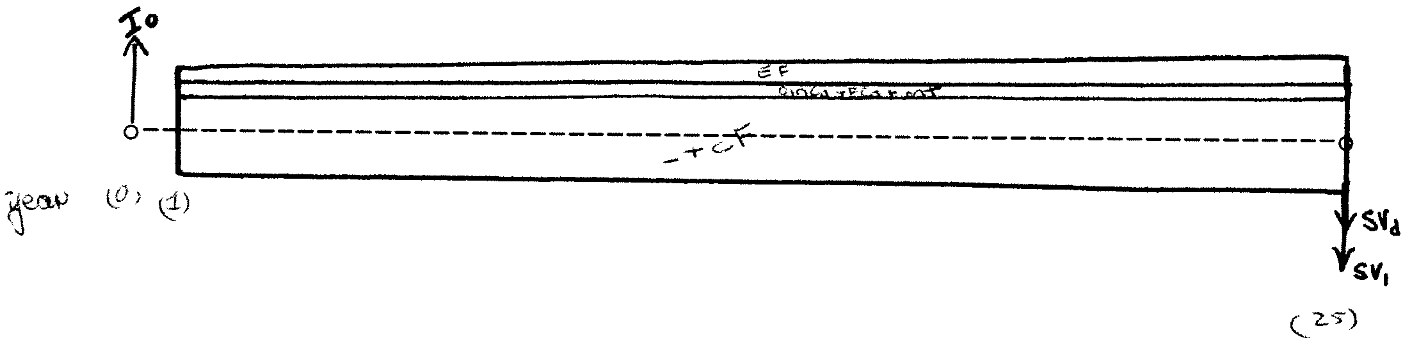
There are many cost measures used in comparing energy alternatives. Some of the most common methods of evaluation are; capital cost, payback method, cost per kwh, internal rate of return and net present value. The capital costs method is used by small electrical owners who favor less efficient sources whose first initial cost (includes the shipping and installation costs) is lower than the owner's capital-raising ability. This does not apply here and is not a correct method of evaluation. The payback method which is the number of years necessary to recoup initial funds initially invested does not take into account many important factors such as the discount factor and is also considered an incorrect method of analysis. The cost per kwh is also not the correct method of analysis because it degenerates (to pass from a good to a bad state) the actual present cost of electrical generation. For example if someone had to choose between two projects with Project_a and Project_b costing \$10 and \$20 (\$1991) respectively, Project_a would be correctly chosen. However if the cost per kwh method was used and $Project_a$ and $Project_b$ produce 1 and 10 kwh of energy respectively then the cost per kwh is equal to 10 for $Project_a$ and 2 for $Project_b$. $Project_b$ is incorrectly chosen because this method degenerates the present costs by placing an emphasis on how much energy is produced. The internal rate of return which makes the present value of a stream of returns equal to zero is an incorrect method of analysis mainly because it assumes that all receipts can be compounded at the internal rate of return whereas the only appropriate rate is the market rate of return. When comparing projects, a project with a lower IRR may have a higher Net Present Value. Multiple rates of return can be also found using this method. The method that will be used in the study is based on the principals of the Net Present Value (Copeland, T.E., 1988) but in the context of a cost effectiveness study since there are only cost savings to consider. The calculations which are done from the viewpoint of society (social utility function) are calculated using constant dollars . There are two alternative situations (one with and one without the wind machine) which produce the same exact product (energy) in the same quantity. To arrive at the final method of evaluation, two situations are examined:

a) Energy production from the original diesel operation with 100 % production from the diesel machine.

b) Equal energy production from the diesel and wind machine with y % production from the diesel machine and (100-y %) from the wind machine.

a) Original diesel operation

(NOT TO SCALE)



The time horizon is set at 25 years for the diesel machine. For the diesel machine year (0) is the initiating, planning and construction phase and the second year (1) is the first year of energy production.

The cost of this project is :

$$\text{Cost} = I_0 + \sum_{1}^{25} \frac{(OMC_d + FC_d)}{(1+r)^t} - \frac{(SVd_d + SV_1)}{(1+r)^{25}} + \frac{EF_t}{(1+r)^t} + \frac{MT}{(1+r)^t} \; (-\,+) \; \frac{CF}{(1+r)^t}$$

I_0 = initial investments (land for the diesel machine, diesel machine etc..).

OMC_d = annual operation and maintenance charges of x% (100%) production from the diesel machines.

FC_d = fuel charges pertaining to the x% production of the diesel machine(s). The fuel costs are included in the operation and maintenance charges in the computer flowchart output.

SV_d = scrap value of the diesel machine.

SV_l = land value at the end of the project.

MT = annual municipal taxes.

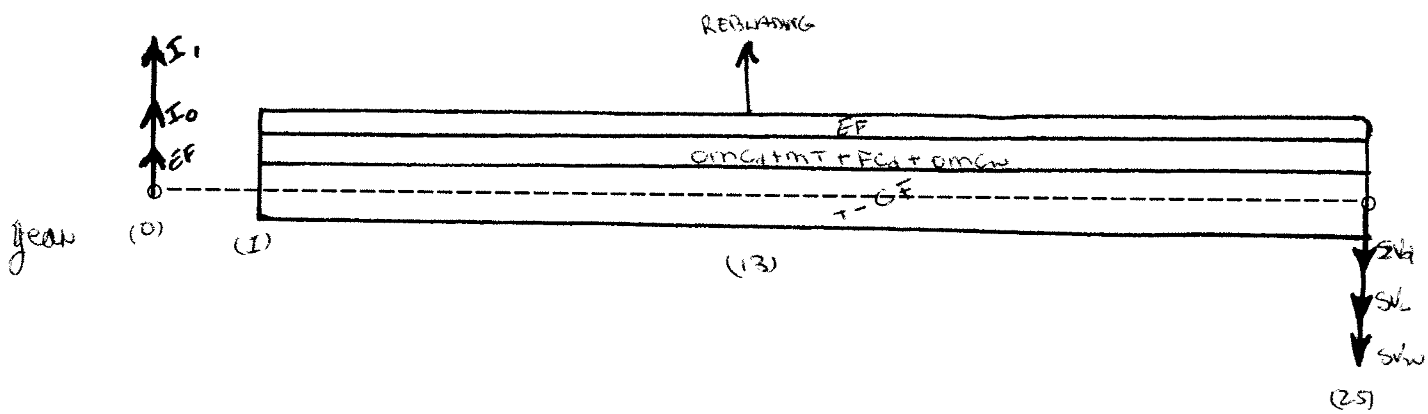
EF = annual environmental (pollution) effects from the diesel units.

CF = correction factors (shadow prices etc..).

This will be discounted at the appropriate discount rate r and time factor t.

b) Wind and diesel operation

(NOT TO SCALE)



The time horizon is set at 25 years for the wind machine. The first year (0) is considered as the construction phase of operation and the second year (1) as the first year of energy production. Reblading has to be considered half way through the life horizon of the wind machine.

The cost of the project is :

$$\text{Cost}= I_0 + I_1 + \sum_{1}^{25} \frac{(OMC_d+MT+FC_d+OMC_w)}{(1+r)^t} + \frac{REBL}{(1+r)^{13}} - \frac{(SV_d+SV_w+SV_l)}{(1+r)^{25}} +$$

$$+ \frac{EF_t}{(1+r)^t} \; (+-) \; \frac{CF}{(1+r)^t}$$

I_0 = initial investment of the diesel (includes the land for the diesel, and other initial investments).

I_1 = initial investment of the wind machine (includes land for the wind machine, and other initial investment).

OMC_d = annual operation and maintenance charges of y% production of diesel.

FC_d = fuel charges pertaining to the y% production of the diesel machine(s). In the computer flowchart output the fuel costs are included in the operation and maintenance charges.

OMC_w = annual maintenance charges of the (1-y)% production from the wind machine.

REBL = cost of reblading half way through the wind machine's life.

MT = annual municipal taxes.

SV_d = scrap value of the diesel machine.

SV_w = scrap value of the wind machine.

SV_l = land value at the end of the project.

CF = correction factors are such things as benefits from increase security of supply, indirect subsidies to manufacturers (shadow price of a good), reduction of currency allocation, etc..

EF = environmental effects of security + sound + visual + electromagnetic from the wind machine and pollution from the diesel machines (annual).

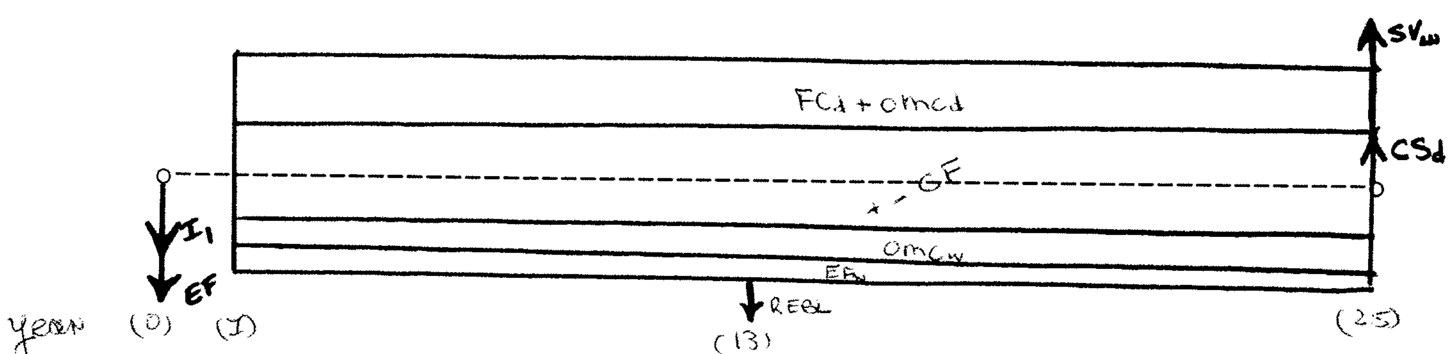
This equation will also be discounted at the appropriate discount rate r and time factor t.

The project with the **lowest** cost will be prefered. The cost savings of installing a wind machine is the difference between the $Cost_{diesel} - Cost_{wind+diesel}$.

The method of evaluation that was formulated which gave the same cost savings as the previous method consisted of taking the difference of both projects ($Cost_{wind+diesel} - Cost_{diesel}$) immediately, instead of calculating both project costs separately and then comparing. If the calculations give a **positive** number using this method then there are positive cost savings from the installation of the wind machine.

Diesel operation-(Wind and diesel operation)

(NOT TO SCALE)



The cost savings of the project is :

$$\text{Cost Savings} = -I_1 + \sum_{t}^{25} \frac{(OMC_d + FC_d - OMC_w)}{(1+r)^t} - \frac{REBL}{(1+r)^{13}} + \frac{CS_d + SV_w}{(1+r)^{25}}$$

$$- \frac{EF}{(1+r)^t} \quad (+-) \quad \frac{CF}{(1+r)^t}$$

I_1 = initial investment of the wind machine (includes the land for the wind machine, etc...)

OMC_d = annual operation and maintenance charges from (1-y) % production of the diesel machine

FC_d = fuel charges pertaining to the (1-y) % production of the diesel machine(s)

OMC_w = annual maintenance charges of the (1-y)% production from the wind machine

REBL = cost of reblading half way through the wind machine's life

CS_d = capital savings which exist because the diesel machines do not produce at a 100% production level with the wind machines and therefore in year 25 their productive lives and their final values increase

SV_w = scrap value of the wind machine

EF = Environmental factors (annual)

CF = Correction factors

The municipal taxes and the initial investment from the diesel (includes land for diesel) cancel out and are not included. The y% diesel operation/maintenance and fuel energy production cost from the wind-diesel operation cancels out with the same amount of y% diesel operation/maintenance and fuel energy production cost from the original diesel operation. In the computer flowchart the cost savings from operation is the difference between the (1-y)% annual operation/maintenance + fuel costs from the original diesel machine operation and the annual cost from the (1-y)% operation/maintenance cost from the wind machine from the wind-diesel operation. If the cost savings (discounted cost savings from (1-y%) operational/maintenance + fuel costs) exceed all the additional costs from the wind machine (including all other economic factors) then the installation of the wind machine is feasible.

2. Parameters

Financial Criteria for the economic evaluation :

Base Year : 1991

Book life : 25 years for a diesel machine (from Kholer Generators, Toronto, Ontario) and 25 years for a vertical axis wind machine (Bectel Group Inc., 1986).

Subsidies to industry :No subsidies to wind machine manufacturers (abolished in 1986) (Chapel, M.S., 1986).

Scrap Values : The manufacturer of the wind machine noted that at the end of the project the scrap value of wind machine would be equal to zero. This will be the value used in the analysis. The scrap value of the diesel machine will be evaluated using the depreciated reproduction cost method (Martin, F., 1989-1990, p. X 20-23). This method stipulates that the scrap value of a machine at the end of a project still has a useful life of 15 years. One can calculate the scrap value using this formula:

$$\frac{15 \text{ (life expectancy)}}{15 + \text{(years machine has already been used)}} = \text{\% of the original value of machine}$$

This is a better way compared to calculating the scrap value using the accounting linear depreciation method. For the diesel machine the scrap value will equal to :

[(Initial Investment) * (15/(15+25))] --> discounted at the appropriate rate.

Exchange Rates for 1991 (Toronto Star, 1991):

Canadian - U.S. exchange rate : 1.1258 or .888257 per $ cnd
Canadian - Sweedish rate : 0.1922 or 5.20 per $ cnd

Discount rate : The Department of Energy Mines and Ressources will be implementing the above project (social utility function). Since the project is using government funds[1] to finance the project the social discount rate of 10% (Jenkins, 1985) will be used.

[1]If the project was evaluated for Hydro-Quebec a 13% discount rate would have been used. This is the discount rate used by Hydro-Quebec for long term investments (Hydro-Quebec, Services des Analyses et Previsions Economique). The British electrical industry discounts pre-tax cash flows at 5% in real terms (8% for nationalized industries in real terms in 1989) (Dimson, E., 1989, 175-180). The OECD requires a rate of return on capital of around five percent for major long term investments such as power plants (Gamble, K.J., 1984). Five percent is used by the International Energy Agency.

An assumptions made in the report was that all locations were 0.5 miles from a public road and it was possible for trucks to reach the plant.

3. Identification of the Cost Savings

Since the project is a " cost effectiveness " study there is only savings in cost of production. In this section the cost savings from the installation of the wind machine are identified. Cost savings from the installation of the wind machine come mainly from two sources :

(i) Savings in fuel cost from the production of (100-y%) of energy production from the diesel machine (replaced by the wind machine).

(ii) Savings in maintenance and operational cost from the production of (100-y%) of energy production from the diesel machine (replaced by the wind machine).

The cost per kwh of energy produced for all the diesel operations in Quebec is given in Appendix 3 (Hydro-Quebec, 1990, 164-208). For Blanc-Sablon :

Location	Production (mwh/yr)	Total Cost per kwh (1991) (includes cost of delivery)
Blanc-Sablon	24 349	0.05987909920

The operational and maintenance cost of a diesel machine is 0.02814 $/kwh for all locations. The difference between the total cost and the operational and maintenance cost is the cost of the fuel (including transport cost). For Blanc-Sablon the total cost per kwh is 0.05675744. Taking the difference of 0.05675744 - 0.02814 = 0.02861744 (fuel) per kwh of energy produced.

The real cost of energy production from the diesel machine is not the lower consumer price (fixed equal throughout the province) that Hydro-Quebec is subsidising but the one that the utility is paying to supply the energy in these remote areas (one shown in previous paragraph). The consumer's cost of energy in Quebec per cents/kwh from Hydro-Quebec is 4.036 in 1990$ (unitary production) (Hydro-Quebec, 1990, 164-208). This cost which is well below the real cost of producing the electricity in these remote locations will not be used to calculate the production savings.

There is one more cost saving to be considered from the wind machine. Since the wind machine is replacing some of the electrical production which would have been supplied by the the diesel units the value of the diesel machines at the end of the project have increased (capital savings). The 200 kw diesel machine (the average of all the diesel machines was 200) will be used in this study. To calculate the capital savings the amount of energy that the diesel units don't need to generate with the introduction of the wind machines must first be calculated for each location and type of wind machine. The capital savings are reflected in the scrap value of the diesel machines in year 25. If for example there are 10 diesel machines producing 875 mwh in the simple diesel operation and inoperable in year 25 then the scrap value of the diesel machines who only require to produce 20% of the 875 MW with the introduction of the wind machines equals to the initial cost of 8 (80%) diesel units plus the scrap value of 2 (20%) diesel units who are considered fully utilized and inoperable (discounted). The capital savings is the difference in the diesel's scrap value ((wind-diesel operation) - diesel operations).

The viability of energy production is not considered to be increased due to addition of the wind machine since there is not one but many diesel machines in each location already able to safeguard for any disruptions in energy production. If this was not the case then the increased viability would be considered as a benefit (production losses in the local economy which are a result of energy disruptions due to breakdowns in energy supply from the diesel machine).

The energy production for each region and for each machine is given in appendix 4. For some diesel locations the computerized wind-energy output analysis was not done because there was no wind speed data given be Environment Canada. The energy output (accounting for the demand and the 95% availability of the wind machine) of these locations is represented by the closest locations which had a computerized wind energy output done. For the Blanc-Sablon case :

	Production (mwh/yr)	
Location	Daf Indal	4 MW Aeolus
Blanc-Sablon	548.4732	14 072.4229

4. Cost estimates of the wind machines

Summary cost of the wind machine is given from estimates made by Bectel (Bectel Group Inc., 1986) :

" Total Capital Requirements is the sum of A) plant facilities investments and B) other capital costs.

A) Plant Facilities Investment:

i) wind turbine investments: Fabrication cost, installation cost, direct and indirect construction cost, engineering and home office cost and fees for material costs.

ii) balance of plant investment: Includes the remaining cost not included in the wind turbine investment which include fences, control buildings,transmission lines etc.. .

iii) technology contingency: Investment which is due to an effort to quantify uncertainty in designs, performance, and cost of mature, commercial equipment.

iv) project contingency: Costs associated with a more detailed design of a definitive project on the actual site.

B) Other Capital Requirements:

i) land requirements (initial):

The land requirement is 120 643 m^2. The cost of the land is \$2.36 per ft^2 or \$2.20 m^2 (used for all cases: \$8 881 per acre). The cost of the land is therefore \$265 416.

ii) prepared royalties: not necessary

iii) organization and start costs: operator training, equipment checkout, changes in plant equipment, extra maintenance, and inefficient use of materials and fuel during start up.

iv) working capital: three months of labor costs, two months of maintenance materials and consumables, and 25% of the above two items.

v) allowance for funds during construction: For regulated utilities the interest on debt is used to calculate the allowance for funds during construction, and for nonregulated compagnies return on equity was used.

Other capital requirements such as, allowance for organization and start up costs.

Operating and maintenance costs include i) operating labor costs, ii) maintenance costs, iii) administrative and support labor costs, and iv) consumable costs.

i) operating costs: staffing requirements.

ii) maintenance costs: costs divided into maintenance of labor and materials.

iii) administrative and support labor costs: for regulated utilities an allowance of 30% of the sum of operating labor and maintenance labor is included for administrative and support labor. For the nonregulated producers an additional allowance of 0.7% of Plant Facility Investment is added for allocated home office general and administrative expenses.

iv) consumable costs: the cost of consumables is estimated from allowance and current market estimates. "

The interest payments on capital which were given by the manufacturers will not be included in the economic analysis. The cost is already taken into account in the discount factor.

Transport costs vary with the distance of travel. The cost of transportation for the northern locations is 3 times the cost of transportation for locations situated at the Gulf of St. Lawrence.

Operation/maintenance and fuel costs for the diesel machines have already been given. The initial cost of the diesel machine takes into account such things as transportation cost, materials and labor costs, startup costs etc.. .

The computer cost chart for both wind machines and diesel units is given in appendix 8.

5. Social Aspects

5.1 Environmental interference

Wind energy like any other energy source has an effect on the environment; human and animal safety, noise disturbance, electromagnetic interference, and it's visual impact. These factors should all be considered in an economic evaluation. The wind machine is considered to be placed in a rural surrounding.

5.1.1 Noise interference

There are two noise disturbances from a wind machine (Milborrow, D.,1989) :

(i) from the blade vibration
(ii) mechanical noise from the gearbox and the generator.

The noise interference problem varies with the topography of the area, background noise, wind speed at the area, distance from the wind machine and the size of the wind machine. For this study because of information, and noise analytical constraints a representative model for all locations is used. Different values were tabulated for different size of machine because this factor had a significant effect on the results.

The noise level which is allowed by law for industrial production and which is considered as the level of interference where human discomfort from noise becomes apparent was found. The area around the wind machine which has a higher noise level than the critical noise level where human discomfort becomes apparent was also found. After review from noise emission reports done in Canada, California, and Europe (Milborrow, D., 1989) (Korber, F., 1989) (Kuipers, J.A., 1990) (Robson, A., 1984) an area of 250-300 meters around the center of a MW power system and 230 meters for the smaller sized wind machines did not pass the db(a) critical minimum value for Quebec of 40 db(A) (Comeau, M., 1988, p. 65-68).

5.1.2 Electromagnetic interference

It is not recommended (Kuipers, J.A., 1990) placing a wind machine close to an airport or navigational freeway. Wind machines must be installed farther than 50 meters from the center line of a fixed service link (broadcasting services).

Wind machines cause television interference. Degree of impairment of a T.V. signal is classified on a five grade scale by the Comité Consultatif International des Radio-Communications (Robson, A., 1984) : Impeccable (5), Perceptive but annoying (4), slightly annoying (3), annoying (2), and very annoying (1) are graded. Using this scale complaints from T.V. interference can be expected at about 1000 to 4000 meters from the wind machine. A more detailed study (Barak, M., 1989) found a distance of 200 meters in the backscatter region of the wind machine and 1.3 km in the forward scatter region (area in front of wind machine from the transmiting station). An area of 2 500 meters in the forward scatter region and 200 meters in the back scatter region of the wind machine will be considered having T.V. interference.

5.1.3 Visual impact

There are two factors to take into account when analyzing the visual impact of a wind machine:

(i) driver disturbance
(ii) disturbance to residents living in the area.

One study (Barak, M., 1989) found that there was no driving disturbance from wind machines. From all drivers who passed a wind facility only 90% of drivers noticed the wind machine. The study concluded that driving behavior was not affected by the wind machine's presence. Even with this finding a cautious safety zone of 100 meters is found to be necessary to reduce driver distraction. For the disturbance to residents living in the area, Swedish researchers using visual simulations found decreasing visual effect with increasing distance from the wind machine (Robson, A., 1984). The machines were found (Robson, A., 1984) disturbing at a distance of up to three times their height. An area of 120 meters around the Daf Indal and 330 meters around the 4 MW Aeolus will be considered to be visually intrusive.

5.1.4 Bird and animal considerations

There have been no incidents of significant bird deaths at any wind turbine to date. Overall for small and large wind machines there is no hit and effect from birds or animals (Robson, A., 1984) (Hydro-Quebec, 1983). A wind machine should not be installed where birds frequently pass by during migration. There is no environmental cost since it is not considered placing wind machines in any migrating field.

5.1.5 Agriculture considerations

The wind machine has no detrimental effect on farming (Kuipers, J.A., 1990) (Hydro-Quebec, 1983). The area around the wind machine can still be used for farming if all the other pollution factors are ignored.

5.1.6 Risk, accident and human safety considerations

Risk from a wind machine exits because the blades of the wind machine can become detached during operation. It has been found (Barak, M., 1989) that the probability of a person being hit from a blade detachment ranges from 10^{-2} near the tower to 10^{-5} at 600m. Mac Quental (1983) estimated the probability of a blade becoming detached during the wind machine's operation at less than 10^{-5}. If this is also taken into account the probability of a blade being thrown and hitting someone is 10^{-7} near the tower (250m) and 10^{-10} at 600 meters from the machine per year. In the Netherlands a political choice of acceptable risk is equal to less than 10^{-7}. Taking this into account a safety zone (which exceeds the acceptable risk level of 10^{-7}) equal to 250 m around the wind machine is necessary in case of wind blade detachment. This is also known as the international buffer zone for vertical axis wind machines (Kuipers, J.A., 1990).

5.1.7 Overview of the environmental factors

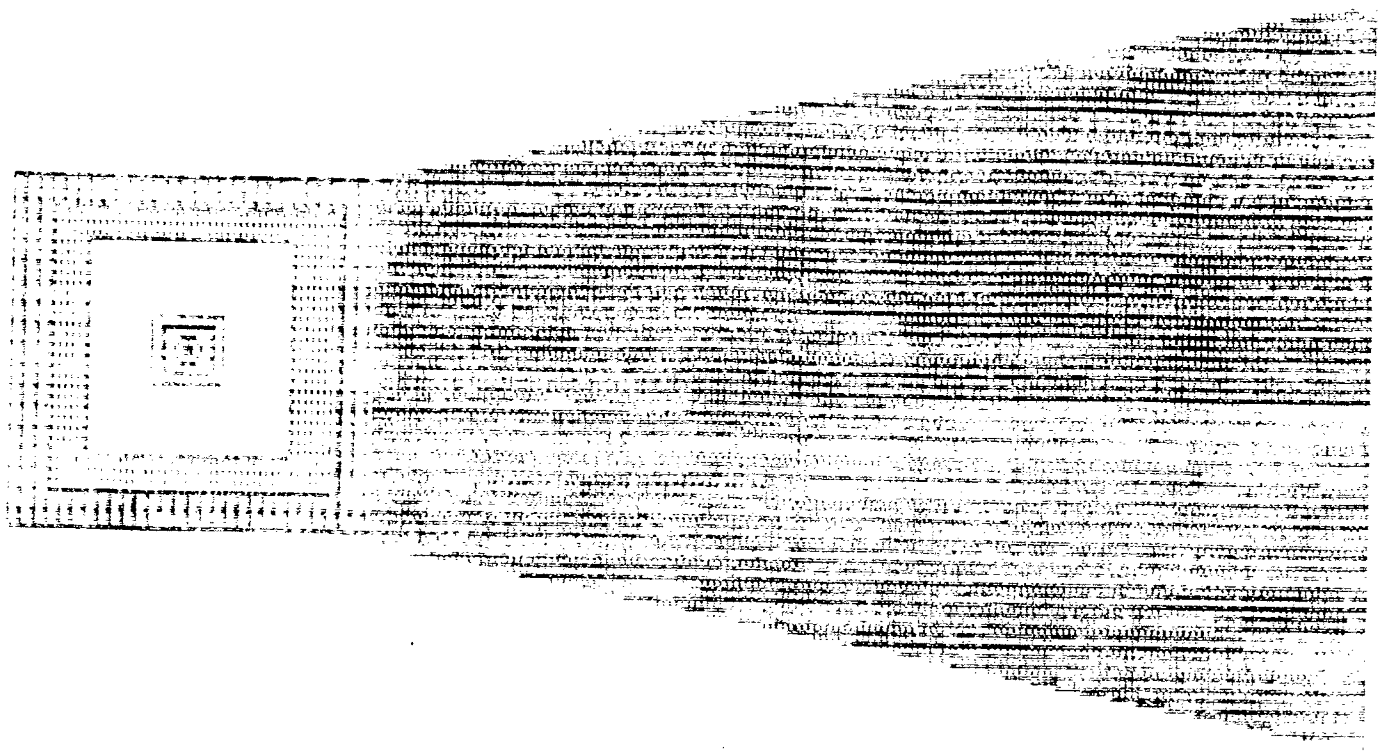
The environmental cost was evaluated only for the 4 MW machine because it will be shown later in the paper, the 500 kw wind machine shows a considerable negative cost savings even before the environmental cost is included. Considering that the environmental cost adds to the total cost of the wind machines, it will not be evaluated for the 500 kw wind machine. If it was necessary to evaluate this cost for the Daf Indal the same method described below for the 4 MW could also be used.

For the noise and safety factor a buffer zone of 250 meters is necessary, which is also found to be the international safety distance given to wind machines. This area will have to be bought up by the wind facility operators to eliminate the danger present to human life. For the noise interference an area of 300 meters around the wind machine will be affected by the 4 MW machine. Since the area of 250 meters is given as a security buffer zone only the additional 50 meters around the 4 MW machine will be analyzed as a noise polluting externality. It has been evaluated in airport or road noise pollution studies (Gautrin, J.F., 1975) (Mieszkowski, P.,1978) (Nelson, J.P., 1979, 1978) (Whitbred, M., 1978) that for each increase in db(A) above this minimum noise pollution factor (40 db(a)) the value of the land will decrease by .4 %. For the visual disturbance of the the wind machine an area of 3 times the wind machine's height has been found to be visually intrusive. This gives an area of 330 meters around the wind machine. Economist generally haven't tried to estimate the aesthetic phenomena because it usually was seen as intangible. Nevertheless there have been some studies on this factor that help resolve the economic value of visibility for this analysis. Some studies (Englis, J., 1991) have quantified the economic value of visibility with hedonic travel cost functions which measure the recreational value of site quality. Other studies (Rowe, 1976) estimate the economic value of visibility by illustrating photographs to individuals of sites before and after visible pollutants with various combinations of state of visibility and topographical features. The respondents are asked to quantify their willingness to pay for the removal of the visible pollutant or how much they would have to be paid to accept the visible pollutant. The two methods are called the Equivalent Surplus method and the Compensation Surplus method. The Equivalent Surplus method (ES) is the maximum an individual is willing to pay to return to the original situation where there was no visible pollutant while the Compensation Surplus (CS) is the minimum amount of money an individual would have to be paid to accept the introduction of the pollutant. Correcting for problems of biases which arise from the study (Rowe,1976) there was an average yearly ES bid of $82.20 in 1976 dollars. In another study (Randal, 1984) identified in the same article (Rowe, 1976) found average yearly bids of $85.00 in 1972 dollars. The average of both annual bids were taken and gave a value of $170.10 per year per resident in 1991 dollars. For the electromagnetic interference an area of 2500 meters in the forward scatter region of the wind machine and 200 meters in the backscatter region of the machine is considered to affect television reception **(see figure 3)**. Supplying free cable to all the residents affected will solve the problem of T.V. interference. Since there was no study found on the economic cost of electromagnetic interference and that the problem is usually solved by the wind power utilities supplying free cable to the residents affected, the free cable supply will be considered as a viable solution.

In the 250 m buffer zone the human safety pollution factor makes the land non-usable for any purpose (puts this land's value = $0 during the project). Given this, the other pollution factors in this buffer zone are not counted as additional costs since the value of the land cannot be put at a value below zero. The 250 meters contour around the wind machine will have to be bought up by the wind energy manufacturer. Considering the manufacturer has already bought up 150 meters around the wind machine only an additional 100 m contour around the wind machine will have to be bought. This area like the original 150 meter contour will be sold at the end of the project at it's original value (the value will be discounted at the appropriate discount rate). The area of 160 000 m^2 will bring an additional cost of $2.20 per m^2 X 160 000 = $325 000 in year 0 and bring a benefit of $\$325000/(1.1)^{25}$ = $ 29 996 at the end of the project. The environmental effects are only for the duration of the project.

For the noise pollution factor an area of 110 000 m^2 will be affected. Given a db(A) reading of 45 the land value decrease will

Figure 2



Fence and security zone which also includes noise, visual and electromagnetic interference

noise and visual zone which also includes electromagnetic interference

visual zone which includes electromagnetic interference

electromagnetic interference zone

be ((45-40)db(A)* .004) (what the land value decrease will be) * 10% (what the land value would have been giving yearly) * (110 000 m^2*$2.2 per m^2) (what the land value was originaly) = $484 per year (will be discounted).

The visual pollution factor will comprise of an additional area of 75 600 m^2 along with the 110 000 m^2 which also includes the noise pollution factor. There are ten residents living in the area (hypothesis) which gives an annual visual cost equal to 10 X $197.89 = $1 979 per year in 1991$.

For the electromagnetic interference factor the 200 meter backscatter region will not add to the total environmental cost since it is already in the security buffer zone (see page 45 paragraph 2). This leaves the forward scatter region with an area of 2 136 000 m^2. Given that the locations are in the remote areas of Quebec, the cost of the T.V. interference will be tabulated at a rate of $35 000 (year 0) with an additional $100 per year thereafter. The total cost for the environmental effect of the wind machine is :

Security **:$325 000 (year 0) - 29 996 (year 25)= $ 295 004**

Noise **:$ 484 per year starting in the first year of operation discounted at 10% for 25 years= $ 4 393**

Visual **:$ 1979 per year starting in the first year of operation discounted at 10% for 25 years= $17 963**

Electromagnetic :$ 35 000 (year 0) + $ 100 per year starting in the first year of operation discounted at 10% rate for 25 years = $ 35 908

The total overall environmental cost is = $ 353 268

5.2 **Correction factors**

5.2.1 Subsidies to the industry

There are no subsidies to wind energy manufacturers to account for (Chappel, M. S., 1986). The cost to the consumers of the electricity produced is much lower than what the actual cost of supplying it is. For the consumer there is no change in the price of the energy or in the demand for it with the introduction of the wind machine. The same policy of Hydro-Quebec paying the difference between the fixed price that all the consumers of the province of Quebec pay and the real cost of electricity in these location will still apply. The consumer surplus does not change but the real cost of production decreases for the society (see figure 5).

5.2.2 Benefits from increase security of supply

Contrary to most economic articles there is no benefit from increase security of supply with the introduction of the wind machine. The diesel machines supply energy for home heating in this case so there is no decrease in production in the local economy should there be a considerable shortage in oil supply. If there were any disruptions, alternative energy sources like wood heating can be used.

5.2.3 Benefits from the reduction of currency allocation

The project at hand decreases oil imports. Since the social cost of foreign exchange is higher (6.5%) (Jenkins, 1985) than it's nominal value it is considered as a social benefit. Each barrel of oil that will be saved from the wind machine is considered as an import saving. To calculate this benefit the amount of reduction from oil imports is subtracted from any other imports in the construction and operational phase of the project. The only imports in the wind energy project are the fuel import reductions which are multiplied by 6.5% (and then discounted) to get the economic benefit. A table for all location is shown in appendix 7. For Blanc-Sablon the economic benefit is $ 264 686.

5.2.4 Municipal taxes

The municipal taxes (assumed to be the same in each location) which are being payed, are estimated to be 50% of what actually should be payed (discussion with Martin, F.) (Martin, F., 1989, p. X-58). Since the wind machine project does not **initiate** any additional municipal taxes this factor is not considered as an economic benefit.

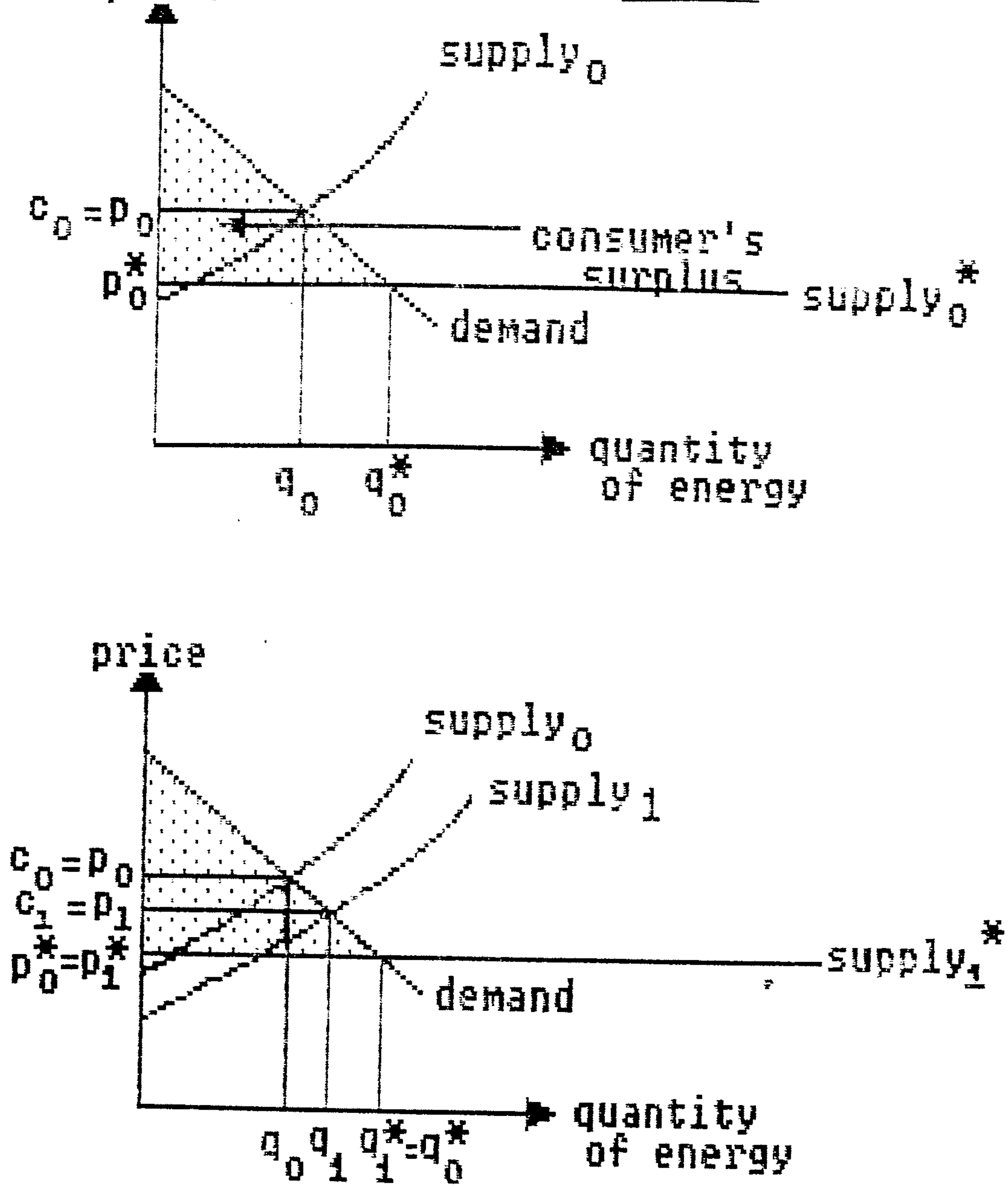
5.2.5 Pollution reduction from the diesel machine

The wind machines reduce the level of energy and pollution that the diesel units produce. Since the level of pollution from the diesel units originaly did not have a significant effect on the air quality in the locations examined (the locations are not in big cities and have open air surroundings) the pollution reduction is not considered a social benefit (source: representative of Hydro-Quebec).

6. OVERALL COST ESTIMATE OF THE WIND MACHINES

The Cost Savings (not including the social aspects) were calculated for all locations and for both wind machines (see appendix 8 for case model). For the Daf Indal all locations gave considerable negative cost savings (the best cost savings was equal to - $796 043) and this wind machine will be dropped from

Figure 5



c=cost to producer q=quantity p=price

'o' = original situation without wind machine

1' = with wind machine

'*' = with subsidies

further analysis. The Daf Indal machine is ideal for high wind locations, higher than what was present in Quebec. For the 4 MW Aeolus machine the locations with cost savings > 0 or close to 0 are shown in appendix 8. The Blanc-Sablon case gives a cost savings of **$ 823 266.**

The total environmental costs for the 4 MW system is equal to: (Security) $ 295004 + (Noise) $ 4393 + $ 17963 (Visual) + $35 908 (Electromagnetic) = **$ 353 268.**

The benefit from currency allocation for Blanc-Sablon is equal to **$ 264 686.**

The total economic cost savings for all the locations are given in appendix 9. For Blanc-Sablon the total economic cost savings is equal to:

$823 266 - $353 268 + $264 686 = $ 734 684.

C. CONCLUSION AND RECOMMENDATIONS

Only the 4 MW Aeolus wind machine in four locations showed positive economic cost savings (appendix 9) : **Kuujjaq $ 2 101 708, Blanc Sablon $ 734 684, Tabatiere $1 747 996, Ile-de-la-Madeleine $2 564 915.** The 500 kw wind machine even though it was compatible to the energy demand of each location did not produce enough energy (compatible to higher wind speed locations) to justify its cost. The 4 MW Aeolus wind machine would have shown positive cost savings in many other locations but the energy demand of these locations did not dictate full consumption of the energy produced. In Kuujjaq even though a substantial percentage of the wind energy is not consumed there is enough energy consumption to justify its implementation.

It is recommended that the 4 MW Aeolus wind machine be installed in the four locations giving a total economic cost saving of $ 7 149 303 in 1991$. The installation of the wind machines in the Ile-de-la-Madeleine, Tabatiere, Kuujjaq should be seriously considered since these three locations show cost savings even at high discount rates. By varying the availability of the energy from the wind machines the locations show positive cost savings at even low availability levels (Tabatiere 72%, Kuujjaq 70%, Ile-de-la-Madeleine 69%).

This paper should be helpful to energy policy evaluators who usually identify but shy away from evaluating the environmental costs of wind energy production.

Other forms of energy production like solar energy might also show positive cost savings in the remote locations of Quebec. The study did not attempt to compare the introduction of different forms of energy production. What the results showed was that if wind machines were installed today there would be considerable economic cost savings in the four remote locations in Quebec.

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E. APPENDIX

APPENDIX I

DAF INDAL

Location	Average annual wind speed (m/s)	ENERGY OUTPUT IN MWH
Blanc sablon	6.98	548.4732
Chapais	3.39	-
Chibougamau	3.32	-
Fort Chimo	4.51	-
Gaspe	3.93	-
Grindstone Island	8.63	831.1446
Inoucdjouac	5.90	142.0079
La grande Riviere	4.87	2.3622
Lake Eon	3.75	-
Matagami	3.46	-
Mont Joli	5.64	122.5535
Montreal Intern.	4.34	-
Montreal Mirabel	3.26	-
Nichicun	4.40	-
Poste De La Baleine	5.09	44.8117
Ville de Quebec	4.43	-
Riviere de Loup	3.93	-
Roberval	4.30	-
Rouyan	3.28	-

Ste. Agathe des Montes	2.99	-
St. Hubert	4.49	-
Sheferville	5.03	29.5429
Sept. Iles	4.81	26.4979
Sheerbrook	2.87	-
Val D'or	3.59	-
Arvida	3.46	-
Border	5.72	241.7911
Bagotville	4.46	-
Amos	3.20	-
Cape Hopes Advances	7.83	787.9662
Cape Whittle	8.14	642.6217
Caplan	5.22	82.5962
Captourmente	3.56	-
Deception Bay	5.16	271.9955
Foret Montmerency	1.97	-
Grand Riviere	4.56	3.4104
Grindstone Island	8.90	911.8981
Harrington Harbour	6.18	209.9596
Inoucdjouac	5.63	58.0933
Jolliette	2.87	-
Quaqtaq	6.09	247.7797
Miniwaki	2.19	-
Montreal McGill	2.87	-
Natashquah	4.89	40.8953
Nortmandin	3.96	-

Parent	2.72	-
Riviere au Renaud	5.57	124.7565
Ste. Anne de Bellevue	3.60	-
Ste. Augustin	4.04	-
Sawyerville	3.71	-
Sheerbrook	3.20	-
Val Cartier	1.48	-

AEOLUS

Location	Average annual wind speed (m/s)	ENERGY OUTPUT IN MWH
Blanc sablon	6.98	14072.4229
Chapais	3.39	-
Chibougamau	3.32	-
Fort Chimo	4.51	-
Gaspe	3.93	-
Grindstone Island	8.63	19093.7866
Inoucdjouac	5.90	9293.5887
La grande Riviere	4.87	4897.9090
Lake Eon	3.75	-
Matagami	3.46	-
Mont Joli	5.64	7958.8920
Montreal Intern.	4.34	-
Montreal Mirabel	3.26	-

Nichicun	4.40	-
Poste De La Baleine	5.09	6044.7528
Ville de Quebec	4.43	-
Riviere de Loup	3.93	-
Roberval	4.30	-
Rouyan	3.28	-
Ste. Agathe des Montes	2.99	-
St. Hubert	4.49	-
Sheferville	5.03	3621.2678
Sept. Iles	4.81	5060.8553
Sheerbrook	2.87	-
Val D'or	3.59	-
Arvida	3.46	-
Border	5.72	6124.7268
Bagotville	4.46	-
Amos	3.20	-
Cape Hopes Advances	7.83	13495.2891
Cape Whittle	8.14	15786.0782
Caplan	5.22	4041.3054
Captourmente	3.56	-
Deception Bay	5.16	7672.9606
Foret Montmerency	1.97	-
Grand Riviere	4.56	2949.1147
Grindstone Island	8.90	20041.3951
Harrington Harbour	6.18	9305.1175
Inoucdjouac	5.63	7618.9576

Jolliette	2.87	-
Quaqtaq	6.09	10039.6842
Miniwaki	2.19	-
Montreal McGill	2.87	-
Natashquah	4.89	4773.3319
Nortmandin	3.96	-
Parent	2.72	-
Riviere au Renaud	5.57	7353.6265
Ste. Anne de Bellevue	3.60	-
Ste. Augustin	4.04	-
Sawyerville	3.71	-
Sheerbrook	3.20	-
Val Cartier	1.48	-

APPENDIX II

Location	Installed Power (kw)	Production (mwh/yr)
REGION RICHELIEU:		
Iles de la Madeleine	57 137	154 429
Ile-d'Entree	1 190	1 092
REGION MANICOUAGAN:		
Baie-Johan-Beetz	1 800	4 700
Natashquan	48 450	10 674
REGION MONTMORENCY:		
Akulivik	850	1 186
Aupaluk	550	775
Kangiqsualujjuaq	1 450	2 049
Kangiqsujuaq	820	1 438
Kangirsuk	1 050	1 492
Kuujjuaq	3 935	8 983
Inukjuak	1 620	3 805
Ivujivik	975	1 118

Kuujjjuuarapik	3 405	6 481
Quaqtaq	900	1 273
Povungnituk	1 800	4 506
Salluit	2 000	3 193
Tasiujaq	550	825
Umiujaq	1 050	1 360
Blanc-Sablon	10 400	24 349
La Tabatiere	6 100	15 737
St-Augustin	3 000	7 460

APPENDIX III

Location	Production(mwh/yr)	Total Cost per kwh (1991) (includes cost of delivery)
REGION MATAPEDIA:		
Iles de la Madeleine	154 429	0.05191644450
Ile-d'Entree	1 092	0.06097056000
REGION MANICOUAGAN:		
Baie-Johan-Beetz	4 700	0.05714576300
Natashquan	10 674	0.05814685250
REGION MONTMORENCY:		
Akulivik	1 186	0.13091240745
Aupaluk	775	0.12724426740
Kangiqsualujjuaq	2 049	0.10671797640
Kangiqsujuaq	1 438	0.10782378520
Kangirsuk	1 492	0.11834935140
Kuujjuaq	8 983	0.11564013250
Inukjuak	3 805	0.14328725150
Ivujivik	1 118	0.13234325250

Kuujjjuuarapik	6 481	0.11724176910
Quaqtaq	1 273	0.12010768825
Povungnituk	4 506	0.12695802480
Salluit	3 193	0.13340314915
Tasiujaq	825	0.12869728750
Umiujaq	1 360	0.11745951105
Blanc-Sablon	24 349	0.05987909920
La Tabatiere	15 737	0.06345864035
St-Augustin	7 460	0.05716826615

APPENDIX IV

Some diesel locations do not have the computerized wind-energy output analysis done because there was no data given on wind speeds and frequencies for these locations. The energy output of these locations is represented by one of the computerized wind-energy location closest to and most similar in characteristic. The " * " signifies that the 4 MW wind machine is not compatible with energy demand of the location since it producing more energy then there is a demand for (overproduction). Given this, only the energy demanded will represent the energy production of the 4 MW wind machine for these locations (accounting for 95% availability from the wind machine).

	Production (mwh/yr)		
Location	Daf Indal	4 MW Aeolus	
REGION MATAPEDIA:			
Iles de la Madeleine	831.1446	20 041.3951	
Ile-d'Entree	911.8981	19 093.7866*	1 037
REGION MANICOUAGAN:			
Baie-Johan-Beetz	209.9596	9 305.1175*	4 465
Natashquan	40.8953	4 773.3319	

REGION MONTMERENCY:

Akulivik	787.9662	13 495.2891*	1 126
Aupaluk	247.7797	10 039.6842*	736
Kangiqsualujjuaq	247.7797	10 039.6842*	1 947
Kangiqsujuaq	247.7797	10 039.6842*	1 366
Kangirsuk	142.0079	9 293.5887*	1 417
Kuujjuaq	247.7797	10 039.6842*	8 534
Inukjuak	142.0079	9 293.5887*	3 614
Ivujivik	271.9955	7 672.9606*	1 062
Kuujjjuuarapik	44.8117	6 044.7526	
Quaqtaq	247.7797	10 039.6842*	1 209
Povungnituk	787.9962	13 495.2891*	4 280
Salluit	247.7797	10 039.6842*	3 033
Tasiujaq	247.7797	10 039.6842*	784
Umiujaq	247.7797	10 039.6842*	1 292
Blanc-Sablon	548.4732	14 072.4229	
La Tabatiere	642.6217	15 786.0782*	14 950
St-Augustin	548.4732	14 072.4229*	7 087

APPENDIX V

```
PROGRAM STEAL ( INPUT, OUTPUT, DONNEES, INFO, PRODUCT, TABLES );

{$U+}
{$R+}
{*****************************************************************************}
{                                                                             }
{            PROGRAM BY DANIEL SARAFIDIS DATING APRIL 20 1991                 }
{            ------------------------------------------------                 }
{                                                                             }
{ THIS IS THE PROGRAM FOR WIND ENERGY ANALYSIS FOR THE REGION OF QUEBEC       }
{                                                                             }
{      ALL RIGHTS RESERVED UNDER THE FEDERAL COPYWRITE PROGRAM 1991.          }
{                                                                             }
{*****************************************************************************}

CONST
VERTICAL = 13;
HORIZONTAL = 33;
MAXCOPY = 52;

TYPE
LIKE = 1..MAXCOPY;
LIMVEL1 = 1..HORIZONTAL;
LIMVEL2 = 1..VERTICAL;
VELOCITY = ARRAY [LIMVEL1,LIMVEL2 ] OF INTEGER;
VOLOCITY = ARRAY [LIMVEL1,LIMVEL2] OF REAL;
SATISFY = ARRAY [1..12] OF REAL;

VAR
TEMPERATURE,PRESSURE : SATISFY;
WINDVELOCITY:VELOCITY;
F   UENCY,SPEED : VOLOCITY;
H  GHT, FACTOR1, FACTOR2: REAL;
CHOIX , I, J ,VERTICALING, HORIZONTALING, LIGNE, CHOICE: INTEGER;
PRODUCT:TEXT;



PROCEDURE INFOREAD( VAR CHOIX : INTEGER; VAR WINDVELOCITY:VELOCITY; VAR HORIZON
ALING:INTEGER; VAR VERTICALING:INTEGER;
VAR HEIGHT: REAL; VAR TEMPERATURE,PRESSURE:SATISFY; VAR FACTOR1, FACTOR2:REAL;
AR CHOICE:INTEGER);

{ WHAT THIS PROCEDURE DOES IS TO CREATE VARIABLES FROM DATA SOURCE ASSIGNED
 BY THE CHOICE (CHOIX) OF THE INDIVIDUAL. IT GIVES THE FREQUENCY AND WIND
 VELOCITY BY KM/H FOR EACH MONTH OF THE YEAR, THE DIMMENSION OF THE DATA OF
 THE AREA UNDER REVIEW AND THE INITIAL PRINTOUT OF THE PLACE WHICH WE WILL
 BE EXAMINING. IT ALSO GIVES THE HEIGHT AND THE WIND SHEAR FACTOR ALONG WITH
 THE TEMPERATURE AND ATMOSHERIC PRESSURE VALUE FOR THE REGIONS WITH AN AVERAGE
 OF 5 m/s OR GREATER. IT HAS BEEN PROVEN THAT AREAS UNDER 5 m/s HAVE COSTS PER
 UNIT OF ENERGY PRODUCTION INCREASED SUBSTANTIALLY, MAKING THEM A NON IDEAL
 AREA FOR WIND MACHINE INSTALLATION.                                          }


VAR
INFO, DONNEES: TEXT;
B   ITEGER;

BEGIN
CLRSCR;
HEIGHT:=1;
{height is the correction factor loss due to ice formation}
{factor is the correction factor for height of machine and topography}
CASE CHOIX OF
```

```
     ASSIGN (DONNEES, 'M1.PAS');
     WRITELN (product,'                    THIS IS BLANC SABLON');
     height:= 0.95;
     factor1:= 1.12;
     factor2:= 1.68;
     ASSIGN ( INFO,'P1.PAS')
     END;
 2 : BEGIN
     ASSIGN (DONNEES, 'M2.PAS');
     WRITELN (product,'                    THIS IS CHAPAIS');
     END;
 3 : BEGIN
     ASSIGN (DONNEES, 'M3.PAS');
     WRITELN (product,'                    THIS IS CHIBOUGAMAU');
     END;
 4 : BEGIN
     ASSIGN (DONNEES, 'M4.PAS');
     WRITELN (product,'                    THIS IS FORT CHIMO');
     END;
 5 : BEGIN
     ASSIGN (DONNEES, 'M5.PAS');
     WRITELN (product,'                    THIS IS GASPE');
     END;
 6 : BEGIN
     ASSIGN (DONNEES, 'M6.PAS');
     ASSIGN (INFO, 'P6.PAS');
     WRITELN (product,'                    THIS IS GRINDSTONE ISLAND');
     height:= 0.95;
     factor1:= 1.12;
     factor2:= 1.68;
     END;
 -   BEGIN
     ASSIGN (DONNEES, 'M7.PAS');
     ASSIGN (INFO, 'P7.PAS');
     WRITELN (product,'                    THIS IS INOUCDJOUAC');
     height := 0.96;
     factor1 := 1.12;
     FACTOR2 := 1.68;
     END;
 8 : BEGIN
     ASSIGN (DONNEES, 'M8.PAS');
     ASSIGN (INFO, 'P8.PAS');
     WRITELN (product,'                    THIS IS LA GRAND RIVIERE');
     height := 0.97;
     factor1 := 1.12;
     factor2 := 1.68;
     END;
 9 : BEGIN
     ASSIGN (DONNEES, 'M9.PAS');
     WRITELN(product,'                     THIS IS LAKE EON');
     END;
10:  BEGIN
     ASSIGN (DONNEES, 'M10.PAS');
     WRITELN (product,'                    THIS IS MATAGAMI');
     END;
11:  BEGIN
     ASSIGN (DONNEES, 'M11.PAS');
     ASSIGN (INFO, 'P11.PAS');
     WRITELN (product,'                    THIS IS MONT JOLI');
     HEIGHT:=0.97;
     factor1:=1.12;
     factor2:=1.68;
     END;
12:  BEGIN
     ASSIGN (DONNEES, 'M12.PAS');
```

```
    WRITELN (product,'                THIS IS MONTREAL INTERNATION AIRPORT');
    END;
13: BEGIN
    ASSIGN (DONNEES, 'M13.PAS');
    WRITELN (product,'                THIS IS MONTREAL MIRABEL AIRPORT');
    END;
14: BEGIN
    ASSIGN (DONNEES, 'M14.PAS');
    WRITELN (product,'                THIS IS NICHICUN');
    END;
15: BEGIN
    ASSIGN (DONNEES, 'M15.PAS');
    ASSIGN (INFO, 'P15.PAS');
    WRITELN( product,'                THIS IS POSTE DE LA BALEINE');
    height:=0.96;
    factor1:=1.12;
    factor2:=1.68;
    END;
16: BEGIN
    ASSIGN (DONNEES, 'M16.PAS');
    WRITELN (product,'                THIS IS QUEBEC QUEBEC');
    END;
17: BEGIN
    ASSIGN (DONNEES, 'M17.PAS');
    WRITELN (product,'                THIS IS RIVIERE DE LOUP');
    END;
18: BEGIN
    ASSIGN (DONNEES, 'M18.PAS');
    WRITELN (product,'                THIS IS ROBERVAL');
    END;
19: BEGIN
    ASSIGN (DONNEES, 'M19.PAS');
    WRITELN (product,'                 THIS IS ROUYAN');
    END;
20: BEGIN
    ASSIGN (DONNEES, 'M20.PAS');
    WRITELN (product,'                THIS IS STE AGATHE DES MONTS ');
    END;
21: BEGIN
    ASSIGN (DONNEES, 'M21.PAS');
    WRITELN (product,'                THIS IS ST HUBERT');
    END;
22: BEGIN
    ASSIGN (DONNEES, 'M22.PAS');
    ASSIGN (INFO, 'P22.PAS');
    WRITELN (product,'                THIS IS SHEFERVILLE');
    height:= 0.98;
    factor1:=1.16;
    factor2:=1.48;
    END;
23: BEGIN
    ASSIGN (DONNEES, 'M23.PAS');
    ASSIGN (INFO, 'P23.PAS');
    WRITELN (product,'                THIS IS SEPT ISLE');
    height:=0.94;
    factor1:=1.12;
    factor2:=1.68;
    END;
2   BEGIN
    ASSIGN (DONNEES, 'M24.PAS');
    WRITELN (product,'                THIS IS SHEERBROOK');
    END;
25: BEGIN
    ASSIGN (DONNEES, 'M25.PAS');
    WRITELN (product,'                THIS IS VAL D'OR' );
    END;
```

```
        ASSIGN (DONNEES, 'M26.PAS');
        WRITELN (product,'                    THIS IS ARVIDA');
        END;
    27: BEGIN
        ASSIGN (DONNEES, 'M27.PAS');
        ASSIGN (INFO, 'P27.PAS');
        WRITELN (product,'                    THIS IS BORDER');
        height:= 0.98;
        factor1:=1.16 ;
        factor2:=1.48 ;
        END;
    28: BEGIN
        ASSIGN (DONNEES, 'M28.PAS');
        WRITELN (product,'                    THIS IS BAGOTVILLE');
        END;
    29: BEGIN
        ASSIGN (DONNEES, 'M29.PAS');
        WRITELN (product,'                    THIS IS AMOS');
        END;
    30: BEGIN
        ASSIGN (DONNEES, 'M30.PAS');
        ASSIGN (INFO,'P30.PAS');
        WRITELN (product,'                    THIS IS CAPE HOPES ADVANCES');
        height:= 0.985;
        factor1:= 1.18;
        factor2:= 1.50;
        END;
    31: BEGIN
        ASSIGN (DONNEES, 'M31.PAS');
        ASSIGN (INFO, 'P31.PAS');
        WRITELN (product,'                    THIS IS CAPE WHITTLE QUE');
        height:=0.95;
        factor1:= 1.10;
        factor2:= 1.60;
        END;
    32: BEGIN
        ASSIGN (DONNEES, 'M32.PAS');
        ASSIGN (INFO, 'P32.PAS');
        WRITELN (product,'                    THIS IS CAPLAN');
        height:=0.97;
        factor1:= 1.1;
        factor2 := 1.45;
        END;
    33: BEGIN
        ASSIGN (DONNEES, 'M33.PAS');
        WRITELN (product,'                    THIS IS CAPTOURMENTE');
        END;
    34: BEGIN
        ASSIGN (DONNEES, 'M34.PAS');
        ASSIGN (INFO, 'P34.PAS');
        WRITELN (product,'                    THIS IS DECEPTION BAY');
        height:=0.99;
        factor1:= 1.21;
        factor2:= 1.70;
        END;
    35: BEGIN
        ASSIGN (DONNEES, 'M35.PAS');
        WRITELN(product,'                    THIS IS FORET MONTMERENCY');
        END;
    36: BEGIN
        ASSIGN (DONNEES, 'M36.PAS');
        ASSIGN (INFO, 'P36.PAS');
        WRITELN (product,'                    THIS IS GRAND RIVIERE');
        height:=0.98;
        factor1:= 1.06;
```

```
        END;
  37: BEGIN
        ASSIGN (DONNEES, 'M37.PAS');
        ASSIGN (INFO, 'P37.PAS');
        WRITELN (product,'                    THIS IS GRINDSTONE ISLAND');
        height:=0.95;
        factor1:= 1.12;
        factor2:= 1.68;
        END;
  38: BEGIN
        ASSIGN (DONNEES, 'M38.PAS');
        ASSIGN (INFO, 'P38.PAS');
        WRITELN (product,'                    THIS IS HARRINGTON HARBOUR');
        height:=0.94;
        factor1:=1.12;
        factor2:= 1.68;
        END;
  39: BEGIN
        ASSIGN (DONNEES, 'M39.PAS');
        ASSIGN (INFO, 'P39.PAS');
        WRITELN (product,'                    THIS IS INOUCDJOUAC');
        height:=0.98;
        factor1:= 1.12;
        factor2:= 1.68;
        END;
  40: BEGIN
        ASSIGN (DONNEES, 'M40.PAS');
        WRITELN (product,'                    THIS IS JOLLITTE');
        END;
  41: BEGIN
        ASSIGN (DONNEES, 'M41.PAS');
        ASSIGN (INFO, 'P41.PAS');
        WRITELN (product,'                    THIS IS QOAQTAQ');
        height:=0.985;
        factor1:= 1.12;
        factor2:= 1.68;
        END;
  42: BEGIN
        ASSIGN (DONNEES, 'M42.PAS');
        WRITELN (product,'                    THIS IS MINIWAKI');
        END;
  43: BEGIN
        ASSIGN (DONNEES, 'M43.PAS');
        WRITELN (product,'                    THIS IS MONTREAL MCGILL UNIVERSITY');
        END;
  44: BEGIN
        ASSIGN (DONNEES, 'M44.PAS');
        ASSIGN (INFO, 'P44.PAS');
        WRITELN (product,'                    THIS IS NATASHQUAH');
        HEIGHT:=0.96;
        factor1:= 1.12;
        factor2:= 1.68;
        END;
  45: BEGIN
        ASSIGN (DONNEES, 'M45.PAS');
        WRITELN (product,'                    THIS IS NORTMANDIN');
        END;
  46: BEGIN
        ASSIGN (DONNEES, 'M46.PAS');
        WRITELN (product,'                    THIS IS PARENT');
        END;
  47: BEGIN
        ASSIGN (DONNEES, 'M47.PAS');
        ASSIGN (INFO, 'P47.PAS');
        WRITELN (product,'                    THIS IS RIVIERE AU RENAUD');
```

```
        HEIGHT:=0.57;
        factor1:= 1.12;
        factor2:= 1.68;
        END;
    48: BEGIN
        ASSIGN (DONNEES, 'M48.PAS');
        WRITELN (product,'                          THIS IS STE ANNE DE BELLEVUE');
        END;
    49: BEGIN
        ASSIGN (DONNEES, 'M49.PAS');
        WRITELN (product,'                          THIS IS STE AUGUSTIN');
        END;
    50: BEGIN
        ASSIGN (DONNEES, 'M50.PAS');
        WRITELN (product,'                          THIS IS SAWYERVILLE NORD');
        END;
    51: BEGIN
        ASSIGN (DONNEES, 'M51.PAS');
        WRITELN (product,'                          THIS IS SHEERBROOK');
        END;
    52: BEGIN
        ASSIGN (DONNEES, 'M52.PAS');
        WRITELN (product,'                          THIS IS VAL CARTIER');
        END
   END;

   {WRITELN(product);}
   RESET (DONNEES);
   RESET (INFO);
   I:= 0;
   J:= 0;

   IF (CHOIX < 26) OR (CHOIX = 28) THEN
   BEGIN
        HORIZONTALING:= HORIZONTAL;
        VERTICALING:= VERTICAL;
   END;

   IF (CHOIX > 25) AND (CHOIX <> 28) THEN
   BEGIN
        HORIZONTALING:=17;
        VERTICALING:= 13;
   END;

   WHILE I<HORIZONTALING DO
   BEGIN
        I:=I+1;
        FOR J:=1 TO VERTICALING DO
        BEGIN
             READ ( DONNEES, WINDVELOCITY[I,J]);
   {          WRITE (product, WINDVELOCITY[I,J] : 5);}
        END;
   {     WRITELN(product);}
   END;

   IF HEIGHT < 1 THEN
   BEGIN
   {     WRITELN (product,' THIS IS THE INITIAL MONTHLY ATMOSHERIC PRESSURE AT TH
   E   A.');
        WRITELN(product);}
        FOR B:= 1 TO 12 DO
        BEGIN
             READ(INFO, PRESSURE[B]);
   {          WRITE (product, PRESSURE[B]:7:2);
             if b = 10  then writeln;             }
        END;
```

```
{      WRITELN(product);}
 {      writeln(product);
       WRITELN ( product,' THIS IS THE INITIAL MONTHLY TEMPERATURE FOR THE AREA.
 ;
       WRITELN(product);}
       FOR B:= 1 TO 12 DO
       BEGIN
            READ( INFO , TEMPERATURE[B]);
 {           WRITE (product, TEMPERATURE[B]:6:2);}
       END;
 {      WRITELN(product);                                  }
 END;
 {WRITELN(product);}
 CLOSE (DONNEES);
 CLOSE (INFO);

 END; {FOR THE PROCEDURE INFOREAD}





 PROCEDURE THEVELOCITY(VAR CHOIX:INTEGER;WINDVELOCITY:VELOCITY;VAR FREQUENCY,SPE
 D:VOLOCITY;HORIZONTALING,VERTICALING:INTEGER;
 VAR HEIGHT:REAL; VAR TEMPERATURE,PRESSURE:SATISFY; VAR FACTOR1,FACTOR2:REAL;VAR
 CHOICE:INTEGER);

 CONST
 STARTSTOPETC =0.95;

 VAR
 TABLES, tables2 : TEXT;
 G  ,Q,P,U,N,M,Y,S,T,Z:INTEGER;
 TOTALYEARPRODUCTION,HEIGHT1, totalhours, FACTOR : REAL;
 moyenne,CORRPRESSURE, KALVINTEMPERATURE, CORRTEMPERATURE, AIRCORRECTION : ARRAY
 [1..12] OF REAL;
 TRYHORIZONTALING,TSYHORIZONTALING,TRYVERTICALING:INTEGER;
 THEAVERAGE, HOURS, MAXSPEED ,THETHEAVERAGE : REAL;
 TOTOFREQUENCY, AVERAGE : ARRAY [1..30] OF REAL;
 CORRSPEED, ANSWER, POWER: ARRAY [ 1..30,1.. 30] OF REAL;
 EOLEWIND,EOLEPOWER: ARRAY [1..2500] OF REAL;

 BEGIN
 TOTALYEARPRODUCTION:=0;
 {For daf indal power curve we have aeolus.pas, for 4MW we have eole.pas}

 IF CHOICE = 1 THEN
 begin
 ASSIGN (TABLES, 'aeolus.PAS');
 assign (tables2,'aeolus2.pas');
 END;

 IF CHOICE = 0 THEN
 begin
 assign (tables2, 'eole2.pas');
 ASSIGN (TABLES, 'EOLE.PAS');
 END;

 RESET ( TABLES);
 reset (tables2);

 FOR U:= 1 TO 1771 DO
 BEGIN
      READ(TABLES,EOLEWIND[U],EOLEPOWER[U]);
 {      WRITELN (u,EOLEWIND[U]:10:3,EOLEPOWER[U]:10:5);}
```

```
 --- ,

 for u:=1772 to 2500 do
 begin
      read( tables2,eolewind[u],eolepower[u]);
 {     writeln (u,eolewind[u]:10:3,eolepower[u]:10:5);   }
 end;



 FOR G:=1 TO 30 DO
 TOTOFREQUENCY[G]:=0.0;

 TRYHORIZONTALING := ((HORIZONTALING-1) DIV 2) + 1;
 TRYVERTICALING:= VERTICALING-1;
 {WRITELN (product,' THIS IS THE INITIAL FREQUENCY OF THE AREA ' );
 WRITELN(product);}
 FOR M:= 1 TO TRYHORIZONTALING DO
 BEGIN
       FOR T:= 1 TO TRYVERTICALING DO
       BEGIN
             FREQUENCY[M,T]:= WINDVELOCITY[M,T]/1000;
 {             WRITE (product,FREQUENCY[M,T]:6:3);}
             TOTOFREQUENCY[t]:= TOTOFREQUENCY[T]+FREQUENCY[M,T];
       END;
 {      WRITELN(product);                           }
 END;
 {WRITELN(product);}

 {FOR T:=1 to TRYVERTICALING DO
 WRITE (product, TOTOFREQUENCY[T]:5:2);

 W   TELN(product);
 w  teln(product);}
 Y:=0;
 P:=0;
 THEAVERAGE:=0;

 FOR S:= 1 TO TRYVERTICALING DO
 AVERAGE[S]:=0;

 THEAVERAGE:=0;
 THETHEAVERAGE:=0;
 TSYHORIZONTALING:= TRYHORIZONTALING + 1;

 for x:= 1 to tryverticaling do
 moyenne[x] := 0;
 {WRITELN (product,' THIS IS THE WIND VELOCITY GIVEN BY THE DATA');
 WRITELN(product);}
 FOR N:= TSYHORIZONTALING TO HORIZONTALING DO
 BEGIN;
       Y:=Y+1;
       FOR S:=1 TO TRYVERTICALING DO
       BEGIN
             SPEED[Y,S]:=((WINDVELOCITY[N,S]/10)*1000)/3600;
 {             WRITE ( product,SPEED[Y,S]:5:1);}
       END;
 {writeln(product);                        }
 F
 F    Y+1;
 FOR S:=1 TO TRYVERTICALING DO
 BEGIN
       SPEED[P,S]:=0 ;
 {     WRITE (product,SPEED[P,S]:5:1);}
 END;
```

```
 FOR N:=1 TO P DO
 BEGIN
      FOR S:=1 TO TRYVERTICALING DO
      BEGIN
             ANSWER[N,S]:= SPEED[N,S]*FREQUENCY[N,S];
              WRITE (product,ANSWER[N,S]:5:1);}
             AVERAGE[S]:= ANSWER[N,S] + AVERAGE[S];
      END;
 {WRITELN(product);                                      }
 END;

 {WRITELN(product);
 WRITELN(product,' THIS IS THE MONTHLY AVERAGE WIND SPEED FROM JAN. TO DEC.');
 writeln(product);}
 FOR S:=1 TO TRYVERTICALING DO
 BEGIN
 {      WRITE (product,AVERAGE[S]:5:1);}
       THEAVERAGE:= AVERAGE[S] + THEAVERAGE;
 END;

 {WRITELN(product);}
 THETHEAVERAGE := THEAVERAGE/12;
 WRITE (product,'THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) ');
 WRITELN (product,THETHEAVERAGE:5:2);
 WRITELN(product);
 MAXSPEED:=0;

 if height < 1 then

 begin

 I  CHOICE = 1  THEN
 BEGIN
 FACTOR := FACTOR1;
 END;
 {IF CHOICE 0 = 4MW}
 IF CHOICE = 0 THEN
 BEGIN
 FACTOR:= FACTOR2;
 END;


      {For 4MW Eole equator height is 55 , and for Daf it is 21.3 }

 {     writeln (product,' This is the air correction factor for the wind machine
 output');}
      for x:= 1 to tryverticaling do
      begin
           corrpressure[x] := pressure[x]/101.325;
           kalvintemperature[x] := temperature[x]+273;
           corrtemperature[x] := 288.15/kalvintemperature[x];
           aircorrection[x] := corrtemperature[x] * corrpressure[x];
{           write (product,aircorrection[x]:6:2);}
      end;
{      writeln(product);
      writeln(product);
      writeln (product,' This is the corrected wind speed for the adjustement of
th  height of machine');
      writeln(product);}
      for x:= 1 to p do
      begin
           for q:= 1 to tryverticaling do
           begin
                corrspeed[x,q] := speed[x,q] * factor ;
```

```
                    write (product, corrspeed[x,q]:5:1);}
                end;
  {              writeln(product);                            }
            end;

  {          writeln(product);
            writeln(product);}
            theaverage:=0;

            for s:=1 to tryverticaling do
            average[s]:=0;

            theaverage:=0;
            thetheaverage:=0;
  {          writeln(product);}

            for n:= 1 to p do
            begin
                for s:=1 to tryverticaling do
                begin
                    answer[n,s]:= corrspeed[n,s]*frequency[n,s];
  {                  write (product,answer[n,s]:5:1);  }
                    average[s]:= answer[n,s] + average[s];
                end;
  {          writeln(product);   }
            end;
  {          writeln(product);
            writeln (product,' This is the average wind speed for each month (correct
 )');
            writeln(product);}
            For s:=1 to tryverticaling do
            begin
  {                write(product,average[s]:5:1);}
                theaverage:=average[s] + theaverage;
            end;
  {          writeln(product);
            writeln(product);}
            thetheaverage :=theaverage/12;
            write (product,'The average wind speed of the year is (corrected) ->',thet
 eaverage:5:2);
            writeln(product);
            writeln(product);
  {          writeln (product,' This is the power output for the specified frequency a
 justed');
            writeln (product,' for height, atmosheric pressure, wind turbine effecien
 , and');
            writeln (product,' start-stop, wake effect, electric losses and availabil
 y losses. ');
            writeln (product,' The variable are as follow: corrected speed , correspon
 ing turbine');
            writeln(product,' wind velocity, corresponding turbine power, corrected po
 er output.');
            writeln(product) ; }
            for s:= 1 to p do
            begin
                for x:= 1 to tryverticaling do
                    begin
                        for z:= 1 to 2500 do
                        begin
                          if (round(corrspeed[s,x]*100)/100) = eolewind[z] then
                            begin
                                power[s,x] := startstopetc*aircorrection[x]*eol
 power[z];
                          {  write(product,round(corrspeed[s,x]*100)/100:8:
 );
                                write(product,power[s,x]:8:3);  }
```

```
                              end;{writeln(product);}
                        end;
                 { writeln(product);}
            end;
            for s:= 1 to p do
            begin
                 for x:=1 to tryverticaling do
                    begin
     {                     write ( product,power[s,x]*frequency[s,x]:10:4 ) ;}
                          moyenne[x] := power[s,x]*frequency[s,x]+ moyenne[x];
                     end;
     {       writeln(product);}
            end;
     {       writeln(product);   }
     {       for x:= 1 to tryverticaling do
            write (product, moyenne[x]:6:3 );}
     totalyearproduction := 0;
     totalhours := 0;
     {writeln(product) ;           }
     {WRITELN (product, CHOIX );}
     {writeln(product, ' This is the corresponding energy output in MWH');}
          for s:=1 to p do
          begin
     {          write ( product,totalyearproduction:16:5 );}
               for x:=1 to tryverticaling do
               begin
                    hours := ((365/12)*24) * frequency[S,X];
     {               write(product,corrspeed[s,x]:15:2,hours:15:2);}
                    totalhours := hours + totalhours;
                    totalyearproduction := hours * power[S,X] + totalyearproduction;
     {               writeln(product,power[s,x]:15:4,round(corrspeed[s,x]*100)/100:15
    4)}
               end;
     {          writeln(product);                                       }
          end;

    {writeln ( product,' these is the total hours ', totalhours:6:2 );}

 --- if choice = 0 then
    begin
         writeln ( product, '   ' );
         WRITELN ( product,' Total year production in mwh/yr -->', Totalyearproduct
    on*height:15:4);
         writeln ( product, ' ' );
    end;

    if choice = 1 then
    begin
         WRITELN(product);
         WRITELN (product, 'THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr-->  ', (TOTALYE
    RPRODUCTION/1000)*height:15:4);
    end;

    CLOSE( TABLES);
    close( tables2);
    end;{height<1}

    E   {procedure}
```

```
                        ...,...,...,DROITE: INTEGER);
  VAR I: INTEGER;
       PROCEDURE TRACERLIGNE (LIGNE,COL1,COL2: INTEGER);
       BEGIN
            GOTOXY (COL1,LIGNE);
            FOR I:=COL1 TO COL2 DO WRITE (CHR(205))
       END;
       PROCEDURE TRACERCOLONNE(L1,L2,COLONNE:INTEGER);
       BEGIN
            FOR I:= L1 TO L2 DO
            BEGIN GOTOXY (COLONNE, I);
                 WRITE ( CHR(186) )
            END
       END;
       PROCEDURE DESSINERCOIN (LIGNE,COLONNE,CODE:INTEGER);
       BEGIN GOTOXY (COLONNE, LIGNE );
             WRITE (CHR (CODE) )
       END;
  BEGIN
       TRACERLIGNE (HAUT,GAUCHE,DROITE);
       TRACERLIGNE(BAS,GAUCHE,DROITE);
       TRACERCOLONNE(HAUT,BAS,GAUCHE);
       TRACERCOLONNE(HAUT,BAS,DROITE);
       DESSINERCOIN(HAUT,GAUCHE,201);
       DESSINERCOIN(HAUT,DROITE,187);
       DESSINERCOIN(BAS,GAUCHE,200);
       DESSINERCOIN(BAS,DROITE,188)
  END; {FIN DE CADRE}
  PROCEDURE AFFICHER_MENU_DE_BASE(VAR CHOIX,CHOICE:INTEGER);
  TYPE CHAINE = STRING[50];
  VAR LIGNE,Q :INTEGER;
       PROCEDURE MESSAGE(CH:CHAINE);
       BEGIN
             LIGNE := LIGNE + 2;
             GOTOXY(3,LIGNE);
             WRITE(CH)
       END;
  BEGIN
       CLRSCR;
       TRACERCADRE (1, 20, 1, 80); LIGNE:= 3;
       GOTOXY(10,LIGNE); WRITE('HELLO!!! MENU FOR WIND ENERGY ANALYSIS IN QUEBEC'
  ;
       MESSAGE('TYPE A NUMBER CORRESPONDING TO THE DESIRED AREA OR ');
       MESSAGE('A ZERO TO QUIT. PLEASE LOOK UP LIST.');
       LIGNE:=LIGNE+4;
       REPEAT
            GOTOXY(3,LIGNE);
            FOR Q:=1 TO 50 DO WRITE (' ');
            GOTOXY(3,LIGNE);
            WRITE ('     INPUT NUMBER PLEASE ----->');
            READLN (CHOIX);
            GOTOXY(3,LIGNE+1);
            WRITE (' 0 - 4MW AEOLUS  1 - DAF INDAL ');
            READLN(CHOICE);
       UNTIL CHOIX IN [0..52];
  END;
```

u
Ce 4)

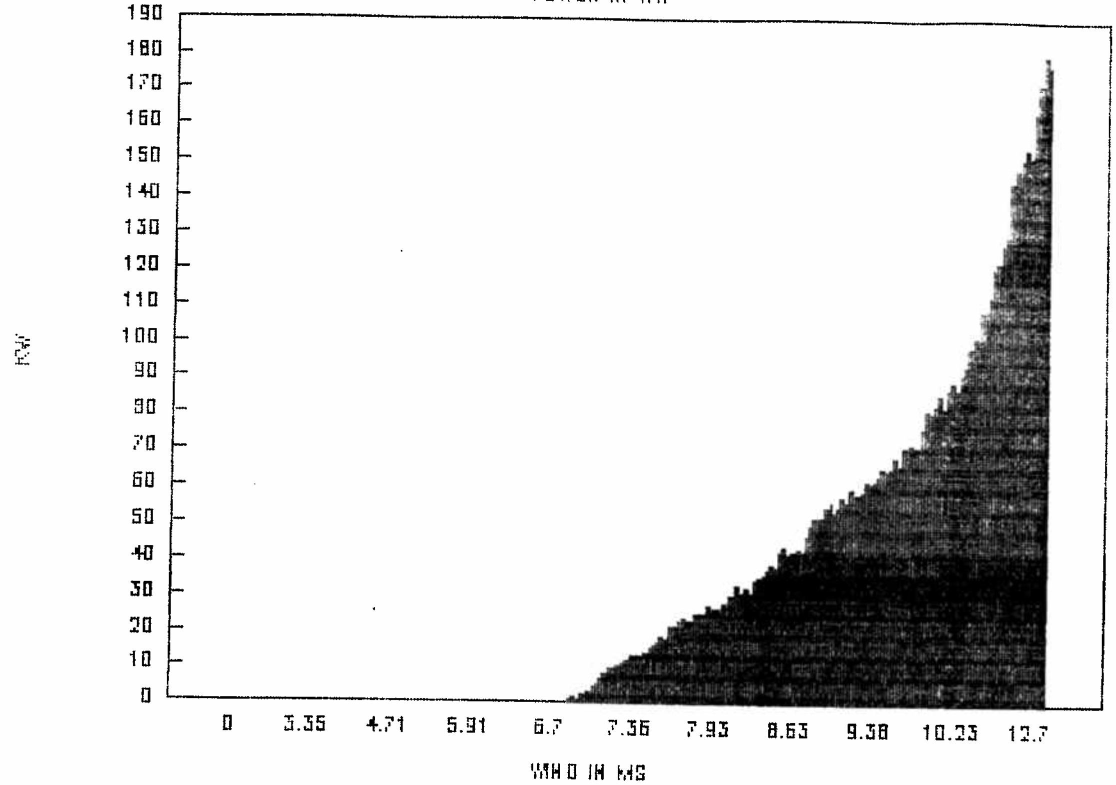
```
BEGIN
ASSIGN (PRODUCT,'c:\turbo\LAISY.LAN');
REWRITE (PRODUCT);
REPEAT
     AFFICHER_MENU_DE_BASE (CHOIX,CHOICE);
```

```
        begin
             for choix := 1 to 52 do
             begin

                  if choice = 0 then
                  writeln ( product, ' This is for the 4MW Aeolus machine');

                  if choice = 1 then
                  writeln (product, 'This is for the Daff Indal machine');

                  writeln(product,' The number chosen is      -> ', choix:4);

                  INFOREAD(CHOIX,WINDVELOCITY,HORIZONTALING,VERTICALING,HEIGHT,TE
PERATURE,PRESSURE,FACTOR1,FACTOR2,CHOICE);
                  THEVELOCITY(CHOIX,WINDVELOCITY,FREQUENCY,SPEED,HORIZONTALING,VE
TICALING,HEIGHT,TEMPERATURE,PRESSURE,FACTOR1,
                  FACTOR2,CHOICE);
             END;
        END;
UNTIL CHOIX = 0;
CURSOR;
CLOSE (PRODUCT);
END.
```

APPENDIX VI

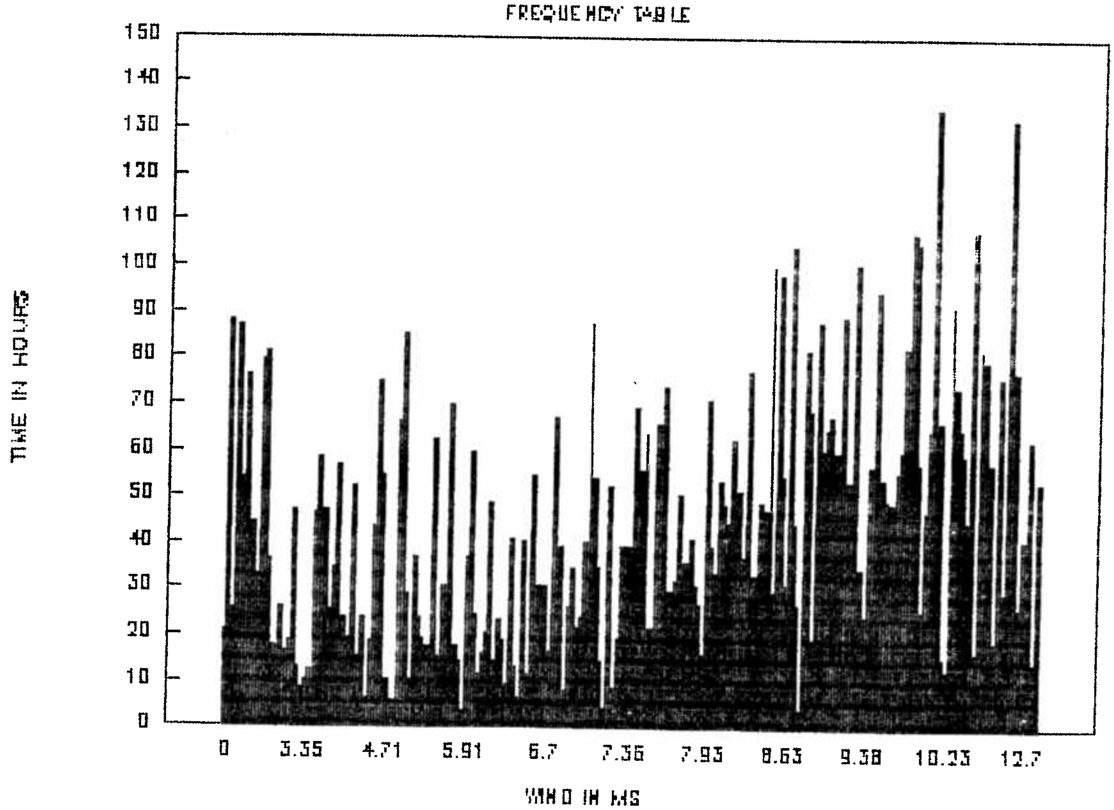
BLANC SABLON

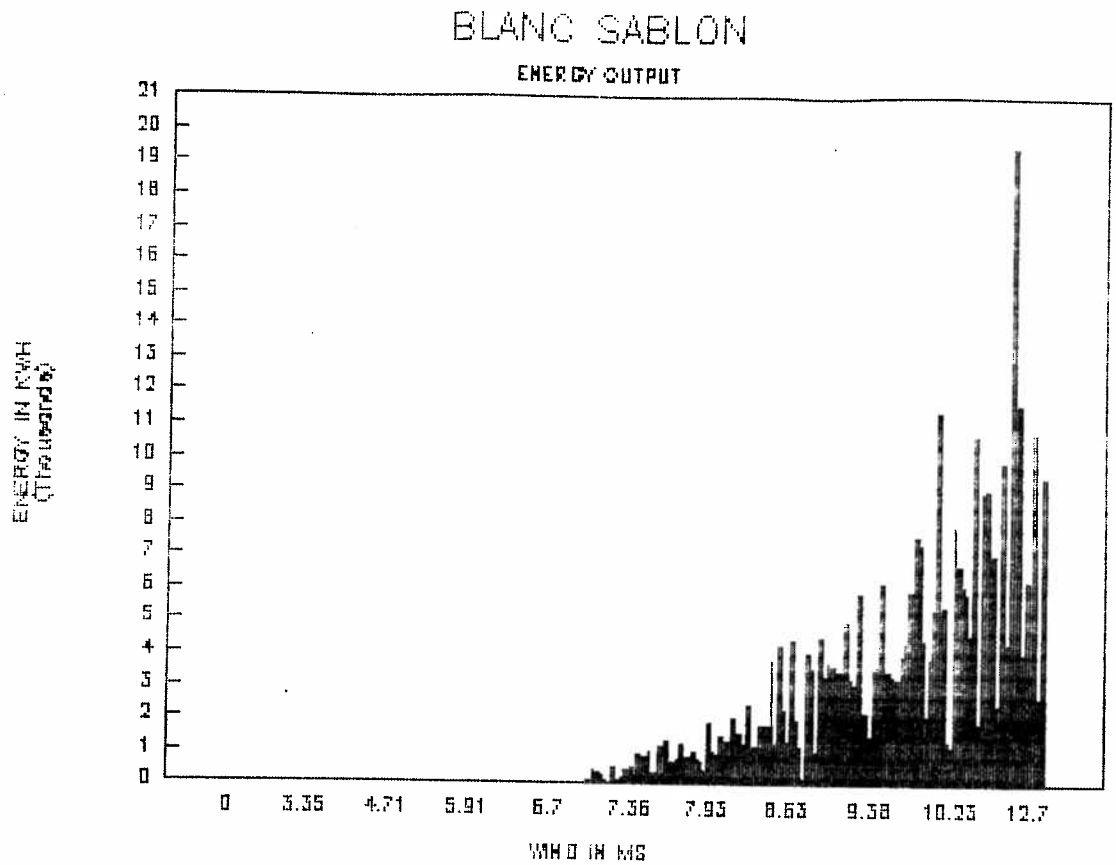
POWER IN KW

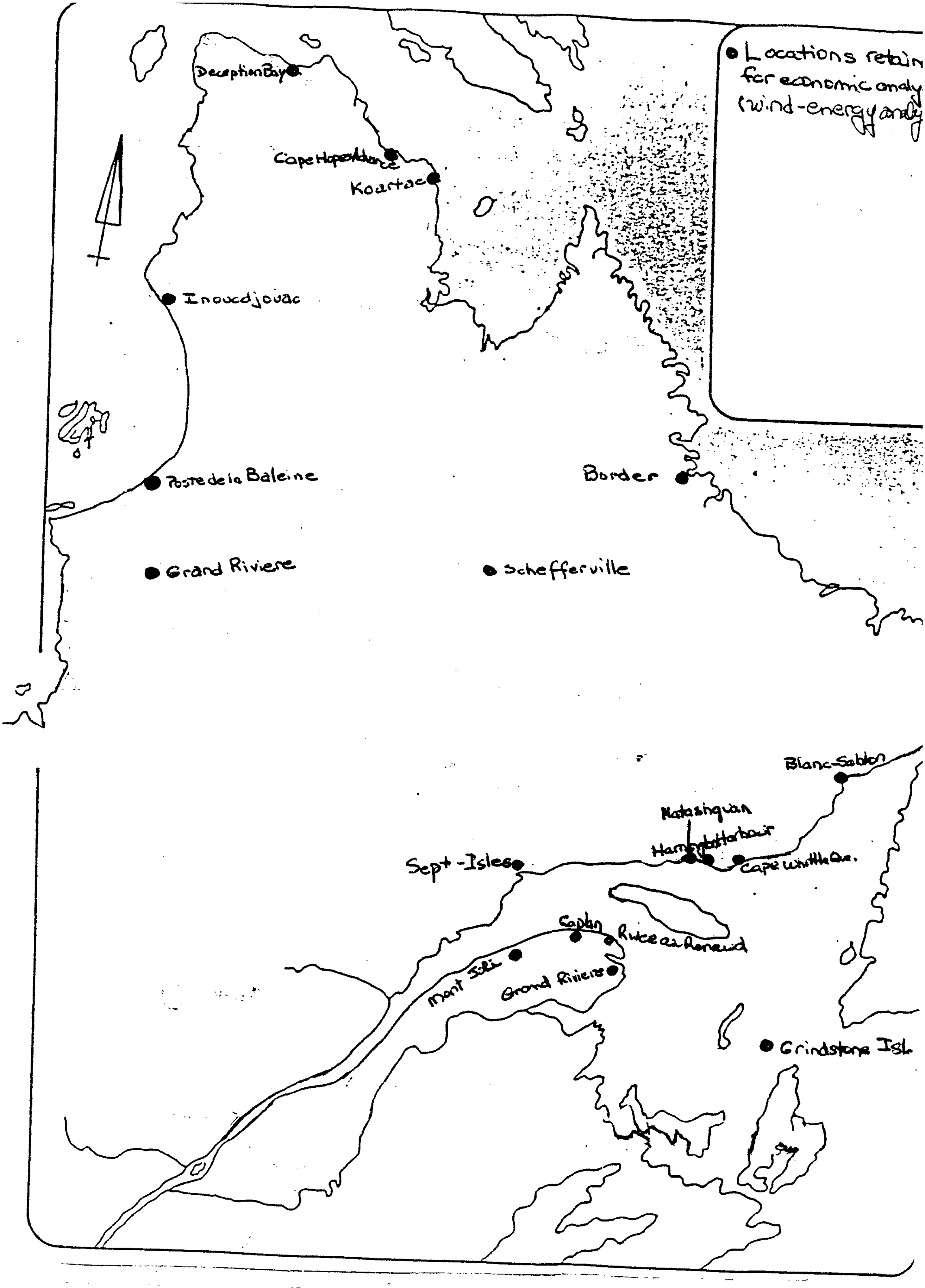


BLANC SABLON

FREQUENCY TABLE




BLANC SABLON
ENERGY OUTPUT
ENERGY IN KWH
(Thousands)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
3.35
4.71
5.91
6.7
7.36
7.93
8.63
9.38
10.23
12.7
WIND IN MS



Locations retain
for economic analy
(wind-energy analy
Deception Bay
Cape Hopes Advance
Koartac
Inoucdjouac
Poste de la Baleine
Border
Grand Riviere
Schefferville
Blanc-Sablon
Natashquan
Harrington Harbour
Cape Whittle Que.
Sept-Isles
Caplan
Rivière au Renard
Mont Joli
Grand Riviere
Grindstone Isl.

This is for the Daff Indal machine
The number chosen is -> 1
THIS IS BLANC SABLON
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 6.98

The average wind speed of the year is (corrected) -> 7.81

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 548.4732
This is for the Daff Indal machine
The number chosen is -> 2
THIS IS CHAPAIS
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.39

This is for the Daff Indal machine
The number chosen is -> 3
THIS IS CHIBOUGAMAU
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.32

This is for the Daff Indal machine
The number chosen is -> 4
THIS IS FORT CHIMO
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.51

This is for the Daff Indal machine
The number chosen is -> 5
THIS IS GASPE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.93

This is for the Daff Indal machine
The number chosen is -> 6
THIS IS GRINDSTONE ISLAND
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 8.63

The average wind speed of the year is (corrected) -> 9.66

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 831.1446
This is for the Daff Indal machine
The number chosen is -> 7
THIS IS INOUCDJOUAC
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.90

The average wind speed of the year is (corrected) -> 6.61

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 142.0079
This is for the Daff Indal machine
The number chosen is -> 8
THIS IS LA GRAND RIVIERE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.87

The average wind speed of the year is (corrected) -> 5.45

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 2.3622

```
This is for the Daff Indal machine
 The number chosen is      ->    9
                THIS IS LAKE EON
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.75

This is for the Daff Indal machine
 The number chosen is      ->   10
                THIS IS MATAGAMI
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.46

This is for the Daff Indal machine
 The number chosen is      ->   11
                THIS IS MONT JOLI
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  5.64

The average wind speed of the year is (corrected) -> 6.32


THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr-->         122.5536
This is for the Daff Indal machine
 The number chosen is      ->   12
                THIS IS MONTREAL INTERNATION AIRPORT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.34

This is for the Daff Indal machine
 The number chosen is      ->   13
                THIS IS MONTREAL MIRABEL AIRPORT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.26

This is for the Daff Indal machine
 The number chosen is      ->   14
                THIS IS NICHICUN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.40

This is for the Daff Indal machine
 The number chosen is      ->   15
                THIS IS POSTE DE LA BALEINE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  5.09

The average wind speed of the year is (corrected) -> 5.70


THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr-->         44.8117
This is for the Daff Indal machine
 The number chosen is      ->   16
                THIS IS QUEBEC QUEBEC
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.43

This is for the Daff Indal machine
 The number chosen is      ->   17
                THIS IS RIVIERE DE LOUP
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.93

This is for the Daff Indal machine
 The number chosen is      ->   18
                THIS IS ROBERVAL
```

THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.30

This is for the Daff Indal machine
The number chosen is -> 19
THIS IS ROUYAN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.28

This is for the Daff Indal machine
The number chosen is -> 20
THIS IS STE AGATHE DES MONTS
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.99

This is for the Daff Indal machine
The number chosen is -> 21
THIS IS ST HUBERT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.49

This is for the Daff Indal machine
The number chosen is -> 22
THIS IS SHEFERVILLE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.03

The average wind speed of the year is (corrected) -> 5.83

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 29.5429
This is for the Daff Indal machine
The number chosen is -> 23
THIS IS SEPT ISLE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.81

The average wind speed of the year is (corrected) -> 5.39

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 26.4979
This is for the Daff Indal machine
The number chosen is -> 24
THIS IS SHEERBROOK
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.87

This is for the Daff Indal machine
The number chosen is -> 25
THIS IS VAL D'OR
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.59

This is for the Daff Indal machine
The number chosen is -> 26
THIS IS ARVIDA
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.46

This is for the Daff Indal machine
The number chosen is -> 27
THIS IS BORDER
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.72

The average wind speed of the year is (corrected) -> 6.63

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 241.7911
This is for the Daff Indal machine
The number chosen is -> 28
THIS IS BAGOTVILLE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.46

This is for the Daff Indal machine
The number chosen is -> 29
THIS IS AMOS
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.20

This is for the Daff Indal machine
The number chosen is -> 30
THIS IS CAPE HOPES ADVANCES
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 7.83

The average wind speed of the year is (corrected) -> 9.23

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 787.9662
This is for the Daff Indal machine
The number chosen is -> 31
THIS IS CAPE WHITTLE QUE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 8.14

The average wind speed of the year is (corrected) -> 8.96

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 642.6217
This is for the Daff Indal machine
The number chosen is -> 32
THIS IS CAPLAN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.22

The average wind speed of the year is (corrected) -> 5.74

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 82.5962
This is for the Daff Indal machine
The number chosen is -> 33
THIS IS CAPTOURMENTE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.56

This is for the Daff Indal machine
The number chosen is -> 34
THIS IS DECEPTION BAY
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.16

The average wind speed of the year is (corrected) -> 6.24

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 271.9955
This is for the Daff Indal machine
The number chosen is -> 35

THIS IS FORET MONTMERENCY
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 1.97

This is for the Daff Indal machine
The number chosen is -> 36
THIS IS GRAND RIVIERE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.56

The average wind speed of the year is (corrected) -> 4.63

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 3.4104
This is for the Daff Indal machine
The number chosen is -> 37
THIS IS GRINDSTONE ISLAND
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 8.90

The average wind speed of the year is (corrected) -> 9.97

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 911.8981
This is for the Daff Indal machine
The number chosen is -> 38
THIS IS HARRINGTON HARBOUR
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 6.18

The average wind speed of the year is (corrected) -> 6.92

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 209.9596
This is for the Daff Indal machine
The number chosen is -> 39
THIS IS INOUCDJOUAC
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.63

The average wind speed of the year is (corrected) -> 6.30

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 58.0933
This is for the Daff Indal machine
The number chosen is -> 40
THIS IS JOLLITTE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.87

This is for the Daff Indal machine
The number chosen is -> 41
THIS IS QOAQTAQ
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 6.09

The average wind speed of the year is (corrected) -> 6.82

THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr--> 247.7797
This is for the Daff Indal machine
The number chosen is -> 42
THIS IS MINIWAKI

```
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  2.19

This is for the Daff Indal machine
 The number chosen is      ->   43
                THIS IS MONTREAL MCGILL UNIVERSITY
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  2.87

This is for the Daff Indal machine
 The number chosen is      ->   44
                THIS IS NATASHQUAH
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.89

The average wind speed of the year is (corrected) -> 5.46


THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr-->          40.8953
This is for the Daff Indal machine
 The number chosen is      ->   45
                THIS IS NORTMANDIN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.96

This is for the Daff Indal machine
 The number chosen is      ->   46
                THIS IS PARENT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  2.72

This is for the Daff Indal machine
 The number chosen is      ->   47
                THIS IS RIVIERE AU RENAUD
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  5.57

The average wind speed of the year is (corrected) -> 6.24


THIS IS TOTAL YEAR PRODUCTION IN MWh/Yr-->          124.7565
This is for the Daff Indal machine
 The number chosen is      ->   48
                THIS IS STE ANNE DE BELLEVUE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.60

This is for the Daff Indal machine
 The number chosen is      ->   49
                THIS IS STE AUGUSTIN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.04

This is for the Daff Indal machine
 The number chosen is      ->   50
                THIS IS SAWYERVILLE NORD
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.71

This is for the Daff Indal machine
 The number chosen is      ->   51
                THIS IS SHEERBROOK
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.20

This is for the Daff Indal machine
```

The number chosen is -> 52

THIS IS VAL CARTIER

THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 1.48

This is for the 4MW Aeolus machine
The number chosen is -> 1
THIS IS BLANC SABLON
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 6.98

The average wind speed of the year is (corrected) ->11.72

Total year production in mwh/yr --> 14072.4229

This is for the 4MW Aeolus machine
The number chosen is -> 2
THIS IS CHAPAIS
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.39

This is for the 4MW Aeolus machine
The number chosen is -> 3
THIS IS CHIBOUGAMAU
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.32

This is for the 4MW Aeolus machine
The number chosen is -> 4
THIS IS FORT CHIMO
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.51

This is for the 4MW Aeolus machine
The number chosen is -> 5
THIS IS GASPE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.93

This is for the 4MW Aeolus machine
The number chosen is -> 6
THIS IS GRINDSTONE ISLAND
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 8.63

The average wind speed of the year is (corrected) ->14.49

Total year production in mwh/yr --> 19093.7866

This is for the 4MW Aeolus machine
The number chosen is -> 7
THIS IS INOUCDJOUAC
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.90

The average wind speed of the year is (corrected) -> 9.92

Total year production in mwh/yr --> 9293.5887

This is for the 4MW Aeolus machine
The number chosen is -> 8
THIS IS LA GRAND RIVIERE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.87

The average wind speed of the year is (corrected) -> 8.18

```
Total year production in mwh/yr -->      4897.9090

This is for the 4MW Aeolus machine
The number chosen is      ->    9
                THIS IS LAKE EON
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.75

This is for the 4MW Aeolus machine
The number chosen is      ->    10
                THIS IS MATAGAMI
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.46

This is for the 4MW Aeolus machine
The number chosen is      ->    11
                THIS IS MONT JOLI
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  5.64

The average wind speed of the year is (corrected) -> 9.48

Total year production in mwh/yr -->      7958.8920

This is for the 4MW Aeolus machine
The number chosen is      ->    12
                THIS IS MONTREAL INTERNATION AIRPORT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.34

This is for the 4MW Aeolus machine
The number chosen is      ->    13
                THIS IS MONTREAL MIRABEL AIRPORT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.26

This is for the 4MW Aeolus machine
The number chosen is      ->    14
                THIS IS NICHICUN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.40

This is for the 4MW Aeolus machine
The number chosen is      ->    15
                THIS IS POSTE DE LA BALEINE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  5.09

The average wind speed of the year is (corrected) -> 8.54

Total year production in mwh/yr -->      6044.7528

This is for the 4MW Aeolus machine
The number chosen is      ->    16
                THIS IS QUEBEC QUEBEC
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.43

This is for the 4MW Aeolus machine
The number chosen is      ->    17
```

THIS IS RIVIERE DE LOUP
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.93

This is for the 4MW Aeolus machine
The number chosen is -> 18
THIS IS ROBERVAL
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.30

This is for the 4MW Aeolus machine
The number chosen is -> 19
THIS IS ROUYAN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.28

This is for the 4MW Aeolus machine
The number chosen is -> 20
THIS IS STE AGATHE DES MONTS
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.99

This is for the 4MW Aeolus machine
The number chosen is -> 21
THIS IS ST HUBERT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.49

This is for the 4MW Aeolus machine
The number chosen is -> 22
THIS IS SHEFERVILLE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.03

The average wind speed of the year is (corrected) -> 7.44

Total year production in mwh/yr --> 3621.2678

This is for the 4MW Aeolus machine
The number chosen is -> 23
THIS IS SEPT ISLE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.81

The average wind speed of the year is (corrected) -> 8.09

Total year production in mwh/yr --> 5060.8553

This is for the 4MW Aeolus machine
The number chosen is -> 24
THIS IS SHEERBROOK
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.87

This is for the 4MW Aeolus machine
The number chosen is -> 25
THIS IS VAL D'OR
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.59

This is for the 4MW Aeolus machine
The number chosen is -> 26
THIS IS ARVIDA

THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.46

This is for the 4MW Aeolus machine
The number chosen is -> 27
THIS IS BORDER
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.72

The average wind speed of the year is (corrected) -> 8.46

Total year production in mwh/yr --> 6124.7268

This is for the 4MW Aeolus machine
The number chosen is -> 28
THIS IS BAGOTVILLE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.46

This is for the 4MW Aeolus machine
The number chosen is -> 29
THIS IS AMOS
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.20

This is for the 4MW Aeolus machine
The number chosen is -> 30
THIS IS CAPE HOPES ADVANCES
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 7.83

The average wind speed of the year is (corrected) ->11.74

Total year production in mwh/yr --> 13495.2891

This is for the 4MW Aeolus machine
The number chosen is -> 31
THIS IS CAPE WHITTLE QUE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 8.14

The average wind speed of the year is (corrected) ->13.03

Total year production in mwh/yr --> 15786.0782

This is for the 4MW Aeolus machine
The number chosen is -> 32
THIS IS CAPLAN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.22

The average wind speed of the year is (corrected) -> 7.57

Total year production in mwh/yr --> 4041.3054

This is for the 4MW Aeolus machine
The number chosen is -> 33
THIS IS CAPTOURMENTE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.56

This is for the 4MW Aeolus machine
The number chosen is -> 34
THIS IS DECEPTION BAY
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.16

The average wind speed of the year is (corrected) -> 8.76

Total year production in mwh/yr --> 7672.9606

This is for the 4MW Aeolus machine
The number chosen is -> 35
THIS IS FORET MONTMERENCY
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 1.97

This is for the 4MW Aeolus machine
The number chosen is -> 36
THIS IS GRAND RIVIERE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.56

The average wind speed of the year is (corrected) -> 7.06

Total year production in mwh/yr --> 2949.1147

This is for the 4MW Aeolus machine
The number chosen is -> 37
THIS IS GRINDSTONE ISLAND
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 8.90

The average wind speed of the year is (corrected) ->14.95

Total year production in mwh/yr --> 20041.3951

This is for the 4MW Aeolus machine
The number chosen is -> 38
THIS IS HARRINGTON HARBOUR
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 6.18

The average wind speed of the year is (corrected) ->10.38

Total year production in mwh/yr --> 9305.1175

This is for the 4MW Aeolus machine
The number chosen is -> 39
THIS IS INOUCDJOUAC
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.63

The average wind speed of the year is (corrected) -> 9.45

Total year production in mwh/yr --> 7618.9576

This is for the 4MW Aeolus machine
The number chosen is -> 40
THIS IS JOLLITTE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.87

This is for the 4MW Aeolus machine
The number chosen is -> 41
THIS IS QOAQTAQ
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 6.09

The average wind speed of the year is (corrected) ->10.22

Total year production in mwh/yr --> 10039.6842

This is for the 4MW Aeolus machine
The number chosen is -> 42
THIS IS MINIWAKI
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.19

This is for the 4MW Aeolus machine
The number chosen is -> 43
THIS IS MONTREAL MCGILL UNIVERSITY
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.87

This is for the 4MW Aeolus machine
The number chosen is -> 44
THIS IS NATASHQUAH
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 4.89

The average wind speed of the year is (corrected) -> 8.22

Total year production in mwh/yr --> 4773.3319

This is for the 4MW Aeolus machine
The number chosen is -> 45
THIS IS NORTMANDIN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 3.96

This is for the 4MW Aeolus machine
The number chosen is -> 46
THIS IS PARENT
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 2.72

This is for the 4MW Aeolus machine
The number chosen is -> 47
THIS IS RIVIERE AU RENAUD
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED) 5.57

The average wind speed of the year is (corrected) -> 9.36

Total year production in mwh/yr --> 7353.6265

This is for the 4MW Aeolus machine

```
 The number chosen is        ->    48
                    THIS IS STE ANNE DE BELLEVUE
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.60

 This is for the 4MW Aeolus machine
 The number chosen is        ->    49
                    THIS IS STE AUGUSTIN
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  4.04

 This is for the 4MW Aeolus machine
 The number chosen is        ->    50
                    THIS IS SAWYERVILLE NORD
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.71

 This is for the 4MW Aeolus machine
 The number chosen is        ->    51
                    THIS IS SHEERBROOK
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  3.20

 This is for the 4MW Aeolus machine
 The number chosen is        ->    52
                    THIS IS VAL CARTIER
THIS IS THE AVEAGE WIND SPEED FOR THE YEAR (UNCORRECTED)  1.48
```

APPENDIX VII

This benefit was tabulated by multiplying 6.5% to the fuel savings column of the computer flowchart in appendix 8.

Ile-de-la-Madeleine:	$ 282 801
Kuujjaq :	$ 441 279
Kuujjjuuarapik :	$ 318 276
Blanc Sablon :	$ 264 686
Tabatiere :	$ 312 770

APPENDIX VIII

Ile-de-la-Madeleine	: $ 2 635 382	good until 16% discount rate
Kuujjaq	: $ 2 013 697	good until 15% discount rate
Kuujjjuuarapik	: $ -518 139	good at the 8% discount rate
Blanc Sablon	: $ 823 266	good until 11% discount rate
Tabatiere	: $ 1 788 494	good until 14% discount rate

WIND MACHINE PLANT FACILITY INVESTEMENT

(CONSTANT 1991 $ Can.)

COSTS GIVEN FOR THE 500 KW WIND MACHINE (1)

	Rotor	Drive	Support	Rotor	Support	Balance	Total
Direct Costs							
Materials	$187,156	$231,500	$26,382		[illegible]	[illegible]	[illegible]
Transport	$4,978	$6,134	$721		$1,478	[illegible]	$16,170
Labour	$8,061	$5,363	$1,022		$11,832	$10,575	$36,854
TOTAL	$200,197	$243,027	$28,706		$68,761	$119,245	$659,936
Indirect Costs							
Distributables	$3,345	$2,226	$429		$4,907	$4,384	$15,291
Engineering	$6,985	$9,325	$315		$3,895	$10,894	$31,414
TOTAL	$10,331	$11,551	$744		$8,902	$15,278	$46,705
Contingencies							
Technological	$17,222	$13,019	$0		$0	$0	$30,241
Project	$34,873	$41,014	$4,525		$11,926	$20,990	$113,328
TOTAL	$52,095	$54,033	$4,525		$11,926	$20,990	$143,569
Total	$262,623	$308,611	$33,975		$89,489	[illegible]	$850,251

OTHER CAPITAL INVESTEMENTS

Land	$265,416
Working capital	$4,190
Organization and startup	$18,771
Prepaid Royalties	$0
Allowance for funding when constructing	$68,379 <-not included later in VAN
TOTAL	$134,244

OPERATING AND MAINTENANCE COSTS

Operating Labour	$0
Maintenance Labour	$9,721
Maintenance Material	$6,536
Administration and Support Labour	$4,860
Subtotal	$21,117
Consumables	$335
TOTAL	$21,452

WIND MACHINE PLANT FACILITY INVESTMENT

(CONSTANT 1991 $ Can.)

COSTS GIVEN FOR THE 4 MW WIND MACHINE (3)

	Rotor	Drive	Support	Tower	Sup. Balance	Total
Direct Costs						
Materials	$1,1[illegible],227	$1,361,077	$158,504	$325,[illegible]	$620,[illegible]	[illegible]
Transport	$19,261	$26,059	$4,036	$8,670	$16,347	[illegible]
Labour	$47,290	$31,517	$6,010	$69,587	$62,153	[illegible]
TOTAL	$1,175,877	$1,425,65[illegible]	$169,750	$404,2[illegible]	$701,287	[illegible]
Indirect Costs						
Distribution	$13,365	$10,084	$2,[illegible]	[illegible]	[illegible]	[illegible]
Engineering	[illegible],354	$54,818	$1,952	$22,8[illegible]	$54,[illegible]	[illegible]
TOTAL	[illegible],700	$67,902	$4,374	$51,744	$85,614	[illegible]
Contingencies						
Technologica	$101,242	$75,533	$0	$0	$0	$177,[illegible]
Project	$205,007	$241,106	$26,601	$70,105	$123,390	$666,210
TOTAL	$306,249	$317,638	$26,601	$70,105	$123,390	$843,9[illegible]
Total	$1,541,857	$1,814,204	$199,726	$526,074	$914,491	$4,9[illegible]

OTHER CAPITAL INVESTEMENTS

Land	$265,4[illegible]
Working capital	$25,3[illegible]
Organization and startup	$112,774
Prepaid Royalties	$0
Allowance for funding when constructing	$414,461 <-not included later in V[illegible]
TOTAL	$818,583

OPERATING AND MAINTENANCE COSTS

Operating Labour	$0
Maintenance Labour	$57,140
Maintenance Material	$38,424
Administration and Support Labour	$28,571
Subtotal	$124,135
Consumables	$1,970
TOTAL	$126,1[illegible]

DIESEL MACHINE PLANT FACILITY INVESTEMENT

(CONSTANT 198[illegible] $ Can.)

COSTS GIVEN FOR A 200 KW DIESEL SYSTEM

Materials	$40,000
Transport	$1,600
Total	$41,600

OTHER CAPITAL INVESTEMENTS

Land	$255,416
Organization and startup	$6,800
Other equipment and consumables.	$20,000
TOTAL	$282,216

OPERATING AND MAINTENANCE COSTS

Operation and maintenance are not given here because they vary with the location.

Municipal taxes are set at $50 000 per year for each location (for either the simple diesel operation or wind-diesel operation)

APPENDIX IX

Location : Cost savings - environmental cost + benefit from currency allocation = Economic cost saving.

Ile-de-la-Madeleine: $2 635 382 - $ 353 268 + $ 282 801 =
$ 2 564 915.

Kuujjaq : $ 2 013 697 - $ 353 268 + $ 441 279 =
$ 2 101 708.

Kuujjjuuarapik : $ - 518 139 - $ 353 268 + $ 318 276 =
$ -553 131.

Blanc Sablon : $ 823 266 - $ 353 268 + $ 264 686 =
$ 734 684.

Tabatiere : $ 1 788 494 - 353 268 + 312 770 =
$ 1 747 996.