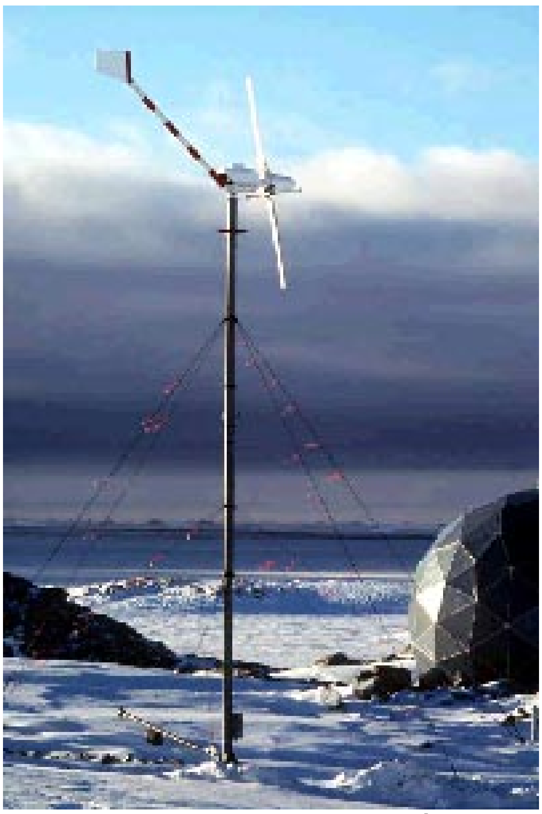
LATITUDE TECHNOLOGIES

Methodology for the Study, Assessment and Testing of Alternative Energy Systems at the Antarctic Stations; Application to the Australian and French Stations.

A paper presented at the Eighth SCALOP Symposium on Antarctic Logistics and Operations, Concepcion, Chile, July 1998



Wind Generator Vergnet GEV710 at Casey Station, Australian Antarctic Territory

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Methodology for the Study, Assessment and Testing of Alternative Energy Systems at the Antarctic Stations; Application to the Australian and French Stations.

by:
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Abstract

The French-Australian cooperative project “Alternative Energy Systems for Antarctic Stations” was originally focused on a broad study of station needs and alternative energy options. It has evolved towards an integrated system combining knowledge and data management, on site monitoring and testing and the development of assessment and design tools. This provides a structure for the conduct of coordinated research work and a support environment for the provision of advice to the two nations’ Antarctic programs for forward planning as well as in response to specific, more immediate operational needs.

The present paper describes the structure put in place and the methods and tools created to study, test and develop new energy solutions and illustrates them with case studies for Australian and French stations. It is a general paper presenting the project. The intention is here to share the project’s ‘operational’ experience and outline methods potentially applicable to other stations and other Antarctic operators.

Résumé

Le projet Franco-Australien “Nouveaux Systèmes Énergétiques pour les Stations Antarctiques” était à l’origine concentré sur une vaste étude des besoins des stations et des nouvelles solutions énergétiques possibles. Le projet a évolué vers un système intégré qui combine la gestion d’informations et de données, l’enregistrement de données et des essais sur site ainsi que le developpement d’outils de conception et d’évaluation. Cela fournit une structure pour mener des recherches coordonnées et un environnement de soutient pour fournir des conseils aux programmes Antarctiques des deux nations, que ce soit pour la planification à long terme ou pour répondre à des besoins opérationels plus immédiats.

Le présent document décrit la structure mise en place et les méthodes et outils créés pour étudier, tester et développer de nouvelles solutions énergétiques et les illustre par des exemples concernant des stations Australiennes et Françaises. C’est un document général de présentation du projet. L’intention est ici de partager l’expérience acquise et de passer en revue des méthodes potentiellement applicables à d’autres stations et d’autres opérateurs Antarctiques.

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1. Background

Since 1993, the Australian Antarctic Division and the Institut Français pour la Recherche et la Technologie Polaires – IFRTP (French Institute for Polar Research and Technology) have developed a project aimed at studying, assessing, testing and validating the use of alternative energy systems at their Antarctic stations. The long term objective is to make stations independent or near independent of fossil fuels and minimise their impact on the environment.

The first few years of the project were dedicated to broad studies of station needs and alternative energy options (see "Towards New Energy Systems for Antarctic Stations" presented at the sixth SCALOP symposium, Roma, 1994). It then focused on investigations of the potential for wind generation, the solution identified as the most promising for immediate implementation (see "Potential for Significant Wind Power Generation at Antarctic Stations" presented at the seventh SCALOP symposium, Cambridge, 1996).

The project's results were very encouraging in terms of generation potential but many aspects revealed to be much more complex than previously anticipated, notably in relation to generation estimates and system assessment as illustrated by a few examples:

- There is a lot more to sizing and assessing wind generation systems than choosing a wind generator model and predicting its output with standard met data:
  - The relation between the standard met data and the actual wind speed frequency distribution, hence the wind generator output, can vary significantly both in time and space
  - Both the lateral and vertical variations of wind speed within a station are significant, which requires the modelling of local wind patterns including adequate model calibration using fine scale wind pattern details and accurate station ground models
  - The number of possible wind generator sites can be limited because of station zoning requirements (quiet areas, fauna or flora protection…) or practical considerations (snow drifts, access for installation, year-round access for maintenance, connection to station grid, proximity of buildings, safety issues…)
  - Some wind generator models well suited to a station's wind patterns may have specific installation requirements that can only be met through a lengthy upgrade of the station's logistics capabilities, from the supply ship to the unloading facilities to mobile cranes
  - The satisfactory operation and maintenance of the wind generators may require some changes in the selection and training of expeditioners
  - The direct addition of wind generator arrays to the existing stations will change the electrical-thermal mix of the current energy networks and may result in significant wastes partially or even totally offsetting the expected or claimed savings

- The introduction of sizeable wind and solar generation units alongside the classic diesel based generators and boilers will create a much more complex, varied and dynamic system. It cannot be a straightforward replacement of the power generation units and will have to involve a variety of renewable systems, a decentralisation of generation and a modification of the energy mix:
  - Although being much more efficient it will be fairly sensitive to possible management and tuning errors
  - Because the success of the system will be intimately linked to the system combination closely matching the station's renewable potential, installations and activities, there is no easy, universal solution and all stations must be treated differently

- It is very difficult to come to grips with the cost of fuel and the current unit cost of power generation at the stations, essential figures for the assessment of fuel displacement systems or full replacement options. There is generally no ship specially chartered for fuel transport and the apportion of multipurpose vessels' charter costs is difficult if not impossible.

It appears in particular that the most delicate exercise is probably not to make a generation system produce power but to actually assess how effective the presence of the system is, that is to assess its benefits on a global station level. It can be tempting to just install a system and claim success because it did not fail, or because it produced so many units of power. Although it can be a catalyst for further actions or an attractive public relations medium, it could also hide the unpleasant reality that the system had little if no positive impact on the station and/or that the power was produced at an unrealistic price.

Another important finding is that the technology is usually there and that we often tend to place too much importance on the apparent suitability of a product to the stations' conditions and not enough importance on the careful preparation or modification of the product, its proper maintenance and its adequate inclusion in the overall station network. This can lead to the development of prototypes which can consume significant amounts of resources that could have been better used to adapt and operate commercial equipment and properly prepare and assess their inclusion into the global station system to ensure effectiveness.

These few examples and many other important aspects of the general "problem" identified in the course of the project highlighted its complexity and the need for a far reaching, integrated, flexible approach. A long term, consistent evolution of several different stations and their satisfactory operation cannot rely on a succession of one-off feasibility studies but need the development of an extensive, coordinated and adaptable knowledge and tools structure capable of quickly generating, adapting and updating design options and assessments.

2. Project Focus

In response to that, the project focus has evolved from the simple conduction of feasibility studies to the development of a dynamic support environment. This is intended to provide the background and the tools necessary to a true, effective evolution of the stations' energy systems. The support environment is designed to assist in the development, anterior assessment and posterior validation of system evolutions with a strong focus on true, demonstrated effectiveness.

An important evolution is the shift of priority from the creation of "final" studies to the creation of a "service" structure providing base information for project partners to put together their own studies as well as producing final studies on demand. This provides a structure for both the conduct of coordinated research work and for the provision of advice to the two nations' Antarctic programs for forward planning as well as in response to specific, more immediate operational needs.

This project focus is revolving around the following objectives and priorities:
- Adaptability to local requirements
- Flexibility to respond to time change
- Meaningful assessment for true effectiveness
- Use of off the shelf products
- Integration of different technologies
- Information
- Service to operators

3. Project Structure

3.1. Management

The project coordination and core research work is conducted by a private consultant, Latitude Technologies, under contract with the Antarctic operators whose technical services directly support on-site trials and equipment installations and actively participate in the research activities. The Institute of Antarctic and Southern Ocean Studies (IASOS) at the University of Tasmania can provide support in some aspects of the research work, notably through student research projects, assisted in the past by special grants from the Australian Antarctic Foundation. The project's research activities are approved by the Australian Science Advisory Committee (ASAC) which is the approval body for science projects at the Australian Stations.

This arrangement seems so far to provide a satisfactory balance between immediate satisfaction of operational needs and long term research and to allow flexibility in the scheduling and funding of the project.

3.2. Research Design

The research design is outlined in Figure 1. A detailed description of the design is beyond this paper but the diagram of Figure 1 gives a schematic overview of the research plan, its main components and their relations.

The diagram highlights the extent of "upstream" components and the number of steps needed to reach the system design and assessment stage. It can be seen that achieving the desired objective of a support structure ready to respond quickly to a variety of system design options for a variety of station conditions means having each component continuously ready and updated and having practical, structured and when possible automated, tools to quickly transfer from one component to the next.

An important point to note is that the research environment can be easily extended to include other stations or power systems other than renewables.

Most transfer tools and many elements are not station specific and the research environment can be extended to other stations with reasonably limited efforts and resources.

The Central time series database, its format and input procedures, its downstream extraction and processing tools as well as the system design and assessment tools can all be used to analyse and optimise the existing systems. This actually will be effectively done as part of the standard analysis of possible evolutions of the current systems. The project environment can then extend from a design tool for future, alternative options to an assessment tool for any type of existing system.

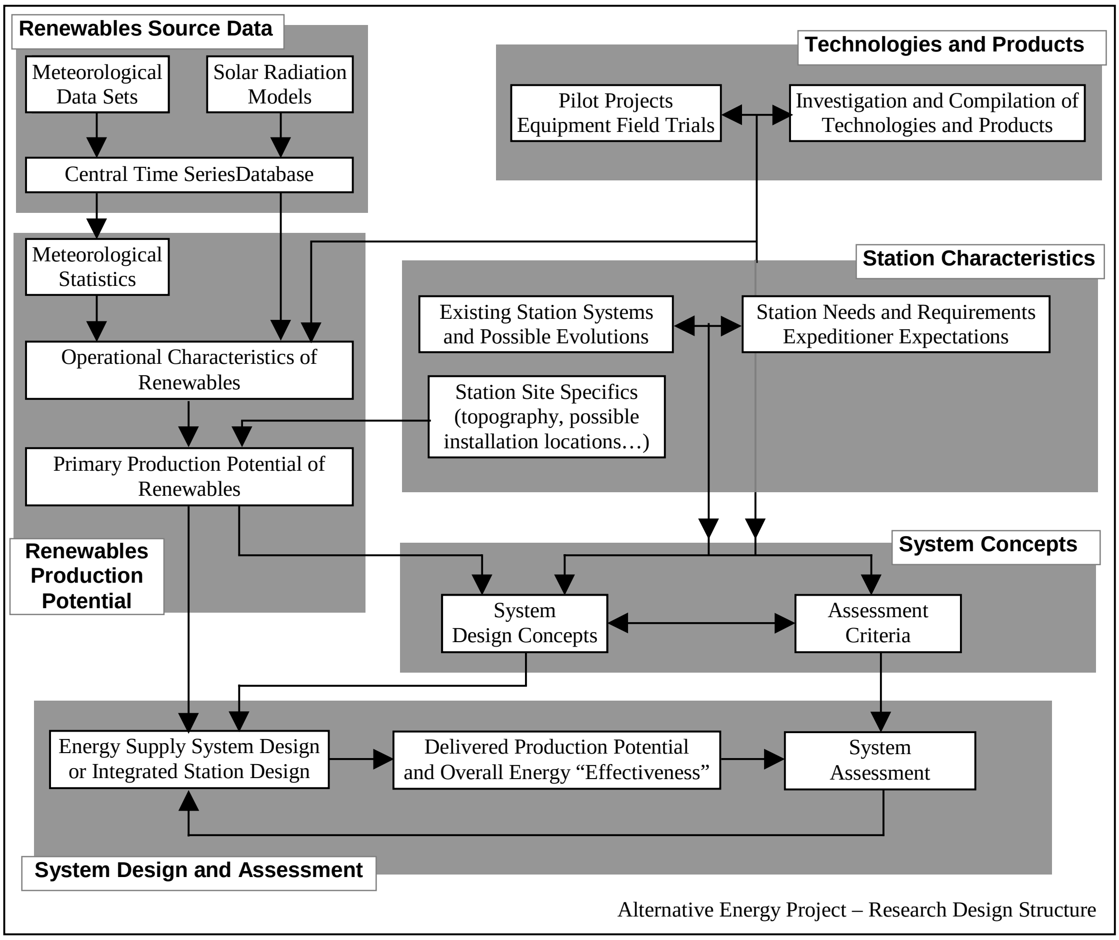


Figure 1: Research Design Structure

4. Case Studies

Three case studies were selected to illustrate methods or results in areas of the research design described earlier.

4.1. Data Collection, Casey Station

The collection of general and fine scale wind and solar data and wind turbine operational data at the Australian Antarctic station of Casey is illustrated on Figure 2 by the layout of the existing monitoring network. Note that it will be reasonably easy to extend the network to the collection of data from the powerhouse, which is under way.

The data is currently stored on site on the computer hard disk and retrieved manually through the network from time to time but an automated process is under development to provide a regular, unattended retrieval of the data and its inclusion in the central time series database. Full documentation for the installation, maintenance and operation of the monitoring network is made available on line for the expeditioners looking after the equipment. Near real time, on line reporting of the data and network status is under consideration.

4.2. Base Wind Generation Potential Estimates

Table 1 presents meteorological characteristics and some base wind generation potential estimates at several stations. These base estimates correspond to the precise origin location of the meteorological data and do not include any advanced correction for the relation between standard meteorological ten minute wind speed averages and actual fine scale wind patterns.

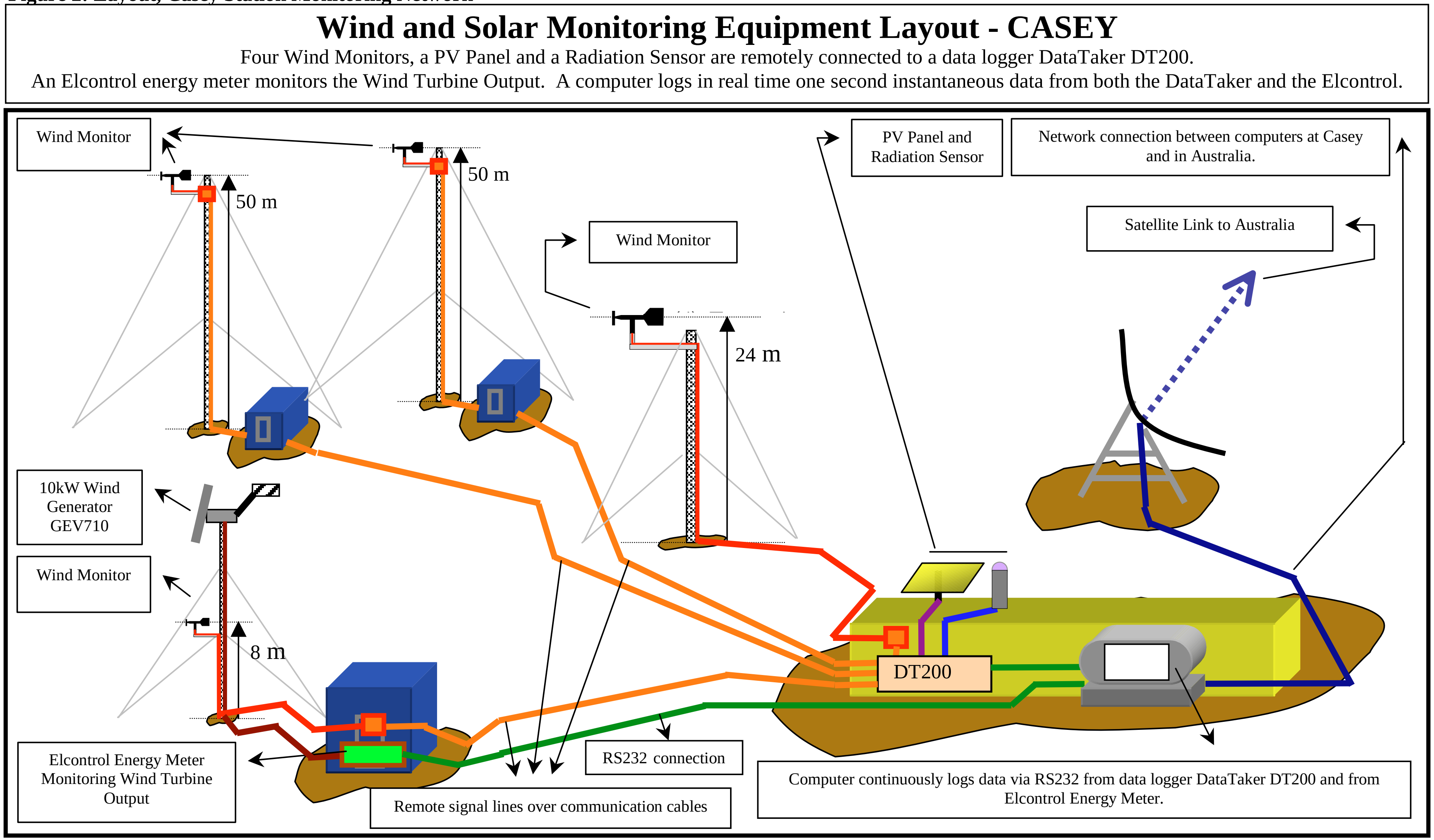
This is an example of simple average output calculated using extensive multi year data sets of 3-hourly data with all parameters calculated on each data point and subsequently averaged. The full time series can also be used to model the actual time evolutions of power output and the impact of such generation systems on the stations. The actual wind speed, pressure and temperature points are used to generate a "standard wind speed" series (corrected for air density) which is then projected at the wind generators hub height using the "Power Law" method and passed on to the wind generator's characteristic curve to provide an estimated power output time series. The fuel savings are based on an electrical efficiency of 0.35 for a generator using diesel fuel of 9.8 kWh Lower Heating Value per litre. The relative capital cost index is based on a "per unit of power produced", and is here indicative of the diminution of costs associated with larger units.

Table 1: Principal Meteorological Characteristics of Selected Antarctic Station Sites, and Average Generation Potential for Two Selected Wind Generators

(Based on 3-hourly meteorological data for full years -no seasonal bias-)

Station	Average Temp. T (°C)	Average Pressure P (hPa)	Maximum Wind Gust at 10m V (m/s)	Average Wind Speed at 10m V (m/s)	Average Standard Wind Speed at 10m Vs (m/s)	Output Estimates Vergnet GEV7.10 on 18m mast			Output Estimates Lagerwey 18/80 On 30m mast		
						Average Utilisation Factor	Average annual fuel savings per 100kW capacity (litres)	Relative capital cost index	Average Utilisation Factor	Average annual fuel savings per 100kW capacity (litres)	Relative capital cost index
Casey	-09.25°C	982	80.8	6.46	6.56	0.230	58 780	1 222	0.170	43 450	529
Davis	-10.11°C	986	57.1	5.10	5.19	0.214	54 690	1 313	0.183	46 770	492
Dome C	-50.80°C	644	17.4	3.03	2.84	0.050	12 780	5 620	0.049	12 520	1837
Dumont d'Urville	-10.89°C	982	90.0	9.60	9.80	0.530	135 450	530	0.414	105 810	217
Mawson	-11.27°C	987	50.9	11.2	11.44	0.678	173 280	414	0.526	134 430	171
Macquarie	+04.70°C	998	28.8	9.45	9.51	0.643	164 330	437	0.541	138 260	166

Figure 2: Layout, Casey Station Monitoring Network



4.3. Unattended Power Supply Options for Dome C

Table 2 outlines some results from a study of options available for supplying constant, year-round, unattended electrical power at Dome C (74°30'S, altitude 3200m). Freight deliveries to Dome C being difficult, expensive and limited in quantity, special attention was given to the weight involved in each option.

The study represented a complete study involving all steps of the research design presented in Figure 1 except for the absence of involvement of any existing system. The sizing, especially for the energy storage, was conducted using full time series data sets.

This study had to be delivered at an early stage of the development of the research environment described earlier and was produced over several weeks using relatively "manual" methods. This is a good illustration of a study whose update or development would require such an amount of work that any significant update would probably be better dealt with by starting a whole new study from scratch.

The development of automated tools capable of taping directly into the time series data base and into a technical database could lower the production time to a few days for the full study and a few hours for an update.

Table 2: Sizing of Hybrid Energy Systems at Dome C for a Constant Demand of 1 kW

(To meet a Constant Power Demand of 1kW)	**System 1** 3x GEV6.5 No PVs 2x gen. sets 4 weeks storage	**System 2** 3x GEV6.5 1.5 kW PVs 1x gen. set 4 weeks storage	**System 3** 3x GEV6.5 1.5 kW PVs 2x gen. sets 0.5 week storage	**System 4** 3x GEV6.5 1.5 kW PVs 1x gen. sets 6 weeks storage
Average generation output	1.316 kW	1.316 kW	1.316 kW	1.316 kW
PV infrastructure	n/a	1.5 kWp 12,755 ECU 435 kg	1.5 kWp 12,755 ECU 435 kg	1.5 kWp 12,755 ECU 435 kg
Wind infrastructure (GEV6.5 units at 18m)	15 kWp 64,410 ECU 1,800 kg	15 kWp 64,410 ECU 1,800 kg	15 kWp 64,410 ECU 1,800 kg	15 kWp 64,410 ECU 1,800 kg
Petrol Generator Sets (6kW capacity units) Annual production Total annual engine hours	12 kWp 6,852 ECU 240 kg 1,967 kWh 437 hrs	6 kWp 3,426 ECU 120 kg 681 kWh 151 hrs	12 kWp 6,852 ECU 240 kg 2,687 kWh 597 hrs	6 kWp 3,426 ECU 120 kg 316 kWh 70 hrs
Battery storage (two hours minimum imposed)	4 weeks 840 kWh 1,482,273 ECU 47,367 kg	4 weeks 840 kWh 1,482,273 ECU 47,367 kg	0.5 week 105 kWh 185,283 ECU 5,922 kg	6 weeks 1,260 kWh 2,223,414 ECU 71,055 kg
Power management equipment	15 kWp 10,204 ECU 225 kg	17 kWp 11,553 ECU 255 kg	17 kWp 11,553 ECU 255 kg	17 kWp 11,553 ECU 255 kg
Total initial infrastructure	1,563,739 ECU 49,632 kg	1,574,417 ECU 49,977 kg	280,853 ECU 8,652 kg	2,315,558 ECU 73,665 kg
Annual maintenance	1,730 ECU	1,826 ECU	1,860 ECU	1,819 ECU
Annual Fuel requirements	1,105 ltrs 349 ECU 824 kg	383 ltrs 121 ECU 285 kg	1,510 ltrs 477 ECU 1,126 kg	178 ltrs 56 ECU 132 kg

5. Conclusions

The project was originally focused on a broad study of station needs and alternative energy options. This produced very encouraging results in terms of generation potential. It also discovered many aspects and areas of importance and showed that many were much more complex than previously anticipated.

The original approach revealed to be limited. In response, the project evolved towards the development of a dynamic support environment designed to provide the background and tools necessary to the development, assessment and validation of new, effective energy supply options. The setting up of this support environment is well under way.

This paper has presented a range of aspects and areas of concern and the structure currently put in place to create the desired support environment. The concepts and tools developed for the project can fairly easily be applied to other stations and other Antarctic operators' needs and it is hoped that the many ideas outlined in this paper can trigger reflections and help define new directions.