TECHNOLOGICAL PRACTICE CASE STUDY | **APRIL 2010**

MATERIALS/ELECTRONICS/ENERGY TECHNOLOGY | **YEARS 11-13**

THE COOLEST WIND FARM IN THE WORLD

A wind farm has been constructed by Meridian Energy on Ross Island off the Antarctic coast, to help power New Zealand's Scott Base research station and the American McMurdo Station. Once complete, the wind farm will make a significant beneficial contribution to the environment, substantially reducing the carbon footprint from science on the ice, and saving both countries a considerable amount of money. This case study examines some of the construction and environmental issues of the project.

FOCUS POINTS INCLUDE:

Nature of Technology

- Sociocultural aspects – collaborative practice; economic benefits; environmental impact

Technological Practice

- Influence of Antarctic environment on BD; PfP and ODE – planning; positioning; material selection and transportation issues; technology used; construction technique

ADDITIONAL SUPPORT MATERIAL

THE COOLEST WIND FARM IN THE WORLD

Wind farms are commonly called "alternative" energy sources, although their design and construction is now fairly mainstream. But the logistics of undertaking such a project in Antarctica have resulted in a world-first development, with the excitement and challenge of a highly innovative engineering endeavour.

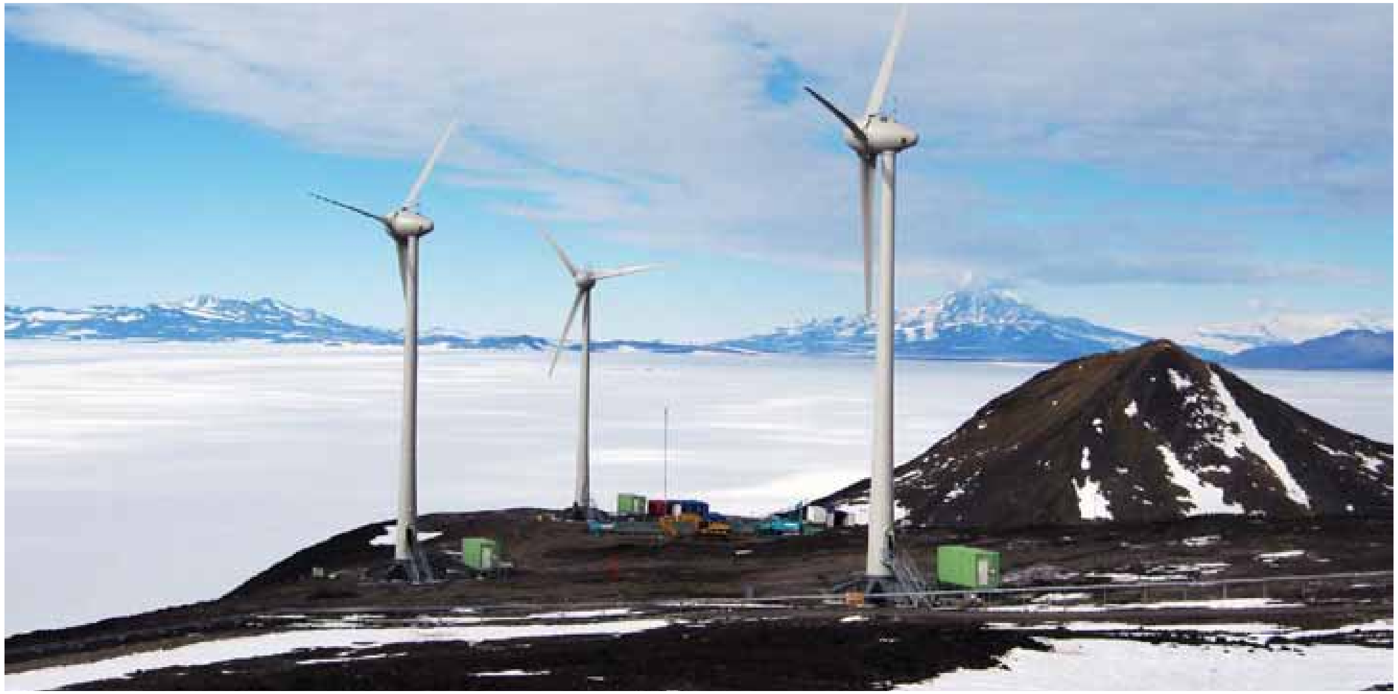
Ross Island is 2,460 square kilometres in area and perched amid the Ross Sea in McMurdo Sound, off the Antarctic coast. Despite its diminutive size, the island is home to four volcanoes, including Mt Erebus which, at 3,794 metres, is higher than Aoraki/Mt Cook. Ross Island is also home to New Zealand research station, Scott Base, and the United States Antarctic Program's McMurdo Station.

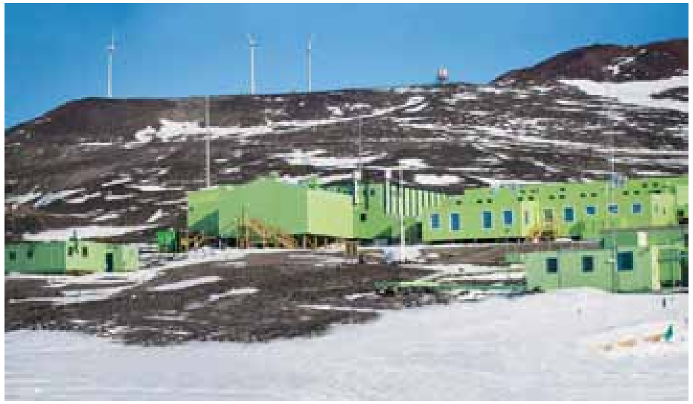
Scott Bennett, Project Manager with Meridian Energy, knows Ross Island well. Over the past two and a half years, he has led a team to develop and realise Stage One of the Ross Island Wind Energy proof-of-concept project. He says it has been a logistically intense project, with limited room for error in terms of time frames, design and installation.

New Zealand-United States collaboration

The rationale for the Ross Island project evolved from several factors. These include wind energy's oft-cited environmental benefits, a need to reduce on-ice research costs, and desire by both the United States and New Zealand to demonstrate environmental sustainability leadership. There's also a fantastic wind resource, and importantly, the need to balance New Zealand's contribution to the Antarctic logistics pool.

Because of the Antarctic's remote and challenging nature, and a long-standing agreement between the United States and New Zealand to pool and share resources, the McMurdo and Scott Base research stations have a close association. As part of our government's contribution to the United States/





The Crater Hill site is one of the few places on Ross Island without ice cover. Photo by Sam Shepherd.

New Zealand joint logistics pool, the project has been developed under an alliance between Meridian Energy (Meridian) and Antarctica New Zealand, with key support from the United States Antarctic Program.

"New Zealand picked up the opportunity to provide a wind farm for the island in part as a way to 'do its share' and because of our considerable knowledge of wind farm construction, operation and maintenance," Mr Bennett says.

The project has had a core team of six – and at times up to 15 – based in Antarctica throughout the construction period over two summer seasons. "We are very conscious that each worker is occupying a research scientist's place, and with overhead costs of $1,000 per person per night, there are plenty of incentives to keep the project timeframe tight. The construction team typically works 10-hour days, six days a week."

The construction phase – overseen by Site Manager Jonathan Leitch – began in November 2008; by the end of February 2009 the three turbine foundations and the electricity network connecting the two research stations were installed. Over the 2009/2010 summer, the turbines were erected and connected to the grid.

Operated by Antarctica New Zealand, the Scott Base research station houses up to 86 people each season, and generates an average electricity load of around 150 kilowatts. By comparison, the American McMurdo Station – operated by the National Science Foundation – is the largest of all the Antarctic research stations, with capacity for 1,250 people and an average electricity load of 1.6 megawatts (ten times that of Scott Base). Although operated by different countries, the two facilities are only five kilometres apart.

The Crater Hill wind farm site is ideally placed to serve both bases, as it is roughly halfway between them. It is also one of the few Ross Island sites without ice cover, although the permafrost starts about 20 centimetres below the surface. Being ice-free was a considerable advantage for the project team, enabling the turbine foundations to be accurately and firmly placed – a critical factor at any wind farm site, but particularly important when wind speeds reach up to 240 kilometres an hour.

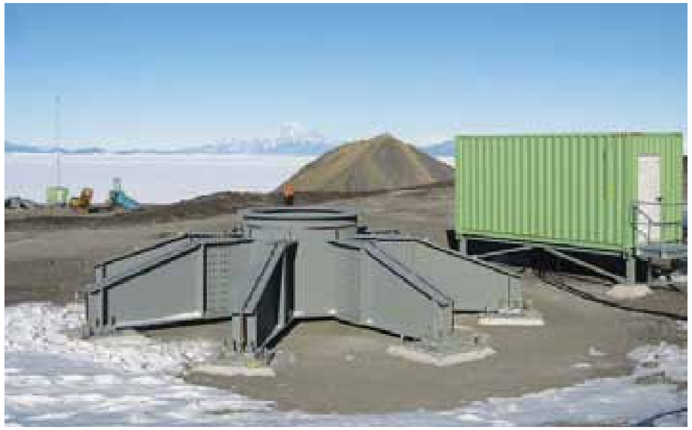
Environmental and cost benefits

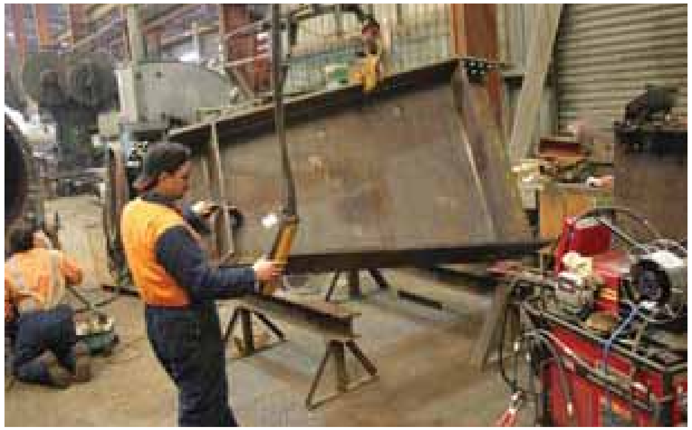
Once complete, the wind farm will make a significant beneficial contribution to the environment, reducing the carbon footprint from science on the ice. Estimates show an expected reduction in the carbon dioxide emissions (from the Scott and McMurdo research stations) of around 1,243 tonnes per annum.

"The project will also help both countries achieve considerable cost savings," Mr Bennett says.

"In an average wind year, we estimate a reduction in fuel consumption of around 463,000 litres per annum (or 11 per cent of the over four million litres combined consumption for the two stations per annum). That figure just reflects the savings from offsetting power generation on the ice, and does not include the reduction in fuel consumed in transporting the fuel to the ice."

The project will also reduce the environmental risks of transporting diesel to the ice.





Top: The foundation blocks were backfilled in 200 millimetre layers with excavated material. Photo by Iain Miller.

Middle: The assembled foundation and transformer building – ready for the 2009/2010 summer season. Photo by Scott Bennett.

Bottom: The steel foundations were prefabricated by Lyttleton Engineering he wind turbine blades were transported to McMurdo Station in February 2009, ready for the 2009/2010 summer season. Photo by Scott Bennett.

German turbines – with a twist

The project team chose the three-bladed German-made E-33 Enercon turbines, with a slightly higher specification than standard models, which can generate up to 330 kilowatts each, and have 33-metre diameter blades with pitch control.

"Ours are not the first industrial scale wind turbines on the ice," Mr Bennett says. "The Australian research station, Mawson, has had two Enercon E-30 turbines successfully in operation since 2003, and we have learnt some valuable lessons from their experience. For example, our turbines have improved sealing brushes in the nacelle to keep out the spindrift, which in a storm can quickly fill the cavity with snow through any small gaps."

Enercon turbines were also selected because all their components – aside from the blades – could fit into standard 12-metre shipping containers, an essential logistics requirement for transportation. The blades were transported in special frames.

The turbines have a direct drive generator, which eliminates gearbox and oil issues in low temperatures. The flexible power electronic supply conversion in conjunction with the control system makes the turbines ideal for wind-diesel integration. Further, they only require servicing once each year.

Proof-of-concept project

A 2005 University of Canterbury energy review of Scott Base provided the catalyst for Meridian to be invited to assess sites on Ross Island. Crater Hill was identified as an ideal potential site, and a monitoring mast was erected in February that year.

By mid-2006, good wind data justified holding discussions with the United States National Science Foundation (NSF), which had been independently investigating wind energy supply for McMurdo Station. In August 2007, a proposal to NSF and Antarctica New Zealand resulted in approval for the Ross Island proof-of-concept project.

Stage One is on target for completion by the end of the summer working season. The three turbines were all erected and commissioned before Christmas, and the team has since focused on completing optimisation and fine-tuning by the end of the season.

"Stage One will enable the Scott Base diesel generators to be entirely switched off," Mr Bennett says.

"When the wind is blowing, Scott Base will receive electricity directly from the wind farm, with the extra generation going to the McMurdo station. On still days, Scott Base will be supplied by McMurdo's diesel generators."

Innovative "spider" foundations

The Ross Island turbines' foundations required considerable thought and innovation. Pre-constructed by Leighs Construction in New Zealand, the foundations are an anchored structural steel design developed by structural engineers at Opus International Consultants.

"Our team for this project was selected not only for its technical expertise, but also for its knowledge and experience of Antarctica," explains Hamish Mackinven GIPENZ, a McMurdo Station veteran and Structural Engineer with Opus in Christchurch.

Prefabricating the foundations provided the team with a "practice run" for the real event, and an opportunity to proactively iron out any potential hiccups. However, unlike traditional turbine foundations, these steel versions – designed to sit above ground – needed to be absolutely level, otherwise the turbine towers would be out-of-plumb, making them unstable and unworkable.

Turbine foundations are usually just a poured concrete gravity pad base, to which the turbine tower is secured. It was not that straightforward in Antarctica.

Structural Engineer and Antarctic veteran Murray Mitchell MIPENZ, also with Opus, boasts an amazing quarter of a century's experience on the frozen continent and used his "inside knowledge" to resolve these sorts of problems. "You simply can't make concrete down there," Mr Mitchell says.

"Firstly there is no aggregate or fresh water available to make the concrete, (all the fresh water is made from seawater) and secondly, concrete just doesn't cure in the extremely cold temperatures – even in summer."

The foundations were designed to be level within an accuracy of plus or minus one millimetre over a 2.4-metre diameter flange. As the turbines and their foundations were manufactured on opposite sides of the world, Mr Mitchell's near-obsession with tight component accuracy tolerances is understandable.

The bottom of the tower section was transported and unloaded ready for assembly at Crater Hill in November 2009. Photo by Johno Leitch.

Consequently, the Opus engineers worked closely with the German turbine manufacturers to ensure the foundations and turbine towers aligned and fitted correctly. The foundations sit above the ground, with eight legs radiating outwards. Each leg is secured to one of eight 13-tonne pre-cast concrete blocks arranged in a circle in an excavated pit, then backfilled and frozen in so the tops of the blocks are nearly flush with the ground. Each block is fitted with two 12-metre ground anchor bolts drilled and held in place with "Antarctic grout" (a mixture of hot water and sand which freezes rather than sets). This system provides adequate strength to support the turbines in the freezing wind gusts which can reach 240 kilometres per hour.

Logistical challenges – and some advantages

Any engineer will tell you most projects raise a few obstacles. But a project in Antarctica would inevitably generate more interesting challenges than most. These have included a tight work programme (between November to February), considerable transportation logistics, project resourcing constraints, and summer temperatures varying between -37 and five degrees Celsius; it's even colder when the wind is blowing, which it often is, given this is a wind farm site.

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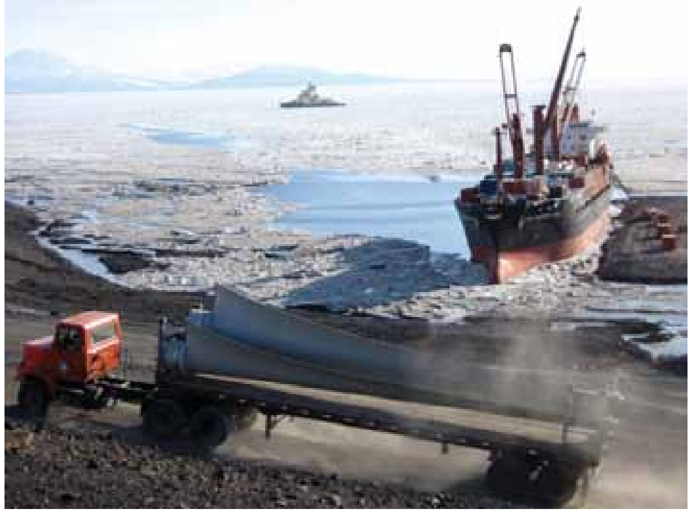

The wind turbine blades were transported to McMurdo Station in February 2009, ready for the 2009/2010 summer season. Photo by Scott Bennett.

"Working in one of the most environmentally sensitive areas of the world while dealing with unique and complex engineering, compounded by extreme climatic conditions meant people with a prior understanding of the environment were a significant advantage for us. Team members had to be able to work hard and overcome unexpected problems along the way, and they had to be able to get along with others, Mr Bennett says.

"The small construction window resulted [not only] in a very aggressive schedule, but also in a 'can do', solution-focused attitude among the contractors, and an elegance of simplicity in the design solutions they achieved. There was also a huge amount of contingency planning involved, and a 'lean and mean' approach to what we needed on the ice. We had to plan and programme down to the last nut and bolt."

The transportation logistics required forward thinking. As the annual Ross Island supply ship arrives at the end of the season, you have to think a year ahead to begin work the following October, as everything needs to be transported in February. One day late with a component delivery could easily translate into the project running a year behind, impacting on its completion.

Other challenges were more mundane. "Everyone understands extreme temperatures are part of the challenge of working on the ice. What is perhaps less obvious, however, are the dexterity constraints imposed by the thick gloves and garments the construction team must wear," Mr Bennett says.

"We had to design some components specifically with this in mind, to ensure tiny parts were not too small and fiddly for workers to install. For example, the steel foundation components had all their edges rounded to prevent any cuts in gloves during handling."

Even simple tasks took time; signing in and out of Scott Base, changing into extreme cold-weather clothing, and waiting for vehicles to warm up added significant time before working days began.

Fortunately, there were some site-specific advantages. "Crater Hill is one of the few ice-free locations in Antarctica, which made getting the foundations correctly positioned and levelled a great deal easier than it might have been," Mr Mitchell says.

Existing road access was also an advantage, as the hill had already been "disturbed" by human activities, so the wind farm's environmental impact was minimal. "Interestingly, although the turbines are located within a kilometre of the sea, corrosion is not an issue," Mr MacKinven says.

"This is because the sea is frozen and hence there is no salt spray. Consequently the foundations only need minimal painting to protect them from the elements."

The dry climate also helped, as although extremely cold, less ice forms on the turbine blades, so there were fewer operational constraints compared to other cold-weather locations.

"Having 24 hours of daylight allowed us a degree of flexibility. There were a couple of times the team worked late to get a project phase completed, for example during a lull following a period of high wind when work couldn't proceed," Mr Bennett says.

Synchronising the electricity supply

The Ross Island electricity network connecting Scott Base and McMurdo Station is the first on the continent to connect two research stations. Innovative thinking was needed to connect them as Scott Base operates with a 50 hertz system frequency, whereas the McMurdo Station operates at 60 hertz.

As the majority of the wind farm energy feeds into McMurdo Station, the Crater Hill turbines generate at 60 hertz, and the connection to Scott Base is achieved via a static 60/50 hertz frequency converter housed in a converted shipping container adjacent to the Scott Base powerhouse.

The network also contains a flywheel system consisting of a three-tonne mass spinning up to 3,600 revolutions per minute which can quickly provide or absorb up to 500 kilowatts of electricity for 30 seconds. This device keeps the system stable when sudden wind changes vary the turbines' output faster than the response time of the diesel generator governors, by providing the energy to make up the load difference.

What next?

"We are very pleased with the way Stage One has gone," Mr Bennett says.

"We would like to investigate the potential for Stage Two, which we believe could offset power consumption on the island by 40 per cent. But first we need to assess how Stage One performs over the coming year."

Mr Bennett says by this time next year the project team expects the Crater Hill facility to have proven its worth to the United States and New Zealand programmes, justifying Stage Two investigations. However, with the Crater Hill site now fully utilised, the team hopes another suitable site is waiting to be discovered somewhere nearby.

Meridian Energy is New Zealand's largest state-owned electricity generator, and generates its electricity solely from renewable sources. Although mostly known for its wind and hydro energy innovation, Meridian is developing experience in other areas of the sustainable energy sector – such as solar – with construction of a five-megawatt plant in California.

"We are keenly aware of the potential in Antarctica for solar energy utilisation. Although there is little or no sun at Ross Island over the winter months, the base is bathed in 24-hour daylight during the summer months, which aligns with the load demand when the majority of science researchers are there," Mr Bennett says.

The plan is to monitor and progress the wind energy project some way further, before exploring the potential for other types of energy capture. "It's all a matter of focus and timing. We know we can do it, we just need to take it one step at a time."

WRITER: Karen Wrigglesworth