CH_2 Setting a new world standard in **green building design**

Design snap shot 17: Wind Turbines

Summary

Introduction

This summary sheet discusses the use of wind turbines in CH 2. The turbines are at the top of the ventilation ducts, which draw stale air out of the office space, and provide fresh cool air into the building, cooling the thermal mass. The thermal mass will store the coolth for use the next day.

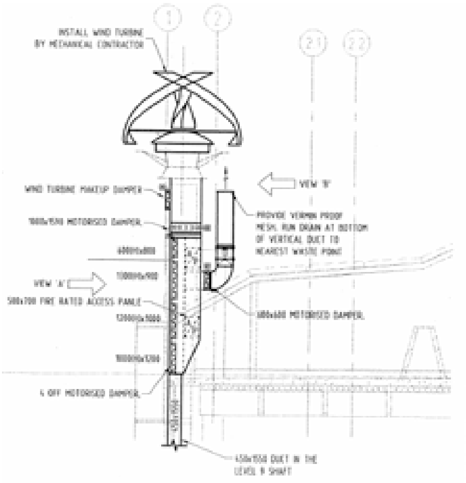


Figure 1. Elevation of the Vawtex system

Drivers and objectives

In a traditional office building, air is extracted by high powered fans. By reducing the use of these fans, a building can save on energy use.

Although the turbine system has been designed to be passive, the turbines need to be controlled so that they do not damage themselves or the building fabric, as they can break when the wind is too strong.

Costs and benefits

Although the turbines seem quite expensive the draw the turbines provide means that there is a reduction of the use of electric fans in the buildings. This simplifies controls and reduces maintenance of mechanical systems. Turbines of a similar type are used on oil rigs and are maintenance free for 5 years, using an automatic lubrication system. During modelling, the turbines produced an extra 6% air extraction at night.

Outcomes

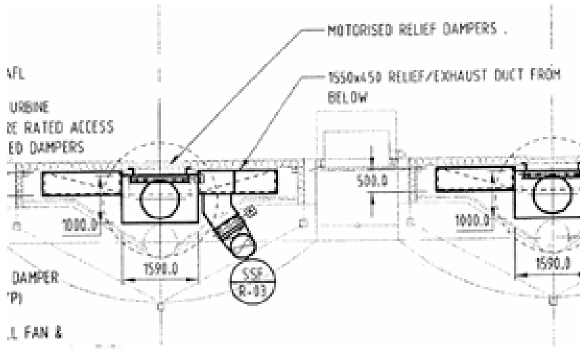


Figure 2. Plan arrangement of ducts

There will be a reduction in the use of energy to extract stale air out of the building. The turbines will also provide a visual symbol of the building's innovation.

Lessons

Nine design options initially drawn by the design team had to be explored to determine the most appropriate. The original idea (option one) proved to be the most appropriate. However when it came to building it, no-one could do it, so a tenth option was developed. It proved to be even better, with power generation possible during the day and improved air extraction by night.

Figure 3. Final turbine design

The appropriate use of models and testing has to be assessed along with the outcomes it will give. The use of salt bath modelling with the turbines provided the most accurate low velocity and pressure readings for a scale model, although it was probably more expensive than other modelling alternatives.

17 Wind Turbines

More detail

There were many discussions on the use of the wind turbines within the design process:

…it is an open book exercise, I mean if we get things wrong or if things don't quite work for us, you'll know about it…we've had a strong internal debate about the turbines and it's been an emotional one, because,…the turbines have been with us since day one, …but we [need to] actually prove it works, in terms of cost benefits.
Rob Lewis, Project Superintendent, City of Melbourne

The discussion was mainly about how effective the turbines would be. The task was to balance the cost of $180,000 against the additional 6% suction they applied to the night purge.

Results from initial cfd tas modeling

To justify the use of the wind turbines AEC were asked to carry out some CFD modeling of the use of the turbines. The results are shown below:

Level 2	Windy Night Purge	Still Night Purge	Daytime
No Turbines	0.562	0.375	1.548
Turbines	0.558	0.375	1.548
Mechanical Exhaust	0.508	0.508	1.548

Figure 43 - Level 2 Airflow Summary

Level 5	Windy Night Purge	Still Night Purge	Daytime
No Turbines	0.482	0.320	1.510
Turbines	0.477	0.320	1.510
Mechanical Exhaust	0.508	0.508	1.548

Figure 44 - Level 5 Airflow Summary

Level 9	Windy Night Purge	Still Night Purge	Daytime
No Turbines	0.336	0.192	1.481
Turbines	0.345	0.192	1.481
Mechanical Exhaust	0.508	0.508	1.548

Figure 45 - Level 9 Airflow Summary

Figure 4. CFD modelling results for building exhaust options for the 2nd, 5th and 9th floors (AEC)

According to their model, the turbines give a 6% improvement of air extraction, more for the higher levels than the lower floors.

TOTAL	Windy Night Purge	Still Night Purge	Daytime
No Turbines	5.631	4.973	13.222
Turbines	5.950	4.973	13.222
Mechanical Exhaust	5.008	5.008	13.222

Figure 46 - Total Building Exhaust Summary

Figure 5. CFD modelling summary for total building exhaust options (AEC)

Other modelling and testing

In the salt bath analysis the use of wind and the turbines was not included as:

The Martin Centre had already done some analysis of Melbourne wind conditions, and found that in the six hot months you don't get much wind, especially in the small hours, which was when they were proposing to do the night purging. So he [Dr Garry Hunt from Imperial College] felt it was a conservative assumption to do modelling where there was no contribution from wind pressure across the building or any contribution from wind turbines ... He felt that given the lack of wind there would not be much turbine pulling power. Michael Shaw, SEAV

The effectiveness of the turbines was highly contested in the project team. However, once the building is operational, it will be clear how the wind turbines have aided the extraction of air, particularly at night when there is not the additional pull of the heat generated by the darker northern exhaust stacks.

Figure 6. Wind turbines in use and image of the 'hands-on' testing done by Principal Design Architect Mick Pearce

Wind turbine development

Ten different design options were considered during a feasibility study of the effectiveness of the design provided by AEC. The Council wanted to ensure that the turbines provided sufficient pull to merit its inclusion in the design. The conclusions reached by this extensive investigation were:

1. The night purge is more efficient on windy nights than on still nights whether or not the turbines are used. This is attributed to the venturi suction effect of the high winds.
2. The wind turbines improve the night purge ventilation of the building by about 6% on windy nights and do not contribute on still nights or during the day.
3. The night purge strategy is effective when it operates under buoyancy-driven ventilation flow.

17 Wind Turbines

This report produced an extensive debate amongst the team members as well from the Sustainable Energy Authority Victoria and Vawtex (the suppliers of the originally designed wind turbines). The use of the turbines at only 6% was at one stage in doubt, and other less active solutions of cowls were considered.

The original proposal is described below as proposal 1, the rest are then outlined and, where possible, costs and benefits shown.

Proposal 1 – Original Concept
This system was designed as shown in the original tendered drawings by consultants Lincolne Scott. All systems work with a mixing chamber linking the rising ducts below the turbine, the fire exhaust system, the damper below the turbine and the relief air dampers allowing the system to work as a cowl when there is no wind. It can also be stopped if the wind is too strong.
Estimated cost $180 000

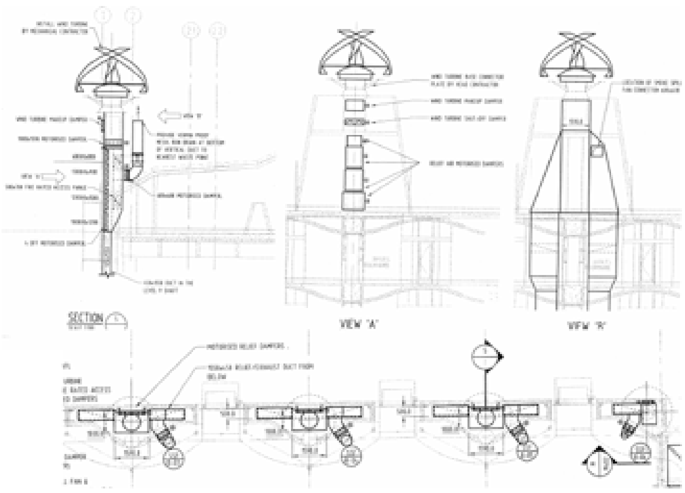
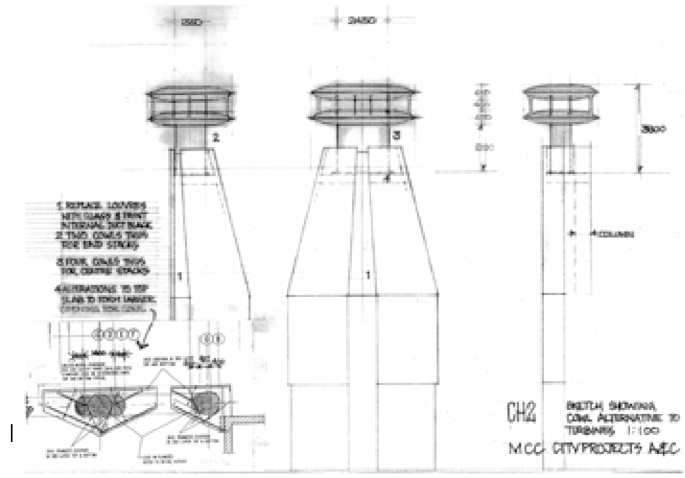


Figure 7. Proposal 1- Original wind turbines

Proposal 2 – Oval cowls
Replace the turbines with oval shaped cowls with minimum impact on the structure. Note the hole in the slab (bottom left) is sized to be 1.54 m2 (from 0.78m2 in case of turbines).

In this case the four dampers and louvers in front of them would be replaced with a glazed opening to trap solar heat to aid the convection of exhaust air.
Estimated cost $ 110 000



Proposal 3 – Solar Accelerators
This solution had some merit for simplicity. It was inspired by Eastgate, a building located in Harare, which Principal Design Architect Mick Pearce was involved in designing.

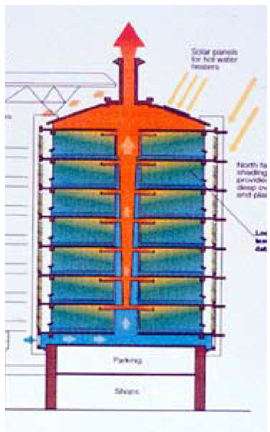


Figure 9. Image taken from Eastgate website (http://archnet.org/library/images/one-image.tcl?image_id=36902# last accessed 4/10/04)

These are solar accelerators made of black precast concrete and would absorb maximum solar heat which would be retained well into the cool of the night and would thereby continue to help exhaust air. The chamber below joins the two ducts and the louvered slot in front of this chamber becomes a glazed opening to trap more solar radiation and thereby enhances the exhaustion of air.

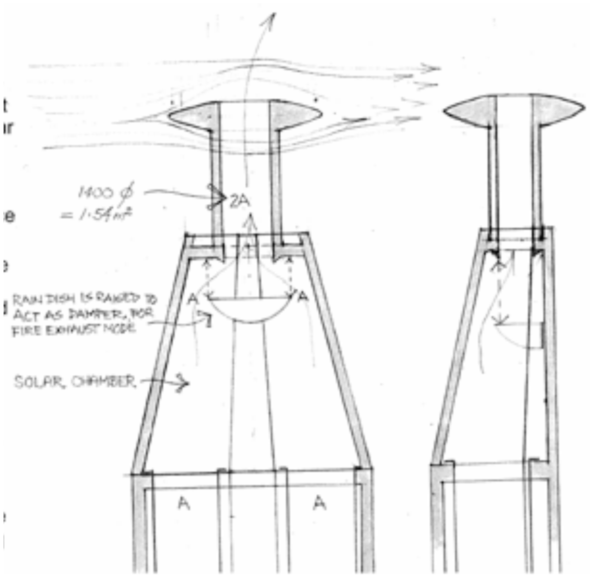


Figure 10. Proposal 3 - Solar Accelerators

- The damper dish acts as a rain catcher and a damper while still leaving enough space around each side for the air to escape upwards without resistance
- The fire exhaust is as originally designed
- The top of the flue is shaped to enhance suction

The problem with this design is that there would be a need for considerable alteration to the structure. These would include a 1000W X 300H up stand band beam and an offset 750X750mm column in order to achieve a 1400mm diameter hole for the exhaust air.
Estimated cost $140 000

During development, the team decided to look for solutions which did not involve changing the structure which was designed to support the top of the stacks and the turbines. Any logical design seemed to demand the removal of the column. This is because a passive cowl would need a larger opening at the top than the turbine (i.e. from 0.78 to 1.50 m2 cross sectional area).

Proposal 4 – Removal of wings
This proposal comprised an option to remove the wings from the turbine. This proposal results in a loss of efficiency of two-thirds compared to a turbine with wings. This, however, would be enough to overcome any negative resistance at the top of the shaft (due to dampers) as one would expect from a cowl.

Further, it would be cheaper than a complete turbine. The advantage argued was that the hole at the top could be left as it was designed and get the same performance as the cowls which would need much bigger holes. Exact costing was not available, however this reduced turbine was expected to cost less than a complete turbine and no more than a cowl.

Mick Pearce developed a document which illustrated all the different modes of operation which could be studied when the building is occupied. This involved trying to establish the comfort levels related to preserved air temperatures and radiant surface temperatures as well as the amount of stratification we can expect when the building is occupied. Its other purpose was to illustrate graphically the expected way air may move to addresses any misunderstanding amongst team members.

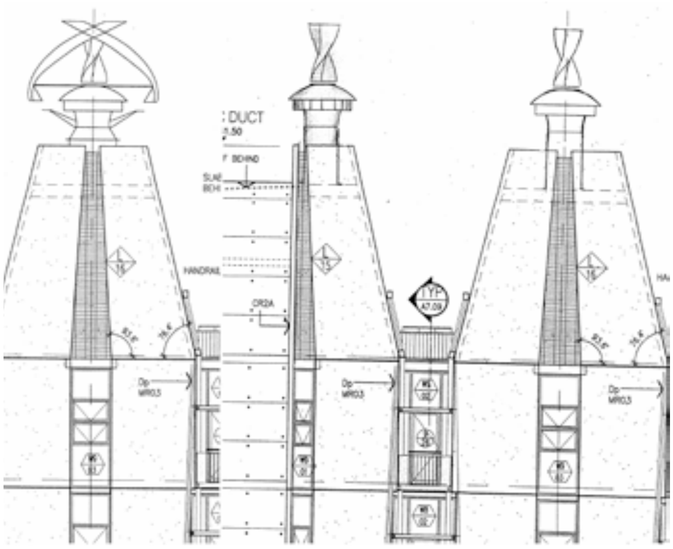


Figure 11. Proposal 4 - Removal of wings

Proposal 5 – Minimum top enlarged exhaust ducts
This proposal kept the front of the top of the stacks exactly as designed, but changed the back in order to rationalise the fire exhaust duct. The top of the shaft was kept the same but with an enlarged exhaust opening at the top. The cowl was a flat topped one in line with one of those suggested by AEC.
Estimated cost $ 135 000

This proposal had some merit provided an architectural solution could be found at a reasonable cost.

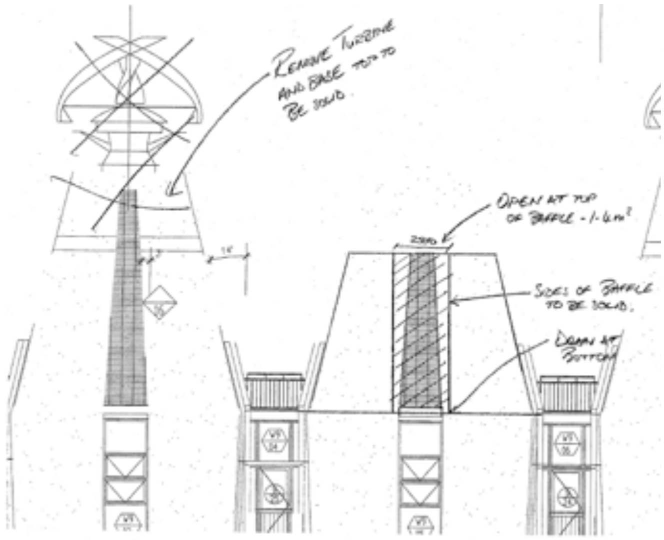


Figure 12. Proposal 5 - Minimum top and enlarged ducts

Proposal 6 – Copper cowl

A more radical solution for the flat topped cowl was explored. This involved changing the top of the stacks by removing the entire concrete structure above roof level and replacing it with a copper clad cowl and skirted chamber. These would be formed on light steel frames which could be prefabricated and lifted by crane onto the tops of each shaft. In architectural terms this seemed the best alternative to the turbines.

Estimated cost $ 498 000

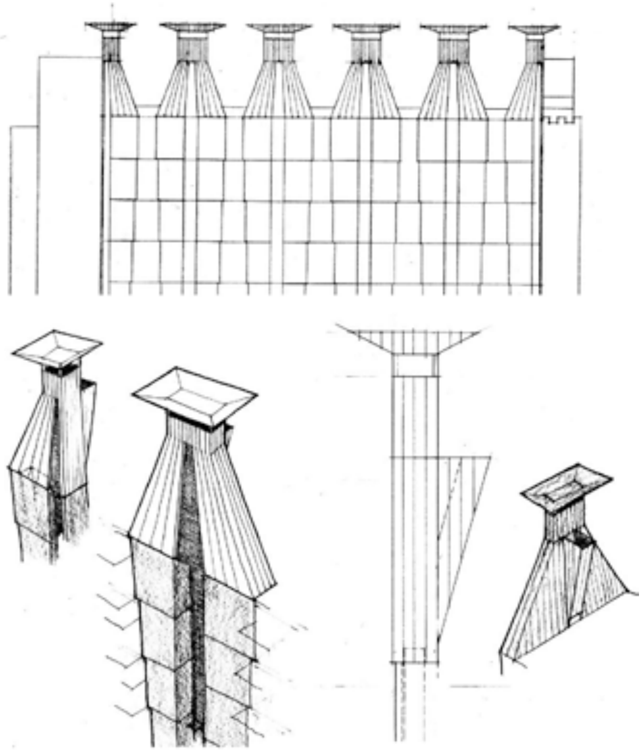


Figure 13. Proposal 6 - Copper Cowls

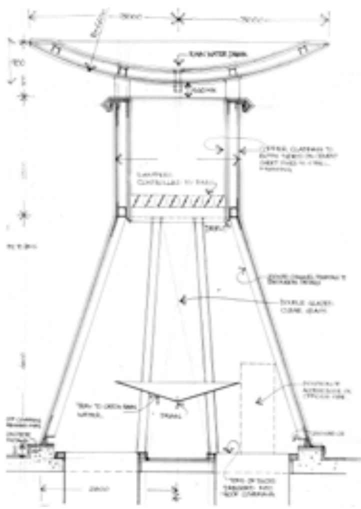


Figure 14. Detail of cowl

Proposal 7 – Long box cowl

Next the team took the baffle designed by AEC and modified it as an attempt to keep all elements which were documented using simple hook over a baffle held by a light steel structure from over the top of the stack.

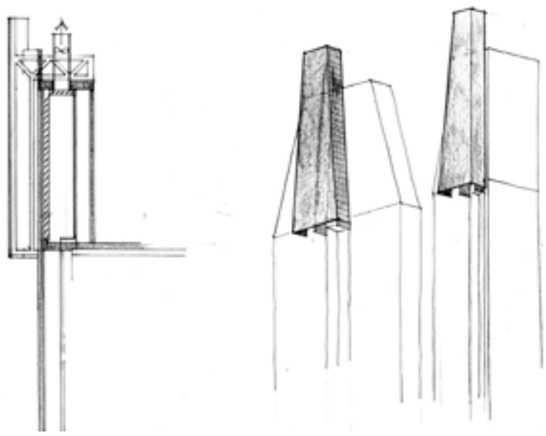


Figure 15. Proposal 7 - Long Box Cowl

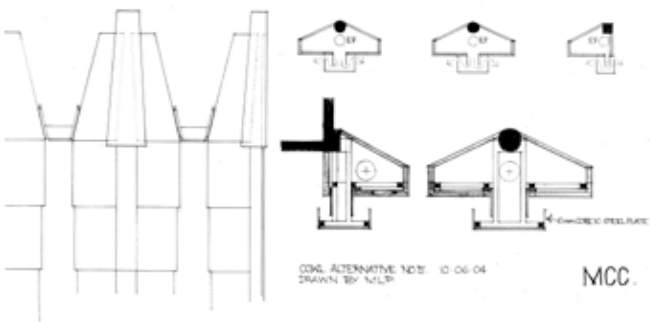


Figure 16. Long box cowl detail

Proposal 8 – Baffle cowl by AEC

This had some merit and provided an architectural solution at a reasonable cost. But it was found that by removing the top of the stacks and reducing their height by 1000mm, would not improve the proportion of the stack and hiding the tapering louvres at the top diminishes the expression of the original design. The architects felt that in order to style the baffle into a form which celebrates the image of CH2, considerable more expression would be needed. This would also increase costs.

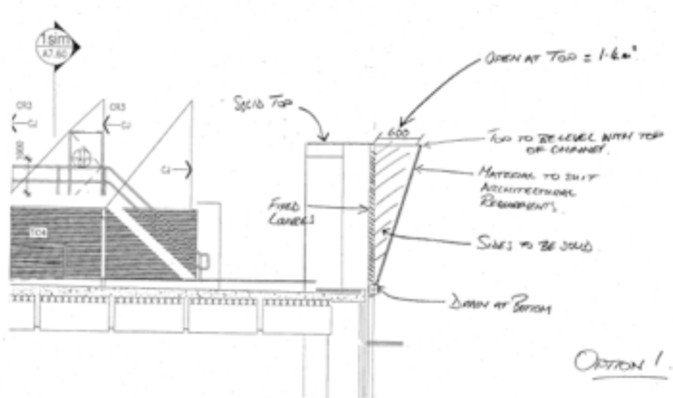


Figure 17. Proposal 8 - Baffle cowl

Proposal 9 – Through flow

AEC's final proposal was to add exhaust louvers on both sides of the tower. This would have to be modified as there is a column opposite the front vertical louvers. The design team felt that this proposal had little merit because the inside roof area is to be landscaped which would undoubtedly interfere with air flows.

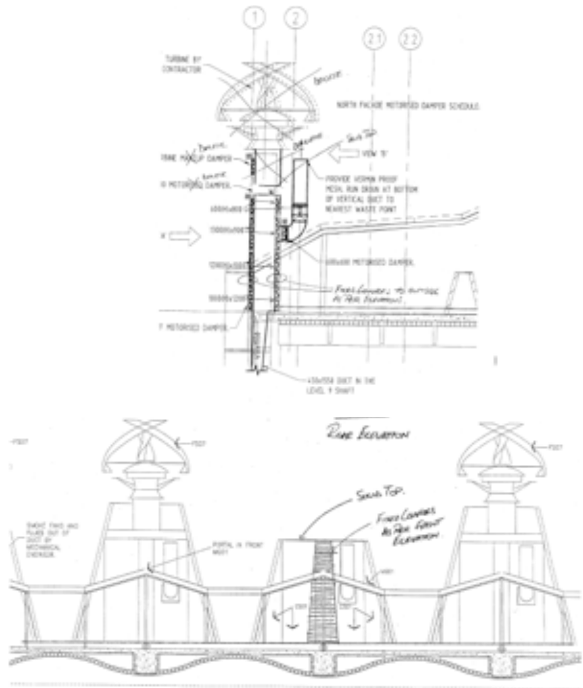


Figure 18. Proposal 9 - Through flow option

Proposal 10

The turbines will generate electricity by day and pull air out by night. The blade arrangement has been arranged so that the top part catches the wind and the bottom part pulls the air out of the shaft below.

Estimated cost $180 000

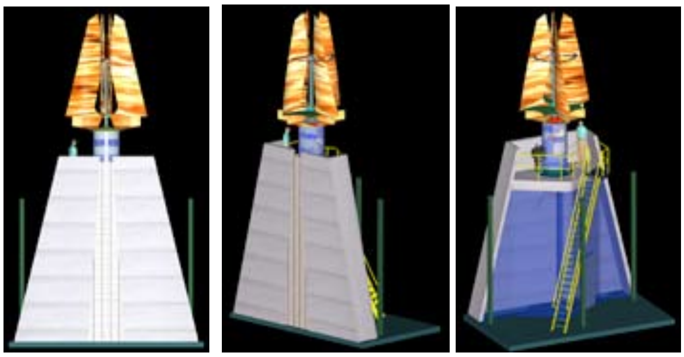


Figure 19 – Proposal 10

Conclusion

At this time the design team concluded that this summary of all the alternatives be made with the aim of reaching a final decision without further delay.

Generally the feeling was that we have exhausted all alternatives to the turbines and that now comparisons should be made based on the three following criteria;

1 Cost

2 Environmental advantage

3 Aesthetic merit

17 Wind Turbines

	Environmental advantage	Aesthetic merit	Cost
Proposal 1	Turbines = no resistance plus 6%	excellent	$ 180 000
Proposal 2	Oval cowl = no resistance	poor	$ 110 000
Proposal 3	Solar accelerator = no resistance	good	$ 160 000
Proposal 4	Reduced turbine = no resistance	good	rejected
Proposal 5	Minimal flat top = no resistance	acceptable	$ 130 000
Proposal 6	Copper top = no resistance	very good	$ 498 000
Proposal 7	Long box cowl = resistance ?	poor	$ 100 000
Proposal 8	AEC Baffle = no resistance	poor	$ 100 000
Proposal 9	AEC Through flow cowl resistance?	acceptable	$ 130 000
Proposal 10	Turbines – day power generation and night extraction	excellent	$ 180 000

Where resistance was recorded, this was due to air having to take a non linear route or a change in area in duct size. The forcing of air through a smaller pipe would increase its resistance and so losses within the system. Based on this study the initial wind turbine with wings was finally approved.