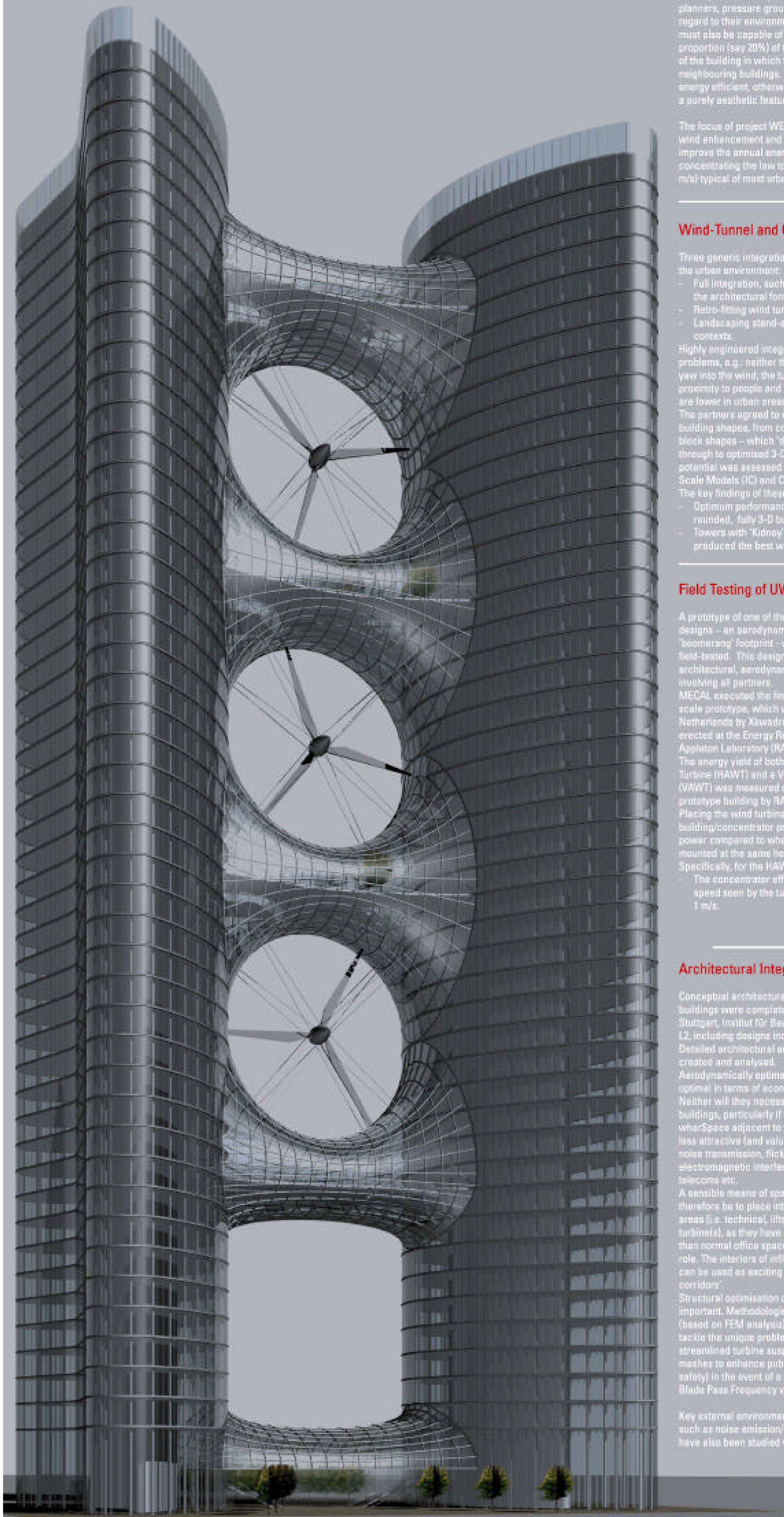
Wind Energy for the Built Environment

The Building as a Concentrator

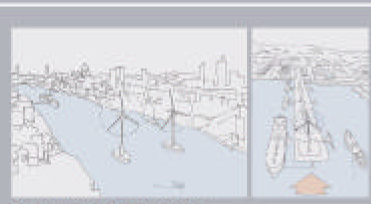


Introduction

Continuing planning problems with the siting of wind farms on land are driving development of huge offshore turbines. Instances of integration in the urban environment, closer to the prime consumers of energy, such as buildings, remain scarce.

Successful urban integration will require proposed developments to fully address the concerns of planners, pressure groups and the general public with regard to their environmental impacts. The turbines must also be capable of producing a significant proportion (say 20%) of the annual electricity demand of the building in which they are housed or of neighbouring buildings. These buildings must be energy efficient, otherwise the turbines risk becoming a purely aesthetic feature.

The focus of project WEB has been the development of wind enhancement and integration techniques, which improve the annual energy yield per installation by concentrating the low to moderate wind speeds (2-5 m/s) typical of most urban areas in Europe.



Stand-alone windturbines in urban locations

This involved balancing and reconciling aesthetic, aerodynamic, architectural, environmental and structural concerns. These techniques have been successfully demonstrated by the field-testing of a small-scale prototype building or wind concentrator with an integrated HAWT and VAWT during the project.

Draft guidance for UWECS developments has also been produced. The guidelines cover the conceptual design process and include methodologies for predicting energy yield, and categorising and assessing environmental impacts and economic costs.

'Wind Tower' placed offshore, University of Stuttgart

Wind-Tunnel and CFD Studies

Three generic integration techniques are available in the urban environment:

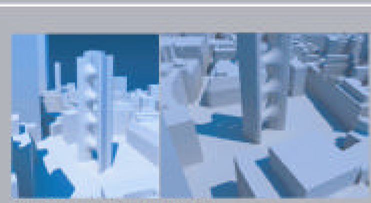
- Full integration, such that the wind turbines drive the architectural form;
- Retro-fitting wind turbines onto existing buildings;
- Landscaping stand-alone wind turbines into urban contexts.

Highly engineered integration faces some formidable problems, e.g.: neither the turbine (nor building) can yaw into the wind, the turbines will be in close proximity to people and property; mean wind speeds are lower in urban areas.

The partners agreed to explore a wide range of building shapes, from conventional square-edged block shapes – which "don't work" aerodynamically - through to optimised 3-D shapes. Their aerodynamic potential was assessed using Wind-Tunnel Testing on Scale Models (IC) and CFD Simulations (BDSP).

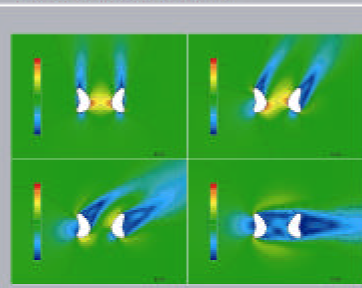
The key findings of these energy studies are that:

- Optimum performance is obtained for smooth, rounded, fully 3-D building forms;
- Towers with 'Kidney' or 'Boomerang' footprints produced the best wind enhancement.



Multi-Turbine UWECS located in London, BDSP

- Aerodynamic wings or 'infills' connecting the towers and creating a close fitting 3-D aerodynamic duct shape (hole) around the turbine are highly effective. They prevent separation of flow and loss of wind enhancement.
- Good wind enhancement can be obtained for angles of incidence up to 40°-50°, and appreciable flow through an aerodynamic ducted hole can even occur at very acute angles;
- the level of power enhancement will be proportional to the increase in mass flow rate through the swept area of the turbine (i.e. to the mean wind speed rather than the cube of mean wind speed). The maximum instantaneous power enhancement factor will be less than 2.



CFD results, Boomerang profile, BDSP

Visualisation of Streamlines in Flow, Imperial College

Field Testing of UWECS Prototype

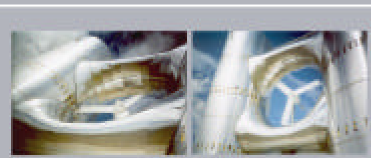
A prototype of one of the most promising UWECS designs – an aerodynamic twin-tower building with a 'boomerang' footprint - was built and successfully field-tested. This design evolved through a series of architectural, aerodynamic and structural studies involving all partners.

MECAL executed the final structural design of the 1/7th scale prototype, which was fabricated in the Netherlands by Kkwadraat (K2); shipped to the UK and erected at the Energy Research Unit at the Rutherford Appleton Laboratory (RAL), near Oxford.

The energy yield of both a Horizontal Axis Wind Turbine (HAWT) and a Vertical Axis Wind Turbine (VAWT) was measured outside and inside the prototype building by RAL (with and without infills). Placing the wind turbines inside the building/concentrator produced considerably more power compared to when they were conventionally mounted at the same height on an open site.

Specifically, for the HAWT testing:

- The concentrator effectively increased the wind speed seen by the turbine by a significant 1 m/s.

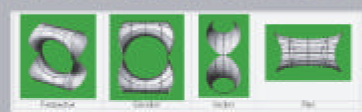


Full scale model, Mecal/Imperial College/BDSP

- The integrated turbine produces enhanced power output for awide range of incident wind angles (+/- 75degs) onto the building.
- The addition of the infills further enhanced concentrator performance (particularly at acute wind angles).

Extrapolating the results, using a calculation method developed during the project, suggested that a scaled-up building with an integrated HAWT would produce at least a 25% increase in annual energy yield in a typical urban setting over a stand-alone machine. Further gains could be realised if the turbine(s) could be safely mounted higher from the ground, thereby benefiting from higher atmospheric wind speeds.

Future testing at a larger scale with bigger, higher inertia wind turbines will be required to confirm these findings.



Computer Model of connecting "infills" between the towers

Architectural Integration

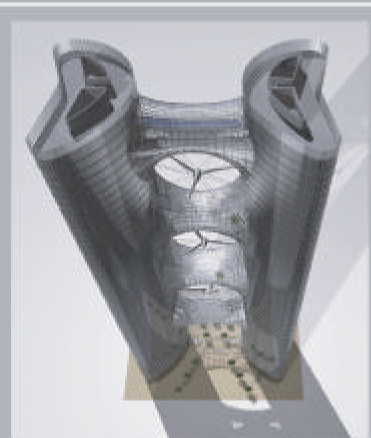
Conceptual architectural designs for several full-scale buildings were completed by the University of Stuttgart, Institut für Baukonstruktion und Entwerfen, L2, including designs incorporating multiple turbines. Detailed architectural and computer models have been created and analysed.

Aerodynamically optimal designs may prove sub-optimal in terms of economic organisation of space. Neither will they necessarily produce energy efficient buildings, particularly if they contain deep sections wherSpace adjacent to the turbines will inevitably be less attractive (and valuable) due to concerns over noise transmission, flickering of the rotating blades, electromagnetic interference with computers and telecoms etc.

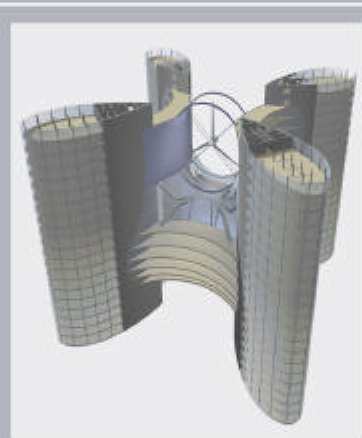
A sensible means of spatial organisation would therefore be to place intermittently used or service areas (i.e. technical, lifts, stairs, cores) adjacent to the turbine(s), as they have less demanding requirements than normal office space and can provide a buffering role. The interiors of infills linking twin tower buildings can be used as exciting transitional spaces or 'sky corridors'.

Structural optimisation of UWECS is particularly important. Methodologies and prototype designs (based on FEM analysis) have been developed to tackle the unique problems posed by UWECS, e.g.: streamlined turbine suspensions from buildings; safety meshes to enhance public safety (and perception of safety) in the event of a turbine failure; solving the Blade Pass Frequency vibration problem etc.

Key external environmental factors for urban sites such as noise emission/propagation and visual impacts have also been studied via computer modelling.



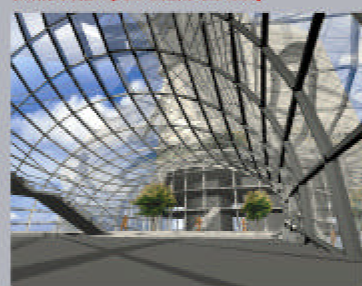
Twin Tower Building with three integrated HAWTs, University of Stuttgart



3D section of a 36m high Omni-directional Tower Building

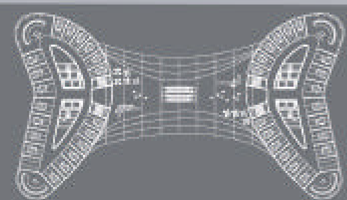
For a multi-turbine twin tower building, providing that techno-economic and environmental constraints can be satisfied, the integrated turbines could provide 20% of the annual electricity demand of the building (i.e. lighting; computers; plant and equipment) based on an achievable average capacity factor of 0.1 - 0.2.

These designs represent a demonstration of how the concept of integrating wind energy into buildings (UWECS) might ultimately be expressed. The same principles could be utilised on a more modest scale or in the form of 'energy or wind towers' – i.e. unoccupied structures used to generate electricity that could be placed on- or offshore.



Twin Tower, aerodynamically shaped Connection-Floor

Twin Tower, typical floor plan



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