Assessing the Urban Microclimate:
Introducing innovative modelling techniques

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ABSTRACT

This paper introduces a new EU-funded research project ("PRECis - assessing the Potential for Renewable Energy in Cities") and summarises the findings of a recently completed project ("Project ZED - towards Zero Emission urban Development"). Project ZED demonstrated the potential of defining key urban form characteristics, using image processing software, and linking these to environmental performance of a section of a city, assessed using computer and physical simulation. Project PRECis goes on to refine and validate this work by relating the theoretical work to actual urban projects as well as microclimatic and energy use data. The result of the research is the development of a simplified urban bioclimatic design tool which responds to intermediate or neighbourhood scale issues.

INTRODUCTION

Cities present us with a dilemma. On the one hand, the concentration of activities provides a necessary and stimulating social, cultural and economic milieu. On the other hand, the high density of buildings and transport use consumes energy and generates atmospheric and noise pollution. This degrades the urban microclimate, which affects both the well-being of people and, crucially, by increasing the demand for sealed indoor environments and air-conditioning, the success of low-energy building design strategies. Air-conditioned and artificially lit buildings can typically double building energy use (and buildings account for half of our total energy consumption). In addition, uncomfortable [1] and unhealthy urban conditions discourage people from walking, cycling or using public transport, thereby encouraging private vehicle use, which in turn leads to more energy consumption and atmospheric pollution. Poor urban microclimates thus have significant implications for energy use as well as health.

However, it is clear that urban microclimates vary considerably, both from city to city and within cities, some areas, for example, being more effectively ventilated by wind than others. This variation can be seen to result from a complex interaction between urban form, climate and human activity. Urban form interacts with climate in other ways too, particularly in relation to solar access, with implications for daylight availability and passive solar design solutions, as well as active solar systems (collectors, photovoltaic cells, etc.). In other words, if we are to extend renewable energy use in cities (which is now where most Europeans live and where most building stock is located), there is an urgent need for developing tools to facilitate bioclimatic urban design.

Unfortunately, no simple methods currently exist that can characterise the microclimate of urban areas at a neighbourhood scale, that is to say at the intermediate scale between the city block and the city region. Individual techniques, such as CFD, allow environmental effects around buildings to be investigated, but they tend to be cumbersome and expensive to use, and to require specialist training. Moreover, there is at present no way of summarising such effects for an urban area as a whole and comparing them to established norms; the urban equivalents of minimum Daylight Factor or air changes per hour have not yet been defined.

However, recent research at the Martin Centre has shown that through the application of image processing techniques to three-dimensional urban textures, connections can be made between urban form, microclimatic characteristics and the potential for renewable energies. This opens up the possibility of a significant advance in predicting urban microclimates and in being able to evaluate, without the need for elaborate models, the environmental impact of alternative proposals for change. These could relate either to a major new development and its immediate surroundings or to incremental measures for gradually improving the environmental performance of an existing area as a whole.

The central purpose of the research described in this paper is to characterise the microclimate within cities in relation to urban form. The specific aims are:

• To describe a simplified urban porosity model [2] that defines the microclimatic characteristics of an urban texture, in overall terms, so that as the physical form of the urban texture is changed, the likely effect on environmental conditions, energy use and the potential for renewable energy can be determined.
• To demonstrate the application of the model and the environmental assessment techniques involved to a selection of representative existing European urban textures.

• To show the application of the model and associated techniques to case study urban sites where major interventions are planned so that alternative proposals can be assessed, and in this way demonstrating the role of the model as a practical bioclimatic urban design aid.

**PROJECT ZED**

The full title of this project was: "Project ZED: Towards Zero Emission Urban Development – The interrelationship between energy, buildings, people and microclimate" [3, 4]. It was coordinated by the Martin Centre, funded under the European Commission’s APAS Programme (DGXII) – contract number RENA-CT94-0016 – and was completed in 1997. The contractors were:

• The Martin Centre for Architectural and Urban Studies, Department of Architecture, University of Cambridge

• Future Systems (architects, London)

• RP+K Sozietät (services engineers, Berlin)

• BDSP (environmental engineers, London)

• GRECO (School of Architecture at Toulouse)

• TÜV Rheinland (Köln).

The objectives of Project ZED were: to analyse and understand the pattern of various urban typologies from planning, microclimatic and energy use perspectives; to use this knowledge to develop new analysis techniques [4]; to use the findings and existing expertise to inform design interventions that demonstrate innovative strategies which result in zero emission urban development [5]; and to propose a framework for dissemination and education [6] (Figure 1).

Of particular relevance here is the theoretical research to understand significant environmental aspects of the urban context. In order to determine the energy potential of buildings in the urban context it is necessary to be able to determine the nature of the urban microclimate. Little understanding exists in terms of the relationship between complex urban form (and therefore questions of planning) and the microclimate (closely related to energy, comfort and health issues). This work has developed innovative and simplified techniques and shows how they can be used to predict the relative environmental performance of any part of a city, either existing or proposed.

The theoretical research carried out for this project demonstrates the significant relationships between urban form and environmental characteristics. In particular, the processes of radiation exchange and ventilation of urban interstices show a good correlation with urban form parameters. The increase in solar energy absorption within urban texture correlates well with the volume to surface ratio. And street ventilation as a function of wind direction relates to the directionality of ‘permeability’ described by the ‘permeability rose’, a new urban form descriptor defined in the project. Such new urban form parameters have been developed in this project and can be extracted using relatively simple image processing techniques to analyse any urban texture (Figure 2).

Project ZED has demonstrated the validity of a simplified urban microclimatic model, describing the key environmental processes that influence building energy use, renewable energy and environmental quality. The urban parameters enable the intermediate scale to be modelled with more detail than existing regional climate models, yet not requiring the precise description of individual buildings. The model provides synoptic results rather than single time frame snapshots.

It is thus possible to analyse urban form in relation to environmental performance (i.e. the urban microclimate). This can then inform the design of urban projects which minimise energy demand and provide on-site renewable energy to meet this demand, with the target of zero emission. Finally, the knowledge and information gained can be made accessible to a wide range of decision makers to inform the way forward Towards Zero Emission Urban Development.

**PRECIS**
The current research project is entitled: "PRECis: assessing the Potential for Renewable Energy in Cities – The characterisation of urban microclimates, urban form and the environmental factors affecting renewable energy use.” It is coordinated by the Martin Centre, funded by the European Commission's JOULE Programme (DGXII) - contract number JOR3-CT97-0192 – and commenced in February 1998. The contractors are:

- The Martin Centre for Architectural and Urban Studies, Department of Architecture, University of Cambridge
- CFD norway (CFD experts, N)
- Ecole d'Ingeneurs de Fribourg (Radiance experts, CH)
- Centre for Renewable Energy Sources (CRES, GR)
- Politecnio di Torino (POLITO, I)
- Municipality of Grugliasco (GRGL, I)

The main objectives and technical approach are summarised below:

1. To establish quantified generalised relationships between microclimatic characteristics at a neighbourhood scale and the geometric morphological properties of urban form.

2. To develop a simplified urban model that describes the microclimatic characteristics of urban texture so that as the physical form of urban texture is changed, the likely effect on environmental conditions, energy use and potential for renewable energy can be determined.

3. As a first step in validation, to apply the model and environmental assessment techniques to a selection of 12 representative existing European urban textures.

4. To apply the model and associated techniques to three detailed case study urban sites in Italy, UK and Norway, where major interventions are planned so that alternatives can be assessed in collaboration with the municipalities.

5. To assist municipalities, and for use more widely, in drawing up of bioclimatic urban design guidelines and potential implications for bylaws, legislation, etc.

The principal beneficiaries of the project will be planners, architects and related urban professionals, for whom the model will be a major advance as a bioclimatic urban design aid, applicable throughout Europe. It will provide an objective means of assessing the environmental impact or potential of incremental or major urban change. The project will thus have wide applicability and contribute to enhancing the quality of life through improved urban environments.

REFERENCES


