5. CAPE White Paper

A Vision for the 21st Century Built Environment

Can a new aesthetic be conjoined with new technology to meet simultaneously the challenges of climate change and improvement in the quality of life?

Introduction

In a world view coloured by concern over climate change there is an irony that the built environment has yet to reflect substantially the changes required in societies' usage of energy and their overall consumption. Over 40% of the total power produced is consumed in the built environment, with space heating, cooling and lighting within buildings accounting for 33% of the UK's end user energy consumption. A lot of that energy is wasted; both in conversion (thermal to electrical) and in transport (transmission losses) and finally, in poor utilisation (inefficiencies and poor thermal management in the premises).

It is also true that modern society has changed substantially with respect to the nature of consumer goods and their usage, and in peoples' lifestyles. Much of this change is in response to what has become called the "knowledge economy". Familiar to most of us it is, nonetheless, little understood how profound and far- reaching these changes have been. With the World-Wide Web, digital broad-cast and mobile "players", it is now becoming clear that much of an individual's leisure and entertainment needs are digitally based. Similarly, the mobile telephone and computing devices have freed many from the office and enabled a mobile and flexible lifestyle.

The coupling of these shifts in technology with a societal need to effect changes in energy management and usage must surely represent one of the "Grand Challenges" for the 21st Century.

The UK, like other developed nations is, however, burdened with an ageing and underperforming built environment, e.g. newly constructed buildings constitute less than 1% of the building stock annually. If meaningful improvements to the built environment and quality of life are to be achieved, efforts to improve the performance of future buildings must be accompanied by cost-effective technological innovations for upgrading existing buildings.

Herein, we will show how contemporary developments (in light control films, thin-film photovoltaics, active waveplate and antennae structures, transflective displays and advanced transparent conductor technology) can be brought together within a programme focus which will both credibly progress businesses and assist in meeting societal imperatives.

The Scattering and Control of Radiation by the Facades and Apertures of Buildings

Aspects of the efficiency and functionality of buildings that may be strongly influenced by the flow of electromagnetic radiation, within and without the structures of buildings, range from the use of surface nano-structures for anti-reflection coating or self-cleaning of windows and photovoltaic panels, to the accidental production of 'dead-spots' at the frequencies used for digital broadcasting by the 'photonic crystal' effects of building structures and frameworks.

The radiation wavelengths involved can range from below a micron to tens of metres, i.e. from the near ultra violet, through the visible and infra red to terahertz, microwave and radio radiation.

Technology, by manipulating these wavelengths, can actively control aspects of the building's fundamental operation; its aesthetics (appearance and outlook), the communication of information within and without it (including internal and external optical and wireless communications, privacy and municipal signage) and the energy and illumination balance between the building and its environment.

Some aspects of this control have been with us for some time, but the pace of developments in such areas as nanotechnology, antennae design, photovoltaic, optical and wireless communications, bright reflective digital signage and 'smart windows' technology suggest that the time has arrived for taking a more holistic view of these possibilities.

Some of these aspects may employ related technology and could be integrated into common structures e.g. using transparent conductors and polymer layers, switchable liquid crystal films and nano-particle suspensions, and are indicated below.

- *Reducing energy demand and enhancing comfort* - The facades of buildings, their outlook and the visual privacy of those inside are controlled by the absorption, reflection and transmission of light from and through its surfaces and windows. The solar gain and energy balance on the other hand depends on visible and infra red radiation through the building fabric. The active manipulation, and particularly the selective transmission of visible and infra red radiation, offers substantial benefits in terms of heating and lighting energy consumption, visual and thermophysiological comfort and occupant well-being. This technology involves actuated switchable liquid crystal and chromogenic films and nano-particle suspensions.
- *Integrated renewable energy production* - In addition to the transmission of radiation across the building fabric the energy balance is also affected by the use of micro-generation devices (such as photovoltaics) and heat exchanging technology, which present opportunities of transforming the building envelope from energy sink to energy source.
- *Integrated communications capability* - Communications signals will be distributed to wireless network nodes by fibre optics and delivered to the mobile end users by wireless frequencies with wavelengths from centimetres on downwards. Transmitting and receiving antennae and related

structures for controlling the ingress and egress of these signals may be integrated into the building fabric, especially into its windows. In principle these could be active control structures using phase arrays and beam steering. This technology is liable to involve transparent conductor technology, radio frequency, photonic crystal structures and transparent tuneable dielectrics.

- *Enhancing interactivity and streetscape quality* - The way in which pedestrians perceive and interact with buildings (particularly with facades) has a major impact on the sense of well being and the value of a neighbourhood. Aesthetic design and ancillary interactive functions may be provided by user selectable ambiance "art-works" through the deployment of electronically addressable reflective display panels at much lower cost and greater energy efficiency than standard FPD.

This theme unites applications being addressed within CAPE, the Engineering Department, and the Cambridge IKC. These include: active privacy and solar control glazing, large area reflective colour displays, photovoltaic technology, optical and radio communications in metropolitan and municipal areas, sub-wavelength and tuneable radio and microwave antennae.

CAPE engagement with Energy and the Environment

ALPS Electric and Dow Corning are already engaged with many of the technologies and market sectors that will be harnessed to address these societal needs. They also have corporate policies to support these aspirations.

We believe that there could be significant benefit to the processes of business development in taking a strategic overview of this area and that this would require the help and support of appropriate supply chain partners.

The objective is to exploit this viewpoint and market oversight by undertaking targeted cross-disciplinary research to support the imperatives of business of our collaborators and of environmental sustainability.

To achieve this objective, we will require a wide partnership of expertise, not all of which exist within the present CAPE structure. We therefore propose that:

- the Cambridge University Structures and Environmental Engineering Group and the Sustainable Development community in the University should be invited to sit alongside the representatives of the current CAPE Partners in confidential discussions on this theme; and
- that we should invite representatives from international companies (who are currently not part of CAPE) from the architectural community, building design companies and a perhaps major manufacturer of building fabrics and facades to participate in advisory group discussions in this technological area.

The specific goal of this CAPE programme that it aims to initiate would be:

To create specifications and demonstrate feasibility for the manufacture of responsive and high performance functional control structures and panels (both glazing and other) which can be integrated into the built environment. In so doing, the programme will provide functional elements designed for 21st Century life-styles whilst also improving energy efficiency and use-ability.

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