

URBAN DESIGN AND CLIMATE CHANGE WITH EMPHASIS ON ENERGY

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In the context of climate change urban design has a dual role to try to limit and adapt to the consequences of climate change. The role of urban design may have been neglected because it deals with a complex set of dependent parts which are hard to quantify. Understanding urban design and climate change means looking beyond the merely technical solutions that deliver energy to meet demand with less carbon emissions. Urban designers are well placed to reassess the patterns of living and building which have turned an energy-hungry modern world into a physical reality.

INTRODUCTION

- > One of the role of urban design is to assist in adapting the built environment to climate change resulting from global temperature rises due to greenhouse gas emissions occurring due to human activity on the planet. Urban design can be an enabler for other disciplines to reduce energy and material consumption – making the job of campaigners, architects, and engineers easier and in some cases even possible at the sharp end of the fight to limit climate change.

WHAT IS THE SUBJECT?

- > In an age of global climate change and carbon emission reduction targets, the energy efficiency of urban development is an important professional and political factor in the planning of our towns and cities. The quantity of energy use from electricity generation, buildings, production and transport are easily compartmentalised. They are only documented at the national level (by the Department of Energy and Climate Change 2009) as part of the fulfilment of the Kyoto Protocol which expires in 2013. The idea of energy use, climate change, and its relationship to urban design is related to the environmental aspect of

sustainability which aims to be balanced with social equality and economic performance. The balance between these three aspects should be considered in the strategic environmental assessment of any development project.



1. Von Borcke's assessment of current and future sustainability balance

source: von Borcke, 2003

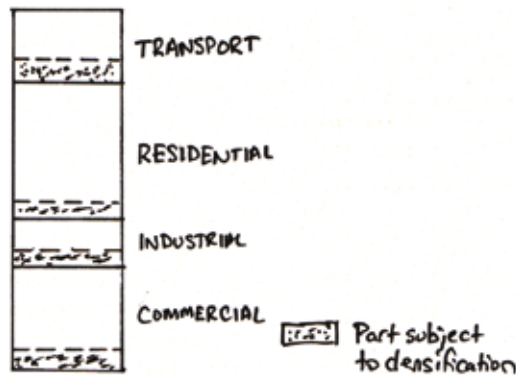
Under the European Sustainable Environmental Assessment Directive 2001, an environmental report must be made to assess the environmental impact of a land use proposal and any viable alternatives possible on the development site. In the context of many member states, including the United Kingdom, the social and economic impacts on the area are also considered in the report. Planners, politicians, and developers tend to feel more comfortable with the social and economic issues facing the site while the environmental side of the assessment is seen as too technical to understand. These issues are therefore dealt with in a superficial manner without much assessment of the meaning or context of the data produced for contamination, energy use, pollution, and waste.

The subject of energy use in urban planning comes under the European Energy Performance of Buildings Directive 2010, which is replacing a 2002 directive of the same name. Currently, there is a requirement for each member state to develop a minimum standard on the energy performance of new buildings and extensively renovated existing buildings over 1000 square metres. All public buildings must have a prominent display of their energy performance. The methodology should include all the aspects which determine energy

efficiency and not just the quality of the building's insulation. This integrated approach should take account of aspects such as heating and cooling installations, lighting installations, the position and orientation of the building, heat recovery, etc. A future directive will force all countries to calculate minimum energy requirements of all new and renovated buildings (without a minimum floor area) according to one European benchmarking methodology. By 1 January 2021, all new buildings, including existing buildings undergoing major renovation, will have to meet 'very high energy performance' (called 'almost zero-carbon' buildings) standards. The directive will also require an energy performance rating for any building constructed, sold, or rented out.

> Government initiatives to limit energy use in the built environment have recently been led by energy conservation in buildings and the use of renewable energy on building sites. In the European Union, buildings account for 41% of all energy consumed with less than 25% each for transport and industry (Steemers, 2003). Significant amounts of research have been carried out on energy efficiency in housing. Mitchell gives a thorough overview of the current literature and methodologies for measuring urban development, form, and energy use in buildings (Mitchell, 2005). In the UK, the Building Research Establishment and the Department of Communities and Local Government have conducted or commissioned extensive research on the efficiency of domestic building types. Energy use in domestic buildings, and their subsequent CO₂ emissions, are assumed relatively well understood (see work of the Building Research Establishment in the UK and the SP Technical Research Institute in Sweden quoted in Mortimer, Ashley *et al.*, 1999). Contemporary developments in energy research has gone beyond dwellings, for example in energy models on the performance of the non-domestic buildings stock at UCL which have classified non-domestic buildings by their size and type (Bruhns, Steadman *at al.* 2006).

However, Ratti *et al.*, (2005) noted that little is known about the impact of urban form and geometry on the energy performance of the building stock taken into its entirety. This debate is taking place without the necessary aggregation of data to identify the amount of energy savings that are directly gained from urban design, as a separately measured aspect of energy use from energy efficiency improvements in buildings, enhancements in transport technologies, or modal split. The environmental value of good urban design is often lost for urban designers and planners as it takes more effort and time to evaluate than is available within a development or a masterplanning budget.



2. The kind of statement that urban designers will eventually have, once they have enough relevant data

The reason for this is the focus on building physics in research on different building envelopes that can reduce the energy needed for space heating, the largest component of energy use in buildings (about 85% in the United Kingdom). The terminology that building scientists use as part of their work include insulation thicknesses, U-values (the air resistance of materials), indoor temperatures, heating system performance, ownership of appliances. The uncertainties surrounding these variables are compounded by poor availability of disaggregated energy use data, poor availability and unreliability of data on

the real permeability of surfaces, as well as very limited possibilities of correlating energy data with physical variables. Meanwhile, the rise of 'gadgets' and electronic equipment is real. Data from the current Domestic Energy Fact File for the United Kingdom reveals that from 1970 to 2006, the energy consumption of lighting and appliances grew by 148% compared to 23% overall (Sharrock, 2008).

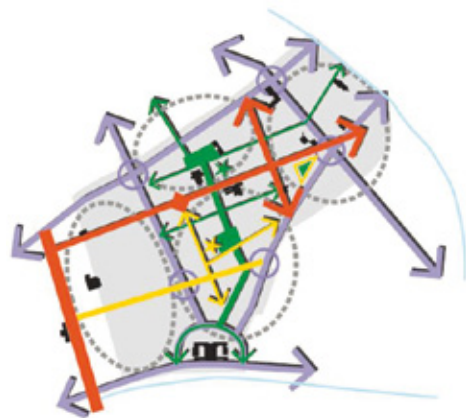
- > For the urban designer, electricity use is related to the reduction of demand caused by high quality public spaces or transport nodes that take people into public areas and draw people out of their home. Conversely, bad design that increases commuting can also reduce hours spent in the home, so urban design may be relatively neutral in relation to energy use.
- > A final issue is how the political realm is perceiving the role of urban design in mitigating climate change to reduce demand. In public life numbers rule: big is better than small, or vice versa, no matter what context may be established. In the case of urban life and impacts of humans, politicians will use anecdotal evidence instead of established qualitative research methods devised by academics. An exception to this is polling and focus groups which are quantitative albeit subjective exercises, such as what percentage of participants agree with a statement, etc.

BEHAVIOUR CHANGE: THE EXAMPLE OF TRANSPORT

- > In current policy and practice urban design deals with indicators of quality of life. This is the most natural space for urban design to have an impact on climate change (Department for Communities and Local Government, 2007). The form and spatial pattern of settlements – where people live, work and shop, and the available choice of how they move about – are a fundamental driver of demand for and consumption of energy (Council for European Urbanism, 2008). These drivers are evident in the objectives of urban design promoted in England and Wales: character, continuity and

enclosure, quality of the public realm, ease of movement, legibility, adaptability, and diversity (DETR, 2000).

The most visible change is in transport modes. The layout of any good urban structure that connects places to each other integrates land use and transport, specifically public transport, walking, and cycling (Department for Transport, 2007). These urban design principles were adopted before considerations for climate change and carbon emission reduction, and they are still valid today. Security is often cited as a reason for illegible and impermeable streets and spaces. Guidance still holds that natural surveillance and designing routes that are overlooked and busy enable the design of housing layouts to make a major contribution to both the prevention of crime and the reduction of fear of crime (Association of Chief Police Officers, 2004). Conversely, legible and accessible spaces contribute greatly to the job of campaigners to promote green travel, and for transport planners to increase the amount of services and convenience of public transport, cycling, and walking.



3. Example of Legible routes, streets, and spaces

source:
DETR, 2000

> The co-location of uses in a neighbourhood is a key area for reducing demand for transportation energy use in a city. Increasing local facilities in an area reduces the propensity to travel further. The viability of large scale facilities such as supermarkets, leisure centres, and health centres have to be considered, but it depends on the existing city structure. A city with a polycentric structure enables the clustering of high quality facilities in its centre, as well as in secondary locations with equal catchment areas. Locating basic facilities such as a primary school, a health facility, or a corner shop within a distance of 400 to 500 metres would reduce many trips to walkable distances. However, the viability of each of the above facilities is related to the local population, and about 2,500 people, or about 1,000 dwellings, would be a workable minimum to allow this to happen. In density terms, this translates to about 100 dwellings per hectare, or around a 1:1 floor to development area ratio, with the assumption that development sites are around 60 percent of the gross area and dwellings have an average of 100 square metres of gross floor area. Different land use and transport models are available (e.g. the LUTS model at the Martin Centre of the University of Cambridge and University College London as part of the Solutions project cited in Mitchell, 2005).

REDUCING RESOURCE CONSUMPTION AND DEMAND

> Emissions from transportation is a major contributor to climate change, but it is far from the only consideration for an urban designer. Urban design can also lessen resource consumption. The effects of infrastructure, embodied energy, building operation energy, locational inefficiencies, lost ecosystem services, lost opportunities for cogeneration, and urban settlements can all induce more demand for energy, resources and emissions-producing activities (Council for European Urbanism, 2008). Higher urban density can promote shorter road lengths, higher intensity public transport options, and a range of uses that can be collocated;

conversely, hyper-density can increase dependence on mechanical ventilation systems and high building material consumption.

Urban design can help reduce the dependence on energy to heat and provide electricity in the building stock. Good use of aspect ratios and street trees can allow solar gain for heat and prevent it when the air is warm, and they are more desirable than energy-hungry climate controls (Baker and Steemers, 1999; Homes and Communities Agency, 2007). Designing streets that allow architects to design groups of buildings with more common parts, from just a party wall to green spaces or even services can be a great contributor to saving both energy for running a building and the resource consumption of building at the start of its life cycle (Williams, 2002). Retaining the concept of the block and plot with some basic rules on cores encourages diversity and adaptability of the urban form, and saves energy in the long term by allowing new individual solutions for incremental growth, instead of a single complex system that is not easily upgraded using new advances in renewable energy technologies (London Renewables, 2004; Mayor of London, 2009). Suburbia and low density uses can be redesigned to facilitate lower energy consumption and to ameliorate resource heavy lifestyles (Dutton, 2000). The approach of urban design as an enabler for reducing resource consumption in construction and running energy cost of our domestic, work, and leisure lifestyles is valuable and should be encouraged as a prerequisite before investing in new technology in renewable energy generation or green roofs and walls.

OVERALL PICTURE

The amount of energy used by an entire community encompasses many facets of human life: food, goods, household waste, local transport, electricity, and heating are all related to activities in buildings. Three questions emerge from the need to reduce energy:

- which strategies equated with energy-saving or energy producing devices, are appropriate to use?

- what is the impact of intensifying urban form on the ability of buildings to perform as expected?
 - what is the appropriate application of these devices on a development site or in a collective arrangement?
- > The devices generally available to reduce the energy requirements of a housing area are solar gain of light and heat for space and water, passive ventilation, and on-site electricity generation. Solar energy for residential properties enables energy to be saved that would otherwise have been needed from electricity for lighting the interior of the home and from natural gas to run boilers that provide hot water for both radiators and water systems; natural ventilation of properties which makes installations of mechanical ventilation systems pushing warm or cool air through the building unnecessary. On-site electricity generation which provides electricity for the use of lights and appliances in the home, is another solution, together with heating and cooling through the use of electric heaters or a heat pump, depending on the site conditions.
- > Densification of cities has an impact on the amount of energy used in a residential building, such as party walls shared by two buildings to provide a direct physical contacts between them. Research shows that the lack of direct responsibility of any one property owner leads to neglect of leakage of heat or air permeability (Chapman, Lowe et al., 1985). At neighbourhood level it is possible to establish the respective responsibility of people for emitting dioxide carbon into the atmosphere. From raw data of energy use and carbon emissions in the city, it seems to appear that people living and working in the central city are the main culprits of carbon emissions. However, research by the Center for Neighbourhood Technology in Farr (2008) reported that measured per person, it quickly emerges that people living in the high-density areas of the city are less 'culpable' of carbon emissions than those in low-density suburbs. This should back up the intuition of urban planners about what influences the energy intensity of the city.

On-site electricity generation using photovoltaic cells, combined heat and power systems and wind micro-turbines for the generation of energy in residential developments needs closer examination. Such sites could be defined either as the plot of an individual building or the combination of plots into a unified whole, ranging from an urban block to the scale of an urban neighbourhood. The use of photovoltaic (PV) cells depends on the amount of sun that can reach the panel, usually erected on the roof of a building (or on the façade, etc). Combined heat and power systems generate electricity retain the heat involved in the process to provide heat to buildings. There is mass scepticism amongst energy engineers regarding the use of wind turbines on individual buildings, as they are not efficient enough to make a notable change in most temperate climates such as northern and central Europe (Bahaj, Myers *et al.*, 2007; Monbiot, 2009). In many situations, renewable energy produced by collective systems such as wind farms or solar farms is more effective in terms of money spent per kilogramme of carbon dioxide saved. However, this is public investment and borrowing, and the financial climate of 2010 is a salient brake to this type of thinking. Instead, favourable tariffs put in place by many European countries such as the UK are encouraging private investment on individual sites which also comes from the public purse and goes to individuals, not even small communities; moreover there is a EU directive which focuses on wind turbines to the detriment of solar and CPH.

PASSIVE SYSTEMS: SOLAR AND VENTILATION

Solar energy methods are the traditional way of addressing the amount of energy that are used in a building. The amount of daylight reduces the need of using electricity to light a building and passive solar heat gain reduces the amount of energy needed for space heating. There are also devices that convert solar rays into electricity through photovoltaic (PV) cells and to heat water through solar hot water systems. In the context

of generally cool, temperate countries such as the United Kingdom or Poland, the urban designer should be optimising the amount of building skin that is facing the south. If one is designing a normal street grid, this would result in east-west rectangular blocks. In the context of PV cells or hot water collectors, about 90 per cent of the potential output can be retained by being up to 30 degrees from the south.

- > As a general rule in northern climates, the more sun available the better, but the problems of overheating need to be considered as well by using devices such as shutters (especially in countries with summers with temperatures over 30 degrees in southern and central Europe), street trees, and awnings. It is possible to achieve high levels of natural light penetration within a tight urban form with streets that are less than 12 metres wide. But a balance needs to be struck between new development and the constraints imposed by local settings, particularly in relation to the land use and street pattern of surrounding areas and the height and roof-scape of other buildings. This should be incorporated into housing guidance – for example, the London Housing Design Guide requires that glazing area of any external wall should not be less than 20% (Mayor of London, 2009).
- > Passive ventilation methods are another way of reducing the energy required for heating and cooling a building. Urban air quality is usually very poor. One guideline for simple residential development is to ensure that rooms with one external wall have a depth of no more than 2.5 times the floor to ceiling height. With two external walls, this can double to five times the floor-to-ceiling height. This does limit the depths of blocks, especially in high-density areas where flats are commonly found to be single-aspect, or having one external wall (Ritchie, Thomas, 2009). In office and commercial buildings, the situation does get much more complicated. One recent solution, for example, is to have a false floor to supply air from under floorboards.

**ONSITE GENERATION:
 WIND AND DISTRICT HEATING**

On-site energy generation is a multi-faceted issue concerning solar, wind, and district heating solutions. Planning rules have previously used a simplistic minimum for the amount of on-site renewable energy. In the UK, this is called the ‘Merton’ rule after the name of the London borough that first mandated a 10% minimum for any normal planning permission. However, complex urban areas cannot always follow these types of minima, and some collective pooling of renewable energy generation should be considered as part of any city’s pledge to use more on-site sources.

Photovoltaic solar panels (PVs) can generate electricity that can directly operate lights and appliances as well as heating and cooling systems in certain circumstances. In the case of passive solar heating and day lighting, the height of the top of a standard window (2 metres above ground level) determines the effectiveness of the sun if sunlight is intended to come directly into the window all year, including the winter solstice. In most of Europe, this would cause the design of streets to fail one of the premises of urban design to provide continuity and enclosure of the street appropriate to its use, especially in residential streets of 4-5 storeys where the expected distance between buildings would normally not be more than around 18 metres (DETR, 2000; Llewelyn-Davies, 2003).

Wind turbines as a source of on-site renewable energy have recently been discredited in the academic and popular science press after the practice had been heavily promoted by politicians in Europe and the United States. Studies in urban areas have found that the energy yield was particularly low, especially if placed below the height of the rooftops (Heath, Walsh *et al.*, 2007). The key for this type of approach is the concept of embodied, or embedded energy. In a normal wind farm, the carbon savings meet the carbon needed to build and install the turbine (embedded energy) at around 3-10 months (Sustainable Development Commission, 2010). In contrast, recent research has

found that the energy payback could be potentially more than four years (Ranikne, Chick et al., 2006). There are also several practical planning issues with installing rooftop wind turbines because they can usually be seen from the street, triggering a higher level of regulation than other devices such as PVs or solar hot water heaters. Conservation and historic preservation laws may also inhibit ideal siting of the device.

- > District heating systems are a further way to reduce energy imports from the electricity grid or additional natural gas for boilers inside the home. An example of this is the use of combined heat and power (CHP) and district heating. According to studies on buildings and energy, an on-site renewable plant called micro-CHP has the potential to deliver heat (55%) and electrical (30%) energy locally to a neighbourhood and reduces the transmission and distribution losses of a larger, more centralised power station – the losses a typical UK electricity power station are around 70% (Steemers, 2003). However, for the balance of heat and power to be optimised the energy demand should mix housing with retail, employment, and leisure activities.
- > Providing an appropriate site is another important issue for urban planners. In the case of Wrocław, Poland (discussed during the European Urban Summer School), the district heating plant for the city centre is situated in a prominent location that would otherwise come under intensive pressure to develop an extension of the urban core. Noise and traffic of the 24-hour operations of a power plant, however small, must also be taken into account in the siting of the plant, along with practical engineering issues of providing enough space and access points in each street for hot water and waste pipelines alongside other utilities.

ADAPTATION AND RESILIENCE

- > Urban designers will need to make existing and future designs resilient to the consequences of climate change, such as greenhouse gas emission induced rising water levels, soil quality, and heat. Technological advances have helped to increase

the safety and security of urban inhabitants and divorced the urban area from local environmental constraints in recent years. An idealised urban form can be conceived for a flood-resilient city that takes into account geographic constraints and the use of sustainable urban drainage systems in small areas (Department for Communities and Local Government, 2008; White, 2008). Care should be taken when designating new urban extensions in viable farmland as keeping arable land near urban areas reduces resource consumption in food production. Finally, urban heat islands are getting bigger and hotter due to climate change. It makes cities warmer than the countryside as insulation is absorbed by hard surfaces, roads, roofs and walls and the consequent heat is only slowly released. Green infrastructure consisting of parks, water, and greenways included in masterplans can help reduce energy use by reducing energy demand for cooling buildings and keeping surface temperatures from rising further despite climate change (CABE, 2009; LUCID, 2009).

CONCLUSION

The evidence base available to planning and urban design is clear. The principles of urban design that promote legible, adaptable, diverse, permeable settlements hold and they grow stronger faced with the challenges of mitigating and adapting to climate change. Energy generation and transport modes are easily understood by the general public, but there are underlying complex and less obvious urban structural issues which planners and urban designers have to de-construct and analyse, to propose innovative solutions. Only then can society maximise the skills and opportunities proposed by the range of specialist professionals that are trying to reduce energy demand and greenhouse gas emissions and make cities resilient to change.