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MINIMUM ENERGY- MAXIMUM SPACE: HIGHER-DENSITY ATTACHED FAMILY HOUSING

N. K. Burford, J. Thurrot, A.D. Pearson

Abstract

In 2016 all new houses in England and Wales must be zero carbon. To date most work in zero carbon housing has been carried out on detached family housing typologies. Practice has shown that one of the overriding factors in the struggle to achieve zero carbon status (Code for Sustainable Homes Level 6) is the projected significant increase in construction cost. While grant funding can offset some of this increase, further costs savings will be required to allow developers to deliver affordable homes within reasonable profit margins. One result of this will be a reduction in design quality; which will impact on the quality of the spaces provided and the robustness and longevity of the construction and finishes. In order to deliver better design standards, higher density attached family housing models should be considered to ensure that a proportion of the projected increase in cost of the building fabric can be transferred to the internal volume of the house, thus achieving better quality living spaces. The following paper reviews the context for future housing provision in the UK and examines two existing medium density terraced housing developments. The existing examples reflect two contrasting approaches: one derived from low-energy principles utilising minimum space standards, the other reflecting the need for high quality spaces but at premium cost. A new medium density terrace model is proposed that deals with these conflicting demands to demonstrate that it is possible to provide affordable, high quality, higher density, family housing whilst meeting low energy targets.

Keywords: *Zero-carbon, Family-Housing, Urban Housing, Sustainability, Medium-Density.*

INTRODUCTION

The aim of this study was to develop a new model of medium-density, low-energy, sustainable urban family housing as an alternative to the more accepted suburban housing typologies. The focus has been on the development of an attached model of family housing that would fulfil future low energy requirements, provide high quality internal and external spaces but not exceed the minimum floor areas defined by affordable housing standards. This design based research used a qualitative approach investigating solutions from the macro level perspective of urban design to the micro scale technologies. The objective was to develop holistically, a new housing model that could be used as the basis for further quantitative analysis.

The following paper reviews the broad context for housing within the UK, critiques two innovative examples of attached family housing and outlines the design and decision making process in the development of a proposed new model for affordable, low-energy, high-quality, urban family housing. In section two, the background to the provision of family housing in the UK is discussed with a particular emphasis on current urban policy, the impact of new energy legislation and how these seemingly conflicting demands may influence the future provision, form and quality of affordable family housing. Section three critiques two innovative but, contrasting approaches to the design of attached family housing. Accordia, Cambridge, reflects the need for high quality spaces but at premium cost whilst BedZed, London, is a zero-energy mixed-use affordable housing development derived from low-energy principles utilising minimum space standards. Section four reviews the decision making process in the theoretical development of the Atrium House – a proposed new model of attached family housing designed to satisfy the parallel requirements of affordability and low energy whilst maintaining high-quality spaces.

TOWARDS NEW MODELS OF HIGHER DENSITY FAMILY HOUSING

DENSITY VERSUS QUALITY CONFLICTS OF HIGHER DENSITY DEVELOPMENT AND HIGH QUALITY SPACES

Living near to one's place of work and having all the social and functional requirements of modern life on the doorstep is intrinsically more sustainable than the high carbon, car intensive lifestyles inherent in edge-of-city, mono-cultural suburban housing developments. City centre living patterns potentially not only reduce the carbon footprint of individuals and therefore housing communities, but more importantly help to reinforce more complex socio-urban cultures which historically have formed the foundation to Europe's compact cities (Mumford 1938). With the majority of people working in towns and cities, higher density housing provides the most sustainable and affordable solution to meeting the predicted market and sustainability demands for new urban family housing in the UK (Schittich 2004)

Over the course of the last 50 years, there has been a significant decline in the numbers of people living in city centres with the majority of new housing being provided in edge-of-city low-density developments. For families, these suburban housing solutions have provided an affordable vehicle to individual home ownership. Coincidentally they cater to the majority of families' aspirations for larger internal spaces and the perceived psychological freedoms that suburban living alludes to - a detached family house, encircled by private protected external spaces on quiet streets surrounded by generous open public space. Loved and loathed, suburban housing is now the domain for the majority of people - more than 80% of the population living in the UK. The suburb through its attributes and failings has become a catalyst for theoretical and political debate concerning the future of housing in a new era where sustainable agendas are gaining credence and continuous urban sprawl is being challenged.

Today's 'suburb' has its origins in the Garden City Movement, originally conceived by Ebenezer Howard. Howard's vision of compact communities, accessible by foot, served by local amenities with places to work and connected by national road, rail and public transport links laid the foundations for many of the current 21st Century sustainability principles (Firley and Stahl 2009). Garden City housing densities were typically below 20 dwellings per hectare (dph) comprising detached and semi-detached housing typologies with open garden spaces, sitting on tree-lined radial boulevards surrounded by generous public parks (Howard 1946). This socio-sustainable utopia contrasted sharply with Corbusier's visual-technical utopia which formed the underlying basis for much of the UK's post 1950's high-density housing development (Scoffman 1984). With the failings of post-war modernist housing, the earlier Garden City concepts became the catalyst for a new generation of low-density development but this was only partly realised in the UK as it manifested into the Garden Suburbs of Gidea Park, London and Wavetree Garden Suburb, Liverpool. These residential 'districts' were the antithesis to the Garden City lacking the commercial and industrial components of the latter, paving the way for contemporary, mono-cultural, suburban development.

Today, the dystopian reality of suburban living for the masses is quite different to the original concepts of the utopian Garden City. Constrained land supply has increasingly lead to higher density developments usually on the edges of existing settlements and disconnected from amenities and public transport links. The continued use of detached housing models has resulted in a compromise between privacy and price with tightly packed detached houses and fewer less generous open public spaces (Figure 1). Densities of between 25-30 dph, combined with minimum footprints, low quality amenity standards and pattern book standardised planning arrangements has lead to smaller plots with poor delineation of boundaries and uncontrolled thresholds. Cluster arrangements defined by loop roads and cul-de-sacs determined by regulatory road requirements have resulted in disconnected streets, spaces and communities - a far cry from Howard's original vision of Town-Country where the Garden City would gain the opportunities of town and those of the country (Hall and Ward 1998).

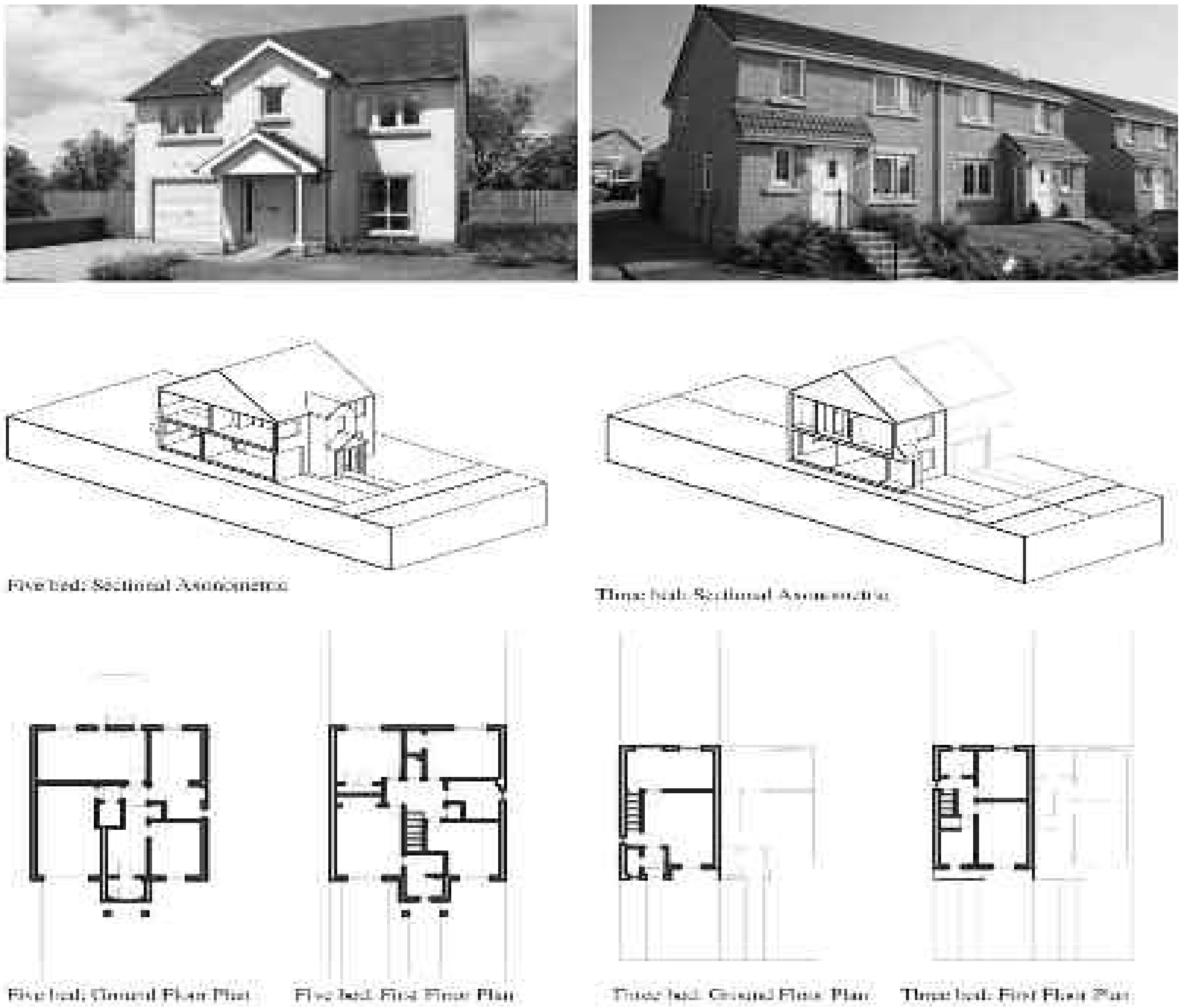

Figure 1. *Typical suburban housing morphologies*

Arguably, the current suburban housing model contributes to urban sprawl and high-cost, carbon intensive lifestyles. Designed to tackle this problem, 'Towards an Urban Renaissance' introduced the concept of a regional sustainable plan comprising compact cities with distinctly defined centres developed around transport nodes, first applied in a simplified way in the London Plan in 2004 (Rodgers 2002, Mayor of London 2008). A central facet to the development of this spatial development policy was to accommodate a city's growth within its boundaries without encroaching on open spaces. In order to encourage people to move back into the city it recognises the intrinsic need to make cities better places to live by promoting social inclusion, tackling deprivation and discrimination, requiring them to be more attractive, well-designed and sustainable. However, in practice the limiting Brownfield policy increases land values needing very high densities to make housing development viable. In so doing the compact city model has resulted in the provision of a limited range of housing tenures – usually apartment typologies with densities in excess of 70 dph (Colins 1998). A greater though less noticed increase in density is occurring through infill development on previously open green spaces such as parks and gardens served by new networks of roads and services amounting to an inner-urban sprawl (Meades 2010). Both solutions cater for high value market sectors, pricing certain income classes - primarily family housing – into out-of-city developments.

Whilst not necessarily the cause of suburban sprawl the compact city policies are serving to continue the trend towards suburban development as the only viable solution for affordable family housing. A long-term result could be a legacy of undesirable housing stock, as the current housing provision (urban and suburban) contradicts the prevailing trend in family housing sectors to demand not only high quality, value-for-money homes but also more space (Risom and Sisternas 2010). In the quest to improve the sustainability of cities and family houses through 'new-style' densification it will be necessary to avoid destroying the suburb's original attributes, namely spacious rooms, privately owned external spaces and access to fresh air. In Europe it has been shown that densities of 40-50 dph are attainable using alternative models of family housing without damaging spatial quality (Cousins 2009). It has also been shown that density alone is insufficient and must be accompanied by other design standards such as lower parking provision, preservation of open space and higher build quality (Stevenson and Williams 2000). This needs to be achieved without resorting to town cramming and high-rise development (Llewellyn-Davies 1994+1998). Arguably, city expansion is inevitable with the predicted increases in private home ownership coupled to the consequent spatial and cost requirements of family housing being in conflict with premium inner city space. New cluster typologies and housing models where buildings and greenery, private and public spaces are seductively entwined could provide a sustainable and more affordable, qualitative approach to family housing requirements. This will only be viable if new higher density attached housing typologies can be conceived whilst still fulfilling the aspirations of the majority of people for clearly delineated, high-quality, private home ownership. Edge of city development based around mixed use neighbourhoods and higher-density 'urban' housing typologies may be the only solution to preserving the qualities of both town and country.

SPACE VERSUS ENERGY BALANCING THE CONFLICTS OF ACHIEVING HIGH QUALITY SPACES AND LOW ENERGY CONSUMPTION

Today, further pressure is being brought to bear on detached suburban housing with the introduction of more stringent legislation, effective in 2016 governing the environmental efficiency of houses. Housing accounts for 27% of all UK carbon emissions from energy needed to heat, light and operate the houses (Wilford and Ramos 2009). Recognition of the depletion of non-renewable fossil fuel based resources and the affects of carbon dioxide emissions in the production of energy has resulted in a renewed interest in developing low energy housing. The goal is to provide superior comfort by conserving heat and by using low or non-carbon emission energy sources. Europe has been a leader in low and zero-energy housing since the oil crisis in 1972, which stimulated research into renewable energy as a means to reduce oil dependency. By the 1990's Germany, Austria and Scandinavia had become leaders in state of the art low energy house design resulting in a number of different approaches to the problem. The Solar House Freiburg showed that total energy autonomy was possible in northern cold climates but was unlikely to be a solution for mass market housing due to the costs of the technology at the time (Hastings and Wall 2007). The Austrian PassivHaus system using highly insulated, air-tight construction and mechanical heat recovery ventilation emerged as one of the most energy efficient and cost effective methods of low energy house design and constituted a step change in thinking. Today, PassivHaus is the world leader for energy saving construction resulting in 80% savings in heat energy demand to that of the 2006 UK Building Regulations (Feist 2004). To date over 10,000 dwellings have been built to the Standard throughout Europe, including 4,000 in Germany, Austria, Norway, Sweden and Denmark (Waltjen 2008). Recent research in Northern Ireland has shown that relaxation of the Standard (originally developed for a central European climate) is possible for UK climates due to the generally milder winters (Anon 2007).

Potentially, this gives more design freedom in terms of the dwellings, spaces, construction and affordability.

Until recently, the UK had fallen far behind Europe in maintaining concerted research or funding programmes to aid the development of energy efficient houses. Only small incremental improvements to energy efficiency were achieved compared to European counterparts until the introduction of Code for Sustainable Homes (CSH) in December 2006. Effective in the UK's 2016 building regulations, CSH is recognised as one of the most ambitious programmes out of all worldwide national standards for the practice of low energy housing (Anon. 2008). Its aim is to achieve Net Zero Carbon Housing, eliminating carbon emissions from regulated energy and unregulated energy arising from the use of appliances (Anon. 2009). It is designed to support the parallel policies of carbon reduction, long term energy security and fuel poverty and adopts a hierarchical approach to achieving zero carbon, namely:

- ensuring an energy efficient approach to building design;
- reducing CO2 emissions on-site via low and zero-carbon technologies and connected heat networks;
- mitigating the remaining carbon emissions with a selection of allowable solutions.

CSH measures the carbon efficiency of housing by creating performance levels on a rating scale of CSH Levels 1-6, with Level 6 being zero carbon. Current housing in the UK built to Part L building regulation standards 2010, would achieve a CSH Level 3 rating (Anon. 2006). Currently, there are only a few examples of prototype houses built to meet Level 4, 5 and 6 requirements. Recently RuralZED™ has received Code 6 certification for the One Earth homes at Upton, Northampton; the first commercially-built terrace homes to receive certification (Lane 2010) With the exception of the Sigma House and RuralZED, all the prototype solutions are designed as detached and semi-detached family housing .

Ousting plays a key role in the national energy strategy in both minimising electricity requirements but also in determining to what extent it can contribute to the supply of electricity to the grid. This places a significant burden on developers and individual home owners in terms of absorbing the additional costs of improved thermal construction as well as the uplift in costs of energy technologies needed to meet Code Level 6. Practice has shown that the construction cost of a standard 92 m^2 home will almost double, the majority of the increase coming from the need to install large amounts of renewable electricity generation (Jury 2009). In contrast, Minergie, the Swiss National Standard which uses similar fabric performance values to the proposed 2016 CSH standards, requires that building costs are no more than 10% higher than base cost to gain certification (Anon. Minergie 2010). This means that the significant increase in building costs necessary to raise detached housing to CSH standards may make the single family detached house typology redundant in the future as a solution for mass-market affordable housing. Higher density attached housing such as row houses and terraces are intrinsically a more sustainable and affordable alternative to detached family houses. (Schittich 2004).

Terrace housing has the advantages of a compact form that tightly controls the use of open spaces and reduces the size of the façade. The small surface to volume ratio of a terrace housing unit compared to a detached unit reduces fabric heat losses and energy costs. The ability to share services and utilities (such as district heating systems) releases more of the building cost into improving fabric energy performance where the major energy losses in housing occur and the greatest payback over time can be achieved. This would allow for further improvements to the proposed fabric energy standards, bringing these more in line with European counterparts thereby significantly reducing regulated energy consumption. Because construction elements and services are shared between units the construction costs are inherently lower. This gives house builders the opportunity to focus on issues that are much more intrinsic to quality of life by improving the housing models through the provision of richer, higher quality external and internal spaces. It has recently been shown that carbon emissions and potentially household heating costs could be reduced by reconfiguring both the demographics of power generation and housing provision (James & Bahaj 2009). It would mean more dispersed power generation located closer to major population centres thereby increasing the capability for utilising waste heat and reducing distribution energy losses from the grid. This approach would greatly reduce the need for individual houses to be energy autonomous as it would allow energy to be dealt with at district and community levels. Importantly, it could pave the way to the development of new types of mixed-use neighbourhoods with higher density housing models opening the door to the development of more sustainable edge-of-city communities and economies.

TERRACED HOUSING
TWO NEW APPROACHES TO MEDIUM DENSITY, TERRACE HOUSING PROVISION

Throughout history terrace housing design has adapted to changing social, economic and environmental conditions. It is particularly relevant today as a model due to its capability to improve the sustainability and environmental efficiency of housing. Flexibility and adaptability of design and the ability to optimise both spaces and construction are fundamental attributes of terrace typologies (Pfeiffer 2010). This makes attached housing particularly suited to an era where continuous and rapid change is in demand due to the potential for producing efficient urban and internal space planning that caters for a great variety of living situations. However, the terrace cannot be considered in isolation because the urban block becomes particularly important in determining the effectiveness of a given house typology in relation to a particular urban condition. It has been shown that the interior to the block is one of the principle elements in determining the quality of the internal and external environments (Firley and Stahl 2009). The following innovative examples of terrace housing illustrate two approaches in which the environmental, urban planning and internal space planning considerations are given contrasting levels of consideration.

Bedzed

BedZed completed in 2002, is the UK's largest mixed use, mixed-tenure carbon-neutral development (Figure 2). Built on a brown field site in Hackbridge, South London, BedZed comprises 82 affordable town houses, maisonettes and flats and approximately 2500m^2 of workspace and offices organised within a single cross section (Dunster, Simmons & Gilbert 2008, Kucharek J 2010). The blocks are planned in terraces with clearly delineated external spaces and thresholds. The town houses are single aspect and face due south with north facing gardens at first floor level. The flats, located above the town houses, are dual aspect with north facing gardens. The compact floor plans are designed for affordable private tenure and make maximum use of the single aspect building form.

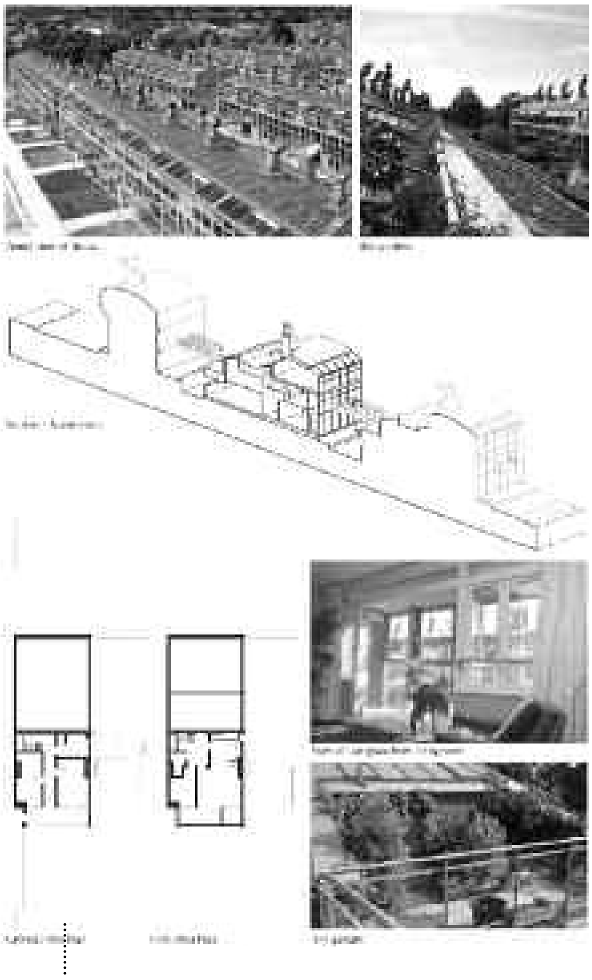

Figure 2. *BedZED housing, Hackbridge, London, UK.*

A combination of passive measures and active technologies are used to achieve carbon neutral status. The houses face south to take advantage of solar gain, are triple glazed and have high thermal insulation. South facing conservatories provide winter garden spaces whilst maximising the use of solar insulation which is stored in the thermally massive construction. The project was designed to use only energy from renewable sources generated on site. Heat and power are generated using both a biomass power plant and large areas of PV panels. Various other environmental measures are taken such as the use of energy efficient appliances, low-impact building materials and water recycling.

Whilst BedZed is a model for high-density, low-carbon residential development, it is not without its problems. The arrangement of the programme within a small planning footprint and single cross-section has resulted in single aspect deep plans and awkward narrow rooms some of which can only be lit through top-lighting. In addition, all the elevated gardens are cut-off from the internal living spaces, thereby putting their effective use into question.

Accordia

The Accordia project, designed in 2002, is a high quality, high density residential development located within the listed garden grounds of Brooklands House, Cambridge (Figure 3). Within this master plan, designed by Fielden Clegg Bradley, three architectural practices developed 23 innovative housing typologies (Keys & Laslett 2009, Latham & Swenarton 2007). These comprise a graduated scale and variety of buildings from two storeys to five storeys organised around a central Boulevard. The combination of building types, heights and scales of carefully controlled public and private external spaces provides nuances of character to offset the monotony of the homogeneous scheme. The relationship of dwelling to ground was a major structuring theme of the project.

The core of terrace townhouses, designed by Macreanor Lavington Architects, are notable for the high quality of internal and external spaces and exceptional natural lighting achieved within very compact planning dimensions. These townhouse types form a continuous four storey terrace of 18 houses. The terrace fronts directly onto a park on one side and a mews lane on the other. The form and language of the townhouses and organisation of internal spaces are derived from a reinterpretation of the Georgian townhouse. The plan maximises the living space and establishes a direct relationship between each primary room and associated external spaces throughout the dwelling.

The traditional construction of the first phase development had high levels of insulation, good air tightness and careful detailing to improve sustainable performance rather than a focus on renewable technologies. The townhouses achieved a 30 percent improvement in energy performance over 2002 Building Regulations.

Whilst Accordia creates housing that is high quality and in demand it would not meet 2016 regulatory requirements and would not be viable as mass market family housing due to its high costs.

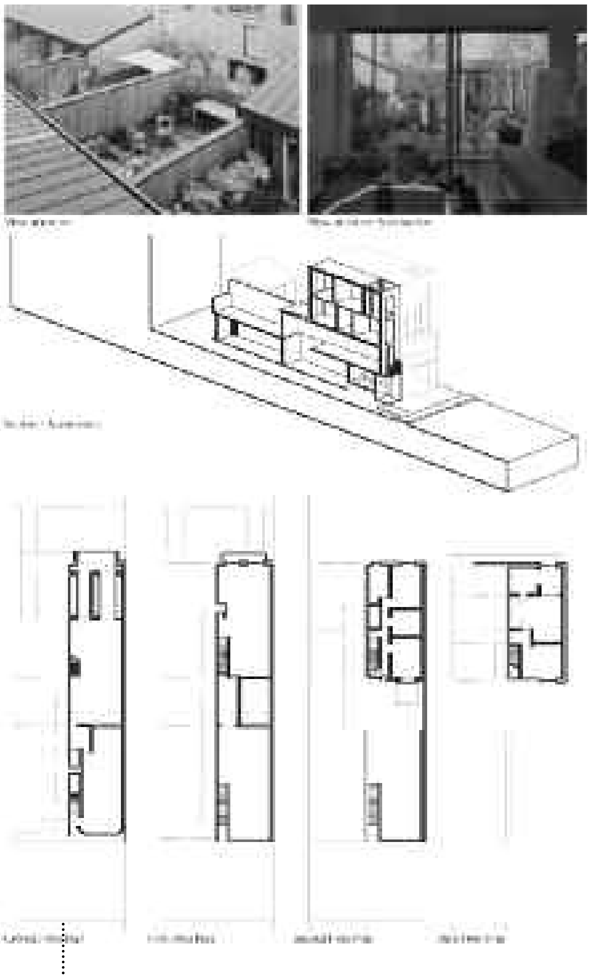

Figure 3. *Accordia housing, Cambridge, UK.*

ATRIUM HOUSE

The historical precedent for the atrium house is a Georgian terraced house, typical of Edinburgh New Town (Figure 4 & 5). The terraced house typology provides medium density housing in a low-rise urban setting.

External Spatial Organisation

The urban framework for the atrium house is based on two New Town typologies: the formal street with shared rear gardens and the mews lane with private rear gardens (Figure 6). In the first typology, the frontage of each house is separated from the public pavement by an enclosed private garden, hence; the distance each house is set back from the pavement is enough to ensure privacy whilst engaging the occupants in a community of houses along the

Figure 4. *Edinburgh new town.*

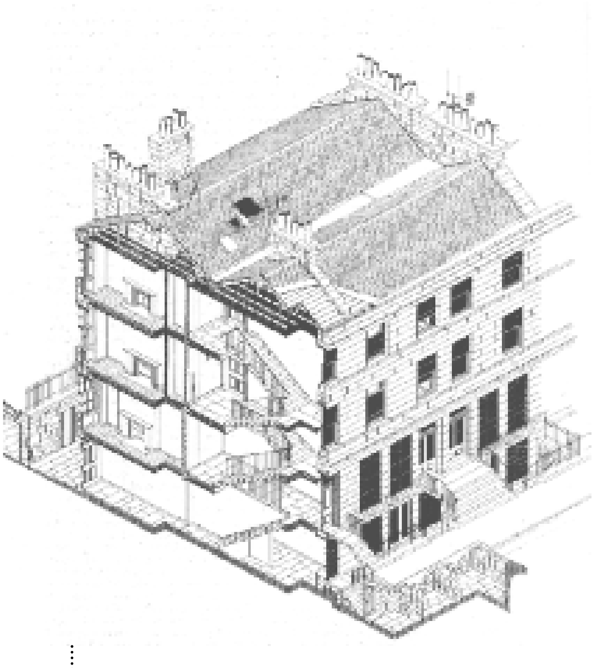

Figure 5. *New town terraced house.*

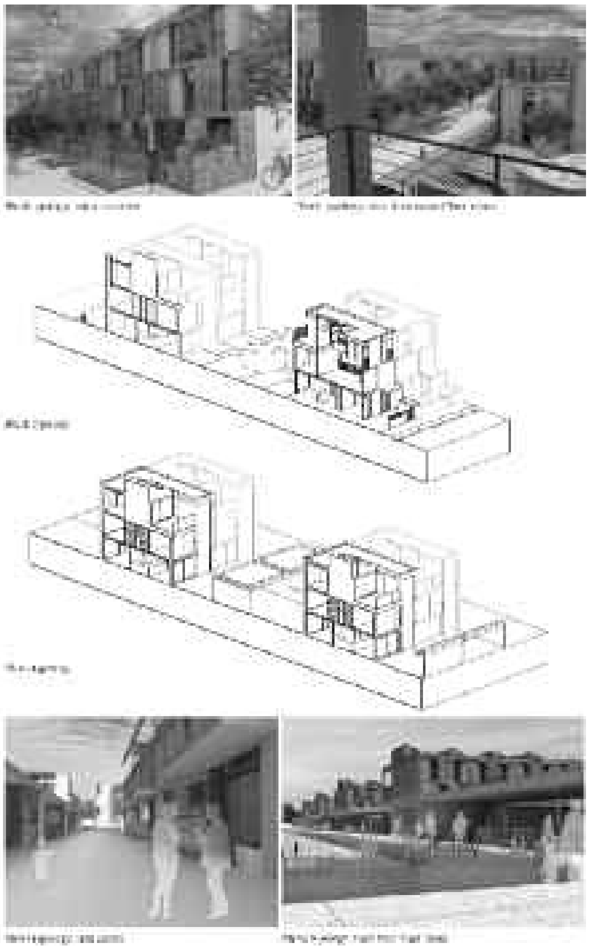

Figure 6. *The atrium house - external spatial organisation.*

street. To the rear there is a private deck, immediately adjacent to each house, with an outlook onto shared gardens. Access to these shared gardens is restricted to the home owners within each urban block; thus they are semi-private in nature. Lack of formal boundary walls between houses within the shared gardens opens up social possibilities between neighbours. In the second typology, the front door of each house is directly accessed from a public mews lane. The lanes run perpendicular to the main street and are of minimal width. The surface is paved in a manner to articulate its shared use: that of pedestrians and vehicles. Car parking is provided for each house in garages located across the lane from the front door. The garages can be enclosed or open and may double as secure play areas for children. The garage infrastructure can be adapted for live/work units or for future expansion of the house should the family grow or there is a need to house elderly relatives.

Internal Spatial Organisation

Although the ratio of outside wall and roof area in a typical terraced house is kept to a minimum thus providing maximum thermal benefits, the plan is usually long and narrow; hence, natural light and ventilation are difficult to provide to the centre of the house. The Atrium house solves this fundamental difficulty by placing a top-lit vertical space in the centre of the plan. In addition to the environmental benefits, one of the primary functions of the atrium is spatial. By introducing a light-filled core in the centre of the plan, the house feels bigger than its statistical footprint. The plan is based on a 3m module: 6m across and 9m deep. A 2m wide zone along one of the party walls contains vertical circulation and bathrooms, thus leaving a rectangular accommodation footprint of 9m x 4m which is divided into 3 bays. These bays can be partitioned off to create rooms or they can be left open, depending on the needs of the occupant. As the floors span the full width of the house, the internal space can be altered without affecting the structural envelope. Although the accommodation within the house is flexible, the proposed hierarchy is based on internal/external relationships, in both plan and section. The ground floor contains a kitchen and dining area with direct access to the rear garden and a room facing the street which could be used as an office or bedroom. The primary living space is located on the Piano Nobile facing the street with a bedroom to the rear. The top floor contains further bedrooms and a roof terrace on each side of the atrium (Figures 7 & 8).

Technology and Environment

Moving to higher density terraced housing provided a number of technological difficulties but several opportunities. The study assumed a reduction in the need for individual houses to be energy autonomous, with electrical energy generation being dealt with at district levels. The subsequent energy concept for the house adopts Passivhaus principles modified to a UK climate based on the guidelines for the design and construction of passive house dwellings in Ireland. Much of the focus in the UK over the last 20 years has been in the development of MMC's to improve the efficiency of construction in terms of quality, cost and buildability. The majority of UK house builders use different forms of off-site timber frame construction which has been proven to be effective in terms of economics and environmental performance. It was considered that if the new design proposal was to gain acceptance by existing housing developers it would need to use similar technologies that could be easily absorbed within the existing manufacturing infrastructure. Timber frame technology was considered to be the most viable solution, not least because of timber's low environmental impact. However, it was recognised that the standard timber frame products offered by current UK manufacturers would need development in order to improve the environmental performance of the building fabric to meet higher energy targets.

The housing blocks are orientated on a north/south axis with the main elevations facing east and west and external spaces between housing blocks orientated due south. The stepped section maximises sunlight penetration into the private external spaces behind the street throughout the day, even in the winter months. The atrium in the centre of the plan faces due south and acts as a solar collector. It bisects the plan allowing every room to receive morning and evening sunlight passively. The roof light can be isolated from the main volume to prevent heat loses at night and to control heat gains during the summer months. All glazed elements can be shut down at night with sliding insulated shutters reducing heat losses. Throughout most of the UK there is little requirement for cooling during the summer. Over this period the atrium and openable windows generate a stack effect assisting in the natural cross ventilation of the spaces. During

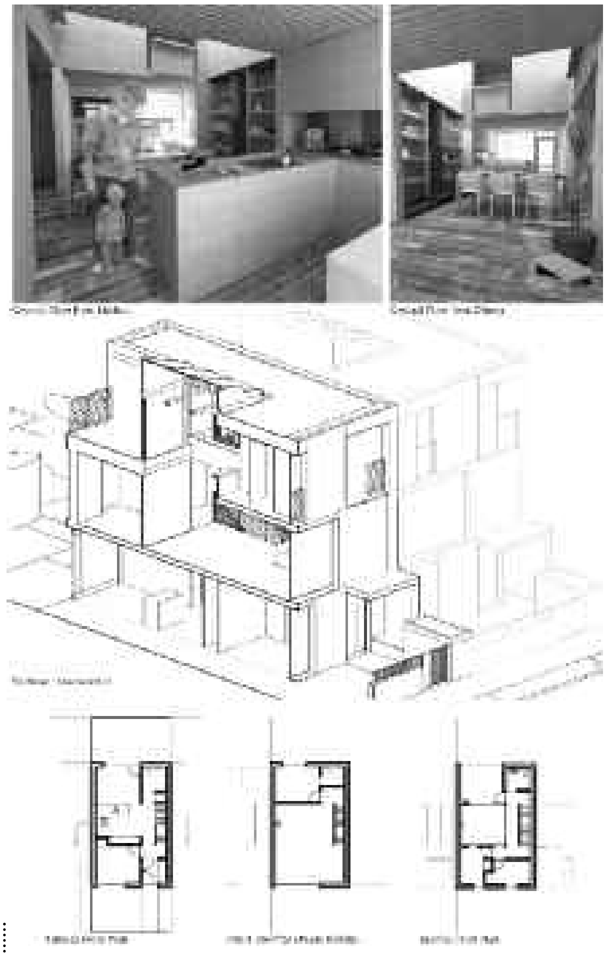

Figure 7. *The atrium house - internal spatial organisation.*

Figure 8. *The atrium house - internal perspectives.*

the remainder of the year, the air-tight construction, mechanically controlled heat recovery ventilation and biomass heater located in the centre of the house is sufficient for space heating and hot water. The cellular spaces are heated via a forced air distribution system. Heating between the intake air and the stove exhaust gases is used to control the temperature of the intake air. The internal floors and partitions use Brettstapel, thermally massive timber construction elements to balance out the internal diurnal temperature fluctuations. These have the additional benefit of providing better acoustical separation between rooms.

CONCLUSIONS

The UK's Code for Sustainable Homes and Germany's Passivhaus are two world leading standards in the drive to develop more sustainable, low energy approaches to housing development. Although they share common goals the ideologies are fundamentally different. Passivhaus leads to very low energy demand housing by improving fabric thermal performance, air-tightness and heat reclamation ventilation to such an extent that additional regulated energy demands are minimal or zero. CSH on the other hand is striving towards total energy autonomy to achieve net zero carbon, but with lower fabric performance values, ultimately having a larger regulated energy demand. Practice has shown that while both strategies are possible Passivhaus is more economically achievable due to the inherent high costs in producing electrical energy at a building level. To date, much of the research in zero carbon has focused on detached or semi-detached housing, whereas it is well known that higher density housing models with lower surface to volume ratios are more efficient from the point of view of energy demand.

Additionally, there are much broader questions as to the overall viability and sustainability of low-density suburban models, particularly as the UK moves towards a low carbon future. BedZed and Accordia are two innovative high-density housing developments that demonstrate the conflicting requirements of achieving good quality internal and external spaces within the limitations of low-energy and zero carbon contexts. The Atrium House attempts to show that if low-energy is considered rather than zero-carbon, it is theoretically possible to develop high-density, housing with high quality spaces using minimal plan areas. While the Atrium House concept remains to be tested quantitatively, both the urban planning and spatial configuration of internal spaces allude to a potential solution for creating more sustainable, high quality, mass market housing.

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