Achieving energy and resource optimisation within urban mixed use developments utilising passivhaus premium design strategies

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Abstract. Cities in 2020 consume 75% of the world’s resources in the form of energy, water and materials; 55% of the world’s population live in these urban environments and by 2050 this figure is expected to rise to 65%. These facts combined with the reality that residential energy use alone, accounts for almost 40% of global energy emissions indicates that the challenge of reducing our profligate use of residential energy, and thus reducing our greenhouse gas emissions, is first and foremost an urban challenge and opportunity. The theme of this paper is prioritisation. By prioritising the development of low rise, integrated-mixed-use developments we are facilitating energy use in the most efficient and beneficial way, toward achieving these reductions. Furthermore the paper argues that such developments are also societally enriching by the creation of another layer of understanding of the urban environment, achieved through reflecting key energy engagements between buildings, uses and sites. The energy logic of such mixed use developments is further justified and enabled, if combined with the reuse of serviced ‘brownfield’ urban sites, a variety of user profiles, long life facilitation of habitation use, and resource efficiencies; all achieved whilst facilitating low carbon living at an urban microscale.

1 Introduction

This paper wishes to reflect on best practice in Urban Design from an energy and resource perspective, using case studies of both existing developments and a proposed low energy mixed use development located near Dublin City, in Southern Ireland.

Such case studies are of value, not for being representative of a ‘status quo’ but rather as a reflection of methodology insights, demonstrating the optimisation potential of mixed-use urban development, using integrated Passivhaus (PH) design strategies, within 21st century, post carbon cities. There is a growing and recognised challenge and opportunity within contemporary Urban and City Design to create sustainable mixed use developments which allow people the opportunity to live, work, dine, shop and socialise, without excessive travel or commuting. There is also a growing desire for these spaces to be community-friendly with an emphasis on well-being, scale and environmental credibility. Initiatives such as the Walkable City and the Economic City are direct reflections of these aspirations.

Central to such environmental credibility is the need to make such mixed use developments (i) energy efficient in use, and (ii) low carbon in construction and operation and (if part of a cohesive urban strategy), (c) supportive in energy terms of that strategy. The complexity of these needs brings with it a number of challenges across the key early design phases, within which the initial concepts and strategies are formulated. On brown field sites these early strategies require an urban design sensitivity.

Urban Design itself has always had a difficulty in establishing its own authenticity within the design professions; very often the practice of Urban Design has been lost somewhere between ‘architecture’ and ‘framework planning’; often it has been seen simply as a control methodology for building out large scale infrastructure. However the post carbon city requires a greater urban skillset. The emerging legislative requirement in Europe for the design of nearly Zero Energy Buildings (nZEB), across all building typologies, is an opportunity and catalyst to investigate how nZEB needs might challenge and merge with urban design to best create sustainable mixed use developments in the context of our future urban and city planning practices.

2. Contemporary urban design

What constitutes ‘Urban Design Practice’ has been a subject of wide ranging preferences throughout history. In a hierarchical sense there is, at the bottom, the prosaic public policy creation and implementation, in the hope that continuity, rigor and the market place will allow a coherent urban fabric to emerge, reflective of a societies aspirations. The typical development plan of Irish local authorities aspires to this low level. Further up the scale
there is the deliberately beautiful city of Piranesi’s Rome or Hausmann’s Paris. In recent years the free wheel ‘Ballet of Urban Life’ promoted by theorists such as Jane Jacobs [1] have been identified as worthy of consideration and implementation. In all cases the endeavour of understanding how vibrant and exciting urban (and suburban) environments come into being has been central to the task in hand.

In our post carbon city however our engagement with end uses, and end users, must begin with our concept of an ‘Energy of Uses’ and an eye to resources. Heretofore the common metrics of urban planning would have related to controlling specific site design criteria such as zoning use, site coverage, site ratios and contextual heights. The challenge of city design in a post carbon reality however, is to ask how such metrics facilitate a low carbon future respectful of resource allocation? This question requires us to give voice to metrics promoting energy and carbon optimisation; in buildings this presupposes optimal orientation for solar gain, fabric design to reflect this, shading optimisation, energy storage and sharing, distribution of energy and site biodiversity. In such a way the urban quarters of the post carbon city are energy quarters with optimised district area energy controls and distribution; in effect an optimisation of energy mixed use profiles and a disparate and complimentary engagement between end users.

Unlike current urban design practice this new urban design of the 21st century, must address itself to the paradigm of optimal supply to meet an efficiency of use; this is ‘microsurgery’, just-in-time localised delivery, particular to a specific location, use and time. It is in contrast to, and opposed to, the current paradigm of concentrating on grid infrastructure and traditional delivery with large inefficient centralised generation, a type of ‘open-heart surgery’ whereby the efficiency of supply is uppermost in prioritisation, without questioning the efficiency of use, to which the energy is put and whether that use is optimal.

The current ‘near Zero Energy Building Directive’, (nZEB) promotes the latter paradigm, and the specific fabric specification is a reflection of energy policies going back as far as 2005. In contrast the theme of this paper is that we can, (if we promote a more demanding wholistic design approach utilising fabric first principles and significant local energy reduction, production and efficiency), optimise supply and carbon emission control. What then are the determinants of such an Urban Design, Energy and Resource approach?

2.1 The Determinants of ‘Genius Locii’

The great Urban Design theorist, Norberg-Schulz in his analysis of ‘Genius Locii’, (Spirit of Place), identified three prevailing determinants, or characteristics, of cities which render then identifiable and visually cohesive; in effect pleasant places to be in. These included an understanding and engagement with (a) Comprehensible City Patterns, (b) Consistent Building Typologies and (c) Consistent Building Morphologies, reflecting the way things are made, materials used and facades created. These were considered traditional key determinants. [2]

The expansive internationalism of the 1950’s through to recent years wiped away these coherent architectural expressions. Materials and building typologies transcended beyond their location, their region and their climatic context. Architectural design spoke to formal design theories, methodologies, and post-modern facadism. In response the architectural critic Kenneth Frampton wrote of the imperative of an architecture of ‘Regionalism’, all this in an era before climate change itself became an impelling reason for such a call. Now Frampton’s ‘Critical Regionalism’ is a compelling metaphor for responsible design and zero carbon priorities, creating the determinants of the new post carbon city. [3]

‘Urban Mixed-Use Developments’, designed as energy positive developments, where activity and urban life is energised through localised use patterns and engagement, offer themselves as potential anchors for such zero carbon cities. They in effect express a reality that such cities must consist of smart interlocking parts, epitomised by such mixed use energy positive developments.

2.2 The determinants of energy in urban design

People are attracted to and attune to urban environments they have a tangible understanding and comprehension of. [4] ‘Energy-collated’ developments therefore offer an opportunity for communities of energy users to develop, and social engagement to emerge, from an acknowledged and shared understanding of careful resource utilisation, and energy efficiency; thus attracting understanding and enjoyment.

Since cities account for 30% of total CO2 emissions within the construction sector, cities are the single largest contributor to climate change. Thus it is important that we progress the insertion of low-carbon infrastructure into cities to reduce CO2 emissions now and eliminate them by 2050. A range of planning approaches—collaborative, systemic, and market shaping have developed over the years to endeavour to achieve this. Invariably we have seen new building typologies develop and the strengths and weaknesses of our planning support structures exposed. Such strategies have managed to improve contemporary practices, however decarbonizing the built environment has remained a complex undertaking requiring a more comprehensive understanding of sustainable solutions.

In the missed use domain the dynamics of reducing carbon emissions and addressing environmental policies has been intensively explored with solutions ranging from energy efficiency constructions, combined with building informatics, user behaviour modelling and building information monitoring.

The determinants of success lie in the ability of our buildings to give vision to a virtue; an architecture to provide a ‘protected space’ in which low-carbon systems and leadership can develop. Without the vision, the virtue becomes eroded by the real challenges (and...
failings) of low energy design:- summer overheating, end user dissatisfactions, performance gaps and poorly coordinated mechanical installations and software. None of these difficulties are significant impediments in themselves, if the design and performance indicators are shared by all, are clearly understood and sufficiently robust. Local electrical generation is key.

The first determinant therefore must be a cohesive pattern of energy use and distribution, with an understandable energy hierarchy, the more localised the better. [5] Secondly in mixed use terms the energy needs of spacial adjacencies ought to be complimentary in regard to balancing and utilising energy demand. Thirdly these needs will give rise to increasingly flexible building typologies that are capable of meeting different end uses without significant remodelling. All buildings will need to be capable of natural (minimal) ventilation, optimal orientation and specific façade design, the trade mark ‘curtain wall’ is perhaps a thing of the past, both in regard to customisation of facades, energy and airtightness.

To progress understanding we provide examples of two contributions to this endeavour dating back to 1998, when we had an opportunity to address our carbon emissions and global temperature variation was 50% (.3C) less than the 2018 figure of 0.6C (Figure 1) [6].

![Image of Global Average Temperature Increase](https://example.com/image.png)

**Fig. 1.** Temperature increase globally since 1999. (Our world in Data) [6]

Across the intervening years we have failed to meet our energy reduction commitments. believing that the market place will give rise to natural adaptation when in fact time and resources are running out. [7]

*The central theme of this paper therefore is to press the energy advantages of ‘energy optimised, mixed use developments’; creating energy positive developments which grant measurable return on scarce resources, provide fossil-fuel-free energy to older poorer performing adjacent buildings, reducing their immediate fossil energy needs, and thus buying us time to create closed loop supply chains to progress the time consuming effort of retrofit with controlled embedded carbon via biobased materials.*

Since such developments must be energy positive, nZEB cannot therefore, in its current configuration be an energy standard ‘fit for purpose’, as the energy reach is too low, and the expectation of ongoing variable building types for non-domestic buildings is naïve in the face of the growing resources timebomb. Building typologies will need to coalesce to ensure their greatest possible level of flexibility, as to their future use. Additionally the nZEB energy demand criteria in Ireland lack specific performance indicators and incentives to reduce energy use.

However despite these shortcomings nZEB is now the common legislative energy language for buildings across all use-sectors in Europe. In this given context, this paper seeks to demonstrate how nZEB optimisation may be developed by improving its metrics to reflect Passivhaus (PH) design strategies (Premium) across in particular, mixed use developments, and utilizing resources to optimise benefits to all. What is proposed is not new however the import of its success has now a focused relevance.

Below we record current, previous and proposed efforts at such mixed use developments and suggest lessons to be learned from the endeavours in optimising energy efficiency with respect to several energy metrics. We formulate also a real development which is in design efforts at such mixed use developments and suggest lessons to be learned from the endeavours in optimising energy efficiency with respect to several energy metrics. We formulate also a real development which is in design

### 3 Three case studies: ‘now, then, & tomorrow’

Energy simulations and built prototypes of different types of buildings indicate that detached and attached houses can achieve an energy positive status, under most climatic conditions. Passivhaus has become a recognised methodology for achieving such low energy buildings across a range of performance criteria from its ‘Classic’ model of design, through Passivhaus ‘Plus’ and Passivhaus ‘Premium’. [8]

Difficulties arise in regard to larger buildings such as apartment blocks, and offices, which are capable of supplying only a small proportion of their energy consumption needs from on-site generation due usually to the limited availability of roof surfaces relative to the occupied volume and energy demand. In Urban design terms, six stories appears to be the modest equilibrium, whereby achieving carbon neutral and energy positive use within a building / development becomes compromised by its height. [9]. Emerging examples exist of buildings, which generate a large peak electrical output and associated battery storage. An nett zero energy building selling power to the national grids [10].

#### 3.1 Ransom energy

The operational benefits to the grid is significant; in effect we are paying through these nett zero energy buildings a ‘ransom energy of atonement’ back to the grid to compensate for the sins of our poorer performing existing buildings elsewhere. However this reality buys us time to meet the challenge of retrofitting these existing buildings. This is not possible if our new
buildings are not energy positive and are not ambitious in regards to fabric controls and IAQ; in these circumstances, it is an opportunity lost and scarce resources not used to their optimal societal benefit. We are creating no inherent societal value and creating a lock-in of poor standards that will stay with us for at least 50 years. [7]

However if we can reduce grid peak energy demand through energy plus developments, we can reduce the need for new power stations and centralised windfarms where significant energy is lost in transit and millions of euro spent on building, operating, fuelling and, eventually, decommissioning these. Instead we build, create, convert more buildings, producing more savings in power station expenditure, and more low carbon jobs; a really healthy feedback loop.[10]

3.2 Ransom Energy: then

**Fig 2.** Aerial view of Temple Bar Development looking South

In Dublin in 1998, the city embarked on two adjacent but disparate development projects; the conservation, protection and development of an area of the inner city known as Temple Bar, full of characterful but poorly performing buildings in energy terms, and on an adjacent site, the construction of a large new office building; in effect a new City Hall. The project of linking these two construction projects to achieve an overall energy and carbon reduction was initially commissioned in 1996 and after five years of operational monitoring received the Bremen Partnership Award in 2001, beating 140 other international projects for innovative energy management. The project achieved a 40% reduction in Carbon Dioxide emissions compared to conventional heating systems of the time.[11] This was achieved through the use of a gas fired combined heat and power (CHP) plant which generated heat and electricity for the offices and heat for the neighbouring buildings, (Fig. 2). This match between energy need and energy generation is the key challenge and opportunity in the optimisation of energy usage within mixed use developments. Energy storage and intelligent energy management become significant issues in addressing the seasonal variations where the peak generation can be either significantly higher or lower than the use requirements. This energy challenge therefore represents an opportunity in mixed use developments, whereby the different energy use profiles, can be combined to minimise/eliminate the energy gap across the whole development and contribute to its overall energy performance.

![Fig. 3. Comparative energy and carbon performance across Temple Bar Development, (standard vs installed) (Vertical metric units as indicated.)](image)

In the case of the Temple Bar project any short term differences in return water temperatures from the serviced adjacent buildings (four hotels, one hostel and one new apartment building) was compensated for by three shallow wells utilising ground water which controlled the temperature of the water returning to the CHP unit. All of this achieved with Building Energy standards as set by 1991 Irish Building Regulations. Had PH design strategies been operational at the time of the Temple Bar Project the carbon savings would have been dramatically better; (using the current nZEB standard probably in the order of an 80% improvement), and so the opportunity to sustain for a period, the poor energy performance of even a greater number of buildings was lost. This potential energy contribution to buildings beyond themselves, reflective of where 'the whole is greater than the sum of the parts', in itself a working definition of Urban Design.

3.3 Ransom Energy: now

A more recent example of a ground breaking customised low energy mixed use neighbourhood initiative was the Beddington Zero Energy Development (BedZED) in South London developed by the Peabody Trust and constructed 2000 through to 2002 to be an exemplary zero carbon neighbourhood with 82 homes, 17 apartments and 1,405 square metres of live work units.
The woodchip fuelled centralised CHP plant never performed to its intended specification and subsequently was replaced by condensing gas boilers. The principle however of the overall zero heating specification was to minimise space heating and as the overall resulting thermal demand is for hot water only, this remains consistent all year round; facilitated with oversized local hot water storage tanks, that can meet peak demands (space-heat and water) whilst still allowing trickle recharging throughout the day. This allowed the power plant to more or less match average electrical demand, exporting to grid when surplus power was generated on site - and importing to meet peak demand. [12]

What BedZED did show clearly was the benefits of building to a fabric first principle, which ensured overall internal comfort levels despite some summer overheating issues. It also displays an attempt to create flexibility in use, of the units constructed. All blocks of accommodations have similar technologies and physical properties and so, some work spaces have been converted into residential use with little difficulty.

3.4 Ransom Energy: tomorrow

Both of the low energy developments referenced above reflect the favoured methodology of the 1990’s, of creating efficient energy, through optimised combinations of heat and power, CHP.

However neither of the developments referenced stand as role models for similar future developments. At Temple Bar the buildings being serviced were poorly insulated by contemporary standards whilst the low discounted energy led to a rebound effect of increased (or rather unnecessary) energy use in the served buildings. [11] The CHP plant in Temple Bar utilised fossil based energy, (gas).

At BedZED, the energy demands of the various building types were significantly reduced, however the Biomass CHP plant carried significant operational failings and defects.
The mixed use developments of the future will be smaller in scale, will have an energy use profile so low that the overall energy need will be negative, allowing energy to be dissipated back into the grid or used locally to promote energy protection for adjoining sites, uses and buildings, all of which determines and supports an urban design aesthetic and discipline.

This is a particularly attractive option where urban environments contain buildings of architectural or historic significance where retrofitting to a low energy need may not be possible due to fabric constraints.

**Fig. 5. Proposed mixed use development, (Murray Mews) (Martin Murray Architects)**

The Murray Mews project, (in design development), builds on the lessons of these previous case study developments.

The site of approximately 0.1 hectares is located in the centre of an Irish provincial town, close to Dublin. In design terms it contains all of the typical opportunities and challenges which an urban site of this type, will offer by its nature. An energy positive development in this part of the old town will greatly facilitate energy supply to adjacent older buildings and will be able to sell energy back to the national grid within the next two years due to recent recast Renewable Energy Directive II (RED II) which was adapted by the EU in December 2018. This new directive sets a binding target that 32% of the EU’s energy demand be met by renewable technologies by 2030, with a proposed review to alter targets as necessary in 2023.

What is notable is that the RED II compromise agreement sets unequivocally an ‘energy efficiency first’ principle by acknowledging that the ‘cheapest and cleanest source of energy is the energy that does not need to be produced’. As this paper argues, faced with the climate change predicament which has emerged and the associated need to significantly and immediately reduce our Greenhouse Gas (GHG) emissions, we must evolve and expand our understanding and implementation of this ‘nearly-Zero Energy Building’ paradigm to nett Zero.

The design of Murray Mews therefore is focused on optimising flexible plan configurations with a fabric first design principle of high embedded carbon and a low carbon threshold for manufactured construction materials. Walls will be biobased materials reflecting a closed loop supply chain. The array of solar panels will support both reduced operational carbon, and low carbon energy supply for tangential uses, such as car movement and community engagement. The operational use of the buildings will encompass a balance of retail, office and residential use and design development is investigating scenarios of maximum proportionality of façade, roof and orientation to ensure maximum on-site Primary Energy (Renewables), PER.

Preliminary Design and merging case studies would suggest that a peak electrical output of c. 32.00kW on a sunny day from 160m² of solar photovoltaic panels (PVs) is possible, (modelled). Excess power will go to the local electrical grid, (however at present in Ireland a 6kW energy export limit applies), requiring a 32 kW battery installation. (Current data suggests that as a general rule, 1kWh of battery storage per 1kWp of PV).

The software model is currently based on the Passive House ‘Plus’ standard however design exploration is intended to progress toward the Premium Passivhaus standard and the Living Building Challenge also, due in particular, to the latter’s identification of ‘step change’ benefits across sites.

Optimisation of on-site energy generation, storage and management has been developed through the Passivhaus 3d project software. Statutory Planning permission is being sought in the summer of 2020, following final engagement with local planning authorities, neighbours and the creation of dynamic energy simulations to analysis energy balances/uses across the site.

**4 Conclusion**

The premise of this paper is that Mixed Use Urban Developments, utilising proven and focused low energy methodologies such Passivhaus ‘Plus’ and ‘Premium’ offer the greatest hope of reducing our carbon emissions to zero within the suggested time limit of 30 years. The ‘Passive House Premium’ energy standard, (the economic and ecological challenge of which is justified by the societal benefits), is the ideal standard for achieving this.

This paper argues that by minimising the initial energy demand, we can begin to tackle time and seasonal disparities across uses thus allowing optimal local energy distribution. In particular such developments feeding into the national grid have the capacity to buy time in regards to allowing us the operational space to ramp up our national retrofit programmes particularly in regard to closed loop supply chains.

Such developments will only achieve energy optimality if the building fabric standards are sufficiently robust so as to minimise the energy needs of the overall site and create a ‘flat line’ energy profile. Additionally the ‘mixed use’ profile ensures the maximum beneficial use of all energy locally, addressing troughs and peaks of use and need.

The significantly reduced energy demand, combined with optimal energy use and supply will contribute greatly to successful urban planning and thus contribute to addressing the emerging climate emergency. Mixed Use Development in this way allows for a clear Urban Design Strategy with well-defined methodologies and reflecting significant benefits within urban
environments, thus fulfilling the urban design criteria of the ‘whole being greater than the sum of the parts’. This is Urban Design for the 21st century.

This research is performed as part of a PhD study funded by the University of Ulster at Jordanstown. I wish to thank them for their sponsorship of these studies.

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