more | better :

an evaluation of the potential of alternative approaches to inform housing delivery in Wales

Dr Ed Green with Professor Wayne Forster

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

final report rev. D | 13.02.2017

This report was funded by Welsh Government's *Homes and Places* division.

It can be downloaded at http://orca.cf.ac.uk/98055/

To cite the report: Green, E.and Forster F (2017).*More | better: an evaluation of the potential of alternative approaches to inform housing delivery in Wales*. Cardiff: Cardiff University.

For queries about the report, contact Dr Ed Green at greene11@cardiff.ac.uk

0.0 | executive summary

Responsible government is not just about delivery in the here and now, vital though it is. It's also about looking towards the end of the decade and beyond, with a vision of the Wales we want for the future. Rt Hon Carwyn Jones AM, First Minister of Wales

There is a clear need in Wales for diverse, high quality housing that is not being met. This need is not likely to be met through volume house-building methods. There are also clear and emerging drivers for change, which should prompt legislators and commissioners of housing to engage in broader debate on the nature of new housing. This debate will include the process by which housing should be delivered, the standards it should be built to, and the ways in which performance, affordability and value should be measured. Among these drivers for change are increasingly stringent limits to energy consumption and carbon production, and an increasing public aspiration for quality, in terms of place, design, workmanship, fuel efficiency, longevity and, crucially, affordability.

Analysis of a range of case studies, combined with commentary from expert contributors, concludes that there is no single 'silver bullet', but that there is potential for more, better housing through a combination of innovative delivery pathways and construction techniques.

The Well-being of Future Generations (Wales) Act 2015, together with the Environment Act, demands a focus upon long term gains over short term expedience. The seven well-being 'goals' enshrined in the Act can be translated into a set of aspirations for housing development in Wales, as follows:

A globally responsible Wales	**Setting higher standards – reduced carbon footprints and energy-positive communities**
A prosperous Wales	**Developing an integrated all-Wales supply chain using local resources and a sustainable economy**
A resilient Wales	**Future proofing with long term flexibility, adaptability, ecological value and climate resilience**
A healthier Wales	**Reduced pressure on the health service through homes that promote physical and mental wellbeing**
A more equal Wales	**Eliminating household poverty by delivering affordable housing for all**
A Wales of cohesive communities	**Stronger neighbourhoods that support co-housing, self-build and cohesive communities**
A Wales of thriving culture and language	**Promoting diversity through Wales' unique cultural heritage, context and landscape**

The Welsh construction industry has access to innovative alternative construction techniques. Alone, these techniques cannot 'solve' the affordable housing crisis. However, combined with similar innovation in housing delivery, they could produce **more** housing that meets the above aspirations, in terms of building sustainable communities and making **better** quality homes accessible to households that are currently excluded from them.

no single silver bullet

This report concludes that there is *no single silver bullet* to 'solve' the housing crisis. A range of different approaches were evaluated. Each could deliver different benefits. Some benefits relate to project delivery (eg. affordability, reduced site time, fewer defects). Others relate to the development 'in use' (eg. reduced fuel bills, lower carbon footprint, energy generation). Other benefits impact on the wider context (eg support for local supply chain, community socio-economic benefits). Such considerations should inform choice of approach – fig.1.

Alternative approaches considered were *delivery pathways* (eg development partnership, community-led, self-build) or *construction techniques* (eg timber frame, offsite, modular).

delivery pathways (section 7.2)

The private sector, public/private partnerships, custom build, cooperative housing and self-build all have a part to play in the delivery of affordable housing. Quality design is needed, to ensure that homes are fit for future generations and a more consumer-oriented market.

Pathways that encourage households or communities to build their own homes result in new homes being delivered *in addition* to homes delivered through conventional routes, not in place of them. These pathways could make a meaningful contribution to housing supply. Community-centred initiatives are already happening in Wales. It is crucial that those involved understand the benefits and limitations of alternative approaches.

RECOMMENDATIONS:

- Land should be made available for the delivery of social / affordable housing projects, through a mechanism that encourages exploration of innovative delivery pathways.
- Locally administered registers could assess appetite for self-build and community projects, and connect people that have a better chance of success working together.
- LAs could facilitate such projects by providing serviced plots with 'principles of development' in place. Affordable land removes the two biggest barriers to self-build.
- There are around 23,000 empty properties in Wales. Well placed infrastructure projects could unlock significant quantities of housing without building a single home.
- Powers that enable Local Authorities to tackle derelict or empty infill sites, unoccupied buildings and land-hoarding by investors should be exploited.
- The location of new housing should not only be influenced by short term 'need', but also by resource availability (land, skills, materials) and a wider understanding of longer term growth (e.g. population migration to 'urban' areas).

construction techniques (section 7.3)

Most housing is built by a small number of nationally operating housebuilders using traditional construction techniques, typically 'bricks and mortar'. Disincentives for the uptake of alternative construction techniques include established supply chains and standardised designs. Incentives for smaller 'alternative' operators to up-scale are limited in Wales by a lack of larger residential developments. By expanding, they would expose themselves to greater risk through a lack of consistent demand. Also, the use of alternative forms of construction at scale would necessitate widespread reskilling and retooling. However, unless these techniques are delivered at scale, their full benefits will not be realised.

Alternative techniques use less cement than 'bricks and mortar'. Many are timber-based, a sustainable resource existing widely in Wales that 'locks' carbon into buildings, improving carbon footprints, and providing opportunities for local resource use and economic benefit.

Selection of approach:

Key considerations

delivery

Who is delivering the project?

How will it be delivered?

What is the capital budget?

What are the timescales?

What relevant expertise exists?

in-use

Who is the housing for?

How will the homes be used?

How might user needs change?

How likely is future adaptation?

What is the long term intention?

context

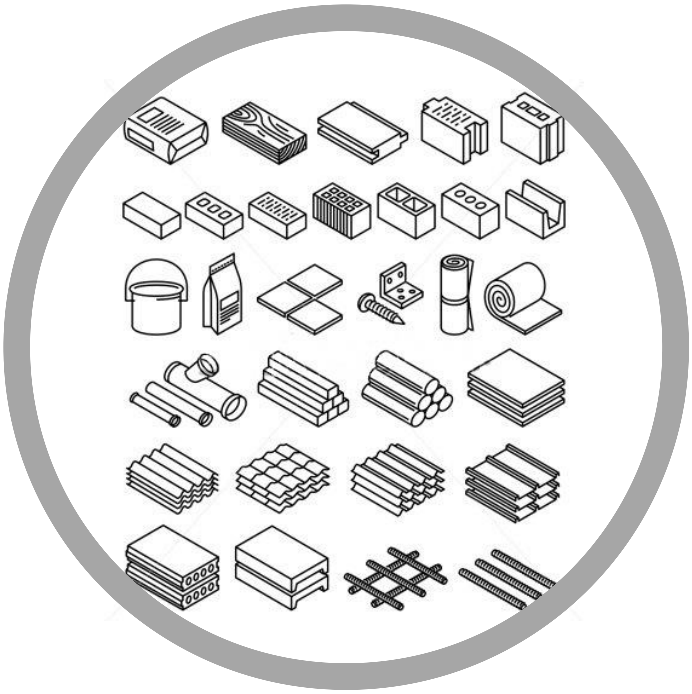
What is the physical context?

What is the local climate?

What materials are available?

What skills are available?

What resources are needed?



delivery

More affordable construction

Shorter timescale, less defects

Lower embodied energy

Less impact, carbon storing

Improved ecology

in-use

Lower primary energy use

Reduced heating bills

Reduced CO_2 production

On site energy capture+storage

Future source of revenue

context

Less pressure on local systems

Community training / skills

Revitalising existing community

Supporting local supply chain

Contributing to local economy

Potential benefits

Fig 0.1: Potential benefits and key considerations affecting choice of approach

Some of the case study techniques (and others, not captured by the study) are emerging, with limited track record, and represent relatively high risk / high cost options at this time.

However, each technique has different potential benefits. Some reduce specialist skills, increasing their applicability. Others lend themselves to densification of existing neighbourhoods. Some alternative approaches support greater levels of flexibility and adaptability, while others can deliver higher quality, even zero-defect, building. Pop-up factories establish opportunities for local training, and promote the use of local materials and resources. Some approaches would put development directly into the hands of communities.

RECOMMENDATIONS:

Affordable housing projects should be used to test emerging Welsh Housing Standards, and to identify the benefits and limitations of different construction techniques, by means of:

- performance comparisons (primarily energy and carbon, during delivery and in-use).
- potential for flexibility, adaptability, ease of maintenance and eventual re-use.
- applicability for alternative delivery pathways or skills training.
- use of local resources / products that might be developed into a Welsh supply chain.

Projects should be monitored during construction and post occupation, using an open, inter-disciplinary protocol for data collection, reporting and dissemination. Affordability and the wider value of each construction technique should be a focus of monitoring.

cost versus value (section 7.5)

According to BCIS data, the cost of new housing in the UK is among the most expensive in Europe, at around £1050/m^2. Changes to Building Regulations (Part L1, Wales 2015) have improved performance, but added to cost. Accessibility adds further costs, particularly in locations with challenging topography, as does the recent requirement for sprinklers.

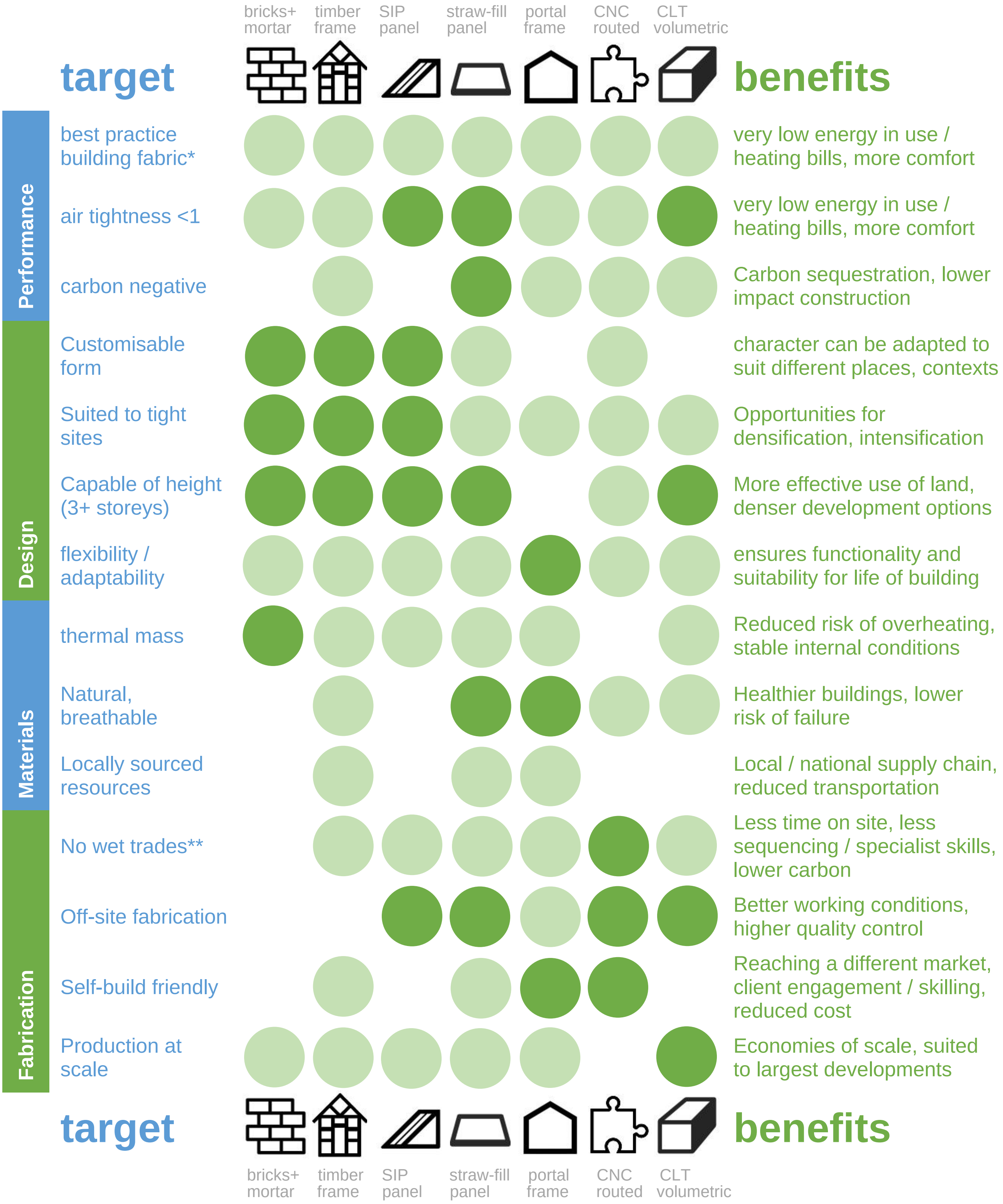
In the drive for better performance in terms of energy efficiency, historical social / affordable housing pilot projects attempting to attain higher standards (for example CfSH level 5/6) have often done so by adding ‘bolt-ons’ to traditional approaches rather than considering alternatives holistically, which has resulted in untenable cost increases: “…the Code Pilot programme supported the emerging trends and understanding that the cost of delivering zero carbon on site was prohibitive, and could offer serious challenges in both cost and design principles.” (BRE, WG Code Pilot Programme Technical Report ref. 285-001, 2013)

For lower income communities in Wales, the prospect of purchasing new housing outright at elevated costs is unrealistic. Alternative approaches are needed, that deliver ‘better’ affordable housing without untenable cost increases. The financial implications of each are difficult to report without complex, in-depth cost analysis, because impacts are interrelated. All case studies improved performance and reduced (and in some cases offset) heating bills.

Capital costs for case studies are in the range £500/m^2 to £1500/m^2. At the lowest end, capital costs do not deliver ‘finished’ buildings, only shells. Self-build construction dominates the lower cost case studies due to savings on labour (25-45% of total cost), but is limited in its applicability. Other approaches propose to deliver better value homes in terms of energy conservation and reduced heating bills, without considerably increasing capital costs.

It is important to distinguish between cost and value. Alternative approaches can deliver better value than traditional approaches, through wider benefits such as reduced pressure on local systems (including environmental systems and healthcare), skills provision, increased local employment, and benefits to the local economy.

Comparison, seven construction techniques:



* facility to achieve thermal performance equivalent to Passivhaus standard
** excluding foundations

Potential benefit   Delivered benefit

Fig 0.2: comparison of 'potential' and 'delivered' benefits, by construction technique

Developing appropriate technologies in Wales would build capacity for local construction. An all-Wales supply chain would keep much of the expenditure within Wales, reinvest capital in Welsh industries and, longer term, develop expertise and products for export.

Three of the case studies generate significant income through renewables (PV). In the right context, renewables provide a means by which housing delivery can be re-considered as an income stream, offsetting rentals to deliver more affordable housing. However, in order to be successful, energy generation must be properly integrated into the projects – in terms of design, construction and operational / maintenance programmes.

Initiating a step change (section 7.6)

To facilitate a step change in the quality and quantity of housing, Welsh Government should:

- Task a working group with understanding housing in the context of the WFGW Act.
- Map existing / emerging housing standards against existing performance standards.
- Liaise internationally with innovative policy makers, commissioners and practitioners.
- Establish an open-access forum for anyone interested in building homes.
- Map housing need, supply and opportunities in a transparent, joined-up way.
- Nurture industry in Wales with potential to contribute to a Wales-based supply chain.
- Explore the densification of existing low density communities in viable locations.
- Translate this learning into a clear, concise, flexible, adaptable housing standard.

A new Welsh Housing Standard should promote quality, diversity, sustainability, shared learning and equality. It should be capable of adapting to emerging best practice and demand excellence in the built environment, to ensure that Wales has a clear pathway to decarbonisation, and a means of developing sustainably for the future.

In conclusion

Wales should lead the way by placing affordable housing and affordable warmth at the centre of national policy, with homes and places that meet our needs, now and in the future. We must stop thinking purely in terms of capital costs. Construction that drains resources should be replaced with buildings that generate resources – that are energy positive and carbon negative. This fundamental perspective shift is in line with the WFGA (Wales) 2015.

By employing alternative approaches, we could be constructing new homes and neighbourhoods in a more contextually appropriate way, with greater long term value.

Alternative approaches have the potential to deliver affordable homes *in parallel* with more established methods, so long as knowledge is shared with commissioners and constructors.

Different delivery pathways and construction techniques could lead to more diverse housing that is better quality, more fit-for-purpose, more affordable and more sustainable.

Further benefits could include the growth of employment in Wales, a national supply chain, greater long term resilience, and renewable energy infrastructure as a source of income.

The creation and maintenance of sustainable communities could provide a new focus for post-industrial Wales, facilitating joined-up development that works at a local level.

delivery pathways: step change impact

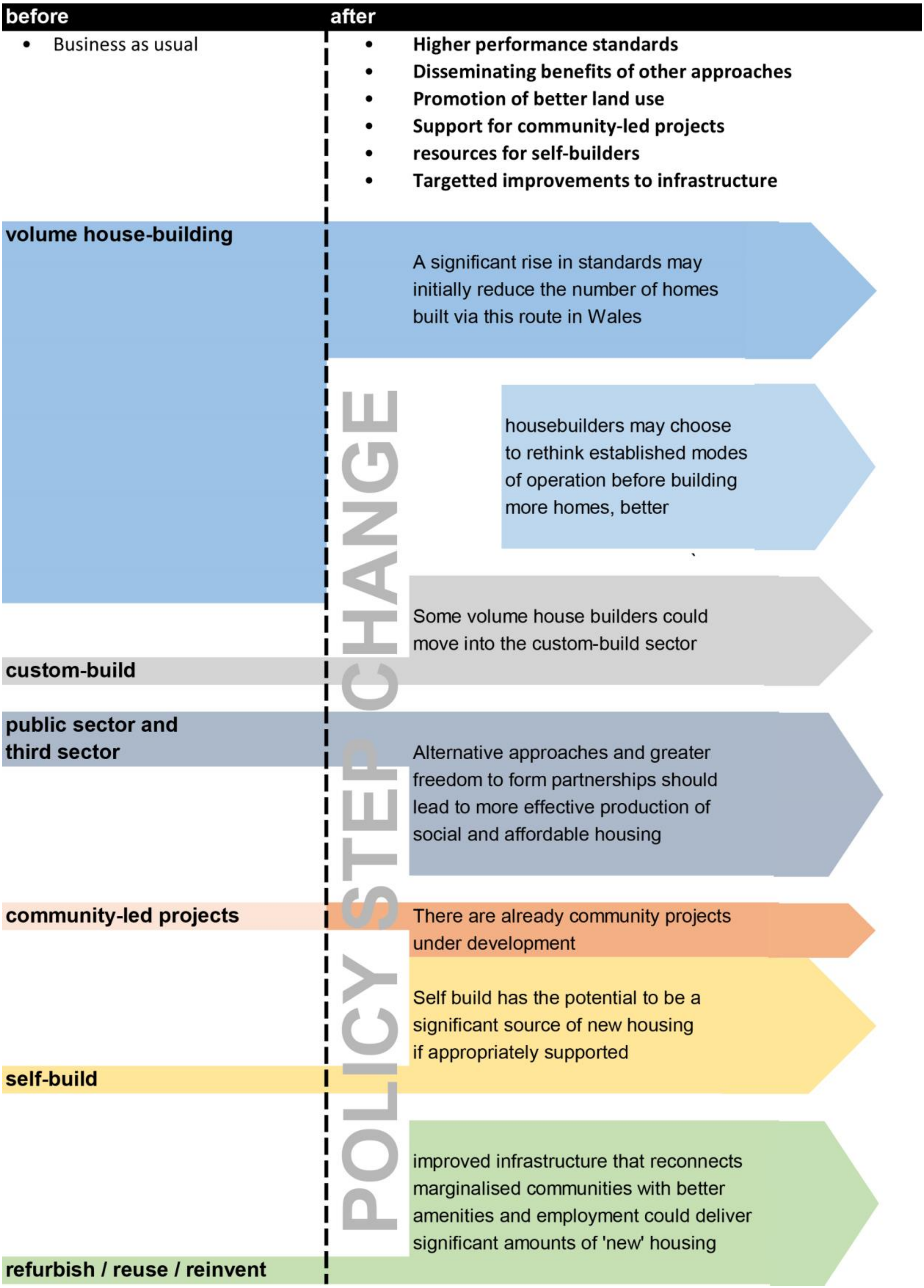


Fig 0.3: Conceptual impact of a policy-led step change on housing delivery pathways

If Wales is to rise to the challenge of the housing crisis by constructing a legacy of homes that future generations consider to be a blessing and not a burden, the correct standards, incentives and monitoring must be put in place to encourage *all* existing pathways, along with some that do not yet exist, to produce more, better housing.

"We are forced to choose between **three courses of action**:

The first is to build only the **small amount** we're likely to be able to afford. This is to acknowledge defeat.

The second is to accept a **drastic reduction in space and quality** while maintaining the same total. This again is defeat, and why should we accept defeat in this, when we have accomplished so much in other fields – radar for instance, nuclear fission, or jet propulsion?

The third course is to approach the whole problem of building afresh, with the objective of devising a fundamentally simpler technique, **a technique which will give us greater beauty, comfort and value at a lower cost**."

RMJM co-founder Stirrat Johnson-Marshall, faced with similarly austere circumstances following the Second World War (speaking on the BBC's Third Programme in 1950)

construction techniques: step change impact

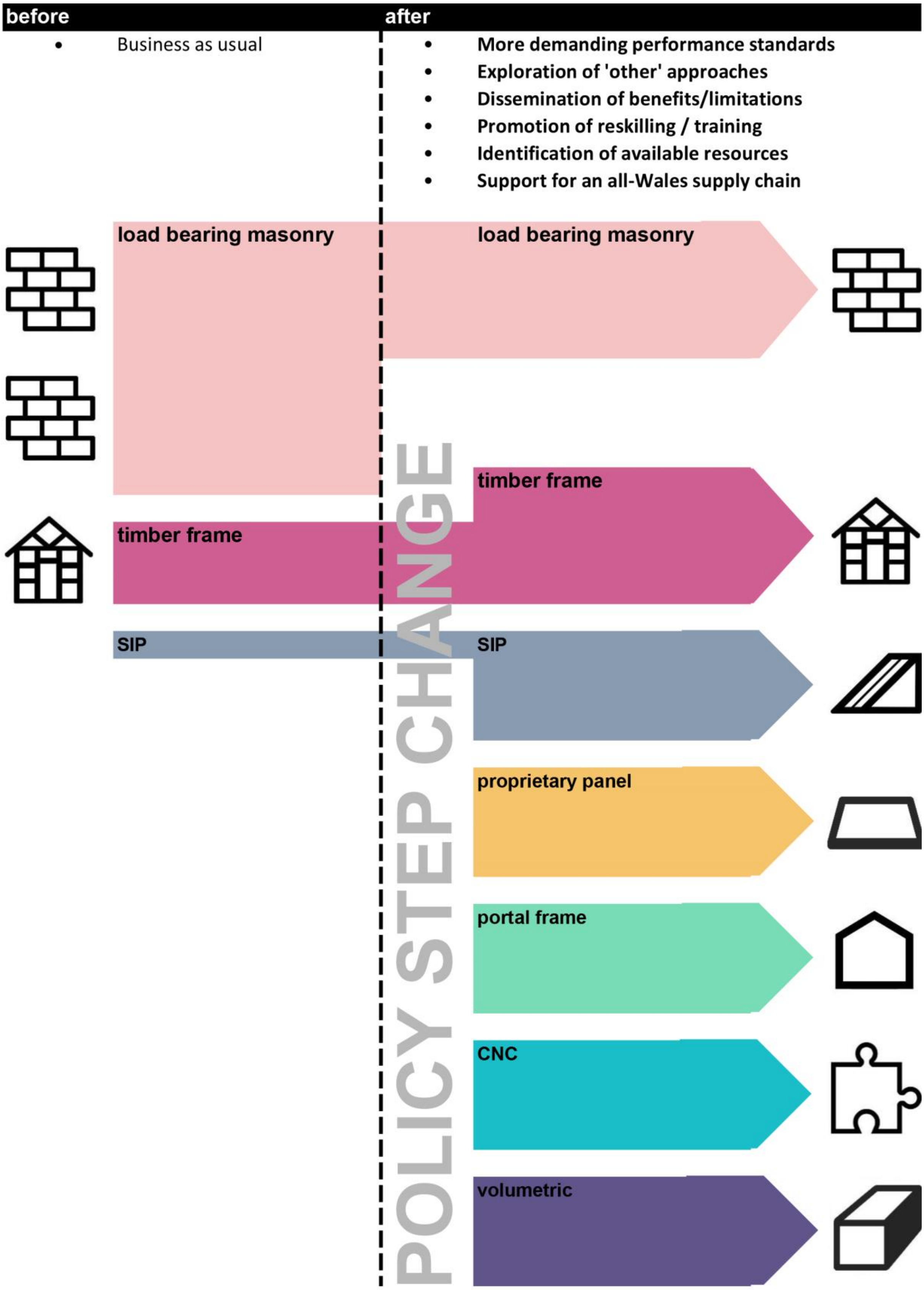


Fig 0.4: Conceptual impact of a policy-led step change on housing construction techniques

1.0 | contents

Scope of study:

This report is the product of an evaluation of alternative approaches to housing delivery, funded by Welsh Government, and conducted between April of 2016 and January of 2017. The evaluation was a wide ranging exploration of various approaches currently being employed in the delivery of housing at a range of scales – predominantly in the UK, but also overseas. The report assesses different considerations in the selection of alternative approaches to housing delivery and explores the potential for wider benefits, rather than making approach-specific policy recommendations. Specific policy responses require careful design and consultation, and this report is designed to contribute to the beginning of such a process, rather than be the conclusion of it.

The report is in no way comprehensive; this would require a considerably wider remit and a significantly longer research programme. Thirteen ‘case studies’ have been included, based on their ability to indicate the breadth of approaches in existence, and on the basis of access to information. Data were collected to facilitate informed cross-case study discussion that establishes overarching, recurring benefits and limitations associated with each approach.

The report provides a clear account of the key distinctions between the different approaches that are employed for each case study (in terms of relevant ‘themes’ based around recurring / commonplace performance targets), and assesses the applicability of each approach for different project types. The report also assists in the identification of relevant themes / performance targets for an emerging Welsh housing standard; one that might encompass, or even encourage, alternative approaches.

Where possible, comparable data have been provided across the case studies. However, many of the projects described in the report are, by their nature, fundamentally different from one another and from established practice in terms of their procurement, their performance, or their construction. Moreover, many of the case studies described by this report are prototypes, or have not yet been lived in for a significant period of time. As such, there are limits to the degree to which data should be compared.

Because many of the case study projects included in the report are work in progress, and in various stages of development, the report should be read as a working document. Data sets are as complete as they can be at the time of publication.

Identification of ‘better’ and ‘worse’ aspects of a particular approach inevitably requires that generalisations are made regarding the context in which the approach is being applied. Where possible, generalisations have been minimised, but without them it would be difficult to provide any direction on the wider applicability of each approach. A central thrust of the report is the assertion that **there is no single silver bullet**; a project’s brief, procurement, climate and context should all be considered in the selection of a ‘best fit’ approach.

Equally importantly, the nature of the desired benefits (e.g. low energy, carbon negative, high quality, community engagement, benefit to the local economy) will inform the choice of approach. The application of high level strategic recommendations to an oversimplification of a project’s context would inevitably obviate many, if not all, of the wider community and socio-economic benefits offered by these alternative approaches.

2.0 | introduction

In Wales, we are building approximately half the new homes that are needed. Different forms of housing are needed as a result of changing demographics, and shifts in the locations where housing is required. The housing that is currently being built may not stand us in good stead for the future. Much of it is either inflexible, fails to perform to acceptable standards, or generates secondary problems, such as increased dependence on cars.

“We are still nowhere near tackling our national housing crisis, which is causing misery for millions of people who are unable to secure a decent home at a price they can afford.”
Grainia Long, chief executive Chartered Institute of Housing

The housing crisis is well documented, as are the key underlying factors that limit the supply of new homes; the availability of land and the value attributed to it, the cost of building new homes to contemporary standards, and the methodologies adopted by a relatively small number of national housebuilders, who dominate the supply of new housing in the UK. What is less well documented is the range of **alternative approaches** to house-building currently in existence, some of which are established, and others which are emerging. Some of these alternative approaches relate to alternative methods of **construction**, while others are related to alternative **pathways –** and to commissioning or procurement.

Some of these approaches have the potential to impact on the cost of building new homes, whilst others could improve the performance and quality of these homes. Yet more have the potential to encourage individuals, organisations and communities to develop and build for themselves, or to do so more economically, or more appropriately. Some facilitate different pathways to housing delivery, which may unlock land previously considered undevelopable. Many also provide opportunities for capital expenditure to stay in Wales. Together, these implications could significantly increase our capacity to build **more** homes, **better**.

As a nation, we are embarking on a new post-industrial era, spurned on by the availability of information. Social and affordable house-building programmes are underway, and propose to deliver housing in quantities not seen for several decades, and to the highest energy efficiency standards ever built in Wales. Community groups are clamouring to build for themselves. Statistics tell us that self-build and custom-build are both historically relevant, and already burgeoning over the border in England. Planning approvals in Wales were up 71% in 2015, the biggest increase across the UK. But if we do intend to embark on a new regime of home- and community-building, what should we be building, and how, in order to avoid a legacy of housing that is not fit for purpose, or in line with Welsh policy?

“Responsible government is not just about delivery in the here and now, vital though it is. It’s also about looking towards the end of the decade and beyond, with a vision of the Wales we want for the future.” Rt Hon Carwyn Jones AM, First Minister of Wales

The **Well-being of Future Generations (Wales) Act 2015** came into force in April 2016. The Act requires that public bodies take a more joined up approach by thinking longer term, working better with people, communities and internally – helping to create a Wales that we all want to live in, now and in the future. Taken together, the Well-being of Future Generations Act and the Environment Act are very ambitious. They demand a focus upon medium term gain rather than short term expedience. The seven well-being goals enshrined in the Act provide a framework for an investigation of the drivers for more | better housing:

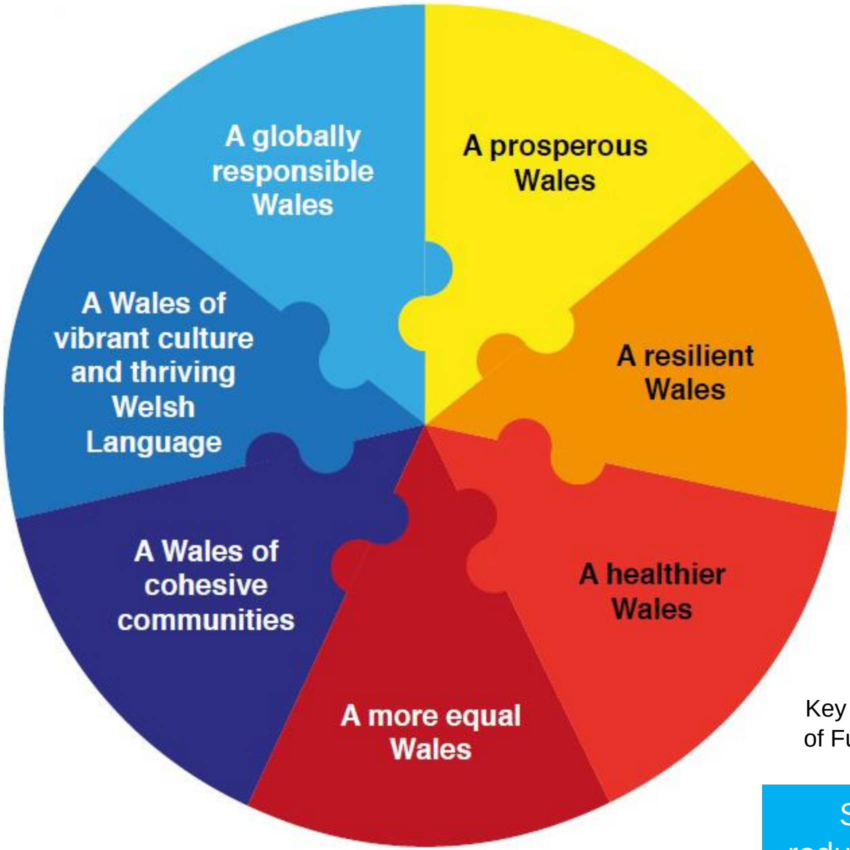


Figure 2.0A:

Key findings mapped onto the Wellbeing of Future Generations Act (Wales) 2015:

Setting higher standards – reduced carbon footprints and energy-positive communities

Developing an integrated all-Wales supply chain using local resources and a sustainable economy

Future proofing with long term flexibility, adaptability, ecological value and climate resilience

Reduced health service pressure through buildings that promote physical and mental wellbeing

Eliminating household poverty, by delivering affordable housing for all

Stronger neighbourhoods that support co-housing, self-build and cohesive communities

Promoting diversity through Wales' unique cultural heritage, context and landscape

This report evaluates a range of alternative approaches that are currently being used to deliver housing. It considers alternative approaches to construction, as well as alternative pathways for housing commissioning, procurement and delivery. The report provides a range of perspectives, with a clear focus on affordable / social housing.

The principal aim of the report is to demonstrate potential impact and significance to prospective funding bodies, to inform local and national policy development, and to increase awareness of alternative approaches to housing delivery in Wales among commissioners of new affordable and social housing in Wales.

Practitioners, industry partners and academics with relevant experience of an alternative constructional approach or an alternative delivery pathway have collaborated on this report in one of two ways. Some have provided themed essays explaining their particular perspective and experience in detail. Others have contributed case studies. Case studies typically include a description of the approach, system or technology that their direct experience relates to, and an outline of the key benefits that drew them to use of the system, along with any restrictions in its applicability, or unanticipated consequences of its implementation. For a full list of collaborators, see section 9.0.

The report draws from this material to make observations regarding the future use of alternative approaches to improve housing delivery in Wales. This includes an analysis of potential incentives and constraints that might affect the use of alternative approaches, and an examination of implications for clients and end-users.

The report is broken down into the following sections:

2.0 introduction

Following this preamble, section 2 goes on to provide a more in-depth account of the reasons why more | better housing is needed in Wales:

An essay by PPIW draws a statistical picture of the need for housing in Wales. Cardiff Council's HPP programme is used to describe a city-wide approach to housing delivery.

Ted Stevens, chair of the National Self and Custom-build Association (NAcSBA) describes alternative pathways to *more* housing. The Graven Hill Village case study is the largest self-build project in the UK, and uses alternative approaches to regulation and procurement.

Chris Brown talks about *better*, in terms of the quality that IGLOO Regeneration strive for in their developments. Porth Teigr, an IGLOO case study, is an application of their Footprint policy, and includes project-specific analysis of different constructional approaches.

3.0 standards

This section explores the various standards that define, control and influence housing design in the UK. It identifies key factors that are typically influenced by housing standards, and discusses the ways different factors can shape our homes and communities.

Themed essays by informed practitioners go on to explore three very different housing standards, and discuss the implications of adopting each one. The standards are Passivhaus, the Fabric Energy Efficiency standard, and the Living Building Challenge.

Case studies describe three projects that have been developed to different housing standards, discuss key implications, and outline the levels of performance that each project has obtained, or proposes to achieve.

4.0 thinking local

Section 4 discusses the importance of local factors in housing delivery. The first essay discusses a range of community-led projects and approaches that have gained momentum in recent years, backed up by a case study describing the LILAC cohousing scheme, a successful community-led project.

The second essay focuses on embodied carbon in construction, and discusses the impact of locally available materials, specifically Welsh timber, on the built environment and on the wider community. The case study describes Ty Unnos, a constructional system that arose specifically out of the desire to exploit underused, home-grown Welsh timber.

5.0 making places

Section 5 explores how understanding place and context are central to good housing. The first essay explores the benefits of rooting new housing in existing communities, rather than on the fringes of settlements or in suburban/out of town locations. The case study describes the approach adopted in developing a range of infill social housing sites across Bristol.

The second essay discusses the predominantly low density, rural nature of Wales, and asks what sort of housing truly suits the Welsh context. The case study, Barnhaus, proposes forms borrowed from agriculture for high quality, affordable housing in rural locations.

6.0 building alternatives

Section 6 introduces three more alternative approaches. The first essay discusses the implications of ‘scaling up’ for a fabricator of alternative construction, and the hurdles that inhibit widespread uptake. The case study describes how SIPs (Structural Insulated Panels) have been used to deliver the first fully privately funded affordable housing in the UK.

The second essay discusses volumetric / off site manufacture and construction, in terms of its benefits and limitations. One case study describes the real successes delivered by the UK’s first volumetric affordable housing more than ten years ago. Another case study brings us up to date with emerging plans for volumetric housing at a very different scale.

The third essay explores the benefits and implications of both open source information sharing and DDM (Distributed Digital Manufacturing), and looks forwards to predict further changes ahead. The case study, the first occupied Wikihouse in the UK, demonstrates that these cutting edge technologies are already here.

7.0 findings

The final section of the report draws from the earlier sections, and summarises key observations through a series of one page ‘headlines’, as follows:

- performance: what works
- construction techniques
- delivery pathways
- local leadership
- cost versus value
- initiating a step change
- promoting more | better

8.0 useful links

9.0 list of collaborators

the case studies: an overview

The table below provides a concise overview of the case studies included in this report. They are grouped by construction technique (indicated by the icon on the left of the table). Additional information relates to project size and housing type, geographic location, delivery pathway, key targets / standards, and the current status of the project.

An equivalent table encapsulating the thematic analysis of each approach is included in section 7.0 (figure 7.0A). For an analysis of the comparative performance of each case study, see section 7.1 (figures 7.1A to 7.1D).

ref.	case study	housing	location	technique	pathway	targets	status
2.3	Porth Teigr	100 mixed units for sale	Cardiff Bay	masonry	privately funded	IGLOO Footprint standard, Building for Life (CABE)	tender
2.1	Cardiff HPP	487 council housing units	Cardiff, various	masonry	LA / private partners	Cardiff standard (17%+ over Part L), tenure blind, maximum delivery	planning
6.2A	Murray Grove	30 affordable housing units	Hackney, London	volumetric, light steet	RSL	High performance, zero defect, 50% programme time	occupied since 1999
6.2B	L & G Homes	factory for mass housing	Leeds	volumetric, CLT	privately funded	High performance, affordable, reduced programme time, at scale	prototypes complete
2.2	Graven Hill	single private home	Bicester, Oxfordshire	SIP	custom build	Affordable, low fuel costs, FEE standard	on site
3.2	SOLCER	single prototype dwelling	Bridgend	SIP	research project	DQR compliant, very low carbon, energy positive	completed in 2015
6.1	William Street	200 mixed tenure houses	Barking, London	SIP	privately funded	first 100% privately funded UK social housing, CfSH lvl 4	occupied since 2011
4.1	LILAC co-housing	20 dwelling cohousing	Leeds	straw-filled panel	community-led	Affordable, low fuel costs, carbon negative, CfSH level 4	occupied since 2013
3.3	Ty Solar	6 affordable houses for rent	Pembroke-shire	timber frame	privately funded	Affordable, energy positive, PV as source of revenue / rental offset	completed in 2016
3.1	More Homes	18 council housing units	Swansea	timber frame	LA	High performance (Passivhaus std), low maintenance, community focus	planning
5.1	BCC passivhaus	12 council housing units	Bristol, various	timber frame	LA	deliverable 'fabric-first', low energy / fuel bills (Passivhaus std)	on site

Figure 2.0B: summary of case studies

Load bearing masonry

Volumetric construction

Sandwich, eg SIP

Panelised system

Timber frame

Portal frame

DDM

Notes:

The taxonomy of approaches covered by the case studies is not comprehensive. Case studies were selected for their ability to represent a particular approach (either delivery pathway or construction technique). So far as possible, data are drawn from comparable sources. There will inevitably be inconsistencies between data sets. However, they serve to describe key differences between the approaches documented in the report.

2.1 | future need and demand

The Public Policy Institute for Wales *(PPIW) was established in January 2014 to provide the Welsh Government with authoritative independent analysis and advice. The Institute is co-funded by the Economic and Social Research Council and the Welsh Government, and seeks to use evidence to improve policy and practice in Wales and beyond.*

Lauren Carter-Davies *manages bespoke assignments for Welsh Government Ministers and provides research support to the Director and Deputy Director. Her work includes scoping assignments and assessing evidence, commissioning experts, writing and editing reports.*

The housing sector in Wales faces a challenging, rapidly changing landscape. As legislation and policy diverge from Westminster, Welsh housing policy shifts further from England than ever before. We have new legislation and emerging policy, meanwhile social housing providers are feeling the tension between Welsh housing policy and UK welfare policy.

The benefit cap reduction has pushed some tenants out of the private rented sector, leaving them in need of social housing. Meanwhile, the 'bedroom tax' has increased pressure for smaller properties, and there is increasing evidence that social housing providers are facing a change in demand. Simultaneously, private sector rents are rising in parts of Wales, increasing the pressure on social housing and pricing people out of housing within their local area.

The Renting Homes Bill bought in a new licensing scheme and tenancy reform, but the private rented sector too is changing. Despite an increase in private rents, our research from the PPIW suggests that growth within the private rented sector dominates tenure changes in Wales, with around one in seven households now privately renting. The traditional view of renting as a temporary situation is changing and transforming the sector at an alarming rate.

Driven by necessity more than choice, a large proportion of the Welsh population now live in rented housing, and this trend is set to increase unless more affordable housing is made available. At the same time, projections predict a continuation of annual increases in the total number of households in Wales, ranging from negative growth in some rural and northern regions up to 30 per cent growth in Cardiff.

These challenges throw into question whether we currently have the right properties in the right geographic areas, whether there is enough social housing, and whether welfare reforms mean that social rent levels are unaffordable for some. While house-building has increased in Wales in recent years, affordable housing targets for 2014-2015 were still not achieved. What is now certain is that there is a desperate need for more affordable housing in Wales. But how much?

Our analysis of future housing need and demand in Wales, published in October 2015, concluded that the Welsh Government's official projections might underestimate future housing need, and there may be a need to build sixty thousand more homes than was previously thought. This analysis suggests that we will only meet the demand for housing over the period 2011 to 2031 if the rate of house building in Wales returns to levels not seen for almost 20 years.

Former Assembly Members have unanimously agreed on the need for more housing. Indeed, all party manifestos pledged to build more homes while in office. The new government has now committed to deliver an extra twenty thousand affordable homes over their term in office. But what form should this house building take?

We have an increasing, and increasingly diverse, ageing population. Our research centred on the need for older people's housing concludes that Wales lacks an adequate supply of 'housing with care' accommodation (also called extra care housing) which meets established policy goals by promoting independent and autonomous living for older people. Our experts recommended the development of short term measures and a long-term strategy to provide 'future-proofed' and 'age-sustainable' housing solutions.

Meanwhile, we also have an increasing number of younger people in need of support. Our work on the housing provision for young care leavers suggests that the number of care leavers across Wales is increasing, that there are serious concerns about increases in the number of care leavers with complex and multiple needs, and that there is inconsistent service quality across local authorities to combat the risk of homelessness among this group.

A rapidly-changing housing sector requires careful monitoring and informed research, in order to help us understand the size and shape of future housing provision need. The future for housing in Wales is uncertain, and much of the challenge sits outside the control of powers in Wales. The extent to which the existing volume house-building industry can be expected to meet the diverse and changing housing need in Wales is unclear. Research that explores alternative pathways to housing delivery, and that could help to address the gap between need and demand for housing in Wales, is to be welcomed.

2.1 case study: **Cardiff HPP**

Client City of Cardiff Council

Architect Pentan architects

Location Various (forty sites across the city)

Background

The City of Cardiff has partnered with developer Wates Living Space to develop new homes across a range of sites covering forty hectares of land and delivering up to 1,500 units[1]. The Housing Partnership Programme (HPP) is a priority for Cardiff Council. The Council aspire to build tenure-blind high quality, energy-efficient homes in areas of need. These homes, integrated with their surroundings, will create local jobs and training, and deliver wider community benefit and long term investment. Four overarching HPP objectives are to:

- maximise the deliverability of affordable housing
- build sustainable homes
- maximise the Council's resources (land and capital)
- build sustainable communities.

Description – the Cardiff Standard

The Council has developed a set of design and sustainability principles specific to the programme. The 'Cardiff Standard' sets out build requirements in terms of construction types, layouts and energy standards which apply to both the open market and affordable units. At least 40% of the units are to be affordable, with the remainder for private sale.

The Council aims to set the standard for other developments in the city by encouraging greater environmental sustainability, tackling fuel poverty and to providing greater energy and environmental resilience. Space standards required by the Cardiff Standard are larger than the Welsh Governments DQR standards (and very slightly larger than the London Design Guide).

Some of the sites are challenging. A key aim is for the programme to cross-subsidise across sites, ensuring the portfolio can be delivered in its entirety. Building the right properties in the right areas ensures that an appropriate mix of open market and affordable housing is provided on each site, enabling sustainable development across the city.

Environmental approach

One of the main aims of the HPP is to deliver energy efficient homes that will assist in tackling fuel poverty within the city. To achieve the HPP requires that bidders offer a holistic approach to the developments to maximise energy efficiency.

The Cardiff Standard will achieve a 17% uplift in building performance over Part L of the Building Regulations Wales 2014. The preferred route is by means of 'fabric first', as demonstrated by the recent AIM4C Project, and Cardiff Council has set minimum fabric performance standards, efficiencies for u-values, heat generation, and thermal bridging.

---

[1] The land includes large sites in excess of 100 units, medium sites of between 25 and 100 units, and smaller sites - some containing as few as one or two units.

Construction and materials

Structure	Power-floated ground bearing in-situ concrete slabs where possible, but some sites require piling / raft foundations. Loadbearing masonry external envelope. Upper floors are to be 200mm deep precast concrete planks (party floors, flats) or 300mm deep engineered timber joists (houses), to provide a clear span, gable to gable. Pitched roofs are to be formed with un-treated timber trussed rafters.
External fabric	Traditional partially filled cavity wall construction (insulation thickness varies) with a 50mm clear cavity. External leaf of clay facing brickwork, with aircrete block inner leaf. Roofs are to be finished with interlocking concrete tiles, with no projection at either eaves or gable. Double glazed u-pvc windows / doors.
Heating	gas fired wet central heating / hot water (combi) with radiators
Renewables	The client advocate FEES (Fabric Energy Efficiency Standards) without renewables, but other approaches will be considered.
U-value (affordable)	walls 0.17 roof 0.10 floor 0.15 glazing 1.0 / 1.2 W/sqm°C
Cardiff Std. min:	walls 0.18 roof 0.13 floor 0.15 glazing 1.4 / 1.6 W/sqm°C
Air tightness	target <4 $m^3/h.m^2$ and >3 $m^3/h.m^2$ (natural ventilation with extract)
Performance target	FEEs of 49 $kWh/m^2.yr$ (detached/semi) and 41 $kWh/m^2.yr$ (terrace/flat) Improvement of 17-21% over Building Regulations Part L (Wales)2015
	SAP rating: Energy efficiency 86, Environmental impact (CO_2) 89
Procurement	An extensive and in-depth tender process (2013-2015) led to the appointment of Wates Living Space and their design team for the HPP
Capital costs	currently estimated at £1450/sqm across the project as a whole

Current status

The Council has approved a Capital investment of up to £33 million to support the project, and fund the development of quality affordable homes. The housing will be delivered in three development phases over ten years. Phase I of the HPP has been submitted for planning and is due to be determined Sept / Oct 2016, with commencement by the end of 2016. Phase I is programmed to conclude in 2020, and will provide almost five hundred homes:

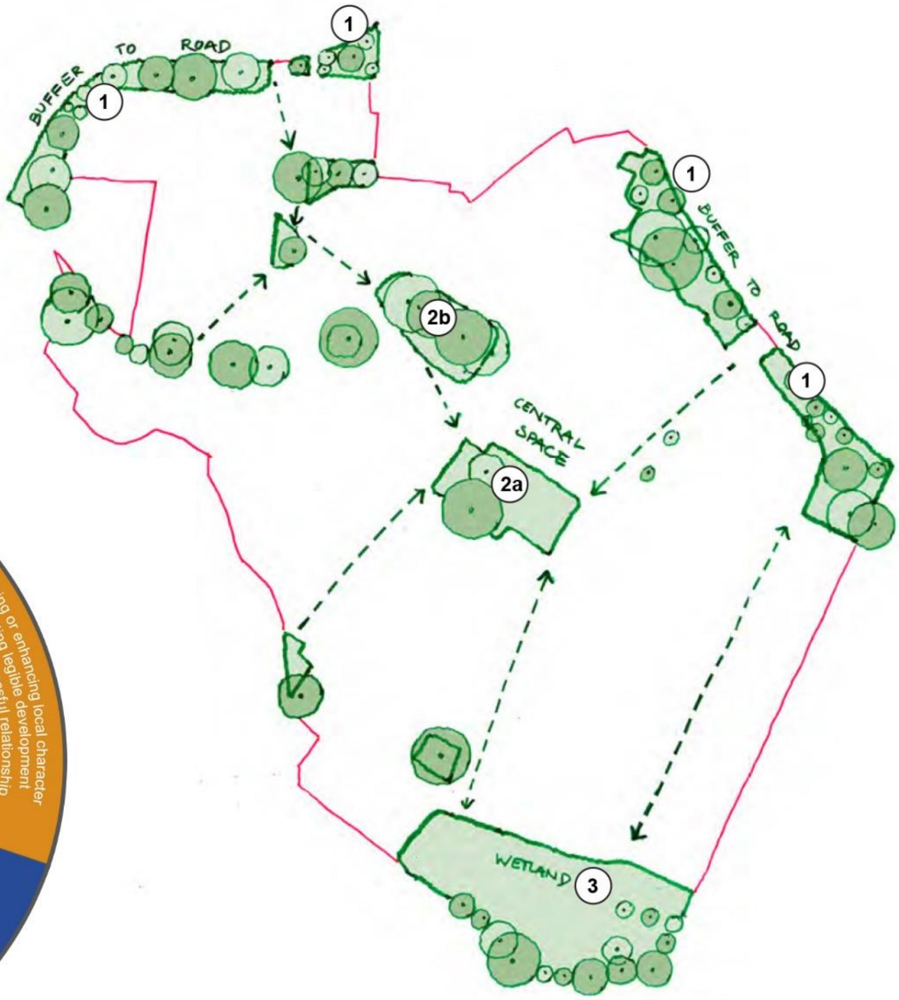
#	site	no. units
1	Snowden Road and Wilson Road, Ely	20
2	Ty Newydd, and Heol Trenewydd Caerau	16
3	Briardene, Gabalfa	42
4	Highfields , Heath	40
5	Walker House, Llanishen	16
6	Braunton Crescent and Clevedon Road Llanrumney	106
7	Llanrumney Depot, Mount Pleasant Lane	31
8	Llanrumney Housing Office	1
9	11-57 Llandudno Road and Pwllheli Court, Rumney	16
10	Willowbrook West, St Mellons	192
12	11-22 Ty To Maen, Old St. Mellons	8
	Phase 1 total	**487 units**

Figure 2.1A (right): Willowbrook site plan

Use of existing featurers is one way that difference is exploited across the sites

Figure 2.1B (below):

The five key objectives of good design (TAN 12) are at the heart of the proposals.



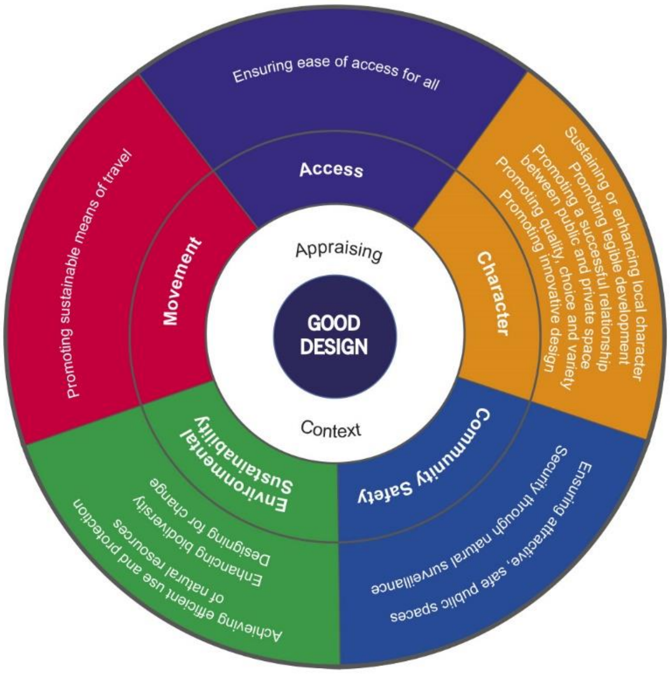
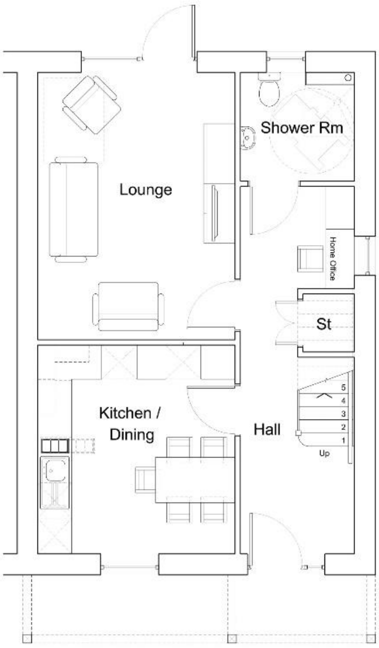
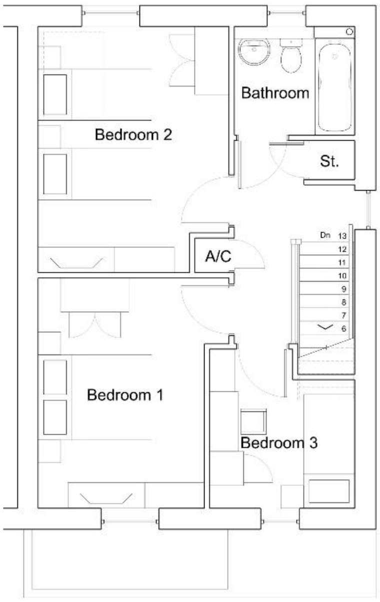


Figure 2.1C (below):

Willowbrook site – proposed view at site entrance



Ground Floor



First Floor

Elevation with materials

Figure 2.1D: Typical dwelling floor plans

Figure 2.1E: Willowbrook site – proposed street view

APPLICABILITY ASSESSMENT: LOAD BEARING MASONRY

Description

Traditional load bearing partial fill cavity wall construction, insulated to meet high Fabric Energy Efficiency standards, with no reliance on renewables or bolt-on technologies.

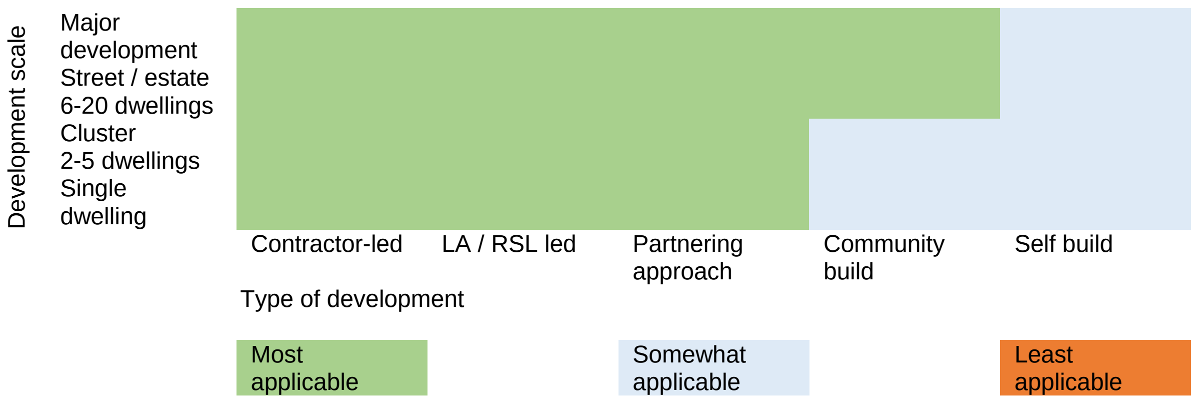
.Benefits and limitations

Key benefits	**During construction:** • Approach delivers robust buildings using proven techniques • Site operatives are generally familiar with the materials / detailing employed • Use of generic, widely available materials and products
	In use: • Very low energy use for space heating, due to highly insulated building fabric • Low maintenance, suited to UK coastal climate, straightforward to adapt • Masonry inner leaf provides thermal mass
Key limitations	**During construction:** • Large carbon footprint due to cementitious products and ‘wet’ construction • Sequential programme that is weather-dependant • Reliant on good workmanship on site, air tightness requires additional layers
	In use: • Non-porous envelope does not encourage moisture to pass through fabric • Air tightness tolerances combined with unpredictable performance can lead to condensation issues where MVHR is not employed.

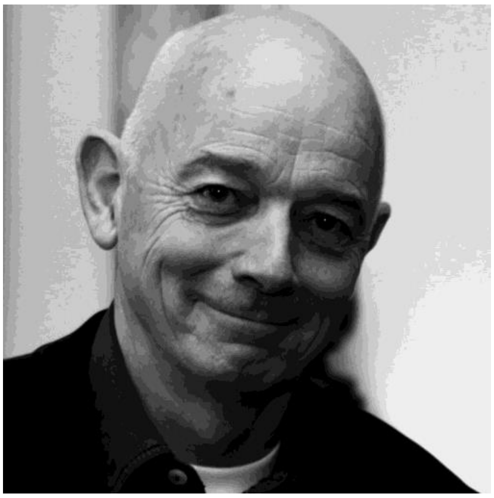
Thematic analysis

Space standards	No implications, small module sizes benefit small sites/builds
Flexibility / adapt.	Highly flexible and robust. Adaptation is messy and time consuming
Env. Performance	High thermal performance / air tightness, dependent on workmanship
Resilience	High level of thermal mass typically, very low maintenance
Materials	nationally distributed cementitious products with high carbon footprint
Character	Flexible aesthetic typically suits established urban/suburban character
Density	Low / medium / high density are all possible
Ecology	High impact construction, typically generating significant waste on site
Health	Non breathable fabric without MVHR can generate moisture issues
Connectivity	Reliant on specialist [wet] trades, not suited to self / community builds

Applicability matrix



2.2 | more



The National Custom & Self Build Association (NaCSBA) *was set up by network of companies and individuals with the common aim of promoting self build and custom build as an alternative form of delivery that can make a significant contribution to home building. NaCSBA brings together developers, architects, planners, manufacturers, community groups and local authorities to develop, share and promote best practice.*

Ted Stevens *is a former award winning architectural journalist and Editor of Planning magazine. He founded NaCSBA in 2008, and was awarded an OBE in 2014 for his services to the housing sector.*

For decades, Britain has failed to build anywhere near enough new homes to meet the growing number of households. People living longer, more people living alone, and a growing population together mean that the UK needs to build 250,000+ new homes a year. Last year – which was the best since 2008 – we delivered around 141,000. Last year in Wales just 6,789 new homes were built – a significant increase on the average for the last five years, but still a long way short of the 14,000+ homes that are required.

So what's the problem? Why have successive Governments failed to boost the levels of new housebuilding? The answer is mainly due to the increased consolidation of the private housebuilding sector – with fewer and fewer major companies responsible for the construction of an increasing proportion of our new homes. Most of these businesses are listed on the Stock Market and they therefore have to do their best to maximise their profits. And how have they done this?

By managing the rate of delivery, so that there's always more local demand than supply (this helps to ensure high house prices). And by 'value engineering' every element of the homes they build (so they 'squeeze' the homes into as tight an envelope as possible, and they work hard to minimise the construction cost). The end result is that Britain's new homes are now among the smallest in Europe, and also the most expensive.

The quality of the standard products produced by the volume housebuilders has also come in for a lot of criticism. A survey conducted by YouGov on behalf of the RIBA showed that three quarters of the public would not choose to buy a new house, mainly because of the small size of the rooms. And the ongoing All Party Parliamentary Group enquiry into the quality of new housing has received a torrent of submissions citing poor workmanship and defects….so much so that the Group has already called for a New Homes Ombudsman to be set up, even before the Group has published its report.

Over the last two decades Britain's housebuilding behemoths have gobbled up many smaller and medium sized housebuilders so, unlike most other countries, we now have very few small to medium sized regional or locally based housebuilders. In the 1980s there were 12,000 of them across the UK – now there are fewer than 3,000. Other countries haven't concentrated their housebuilding sector like this; they've managed to retain their local and regional housebuilders. And they've positively encouraged new, innovative and diverse ways of adding additional housing supply. For example: -

- In Berlin around a sixth of all the new homes completed in recent years were directly delivered by local building groups (baugruppen), who hired their own architects and contractors and therefore got the bespoke homes they wanted (and saved themselves about 25% of the total cost)
- In the Netherlands the number of self-organised homes has doubled thanks mainly to the strong political backing of many council leaders. In several Dutch cities you can now go to a 'Plot Shop' to buy a serviced plot, and you can get your home constructed in a matter of weeks
- In the USA more than 50,000 low cost homes have been delivered by charitable organisations that help people on lower incomes to do some of the construction work, to keep the costs down
- In Strasbourg one council officer has 'enabled' 16 new community led housing projects to get on site, delivering eco-homes for 140 families.

In most developed countries, large housebuilders are only responsible for a modest proportion of new housing; smaller regional / local housebuilders usually contribute more. And in almost every other European country around a third to a half of all the new homes that are built or are directly organised by individuals or communities themselves. So they find a plot, they select an architect (or choose a house design from a catalogue), and then a contractor is hired to do the building work (or a kit home company manufactures their home in a factory and assembles it quickly and efficiently on their plot). The process is well understood, well organised, efficient and risk free.

In Britain less than 10% of homes are currently built this way. By comparison, roughly a half of all German homes are self-organised; in Austria the figure is 80%. A few generations ago we used to build most of our homes this way too. But, over the years we've lost the knack. Today, we struggle to find plots, and finance can be challenging.

Despite these challenges, the demand from people that want to organise the design and construction of their own homes is huge. A recent NaCSBA / IPSOS Mori survey suggested that 14% of the UK population is currently researching how they might build their own home – in Wales that equates to more than 400,000 people. The survey also suggests that around 2% of the Welsh population (60,000 households) would like to acquire a plot and start building in the next 12 months.

The market, at present, falls broadly into two groups:

- Older homeowners looking to 'right-size' and build their ideal retirement home. Most have reasonable financial resources, and their priority is to get the home they really want. Many opt for eco features to ensure that future running costs are minimised.
- Younger families on modest incomes who are seeking to afford their first home. Their priority is affordability. They recognise that a self-organised home can deliver big savings – anywhere between about 25% and 40%, depending on how much work they do themselves. They are more likely to be keen to work collectively.

For most people who want to build, the biggest hurdle is finding a plot of suitable, affordable land. In other countries, public authorities go out of their way to help, by providing 'ready-to-go' serviced plots, and supporting groups that want to build together. In Holland, councils run 'Plot Shops' to facilitate the delivery of simple, serviced, affordable building plots. Some councils even offer plots on a leasehold basis, which can be helpful for people who find it difficult to fund the upfront cost of a freehold plot. In Germany, there are simple, affordable plots available on the edge of most towns and villages. Local councils see it as a community service they need to deliver. The provision of plots like this helps to stop depopulation in rural areas, and makes housing more affordable for those in urban centres.

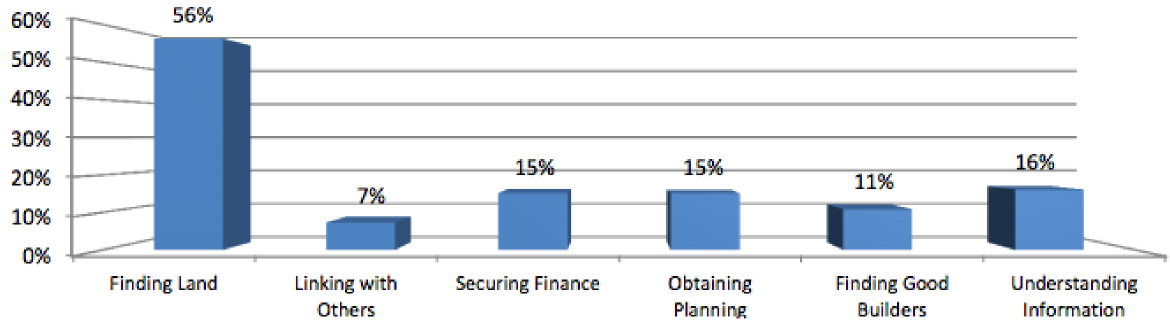


Figure 2.2A: Land remains the biggest hurdle for people looking to build their own home

Serviced plots are also provided in France, Belgium, Spain and most of Scandinavia. Price is dependent on location and size – but can be as low as £10,000. Even in high land value areas like Munich, modest plots on the edge of the city can be acquired for about £60,000.

By offering fully serviced plots, where the principle of a new home has already been agreed by the planners, and all utilities are ready to be connected, the process has been made simple and risk free. In the UK, Cherwell District Council is offering nearly 2,000 ready-to-go building plots on its Graven Hill development (case study, section 5.2).

Many councils in Europe have been big supporters of community-led housing, recognising that local communities often produce better quality than developer-led housing. The scale of housing built by communities across parts of Europe is now impressive:

In German cities like Freiburg and Tubingen, thousands of homes have been organised and delivered by groups. In Berlin and Hamburg hundreds of communities have built homes collectively. On average they are 25% cheaper that an equivalent developer's property. They look stylish, build quality is high, and almost all are built to Passivhaus standards.

Across Germany, particularly on major regeneration sites, councils generally reserve at least 20% of the land for groups. The groups usually have to pay the going rate for the land, but they are given a little extra time to get themselves organised. The end results are spectacular – innovative designs, tailor-made to match the occupants' requirements. And the people that have worked together to procure their homes create really cohesive communities that are proud of their neighbourhoods, look after their localities and support each other.

Community led housing can be seen right across Europe, and there good examples from further afield too. 500 housing co-operatives in South America have built 25,000 affordable homes, and 260 Community Land Trusts have delivered more than 10,000 homes in the US.

The concept of community-led housing is now beginning to catch on in the UK. Over the last few years, hundreds of mainly small-scale pioneering projects have been built. Community led housing projects take many forms – Community Land Trusts, Housing Co-ops, Trusts, or Cohousing organisations. Others are more informal, or are co-ordinated by the Community Self Build Agency. And they're having a significant impact. Across the Scottish Highlands and Islands, a charitable Housing Trust has 'enabled' many hundreds of new homes to be built – the majority of which are classified as affordable. (See David Palmer, section 4.1).

Figure 2.2B: affordable homes built by the Highlands Small Communities Housing Trust

What is needed to boost self-organised homes in Wales?

Political vision, bravery and leadership are vital. Many of the most impressive European developments only happened because they were championed by a local Mayor or a senior politician (eg Almere, Strasbourg). There is evidence that similar champions are having an impact in the UK too. Policy makers and council leaders must support growth of the sector.

Demand is God. In England, new legislation has introduced 'registers' for self-builders in every council. (One such council already has more than 3,000 people on its register.)

Seeing is believing. There is no substitute for taking people to see innovative self-organised projects and communities. Politicians, community organisations, planners, housing associations and small builders need to visit places like Almere, Leiden, Amsterdam, Hamburg, Berlin, Tubingen, and Strasbourg. Once they've seen what has been achieved, they'll be convinced it can be done here too.

Don't re-invent the wheel. Most western countries have tried numerous approaches over the decades, and have refined them so that the processes they use now really work. We just need to import the same processes and apply them here.

Trust people. In the UK we have a tendency to micro-manage everything. In Europe, simple design codes clearly explain the rules on two sides of A4; here we prefer to produce complex documents that only seasoned professionals can decipher. Of course, the home needs to comply with Building Regulations and key planning principles – but we have to make the process simple and easy; not scary and torturous.

The financial world needs to step up to the plate. At present most people who want to organise their own new home have to source their mortgage from one of a handful of local building societies, which are often expensive. And currently there's not much competition. Bigger banks and building societies are now showing genuine interest in developing new products to meet the needs of the sector. This interest needs to be nurtured so that more appropriate financial products are made available in the near future – for individual households and for those who want to build collectively.

Ted wrote this chapter as a personal contribution; he stepped down as the chair of NaCSBA in 2014.

2.2 case study: **Graven Hill**

Client Graven Hill Village Development Company

Architect Glen Howells Architects (masterplan) / Pentan Architects (dwelling)

Location Bicester, Oxfordshire

Background

The Graven Hill Village Development Company (GHVDC) is currently redeveloping nearly two hundred hectares of brownfield land on the fringes of Bicester into the UK's first 'large scale self-build opportunity'. Around 40% of the 1900 new homes will be built by residents themselves, with many expected to opt for custom build homes, along with developer-built homes that customers can tailor finish from a menu of options to suit their budget and lifestyle, plus affordable housing to provide a full range of options. Communal facilities will include a primary school, business space, pub and shops. GHVDC's vision is:

• To offer the largest opportunity in the UK for people who want to build their own home. This will be for households of all sizes, and will include opportunities for people to build as a group and as individuals, within a framework that encourages creativity and flexibility.
• To have a strong sense of character and identity, with extensive open space including woodland, allotments and sports pitches. Existing features will be retained where possible.
• To provide a strategic location for new employment. Creating jobs and training for local people and attracting new investment into Bicester are to be explored wherever possible.

Description – Graven Hill village

The concept behind Graven Hill is that anyone can design and create their own home, from a one bedroom retirement bungalow to a five bedroom family home, taking as hands-on a procurement route as they wish. The programme is expected to span across a decade, but the first plots are being sold (initially to people living/working locally) and developed this year as pilot projects, and are testing a number of innovative approaches:

The Graven Hill site has been masterplanned by Glenn Howells architects, and design intent established through twelve distinct *character components*, each with their own design code. In place of planning approval, a *compliance check* establishes compliance of individual proposals with the relevant design code.

Plot passports establish key criteria for development on a plot by plot basis. Part of the site is covered by a Local Development Order. These blueprints identify the developable area within each plot, and establish maximum heights, floor areas, set-backs, and boundary conditions. They also define elements which are on-plot (customer responsibility) and off-plot (developer responsibility).

To simplify the process of commencing on site, below-ground work has been compiled into a single package which, together with plot, is referred to as the golden brick. This combines services, foundations and ground floor slab through a single point of contract, and delivers benefit to prospective self-builders through economies of scale (particularly useful, as poor ground conditions have necessitate piles on some plots). The works are zero rated for VAT.

The following material describes one of the houses currently under construction on the first ten plots. The dwelling is for a young couple. Their aspiration is to build an affordable, sustainable family home within a setting with a strong sense of community spirit.

The client have a limited budget, but aspire to build a healthy family home with very low running costs, which they intend to occupy for many years to come. At 125sqm, the three bedroom home is compact, with open plan living spaces on the ground floor for maximum flexibility and a double height space located towards the garden, to connect ground and first floors, and to encourage stack ventilation. The simple, rural form is intended to complement the edge-of-settlement location.

SIPs construction was selected by the client, as an approach that delivers the building envelope quickly and affordably, to a high standard of workmanship, through a single point of contact. Combined with the *golden brick*, it offers a straightforward pathway to procuring a shell, allowing the client to decide how much of the remaining work to carry out themselves, at their own pace.

Environmental approach

A fabric first approach has been adopted, based on FEES compliance. The use of SIPs guarantees high levels of thermal performance and airtightness. An exposed concrete floor provides thermal mass. Orientation is maximised for passive solar gains, and overshadowing from adjoining properties has been minimised. It is notable that the development framework, while simplifying the delivery pathway for prospective residents, promotes detached dwellings at low to medium density. However, most self-build estates are inherently likely to be dominated by houses that follow this form.

Construction and materials

Structure	SIP construction (172mm Kingspan TEK) with localised steelwork.
External fabric	SIP, over clad in a breather membrane and a combination of fibre cement tiles (roof and walls) plus natural hardwood timber cladding.
Foundations	Piled, with suspended concrete slab (due to poor quality ground)
Windows / doors	Triple glazed composite (high performance softwood with alu outer).
Heating	gas fired solar hot water (underfloor heating) plus MVHR.
Renewables	Solar hot water panels, with the option for future PV provision.
U-value (W/sqm°C)	walls 0.13 roof 0.13 floor 0.14 glazing 1.3
Air tightness	target <2 m3/h.m2. as built: to be confirmed
Perform. predicted	(FEEs) Improvement of 19% over Building Regulations Part L 2014 SAP: Energy efficiency 86, Environmental impact (CO_2) 89
Procurement	Golden brick groundworks package project managed by GHDC, with SIP envelope by specialist contractor (Timber Innovations Ltd.)
Current status	Under construction. Shell to be completed September 2016.
Cost data	Shell costs: £102k or £810/sqm (excluding site and abnormals, mechanical and electrical installation, fit out or decoration)
of which	Golden brick = 30k (15k abnormals for poor ground), SIP = 43k (supply and install) Cladding 21k Roof = 9k, Windows/Doors = 14k

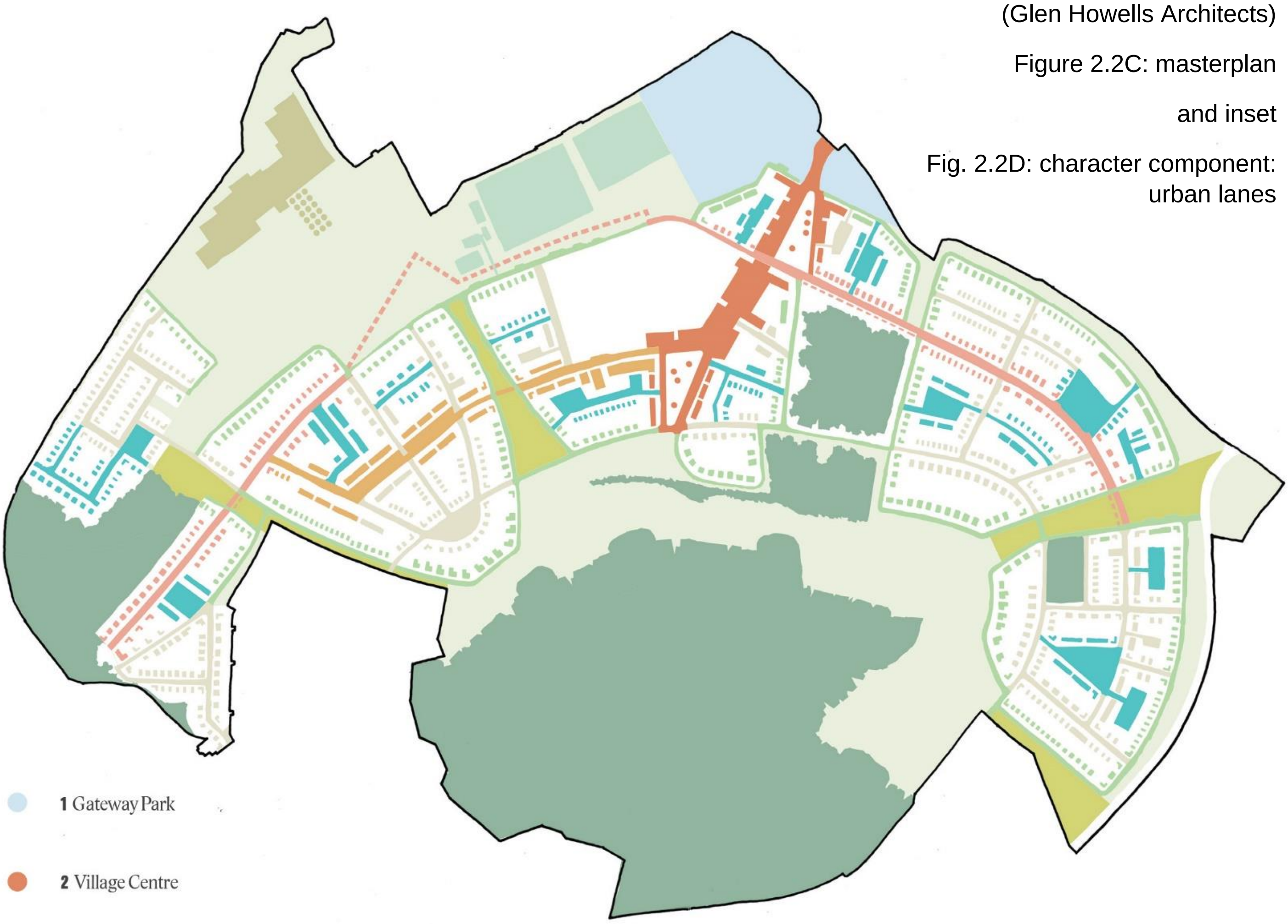
For thematic analysis of the SIPs approach see case study 6.1, William Street Quarter.

Graven Hill Village design guide
(Glen Howells Architects)

Figure 2.2C: masterplan

and inset

Fig. 2.2D: character component: urban lanes



1 Gateway Park

2 Village Centre

3 Tree-lined Boulevard

4 Community Streets

5 Urban Lanes

6 Circular Railway

7 Swale Parks

8 Rural Lanes

9 Meadows

10 Woods

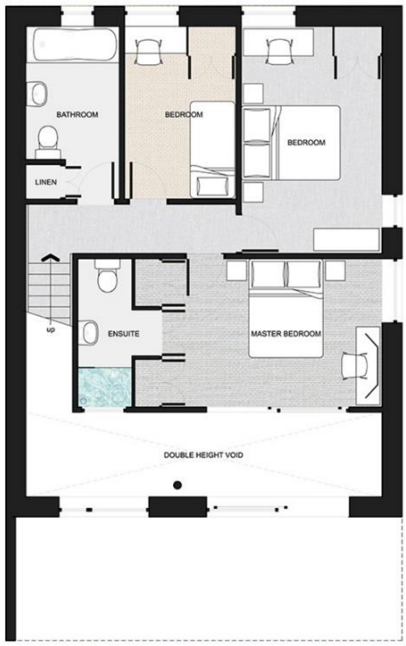
11 Allotments

12 Sports Grounds

Proposed dwelling, plot #5
(Pentan Architects)

Figures 2.2E to I:

Dwelling plans and elevations
as proposed



2.3 | better

The Igloo Regeneration Fund *is a partnership of pension, life and charity funds managed by Aviva Investors. Mixed-use real estate is delivered through sustainable place-making in partnership with the public sector and local communities. All of igloo's investments are screened with its pioneering Sustainable Investment Policy Footprint.*

Chris Brown *is Chief Executive of Igloo Regeneration and a director of Blueprint (Igloo's public/private partnership with HCA). Chris has been a member of the government's Urban Sounding Board, and a witness to the House of Commons select committee on Regeneration.*

Most new housing is produced by speculative housebuilders, and is such poor quality that three quarters of us wouldn’t buy a home from these companies. It’s not that we are incapable of producing great homes in fabulous places in the UK, it’s just that the predominant housing delivery business model doesn’t generally do it.

There are always a few exceptions. Our scheme at The Malings in Newcastle city centre (figure 2.3A, below) designed by Ash Sakula recently won a Housing Design Award. Igloo is a purpose driven business, the UK’s first real estate bcorps, and the founder of the world’s first responsible real estate fund (according to the UN). We aren’t typical!

So how can the system be changed, such that housing produced is routinely the best?

The easy wins involve public land. In Germany, land is valued and then sold at a fixed price to the best scheme presented. In the UK, we tend to do the opposite, so it is not surprising that schemes developed on public land are often of poor quality.

At Porth Teigr in Cardiff Bay we are working in partnership with Welsh Government, on a shared return basis, to deliver a large mixed-use scheme. The BBC have located their Drama Studios (designed by FAT and Holder Mathias) there and other creative companies are following them in buildings like GloWorks (also designed by Ash Sakula).

The next phase is likely to be residential designed by Loyn & Co (see following case study). To maximise the quality of the homes and the place, we used the igloo Footprint approach. It has four elements: design, environment, regeneration and health, happiness and wellbeing. Or put more simply: people, place and planet.

A quality-based league table for house-builders, with performance-based rewards like access to public land or quicker, cheaper planning would be another way to improve quality.

Beyond public land, achieving better quality outcomes in the wider housing market is more challenging. The secret in places like Holland and Germany is to put the people who are going to live in the homes in charge of the design. They call this Custom Build and it's a bit like the self-build that we are familiar with in the UK except that there is a home manufacturer who does all the difficult bits. These countries produce around double the new homes per capita compared to the UK, and Custom Build amounts to around half of that production.

When you visit these schemes you are struck by the difference. Custom-build clients make decisions based on what is valuable to them and to their community. They will choose elements like shared roof terraces, community activity rooms, allotments, waste water recycling and small commercial premises… I've visited one scheme where residents worked in a variety of studios and maker spaces dotted around the building, another with a run of small buildings backing onto a street that were used as cafes, shops, hairdressers and garden sheds (and gave the street real life) and yet another, in Berlin, where the ground floor rooms of a terrace of large homes were being used as professional offices and a café.

Custom Build is growing quickly from a very low base in England. The Government has implemented a number of initiatives of varying impact, including planning requirements, funding streams, pilot sites, tax exemptions and demand registers, to drive it forward.

For our HoMeMade HoMEs Custom Build terraced house model (based on the Dutch approach) we buy the site, obtain outline planning permission and install the infrastructure to create serviced plots which we then sell at a fixed price, first come first served. For the customer, it's a bit like buying a car. They arrange their own finance (we provide a stage payment mortgage), pick their plot and then select from a range of home manufacturers we provide for them. Then they choose the home model they want, and customise their design with the home manufacturer, who arranges all the approvals and builds it for them. The first of these pilot projects is now on site at Heartlands in Cornwall, and the homes typically sell between three and five times faster than standard speculative houses.

We are also piloting the German Building Group approach at the Fruit Market in Nottingham. In this arrangement, a group works with a building group leader (in this case the architects Letts Wheeler) to co-design their homes which are then built by a builder who has been jointly commissioned. This approach works well for small apartment buildings.

Figure 2.3B: Custom Build can deliver up to 10% more home for 10% less cost (because there is no developer’s profit on the build costs). As a result, it is competitive with speculative house-building when buying land.

Another approach that delivers better homes involves Build to Rent. The main drawback of this approach is that it is only currently competitive in buying land where the building is very large or the site has substantial up-front infrastructure costs, and sales rates are low.

This approach works because long term institutional investors have an incentive to maximise the value of the building and the place over the long term. The market for Build to Rent in the UK is currently immature and the quality of the buildings being delivered will improve over time as capacity expands and skills are learnt. Experience from the United States suggests that longer term, quality will be better than achieved by the ‘build it and b****r off’ speculative housebuilding brigade.

In combination, Custom Build, Build to Rent and affordable housing are also the quickest ways of building, as the standard house-type sales rate constraint is removed.

Better homes and better places are not produced by better planning policies or design standards (although these can sometimes remove the worst designs). Successful development is about creating, encouraging and protecting business models that put people who are invested in the long term future of a place in charge of the design process.

FOOTPRINT

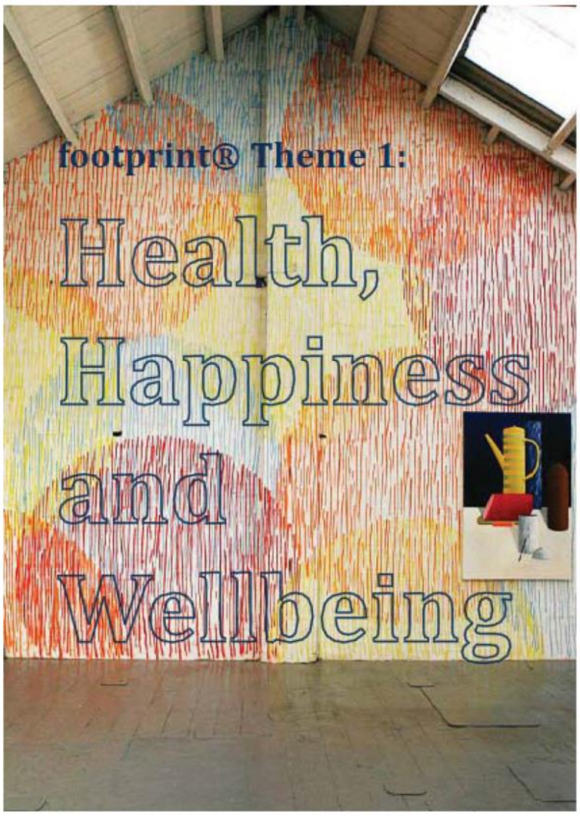


Figure 2.3C:

Four defined Footprint themes

IGLOO are committed to a set of sustainable investment (SI) policies called Footprint, with the aim of delivering long term social, economic and environmental benefits.

The Footprint® policy was developed with URBED (Urbanism, Environment and Design) and aims to screen and assess urban regeneration schemes, in which igloo propose to invest, for their SI characteristics. In order to do this the Footprint policy has four defined SI themes:

Health, happiness and wellbeing:

Investing in people and communities in order to change lives and realise potential.

Regeneration:

Investing not just in physical regeneration but in the social and economic lifeblood of urban neighbourhoods.

Environmental Sustainability:

Investing in more environmentally sustainable forms of urban development, and associated infrastructure and services.

Urban Design:

Investing in place-making to create distinctive, vibrant and mixed-use neighbourhoods that are urban in character.

These themes are based on the belief that IGLOO’s investments will perform better if they contribute to the regeneration of the area they are in (and therefore benefit from that regeneration), if they are environmentally sustainable (and therefore ‘futureproofed’, against higher energy costs for example), and if they are well designed (and therefore more attractive to occupiers).

Above all, IGLOO believes that investment in the health, happiness and wellbeing of people and communities should form the basis for successful regeneration projects.

© Footprint® Policy

2.3 case study: **Porth Teigr**

Client IGLOO Regeneration

Architect Loyn and Co.

Location Plot L, Porth Teigr Cardiff Bay LS5 3AG

Background

Porth Teigr is a joint venture between IGLOO - an Aviva Investors Real Estate Fund - and Welsh Government. The venture is developing 38 acres of land on the south side of Roath Basin in Cardiff Bay, creating a vibrant, environmentally sustainable mixed-use development including commercial, retail, community and residential space.

Description

Igloo commissioned a residential development on the site known as Plot L, Porth Teigr. The design philosophy was to be in accordance with their 'footprint' policy, with key themes of Health Happiness and Wellbeing, Regeneration, Sustainability and Urban Design. Research identified two target markets: 'Next Steppers', young professionals moving from apartments to houses, and 'Empty Nesters', older homeowners who are down-sizing. Both are looking for high quality, well designed housing, amenities and good location.

A dense urban scheme has been developed to include a mixture of housing types with a strong public realm and interconnected of open spaces. The land is approximately 1.2Ha and a density of 85 dwellings per hectare results in the provision of just over a hundred properties. A range of 2, 3 and 4 bedroom homes are to be provided, plus a small proportion of low rise apartments. Car parking is to be provided in line with market expectation, and averages 1 parking space per unit.

Environmental approach

The natural orientation of the site is a key driver behind the architectural solution. The proposals adopt a passive fabric first approach and siting the built forms in accordance with the natural orientation of the site will be a fundamental method for achieving this.

Key design principles

Permeable infrastructure - sensitive handling of vehicular circulation, car parking, bicycle paths and pedestrian movements through the site, with links to public transport

Relationship of built form to its context, and quality external spaces - developed in line with Igloo's Footprint policies, the project uses coastal marram grass to give a strong identity and sense of place to both 'outside' and 'inside' public realm - outside being the waterfront spaces and inside being inland streets.

Enhanced individuality of each unit whilst retaining common themes – matters of detail are considered at concept stage, to ensure that there is a continuity and a relationship between the individual and the collective. This helps give identity and character to a particular place.

Enhanced Project Standards - greenhouses pop up at roof garden level of each property to provide roof access, and protected planting within the exposed site. Each house type is made of components which add value, individualise and tie together the scheme as a whole. Features can be selected, allowing occupants to choose a house that suits their needs.

Current status	Planning Permission obtained (July 2015). Porth Teigr will be delivered in two phases of approximately 50 new homes each. Since obtaining planning, the multi-disciplinary team have developed detailed construction drawings for tendering, and have begun discussions with a Main Contractor.

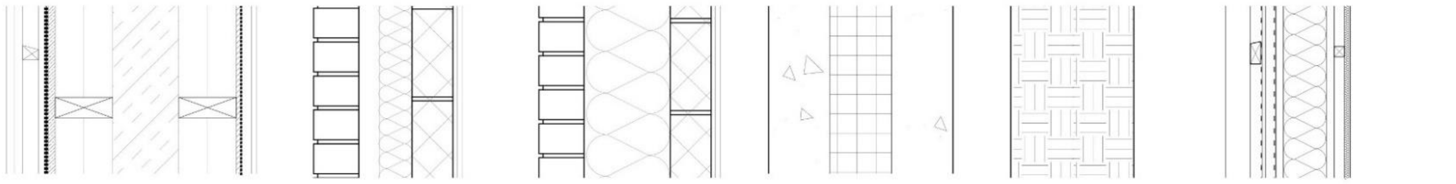
Construction and materials

This case study is useful because although 'traditional' construction is proposed, the client and design team went to considerable lengths to evaluate different constructional options, before concluding that masonry was the most suitable. Their **materials matrix** is overleaf.

Structure	Loadbearing masonry external cavity walls. Suspended concrete ground floors, concrete plank roof deck, posi-joist intermediate floors.
External fabric	Handmade clay brickwork with lime mortar, 50mm cavity, celotex rigid insulation, insulated blockwork internally, skimmed plasterboard finish.
Windows / doors	Timber / alu composite with slatted timber solar shading / screens
Environment	The scheme has been developed with a 'fabric first' approach to minimise the energy required for heating and cooling. Measures include optimised orientation, high levels of insulation, dense terraces rather than detached properties, larger areas of south facing glazing, energy monitoring devices and an allowance for photovoltaics.
Heating	Underfloor wet central heating (mains gas) with MVHR
U-value (W/sqm°C)	walls 0.13 roof 0.15 floor 0.12 glazing 1.0
Air tightness	target <3 @50Pa as built tbc
Energy efficiency	Minimum performance, assuming grid electricity and gas as primary fuels: Between 33% and 42% reduction on 2006 Part L TER. EPC rating not less than B, SAP rating 87(energy efficiency), 88 (CO_2)
Other standards	Building for Life (12) certification – CABE's 'standard' for the design of new housing developments, third edition published in 2015. Secured by Design (pre-build approval) Igloo Footprint Policy: From the start of the project the key sustainability driver behind the scheme has been a firm commitment to designing in accordance with the client's Footprint policy, which covers targets for health, happiness and wellbeing; regeneration; environmental sustainability and urban design. The proposals have been independently rated as 'best practice'. Waste limitation - a modular dimensioning system has been used in the construction of components such as windows and doors to reduce the need for cutting on site, careful selection of materials, and use of off-site manufacture where possible, all to reduce waste.
Form of contract	Design and Build, but with point of novation after detailed design

Post completion data not yet available.

For thematic analysis of the loadbearing masonry approach see case study 2.1, Cardiff HPP.



TIMBER FRAME WALL

[INSULATED]

Approx. U-Value= 0.10W/m²K
Approx. O/A thickness= 610.5mm
[Construction described below from inside to outside faces]

- 12.5mm plasterboard with plaster skim finish.
- 25 x 50mm vertical softwood battens @ 400mm c/s to give 25mm clear service zone.
- 'Pro Clima' DA vapour control layer fixed to inside face of ply.
- 12mm PLY layer securely fixed to horizontal timber stud construction behind.
- 140 x 50mm horizontal softwood timber stud construction fixed to steel frame construction
- 140mm thick Thermo Hemp semi-rigid insulation between stud construction.
- Steel frame. All to SEng design, detail and specification.
- 162mm zone between steel frame to be filled using Warmcel 500 blown insulation.
- 140 x 50mm horizontal softwood timber stud construction fixed to steel frame construction
- 140mm thick Thermo Hemp semi-rigid insulation between stud construction.
- 22mm thick Multiplex-top Gutex Board.
- Breather membrane.
- 19 x 50mm vertical softwood battens @ 600mm c/s
- 38mm wide x EX. 50mm horizontal softwood cross-battens @ 600mm c/s.
- External wall exposed finish to be vertical board on board cladding.

MASONRY WALL

[INSULATED]

Approx. U-Value= 0.15W/m²K
Approx. O/A thickness= 378.5mm
[Construction described below from inside to outside faces]

- 12.5mm British Gypsum wallboard. Plasterboard to be skimmed and to receive paint finish.
- 24.5mm Celotex PL400 insulation between 25mm battens.
- 100mm Thermalite Turbo blockwork inner skin.
- 135mm o/a cavity with
- 85mm Celotex CG5000 foil backed rigid insulation panels. 50mm clear cavity.
- Handmade clay facing brickwork. Lime mortar.

MASONRY WALL

[FULL FILL INSULATION]

Approx. U-Value= 0.150 W/m²K
Approx. O/A thickness= 435mm
[Construction described below from inside to outside faces]

- 12.5mm British Gypsum wallboard, applied to blockwork with 10-15mm dot and dab. Plasterboard to be skimmed and to receive paint finish.
- 100mm Thermalite Turbo block inner skin.
- 210mm full fill Rockwool cavity slab.
- Handmade clay facing brickwork. Lime mortar.

CONCRETE WALL

[INSULATED]

Approx. U-Value= 0.150 W/m²K
Approx. O/A thickness= 450mm
[Construction described below from inside to outside faces]

- 150mm internal concrete skin, self finished
- Full fill insulation between concrete walls to provide a permanent formwork
- 150mm Thermomass 'IP PIR 023' insulation
- 150mm external concrete skin, self finished

RAMMED EARTH WALL

[INSULATED]

Approx. U-Value= 0.245 W/m²K.
Approx. O/A thickness= 425mm
[Construction described below from inside to outside faces]

For a cavity SRE (stabilised rammed earth) wall:
- 175mm SRE inner leaf
- 75mm polyisocyanurate solid cavity insulation and stainless steel wall ties;
- 175mm SRE outer leaf

[UNINSULATED]

Approx. U-Value= 2.25 W/m²K
Approx. O/A thickness= 300mm
[Construction described below from inside to outside faces]

- insulation needs adding in external wall applications

SIPS PANEL WALL

[INSULATED]

Approx. U-Value = 0.10 W/m²·K
Approx. O/A thickness = 314.5mm
[Construction described below from inside to outside faces]

- 92.5mm Kingspan Kooltherm K18 insulated plasterboard. Plasterboard to be skimmed and to receive paint finish.
- 25mm batten to create services zone
- 142mm Kingspan 'TEK' SIPS panels
- membrane to sit in front of 25mm x 25mm vertical counter battens at 400mm c/s
- cladding to sit on 40mm x 40mm horizontal counter battens at 600mm c/s
- 40mm x 60mm vertical timbers

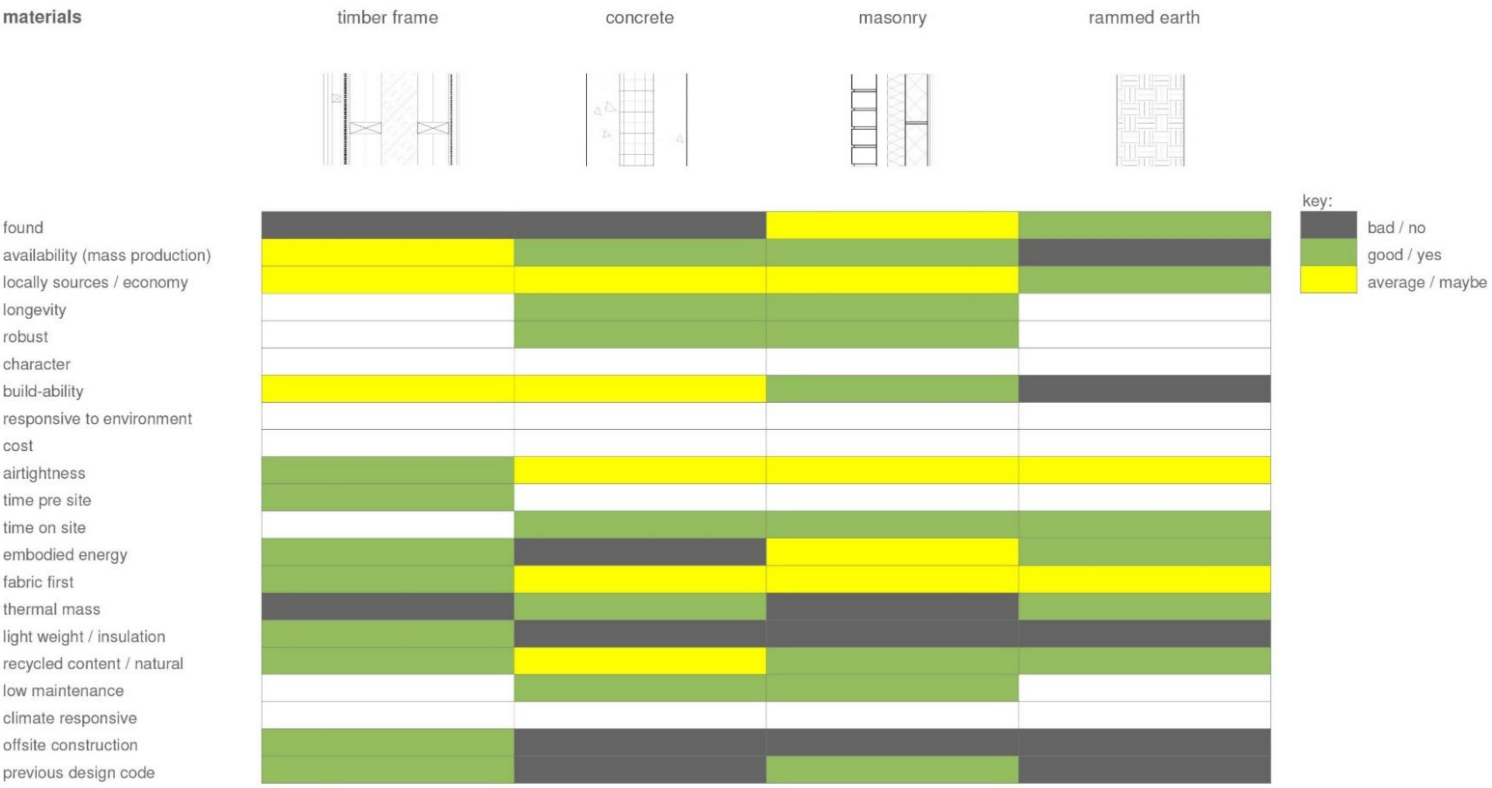
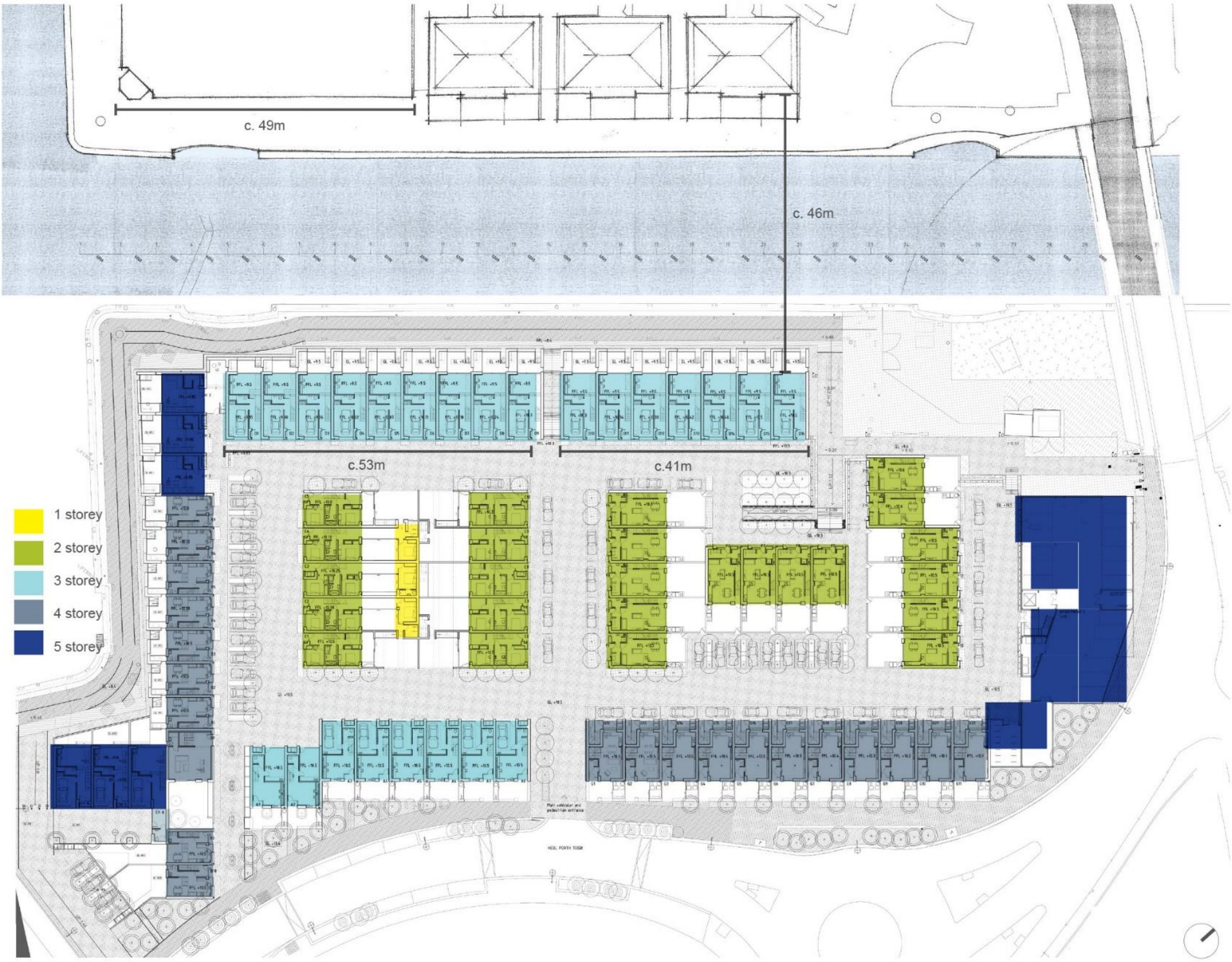
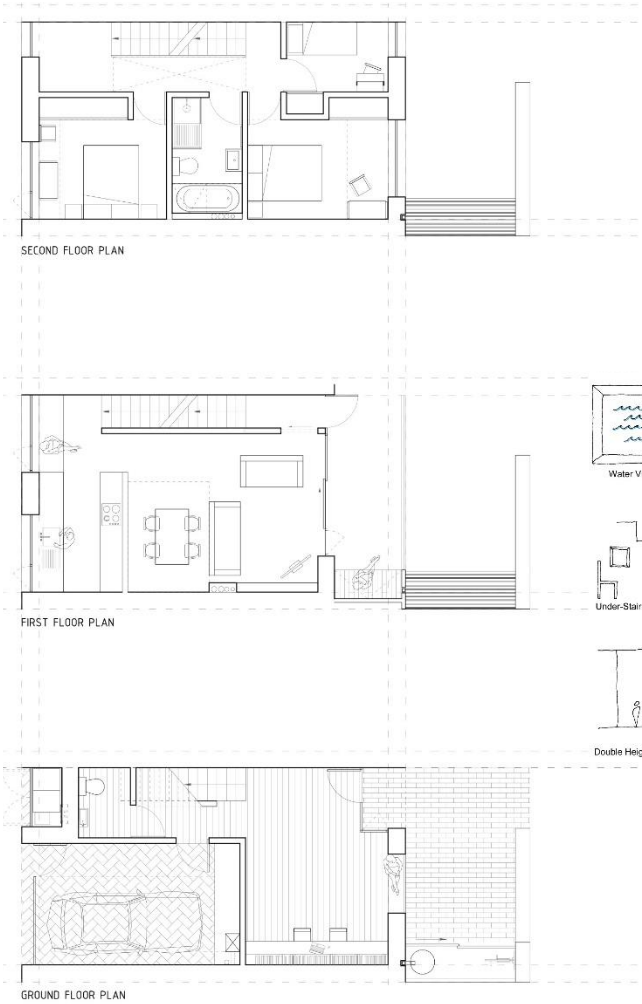


Figure 2.3D: materials matrix and analysis produced for Porth Teigr by Loyn and Co, on behalf of IGLOO

Figure 2.3E: proposed site layout with context

Figure 2.3F: strategic scale and massing





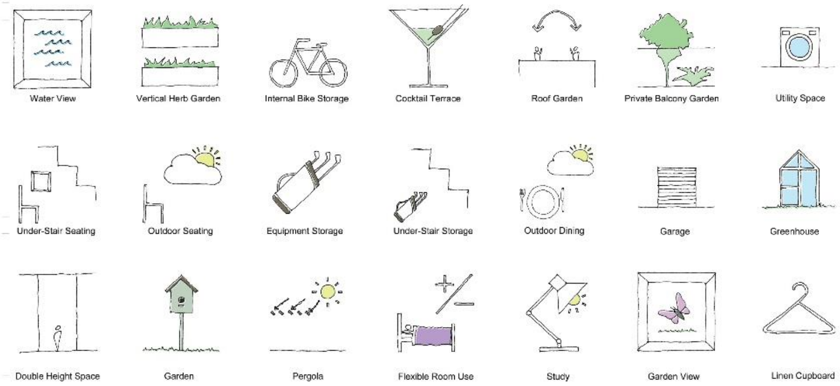


Figure 2.3G (left): typical layout, two bedroom terrace

Figure 2.3H (right): a suite of integrated design features for ‘added value’

Figure 2.3I: street scene from main entrance

3.0 | standards

In the UK, a broad range of standards have the potential to influence the size, location, type, design, specification, construction, quality and environmental performance of housing. Standards are reviewed and revisited periodically, often in line with step changes in legislation or performance targets. Different geographic areas, user groups, and funding streams trigger different standards, some of which are mandatory.

Designers and commissioners of social / affordable housing in Wales must typically work in the context of both national and local planning and environmental guidance. Planning Policy Wales (PPW, 2016) sets out the underlying objective of securing sustainable development and ensuring that “new housing and residential environments are well designed, meeting national standards for the sustainability of new homes and making a significant contribution to promoting community regeneration and improving the quality of life”. PPW sets out the Welsh Government’s five objectives of design as *movement, access, character, community safety and environmental sustainability (see case study 2.3)*. Meanwhile, TAN 12 (Design, 2014) states that housing developments should “aim to:

- create places with the needs of people in mind, which are distinctive and respect local character
- promote layouts and design features which encourage community safety and accessibility
- focus on the quality of the places and living environments for pedestrians rather than the movement and parking of vehicles
- avoid inflexible planning standards and encourage layouts which manage vehicle speeds through the geometry of the road and building
- promote environmental sustainability features, such as energy efficiency, in new housing and make clear specific commitments to carbon reductions and / or sustainable building standards
- secure the most efficient use of land including appropriate densities, and
- consider and balance potential conflicts between these criteria.” (Para 5.11.2)

New social / affordable homes are required to comply with Building regulations, Development Quality Requirements (DQR), Lifetime Homes, and Secured by Design. Until recently, Level 3 of the Code for Sustainable Homes was a stipulation of Welsh planning policy. However, this requirement was withdrawn when changes to Part L of the Welsh Building Regulations come into force in July 2014. In 2015, the Housing Standards Review then scrapped CfSH in England, to simplify housing delivery and increase affordability.

Some of the directives that have potential to affect the most change come from beyond the UK. The Kyoto Protocol came into force in 2005, and implemented the objective of the UNFCCC to reduce greenhouse gas concentrations in the atmosphere to "a level that would prevent dangerous anthropogenic interference with the climate system" (Art. 2). The UK’s response, the Climate Change Act (2008) required that we achieve at least an 80% reduction in the carbon emissions from all homes by 2050, and committed to implementing a Zero Carbon homes policy by 2016. The Act was overturned in July 2015.

In the absence of a national mandate for zero carbon, more onerous standards including CfSH Level 6, Passivhaus and the Living Building Challenge all provide optional pathways to higher standards of environmental performance. Some of these, including the most recent version of Passivhaus, have been aligned with emerging definitions of zero carbon.

We are told that the 'Paris effect' has prompted more corporate entities than ever to support legislation to limit global warming to 2°C, and housing has a significant part to play in this.[2] However, questions still surround the means by which this aspiration might be implemented.

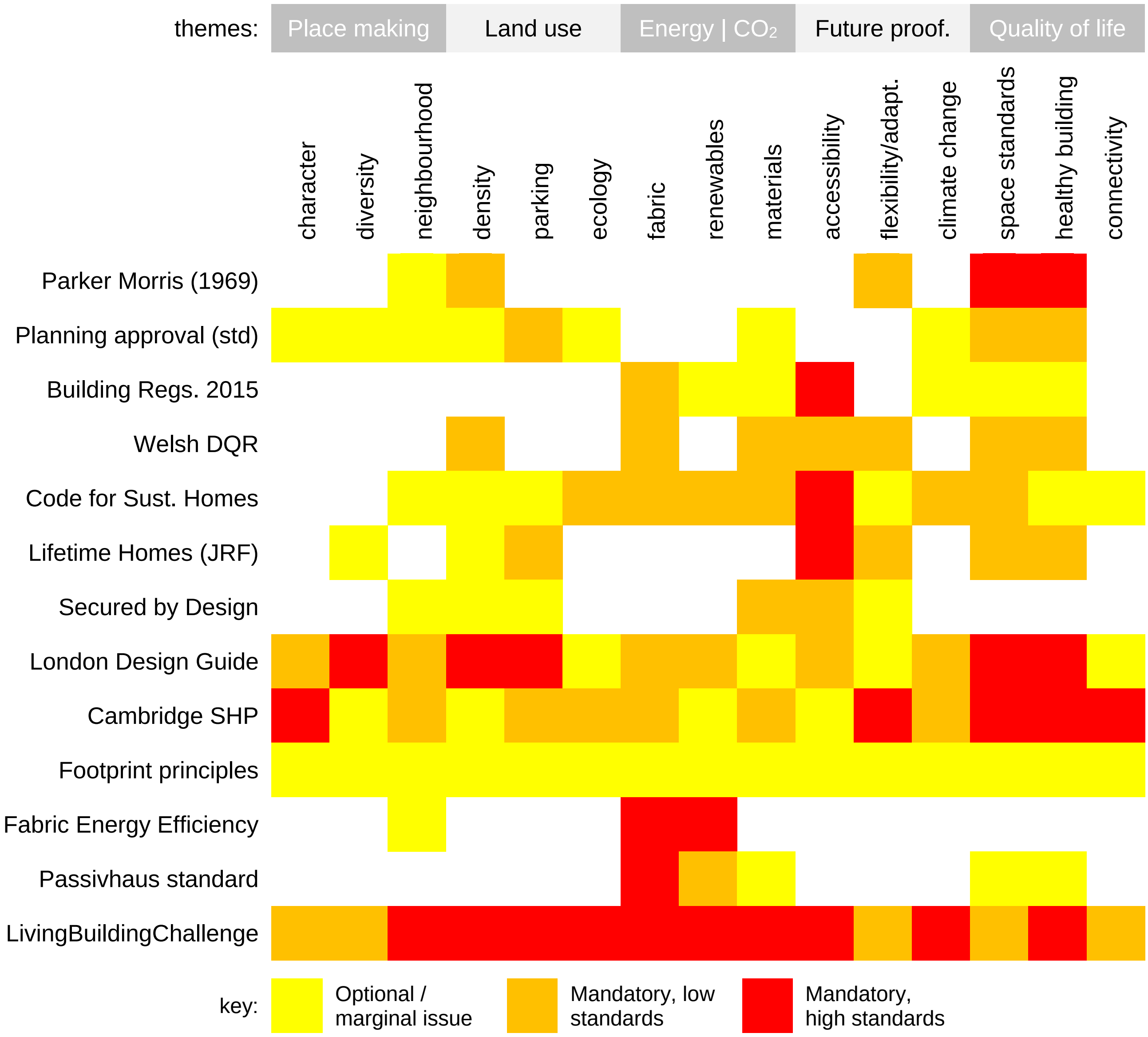


Figure 3.0A: gap analysis of key housing standards and their spheres of influence

Standards cover a wide range of themes relating to housing, as outlined in the table above. Some of these themes are very specific in their focus, while others are extremely broad. Different standards may prescribe different criteria or performance targets in relation to the same themes. Some of these standards are interconnected[3].

[2] The impact of new housing is particularly significant only as part of a joined-up strategy incorporating refurbishment of the existing housing stock – among the least efficient in Europe. See *density*, overleaf.
[3] For example, DQR and the Cambridge Sustainable Housing principles both require compliance with Secured by Design principles.

The chart does not distinguish between standards that are prescriptive and those that are not, or between standards that are / are not mandated. Some standards (e.g. planning approval, CfSH) set relatively low aspirations across a broad range of themes, while others (e.g. Passivhaus and FEES) set high standards in a very focussed way. Most are a combination, for example IGLOO's Footprint standard (see section 2.3), which requires that a broad range of themes be considered, and insists on compliance with a sub-set of 'principles', but the level of performance promoted overall is very high (a genuine sense of place-making, combined with net zero carbon development).

This report uses the following themes to evaluate alternative approaches:

SPACE STANDARDS

In 1963 the Parker Morris Standards set new standards for space in the home, based on anthropometric data regarding the space needed to complete tasks. In 1969 these space standards became mandatory for all council housing, until they were ended by the Local Government, Planning and Land Act in 1980, and for the subsequent fifty years, dwelling sizes dwindled. The RIBA and Ipsos Mori-commissioned report *The Way we Live now* (2012) identified space, inside and outside the home, as being central to better housing.

"No amount of sensitive design can compensate for houses and flats that are too small… Extra space will enable homes to be more than mere dormitories, encouraging sociable rooms within homes, and giving individual family members private space when they need it." London Housing Design Guide, MAE (2012)

FLEXIBILITY / ADAPTABILITY

In 2008, English Partnerships re-introduced space standards that are 10% *more* generous than those of Parker Morris. Lifetime Homes and the London Housing Design Guide have followed these new minimum standards, to allow for accessibility (including mobility aids), flexibility and adaptability, and to find space for key functions (such as dining).

However, such requirements inevitably add cost to housing, and preclude a less prescriptive approach that might lead to a broader range of housing 'options'. Recent high profile international projects have explored the role that starter homes and micro homes might play in the delivery of affordable social housing. Foremost among these is the work of Alejandro Aravenna's practice Elemental (see *Villa Verde*).

ENERGY | CO_2 (FABRIC AND RENEWABLES)

Passivhaus provides a useful target for operational energy as it requires rigour in design and construction as well as post completion testing to 'prove' performance, and evidence suggests that the performance gap is much smaller as a result.

The definition of zero carbon (section 3.2) remains elusive, although most now agree that it must become a tangible, deliverable standard at some point. However, standards focussing on energy-in-use such as Passivhaus do not measure embodied carbon. Arguments have been made for a zero carbon definition that includes embodied carbon (see section 4.2), which would push developers firmly towards timber-based construction.

RESILIENCE

"The majority of people live in urban areas. Whilst the phenomenal growth of towns and cities over the last two centuries has undoubtedly improved people's quality of life, this has come at an increasing environmental cost. Urban society has gone hand in hand with the creation of a consumer society. This in turn has driven increased resource consumption and made people more disconnected from the source of our food, materials and energy and where we dump our waste." Footprint, The world's first responsible real estate fund (2012, see section 2.3)

With increasing awareness of climate change impacts, building in climate resilience has increasingly become a priority. The key focus of resilience is a reduction in the vulnerability of users and communities to the environmental consequences of climate change.

MATERIALS

"Small shifts in the standard specifications of the affordable housing industry can have ripple effects that spread across the building marketplace, transforming a materials economy and providing safe, healthy affordable housing for all." Affordable Housing LBC,ILFI (section 3.3)

The Living Building Challenge provides a framework for ensuring healthy, non-toxic affordable housing projects. The Red List identifies 'banned' toxic chemicals, while the Declare accreditation and Living Product Challenge certification ensure that material specifications meet the Living Building Challenge's stringent requirements. In addition to improved health, some materials provide the facility to lock carbon into buildings, making the correct material choice even more critical.

CHARACTER

The social and economic importance of providing diversity in housing is recognised in the Welsh Government White Paper "Homes for Wales, A White Paper for Better Lives and Communities" (May 2012).

Although homes and their settings share common characteristics, each one is unique and more successful places are usually also diverse. Individual traits reflecting the geography, history, complexity and maturity of a place come together to define its character. These characteristics, which can be summed up as sense of place, should be celebrated by development, not obscured or obliterated by it.

DENSITY

Land is one of our greatest assets. Its productive capacity underpins the economy through the provision of grown resources including food, and through its use for housing, business, transport, energy, recreation and tourism. Balanced densities are needed to make the best use of land, while preserving or enhancing the character of places. Meanwhile, viability testing has shown that unit size and density are key drivers to enable viable developments that do not compromise on affordable housing or other planning contributions.

At a time of renewed interest in the Garden city movement and scrutiny of the green belts, approaches that facilitate denser development or create opportunities to re-use existing, underused, and underperforming existing buildings must be brought to the fore.

ECOLOGY

There are a range of ways in which alternative approaches can deliver ecological benefits. Apart from the selection of renewable or low impact materials and the promotion of brownfield sites, length of time on site can also have a significant effect on ecological impact.

Waste production is another way in which construction tends to perform very poorly. Around 24% of all UK waste comes from the construction industry. Some alternative approaches are particularly well positioned to minimise waste during the manufacturing process. They typically achieve this through standardisation, off-site fabrication, and improved coordination.

HEALTH

We typically spend 90% of our time indoors. The Royal College of Physicians' report *Every Breath We Take* (2016) links 40,000 deaths in the UK each year to air pollution, and yet more to indoor air quality. As the body of knowledge around about harmful VOCs increases, there is a need to communicate that the careful specification of products contributes directly to indoor air quality.

Designing for health is becoming an increasingly important part of what it means to build in an environmentally conscious way. Potential benefits of 'healthy' buildings include improved physical and mental health, improved productivity or quality of life, fewer symptoms such as asthma and allergies, and reduced impact on the health services.[4]

CONNECTIVITY

"We all belong to communities – at home, in our neighbourhoods, at work, at school, through voluntary work, through online networks, and so on. Communities are vital to our lives and wellbeing. But their importance means we need to understand their changing place in our lives, their role in encouraging health, economic prosperity and creativity, their history and their future." Connected Communities, AHRC (2016)

Neighbourhood is not only about context. It is about people. Increasingly in Wales, community groups are connecting with the intention of building their own neighbourhoods (see section 4.1). Connectivity can add to the sense of belonging, improve emotional and physical well-being, and link people to production and resources. However, communities require access to useful information, advice and support, if the resulting neighbourhoods are to live up to their expectations.

Increased standards will almost always increase capital costs. However, as we are told often but rarely consider fully, the running costs for a building (be it a home, an office, or a community centre) will always dwarf capital costs – typically by a factor of ten or more. Modest increases in capital cost related to increased standards may pay for themselves many times over during the lifetime of a building.

Lower cost construction typically increases the pressure on external services, such as energy production, water and waste treatment, flood protection, and other services. These hidden costs are notoriously difficult to quantify, but should not be forgotten. For example, we consistently fail to recognise the impact of poor housing on health, and associated costs to the health service (see above).

Finally, it is worth noting that some of the more comprehensive standards (Passivhaus, LBC) recognise that buildings as-designed rarely perform in line with predictions, and require that compliance be demonstrated post-completion, rather than pre-construction. As we continue to learn more about the performance gap, and the ways in which our built environment fails to live up to its expectations (until it is tested, monitored, and inevitable flaws corrected), we are also stepping closer to buildings that are saultogenic[5] – that support life and community rather than draining resources and producing waste.

[4] Green Buildings and Health, Allen, J.G., MacNaughton, P., Laurent, J.G.C. et al. Curr Envir Health Rpt (2015) 2: 250. doi:10.1007/s40572-015-0063-y

[5] Salutogenesis is a term coined by Aaron Antonovsky, a professor of medical sociology, and describes an approach focusing on factors that support human health and well-being, rather than detracting from it.

3.1 | Passivhaus

Jonathan Hines *became a director of Architype in 1989, and managing director in 2015.*

With a life-long commitment to social and environmental sustainability, Jonathan has led the development of Architype's innovative approach to sustainable design, and managed the teams that have delivered many of Architype's pioneering projects.

He is also a director of ArchiHaus, working to develop high quality Passivhaus housing at an affordable cost, currently undertaking an innovative scheme for 150 houses in rural Herefordshire.

What is Passivhaus?

Passivhaus is a rigorous building standard, designed to ensure optimum internal comfort, for the least possible energy consumption. For many years, building energy policy and regulation in Wales and the UK have been based on notional carbon offsetting, using less than rigorous assessment methods. Passivhaus sets stringent, measurable energy limits, calculated (in kWh/sqm/year) and checked using robust and accurate tools.

Passivhaus is a quality assurance system backed by a rigorous certification process. Its value relies on the assurance that its performance claims are both credible and deliver genuine benefits to both the user and the environment, including:

- minimised energy consumption and fuel bills.
- avoidance of building defects that can lead to mould growth and building failure.
- excellent standards of thermal comfort and indoor air quality.
- optimised lifecycle costs.

The fundamental Passivhaus standards are:

- a limit of 15kWh/sqm/year for total 'thermal' energy
- a limit of 120kWh/sqm/year for total 'primary' energy
- a limit of 5% of occupied hours over 25^{o}C

Passivhaus does not dictate method of construction, nor is it restricted to certain types of building. It simply requires that these standards for comfort and energy are achieved in both design and construction. Performance is ensured through a rigorous certification process.

Passivhaus thus eliminates the 'performance gap' in buildings, the difference between the energy consumption predicted at design stage, and the actual consumption is use – which can typically be three times as much (or more) in many UK buildings.[6]

---

[6] So a building designed to consume 40kWh/sqm/year for heating may, in reality, consume 150kWh/sq/year. The gap can extend to comfort, with buildings being uncomfortably hot or cold and/or poor internal air quality.

During the 1980s, German building physics research exploring ways to eliminate the performance gap led to the development of the Passivhaus standard. Over the last 25 years, across much of Europe, the Passivhaus standard has been thoroughly tested and proven through the design, construction and monitoring of many thousands of buildings. Throughout this period the Passivhaus Institute, which was set up to administer, control and develop the standard, has been continuously refining and optimising it.

Passivhaus does not prevent clients and designers from employing other standards, but it does ensure that dramatic reductions in energy consumption and improvements in internal comfort will be achieved. It has grown rapidly from the 'bottom up' through positive experience in use, rather than through being imposed via 'top down' regulation. It has been adopted by many public authorities as the required standard for their new building stock, including various German local authorities, Exeter City Council in the UK, and all social housing in Austria. It is now increasingly being set as the regulatory standard (eg. for the Brussels region of Belgium).

How is Passivhaus achieved?

Passivhaus does not require complex, risky or untested technologies. It is simply based on good design and on delivering good construction. The highly accurate Passivhaus Planning Package (PHPP) is used as a design tool to optimise the form, orientation, fabric and fenestration of the building, and to ensure that the predicted energy consumption complies with Passivhaus limits. The building is constructed in accordance with the design, then design information is supplied to the certifier, including the PHPP analysis and evidence of construction standards, to the certifier who rigorously checks the information before certifying, or not.

While Passivhaus doesn't restrict construction type or specify U-values, it does require:

- an airtightness of 0.6 air changes under n50 test
- elimination of thermal bridges[7] or inclusion of actual heat losses from any thermal bridges not eliminated
- improved thermal insulation and triple glazed windows
- installation of 90% efficient MVHR to ensure a constant supply of fresh air to living spaces, and constant extract of stale air from bathrooms and kitchens.

Benefits of Passivhaus

Passivhaus delivers benefits in three key areas:

Significantly reduced energy consumption and running costs

A thermal energy consumption below 15kWh/sqm/year is 70% to 90% better than Building Regulations, and reduces annual running costs to around £70 for a typical three bed house. As a result, social landlords who have built Passivhaus homes, including Hastoe Housing Association and Exeter City Council, have experienced significant falls in rent arrears.

[7] elements of the structure or fabric that penetrate the thermal envelope and leak heat

Improved internal conditions

Building Regulations permits ventilation via trickle ventilation, and local extract in bathrooms and kitchens. Such ventilation is not 'designed' to ensure correct or specific ventilations levels, and operates in an uncontrolled way. Occupants shut trickle vents to prevent cold drafts and often avoid using extract fans, leading to rises in internal humidity and CO_2 levels.

Passivhaus ventilation, in contrast, is carefully designed and commissioned to ensure the right level is delivered. Fresh air is pre-warmed and filtered, eliminating cold drafts, reducing pollen, dust and pollution, and guaranteeing a healthy environment and low CO_2 levels.

The Passivhaus overheating limit ensures that solar gains are properly assessed, and uncontrolled heat gains prevented.

A more robust building fabric

Avoidance of cold surfaces by eliminating thermal bridging, reduction in air penetration into fabric by improving airtightness, and control of humidity through correct ventilation, prevents the potential for condensation and mould growth on surfaces or reduces risk of decay within the building fabric.

Does Passivhaus cost more?

Some aspects of a Passivhaus project incur extra costs. These include thicker insulation, higher performance windows and doors, better airtightness, and installing MVHR. There are areas of reduced costs including smaller heating system, simpler controls, and reduced requirement for renewables to meet carbon targets. There are areas of nil cost impact including designing out of thermal bridging, and simplifying of construction details.

Designing using PHPP encourages simpler and more cost efficient building forms, and encourages less complex and most cost effective detailing. Experience tells us that if Passivhaus is established as a fundamental target and designed in from the outset, it can be achieved within standard budgets, with little or no additional cost. Key lessons include:

- use PHPP as a design tool from day one
- whilst industry experience is still developing, work with Passivhaus skilled experts
- encouraging collaborative team working at every stage
- maintain focus on simplicity of design and detailing, along with value engineering
- hold focussed workshops with all key sub-contractors
- undertake rigorous and frequent site inspection

A recent update to Passivhaus provides an alternative route for certification. In lieu of the established 'classic' Passivhaus limit of 120kWh/sqm/year for total primary energy (not including renewables), developers have the option to target Passivhaus 'plus' with a total primary energy of just 60kWh/sqm/year including renewables. This aligns the Passivhaus methodology with current thinking around standards for nearly zero energy compliance.

Passivhaus is not complex or difficult to achieve, but does require a different approach to design and construction. It is simply a rigorous, evidence-based quality assurance process that encourages good design and higher standards of construction, to ensure better internal comfort for the lowest possible energy consumption.

3.1 case study: **More Homes**

Client City and County of Swansea

Architect Architype Architects, City and County of Swansea

Location Milford Way, Penderry, Swansea SA5 7JX

Background

Architype and the City and County of Swansea are collaborating to deliver a sensitive, high quality, high performance pilot scheme for the new stream of social and affordable housing which is due to be rolled across the county over the coming years.

Description

The pilot scheme is being constructed to the rigorous Passivhaus energy efficiency standard, utilising pre-fabricated timber construction. The development is underpinned by a guiding vision to create a residential development of high quality, which establishes a strong sense of place – comprising a mix of house types that integrate with neighbouring buildings and contribute to the established character and appearance of the local area.

The eighteen dwelling project has a strong community focus. A combination of apartments and houses are arranged around a shared communal courtyard and positive green public spaces. A continuous pedestrian route through the site, while individual dwellings all retain private gardens.

The project consists of ten 2 bedroom semi-detached dwellings and eight 1 bedroom apartments. The building designs have been kept simple and efficient in form. This combines with the use of quality building fabric and finishes to facilitate the delivery of a robust, low maintenance and healthy housing solution.

Environmental approach

The first-principles approach to environment is described by the designers as 'eco-minimalist'. A fabric first strategy is employed, focussing on the use of quality building fabric elements such as insulation and windows - elements that would be expensive to upgrade at a later date - to deliver high levels of thermal and environmental performance, without resorting to expensive bolt-on micro-renewables or complicated technologies that will require maintenance in the longer term. PassivHaus levels of performance will significantly reduce space heating requirements, while improving indoor air quality.

The large quantities of timber and cellulose insulation utilised in construction of the homes will store carbon dioxide in the building's fabric - this is often called CO_2 'sequestration'.

The positioning of the buildings on the site optimises the orientation of each dwelling. The houses have wide frontages and generous amounts of carefully positioned glazing in order to maximise natural daylight, useful solar gains and natural ventilation, minimise the use of artificial lighting, and to make the most of available views.

The choice of building materials and landscaping have been designed to help temper the internal environments from the changing seasons. Natural materials/ VOC free materials have been specified where possible, and work in combination with an MVHR unit with pollen and dust filters to create a healthy internal environment.

The homes are to be built using a ‘breathing’ wall concept in which the constituent elements of the external wall are naturally ‘hygroscopic’. This means that they will readily absorb water vapour in the air when the surrounding humidity levels increase, and release it when humidity levels drop. This has the effect of reducing the risk of condensation build up in the wall’s structure and consequently reducing the risk of mould build up.

The brownfield site also provides opportunities to re-establish native flora and fauna, utilise natural drainage such as swales and SUDs, and in doing so link biodiversity corridors to the common green areas, nearby woodland, and surrounding undeveloped landscape.

Current status	Planning approval granted, currently out to tender

Construction and materials

Structure	The simple timber frame construction can be achieved by local manufacturers across the country using easily purchased ‘off the shelf’ items.
External fabric	From inside to outside: Internal lining with a 44mm service zone, super air-tight ProPassiv OSB board from SmartPly; 300mm deep I-beams comprise the timber frame, filled with 300mm Warmcel (recycled cellulose) insulation. 12mm external breather board, 50mm timber battens, and Sto render on backing board.
Windows / doors	Aluminium clad timber, triple glazed.
Heating	Gas fired wet central heating boiler combined with MVHR.
Renewables	None
U-value (W/m^{2}K)	walls 0.127 roof 0.095 floor 0.131 glazing 0.8
	(typically 2x better than current building regulations, combined with thermal bridge free construction.)
Air tightness	Target 0.6 ach (air changes per hour) at 50Pa
Procurement	Traditional

Predicted performance:

Predicted total annual primary energy will be less than 120kWh/m2

Total annual space heating energy will be less than 15kWh/m2

This is approximately 70-80% more efficient than homes built to current regulations.

From SAP:	DFEE	31.73 kWh/m^2
	DER	12.46 (CO_2 emissions: 0.95tonnes / year)
	% improvement of DER over TER	32%
Capital costs	tbc	

Figure 3.1A: Proposed site plan

Figure 3.1B: Proposed plans, section, elevations – 2 bedroom dwelling

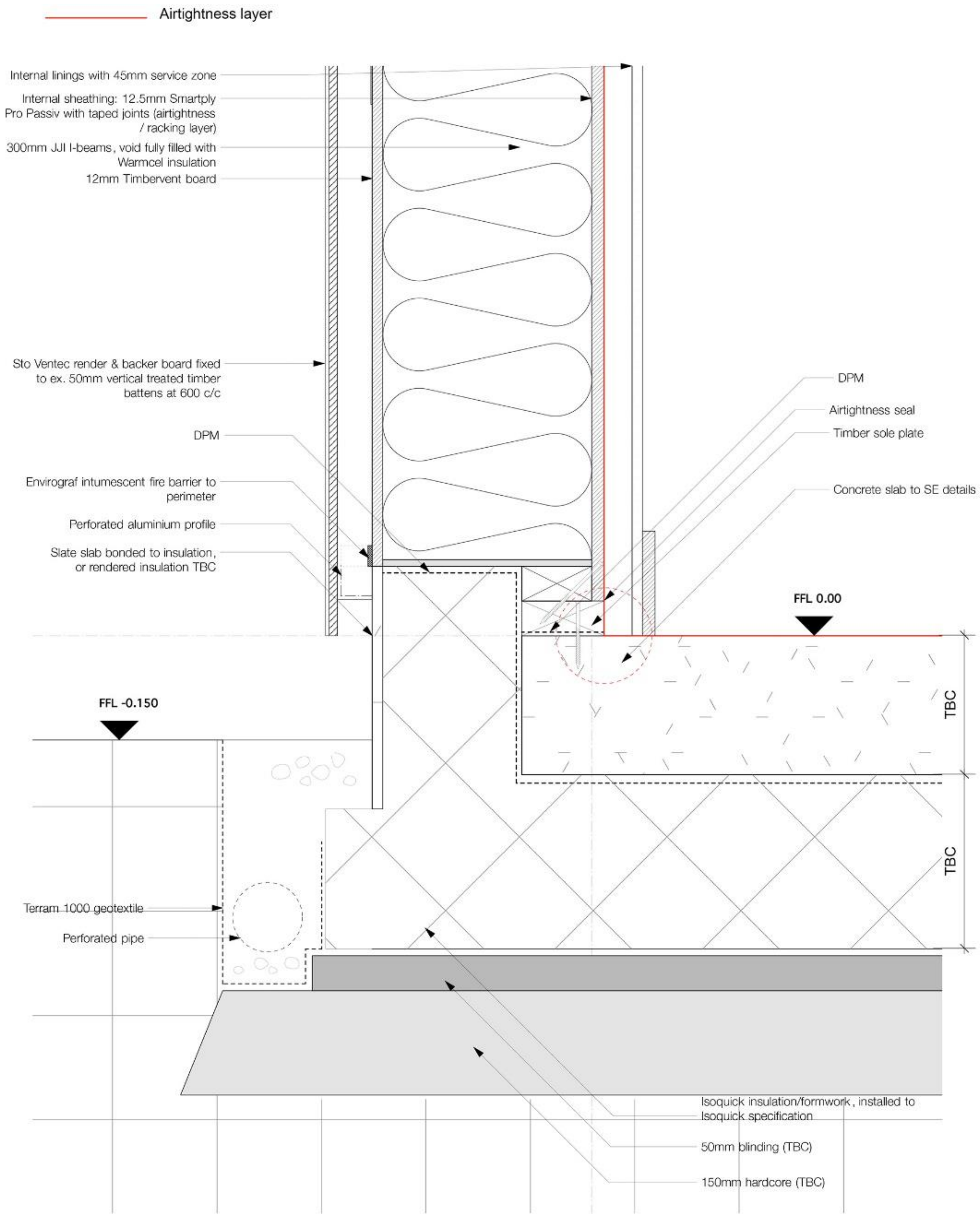


Figure 3.1C: Thermal continuity and airtightness are critical to the success of Passivhaus

APPLICABILITY ASSESSMENT: TIMBER FRAME TO PASSIVHAUS STANDARD

Description

Engineered timber frame or panels, creating 300mm deep cellulose-filled envelope, with design, specification and workmanship to achieve Passivhaus certification.

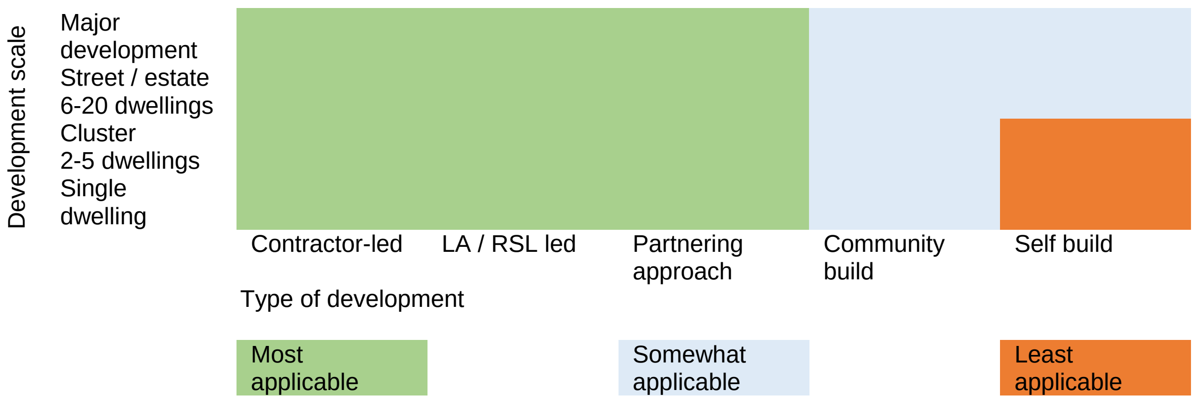
.Benefits and limitations

Key benefits	**During construction:** • certification provides rigorous quality assurance of construction standards • system uses standard readily available building materials • can be prefabricated off-site in panels, or site-built, to suit project needs
	In use: • certification ensures designed energy consumption is achieved in use • achieves very low running costs, as little as £70/year for heating • delivers high level of internal comfort, prevents mould growth / fabric decay
Key limitations	**During construction:** • requires more attention to form, fabric and orientation in design • requires a higher quality of construction to achieve Passivhaus standard • requires buy-in from the entire delivery team
	In use: • requires good user guides to ensure residents understand operation • higher performing fabric and MVHR impose different maintenance regimes for conventional social /affordable housing providers

Thematic analysis

Space standards	No implications
Flexibility / adapt.	No implications (non-Passivhaus extensions could affect performance)
Env. Performance	System ensures consistently high thermal performance / air tightness
Resilience	PHPP can be run using future climate data to ensure resilience
Materials	uses off the shelf, high quality, low carbon materials
Character	modern contemporary, but can be adapted to any aesthetic
Density	Low / medium / high density are all possible
Ecology	Low impact construction using natural materials
Health	MVHR and natural materials ensure very high internal air quality
Connectivity	facilitates limited community involvement and local resource use

Applicability matrix



3.2 | FEEs and zero carbon

__Rob Pannell__ was Managing Director of the Zero Carbon Hub, until it closed for business in March 2016. Rob worked closely with ministers and senior civil servants to advise on zero carbon policy.

Prior to joining the Zero Carbon Hub, Rob was a senior figure in the construction industry with over 35 years of experience with Taylor Wimpey UK Ltd. where he held a series of senior level roles, most recently as UK Director of Production (construction and design). Within this position Rob investigated and established a cost base and technical compliance of practical renewable energy and building fabric solutions to meet the UK policies.

In December 2008 the UK Government consulted on the definition of Zero Carbon Homes. The proposed definition was based around a hierarchical approach to achieving ‘zero carbon’ that included energy efficiency, reducing CO_2 emissions on-site via low and zero carbon technologies and connected heat networks, and where necessary by mitigating the remaining carbon emissions with Allowable Solutions.

In 2009 the Fabric Energy Efficiency Standard (FEES) was developed by an industry Task Group led by the Zero Carbon Hub, in order to help create a strategy for the 2016 zero carbon homes requirement. The Task Group's recommendations were subsequently included in the 2010 update of the Code for Sustainable Homes, with seven out of a possible nine credits given for achieving the FEES.

The Fabric Energy Efficiency Standard should be read as part of a journey towards Zero Carbon, and is best presented through the following graphic:

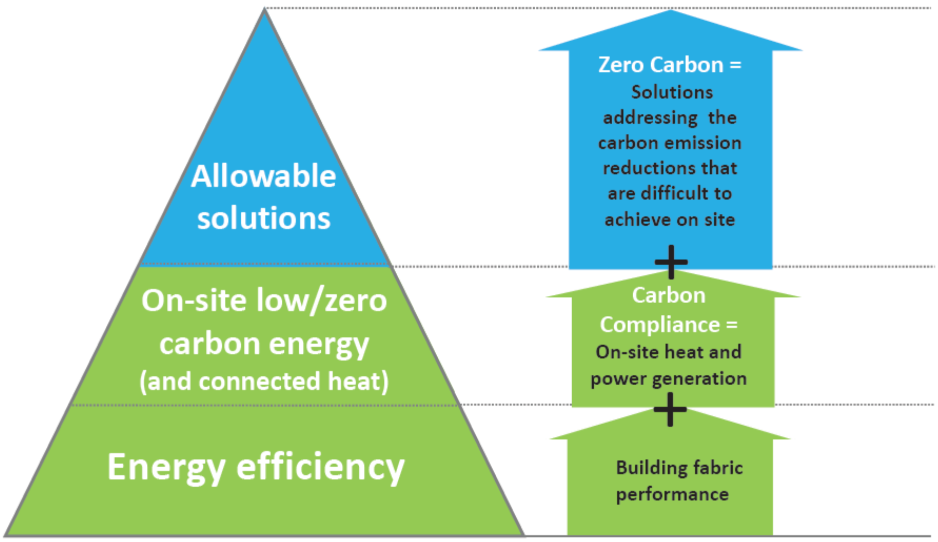


Figure 3.2A: Zero Carbon Hierarchy (credit: Zero Carbon Hub)

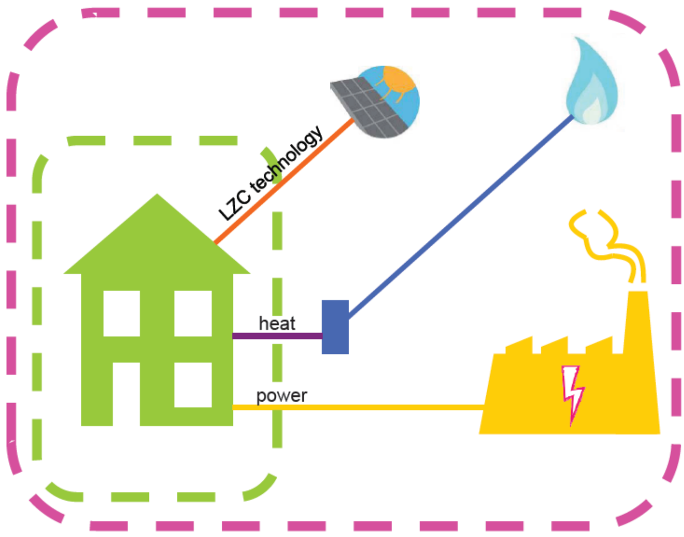
A high level of energy efficiency (‘fabric first’) was embedded within the original ambition for a 2016 Zero Carbon Homes policy. By minimising energy demand, dwellings utilise Low and Zero Carbon (LZC) energy sources in the most efficient way. This supports the parallel agendas of carbon reduction, long term energy security and reducing fuel poverty.
By focusing effort on the comparatively long-lived building fabric, homes are ‘future proofed’. Increased fabric energy efficiency means that homes will be less likely to require difficult and expensive refurbishment upgrades at a later date.

The scope of ‘energy efficiency’

When considering the scope of ‘energy efficiency’ it is important to understand that it is complementary to that of Carbon Compliance and Allowable Solutions, and to the reach of other legislative drivers. There was much deliberation within the Task Group as to the scope of the Standard, but agreement was reached that it should include:

- Building fabric U-values
- Thermal bridging
- Air permeability
- Thermal mass
- Features which affect lighting and solar gains.

The Energy Efficiency Standard must be considered within the requirement of meeting the Carbon Compliance Standard, as set out in the graphic below:



Energy Efficiency Standard

- Building fabric U-values
- Thermal bridging
- Air permeability
- Thermal mass
- Solar, metabolic, lighting & appliance gains

Carbon Compliance Standard

- Heating / cooling appliances (boilers, etc)
- Mechanical ventilation
- Hot water
- Active controls
- Fixed lighting
- All LZC technologies

Figure 3.2B: 'Energy efficiency' as defined by the Task Group (credit: Zero Carbon Hub)

Metrics

The Fabric Energy Efficiency (FEE) methodology considers the space heating and cooling demands of a dwelling. A performance metric of $kWh/m^2/yr$ is used. This metric is widely used and independent of fuel type. This approach:

- Allows design flexibility
- Takes into account building form
- Promotes innovation
- Delivers a specific level of dwelling performance
- Uses an internationally known ‘currency’ for energy efficiency

Levels

The Task Group recommended that an absolute, performance based, figure should be used to define the Fabric Energy Efficiency Standard, and settled on the following:[8]

- Apartment blocks / mid terrace houses: maximum energy demand of 39 kWh/m²/yr
- End of terrace / semi / detached houses: maximum energy demand of 46 kWh/m²/yr

The Fabric Energy Efficiency Standard was set to be equally challenging for different dwelling types. This is because certain types, such as mid floor apartments, which have less exposed fabric relative to the floor area, are able to achieve a higher space heating demand with a less challenging construction specification. A detached house, in contrast, has a much higher ratio of exposed fabric, and is inherently less energy efficient. Setting a single level across all dwelling types would result in either detached homes being required to achieve extreme specifications or little improvement being required by apartments. It was accepted that detached dwellings require a somewhat more challenging specification.

As stated, the FEE is measured in kWh/m²/yr, and is not influenced by building services, such as the heating system, fixed lighting or ventilation strategy. It is a performance standard, meaning that different combinations of building fabric can be used to reach a particular level. This allows flexibility when developing a building fabric specification.

Setting the Fabric Energy Efficiency Standard at a challenging level through a performance-based metric allows for flexibility in design, encourages innovation in both products and processes, and enables the delivery of a consistently high level of dwelling performance.

Buildability and performance

The construction specifications required to achieve the minimum Fabric Energy Efficiency Standard are achievable with a sufficiently wide selection of products and techniques. However, as it is a performance standard, there is flexibility in the individual element specifications used to comply.

The issue of a **performance gap** between designed and delivered projects is widely recognised. The Fabric Energy Efficiency Standard only offers a design standard but subsequent work by the Zero Carbon Hub (2011) recommended that future performance standards for zero carbon homes should be linked to 'as-built' performance to achieve the '2020 Ambition':

> *From 2020 be able to demonstrate that at least 90% of all new homes meet or perform better than the designed energy/ carbon performance.*

In 2013 to 2014, the Zero Carbon Hub undertook a collaborative project with those involved at all stages of the housebuilding process, to start to uncover the extent and impact of the energy performance gap in new homes. Evidence on the issues uncovered were presented, and recommendations made to Government and Industry on how to reduce this gap.[9]

Health and wellbeing

Householder health and wellbeing are recognised within energy efficient dwellings to be of utmost importance. In particular there is currently insufficient research available to fully understand the relationship between indoor air quality and associated ventilation strategies

---

[8] As modelled using specific inputs into SAP (Standard Assessment Procedure)

[9]http://www.zerocarbonhub.org/sites/default/files/resources/reports/Design_vs_As_Built_Performance_Gap_End_of_Term_Report_0.pdf

in homes with low air permeability. The level selected for FEES allows for various air permeability and ventilation combinations but further research in this area is needed.

Cost

Financial analysis was an important factor in the FEES Task Group's decision making process, and both capital cost and whole life costs were considered. Interestingly, the modelling carried out at the time showed that in terms of whole life costs, only going to a very ambitious fabric specification would be more costly than the then current practice to achieve '70% carbon compliance'[10] (See figure 4, below).

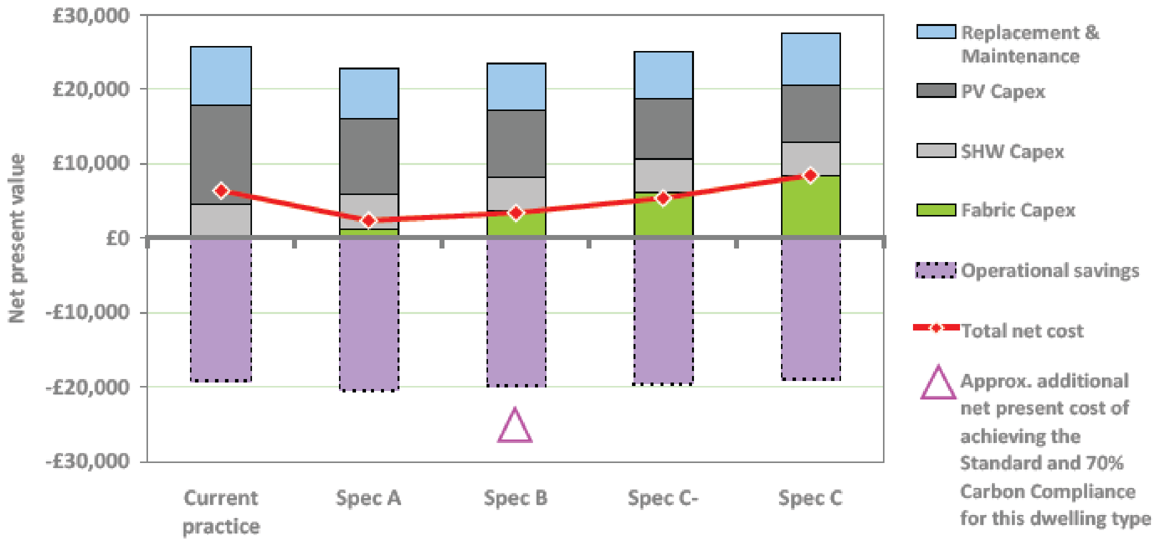


Figure 3.2C: Whole life costings over 60 year period for semi-detached house (2009)

Further developments

There is more work to do on the Task Group's proposed Fabric Energy Efficiency Targets. Recent modelling indicates that some building types may struggle to meet these standards, and setting mandatory limits could mean these buildings would only be able to do so at increased cost. An example of this is detached bungalows, which have relatively high heat loss due to high exposed surface area per unit volume. There are also complications when meeting the standard on specific sites using some dwelling types which defy neat categorisation (e.g. a terrace built on a slope, in which houses have a higher exposed wall area than those in a terrace built on flat ground).There is now some experience within the industry of designing and building to the FEE methodology, especially since its adoption into the Code for Sustainable Homes 2010. When initially conceived, the industry Task Group considered that all dwellings would fall into one of two categories (i.e. the upper and lower limits). This was subsequently adjusted such that a ‘sliding scale’ was applicable to certain mid-terrace units.

Further development of the FEES methodology was considered in the 2012 consultation on Building Regulations Part L. The subsequent implementation of an energy efficiency standard within Building Regulations Part L 2013 moved away from an absolute performance standard and utilised a notional dwelling approach to define the energy efficiency standard for a home. This had the effect of equalising the specification required to achieve the standard across different house types, but took away from the original ambition of including building form in the equation.

[10] A 70% reduction in onsite carbon emissions was the stated 'carbon compliance' level at the time.

3.2 Case study: **SOLCER house**

Client	Low Carbon Research Institute
Architect	Welsh School of Architecture, Cardiff University
Location	Parc Stormy, Stormydown, Bridgend CF33 4RS

Background

In 2014-2015, the Welsh School of Architecture (WSA), Cardiff University built Wales' first 'energy positive' affordable house, as part of the SOLCER project ('Smart Operation for a Low Carbon Energy Region'). The SOLCER House is capable of exporting more energy to the national electricity grid than it uses over an annual period, in order to help meet targets for nearly-zero carbon housing. Both the UK and Welsh Government will continue to set new targets for carbon compliance in housing, and the WSA took the view that to rise to the challenge of zero carbon as a community new innovative ways to build housing for the future should be taken.

The house was built as part of the Low Carbon Research Institute (LCRI) programme, to promote energy research in Wales by uniting low carbon energy research across Welsh universities. The LCRI project was a collaboration between academia, industry and government, and a product of the LCRI's HEFCW and WEFO Programmes (2008 to 2015).

Description

The SOLCER House is located at the Cenin site in Stormy Down, near Bridgend. It has been designed to meet Welsh Government's social housing standards. The components of the building have been sourced, as far as reasonably practicable, from Welsh manufacturers and installers, and the house is being used as a demonstration of advanced Welsh construction technologies. The low carbon market available technologies employed have been designed to be affordable and replicable, for use by local developers to build houses.

Environmental approach

The SOLCER House takes a systems-led approach, combining renewable energy supply, thermal and electrical energy storage and reduced energy demand, to create an energy-positive house at an affordable cost.

Key design principles

To minimise energy demand, the house was built with high levels of thermal insulation and reduced air leakage rates. An integrative approach to construction uses renewable energy systems as building elements; the south facing upper walls incorporate a Transpired Solar Collector (TSC) which preheats the air in the heating system, and the south facing roof is a glazed 4.3kWp PV panel, which allows the roof space to be naturally lit. Using these technologies as building fabric reduces costs and improves aesthetics, avoiding the 'bolt-on' approach often associated with renewable energy systems. The energy systems combine solar generation and lithium ion battery storage to power both a combined heating, ventilation and hot water system, and its electrical power systems which includes appliances and LED lighting.

Space heating is provided by passing external air through the south facing transpired solar air collector (TSC), then through the mechanical ventilation heat recovery unit (MVHR), before delivering it to the internal space. Exhaust air is passed through the MVHR and then through an exhaust air heat pump, which heats the thermal water store. The thermal store heats domestic hot water (DHW). The heat pump is powered by the PV with battery storage.

Current status

The house was completed in February 2015 and was opened by Edwina Hart AM. Due to funding limitations the SOLCER House is currently being used as an office and is BREEAM excellent, but was designed and built as a three bedroom family house and compliant with housing standards.

Now that it has been built, the key task is to ensure that all of the measures utilised are monitored, in order to assess their operational energy use. This information will be used to inform future research projects and industry practice, with the aim of ensuring that Wales remains at the heart of developments in zero carbon housing.

The building demonstrates the feasibility of low carbon technologies at a domestic scale which, it is hoped, will be replicated in other areas of Wales and the UK in the future.

Construction and materials

Structure	Structural insulated panels (SIPs).
External fabric	An innovative energy efficient envelope combines low carbon cement, SIPS and external insulated render with both transpired solar collectors (TSC) and a 4.3kWp photovoltaic panel.
Windows / doors	Composite (timber frame, aluminium-clad) and double glazed (low e).
Heating	MVHR with air source heat pump.
U-value (W/sqm°C)	walls 0.12 roof 0.14 floor 0.13 glazing 1.26 door 1.21
Air tightness (@50Pa)	target <10 as built 2.9
Other standards	Welsh housing standards, Lifetime Homes, Secured by Design (pre-build approval), DQR compliant, BREEAM Excellent (office use).
Form of contract	The project was project managed by staff at the WSA, Cardiff University. Roman Projects were the Construction manager.
Programme	The house was constructed in 16 weeks using local supply chains.

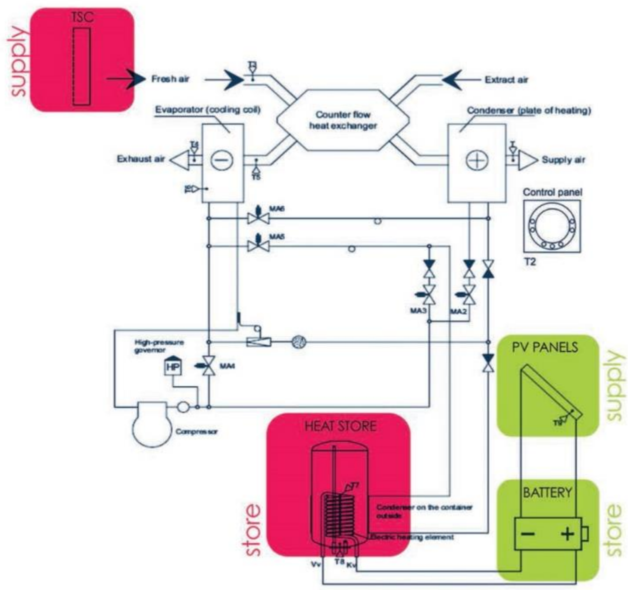
Performance

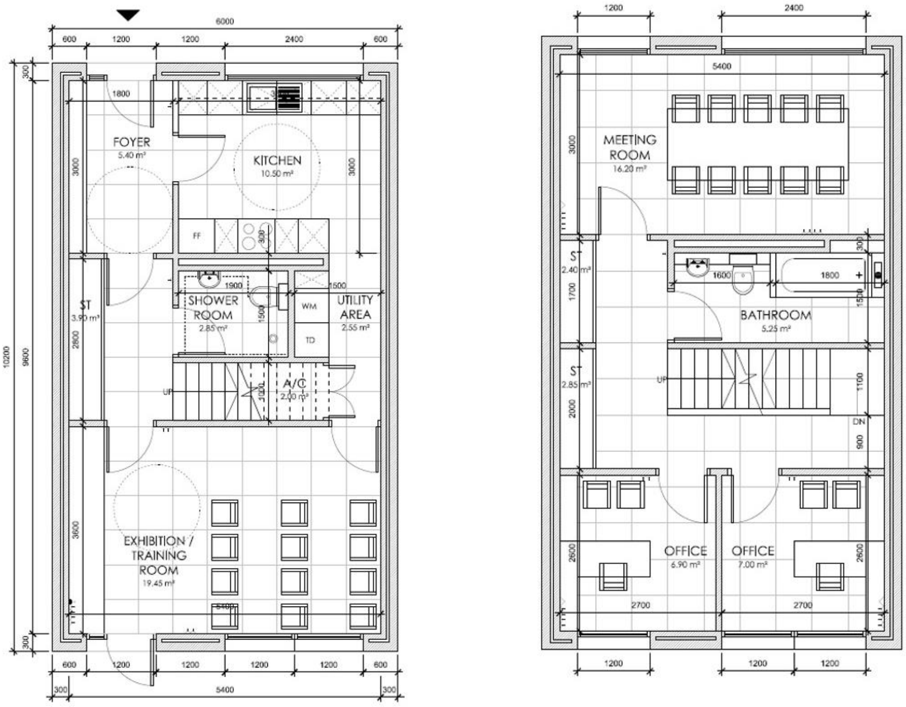
Environmental impact (CO_2)	14.04Kg CO_2/m^2 EPC rating: A (as built) SAP rating 106
Capital costs	The estimated cost of the house is £1,200/m^2.
Costs in use	The house is designed to be energy positive, and uses electricity from the grid only when energy from the PV and battery system is exhausted. The predicted energy performance is 70% autonomous, and the house is predicted to generate 1.5 as much energy as it uses.
Footprint	The aim of the design was to reduce embodied energy in the building's construction, as well as the energy used over its lifetime. The embodied CO_2 of the house (materials) is 340 kgCO_2/m^2, compared with a benchmark for housing of around 500 kgCO2/m^2.

For thematic analysis of the SIPs approach see case study 6.1, William Street Quarter.

Figure 3.2D: The dwelling was completed in 2015.

Figure 3.2E and F: Energy systems combine solar generation and battery storage to power heating, ventilation, hot water supply and small power. Predicted energy performance is 70% autonomous, with a 1.75 grid export to import ratio.





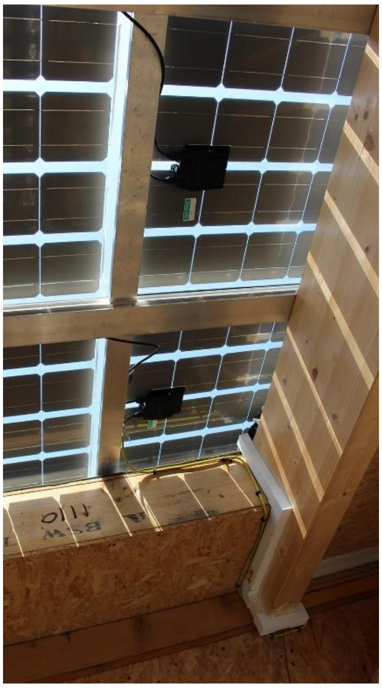


Figure 3.2G (left): The dwelling layout is designed to comply with DQR.

Figure 3.2H (right): Roofpsace acts as solar collector / thermal buffer.

Figure 3.2I (below): Now that the dwelling is complete, the crucial next step of monitoring has begun. This information will be used in order to ensure that Wales remains at the heart of the development of a zero carbon future.

Implementing a new approach:

HAFOD - tackling fuel poverty through innovation

A number of RSLs have expressed an interest in constructing replica SOLCER Houses, seeking to apply the systems-based approach to 'live' housing schemes. One such project was initiated as a result of a wider partnership project in Neath Port Talbot (NPT) with Gwalia (now Pobl), and is in the early stages of development. Pobl have taken over the local authority's Residential Care provision and constructed new care homes, which has freed up existing care home sites. The former Hafod Care Home is situated close to Neath town centre. Pobl and NPT have agreed that it is ideal for a pilot project whereby the energy generation principles employed at the SOLCER House can be applied to a new social housing project.

The proposed project consists of 16 new homes (8 houses and 8 flats) for social rent. In order to qualify for Social Housing Grant, the design will comply with Welsh Government's Development Quality Standards (DQR). The homes will generate more electricity than is used by the occupants, and that Pobl will be able to export surplus power to the National Grid, creating 'energy positive' homes and offsetting household costs for tenants.

Pobl understand that the innovation, the technologies and materials, and the additional design coordination involved in the project will result in additional costs compared to the social housing that they normally develop. However, the development team feel an obligation to innovate on housing projects, to promote a 'step-change' in low energy housing.

Scaling up the "Buildings as Power Stations" concept in partnership with SPECIFIC Innovation and Knowledge Centre, the scheme will be an exemplar low cost 'energy positive' project. It will incorporate building integrated renewable technologies and energy efficient materials which generate, store and release energy. By analysing costs, energy use and performance of the project post-completion and across future sites, Pobl hope to 'mainstream' the principles embodied in the systems-based approach, to reduce the cost of future projects to the point where the approach is considered viable for mainstream housing.

Plots are oriented with sufficient south-facing façade and roof slope to accommodate the required technologies, and individual building layouts maximise solar gains. A 'fabric first' approach is adopted, and key elements will be designed to passivhaus standards for thermal performance. SIP construction is proposed, to allows for more robust detailing and reduce the risk of air leakage. The cladding will then incorporate integrated technologies, with transpired solar collectors (TSC) on the façade and an integrated PV standing seam roof. A mechanical ventilation and heat recovery (MVHR) system with air source heat pump will provide any additional space heating requirement.

One of the most significant challenges will involve introducing tenants to a new way of thinking. The house represents a lifestyle change that requires the buy-in of the design and construction team, the social landlords and the tenants. It relies on the landlord managing the maintenance of the technologies involved. Maintenance contractors must understand the performance and operation of the systems and equipment installed. Systems must be put in place to ensure that any learning is passed on to all who carry out any maintenance works in the future.

To ensure that robust evidence is captured from this innovative housing project it is also proposed to implement an independent evaluation programme. SPECIFIC is currently working with the UK and Welsh Governments to explore how this can be achieved.

3.3 | Living Building Challenge

***Martin Brown** is an innovative sustainability, business improvement advocate and consultant. Through his Fairsnape practice he supports many organisations with practical solutions and strategies to accelerate the emergence of an exciting, vibrant and restorative built environment founded on innovation. With over 40 years international experience, he is a pioneer in sustainability thinking. Martin has been an advocate of the Living Building Challenge as UK Ambassador over the last 5 years. He tweets, blogs, lectures and presents widely on sustainability related topics, and is the author of the recently published RIBA book FutuREstorative: Working towards a New Sustainability.*

Affordable housing is uniquely placed to benefit from the philosophy and application of the Living Building Challenge (LBC). Furthermore, as this essay will set out, the Living Building Challenge aligns well with and will assist with adherence to the Welsh Well-being of Future Generations Act (2015):

- Living Buildings are designed to maximise the positive social, cultural and environmental potential of the built environment, and serve as focal points for inspiration and education in local social and business communities.
- Living Buildings are comprised entirely of healthy, low-impact materials, harvest all water and energy on-site, and place equity and social justice at the forefront of design goals.
- Living Building Challenge Certification (Living, Petal or Net Zero Energy Certification) is based on actual performance over an occupied twelve-month continuous period, not predicted performance.
- As the world’s most rigorous certification, the LBC can enhance the positive impact of affordable housing and mitigate persistent inequalities in low-income communities.
- The affordable housing sector is recognising that holistic sustainable design produces better homes for residents, with improved long-term economics and reduced environmental impact.
- Biophilic Design is at the heart of the Living Building Challenge, recognising the importance of biophilia, the innate relationship we have, and need, with nature for health and wellbeing. We spend up to 90% of our time within buildings that can isolate us from natural environments. Research is demonstrating that increasing occupant exposure to natural patterns can improve individual respect for sustainability and community, and has been referred to the *secret sauce of sustainability*.

Barriers and Opportunities

As a sector we fail to fully appreciate the impact and cost of poor housing on health services. Within our present built environment, applying Living Building Challenge is a cost challenge, it does however force consideration of elements of the project that traditionally have been externalised in pursuit of lower cost construction. Such externalised costs increase the burden and pressures on services that are stretched and approach a tipping point of failure (for example, landfill and sewer sites being eroded through flooding and coastal erosion).

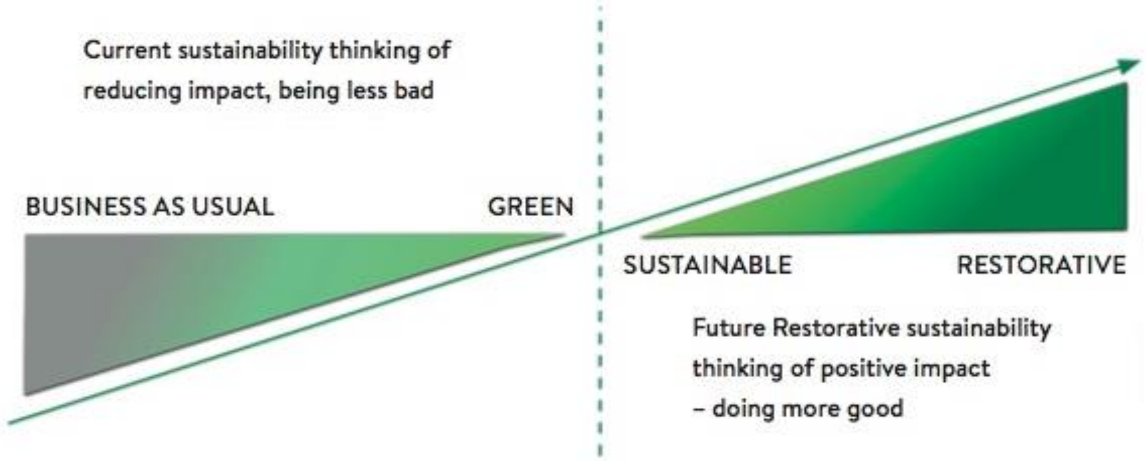


Figure 3.3A: Moving standards into a net-positive zone

The built environment, despite decades of effort to improve, remains woefully wasteful and far from 'sustainable'. To address for current drivers, for example the Paris Agreement to cap temperature increases to 2 deg C, we no longer have the luxury of being less bad, but need to focus on being more good, become restorative in our sustainability approaches in relation to wellbeing, building performance, and throughout the construction process.

The magnitude of waste within the sector has been identified as being 30%, which if harnessed could improve social, economic and environmental costs, freeing resources to enable net-positive and restorative sustainable, affordable housing. The Construction Vision 2025 paper calls for a 30% reduction in cost throughout the life of a building, recognising that such capacity for reduction exists. Better, then, to use this margin of waste to provide sustainable homes, eco-districts and sustainable infrastructures.

The Living Building Challenge

The LBC was founded in 2006 and is part of the International Living Future Institute (ILFI) suite of regenerative programmes. It is an holistic, regenerative sustainability programme for reimagining buildings. It is a philosophy, an advocacy tool for change and a rigorous certification tool. It challenges the way we design, construct and use buildings - but it also challenges wider sector thinking, for example around planning, regulation and materials.

The Challenge aims to transform how we think about every single act of design and construction as an opportunity to positively impact the wider community and the cultural fabric of our communities. It is comprised of seven "Petals": Place, Water, Energy, Health & Happiness, Materials, Equity and Beauty. Each Petal is further subdivided into 20 Imperatives, each focusing on a specific sphere of influence. This compilation of imperatives can be applied to almost any conceivable building project of any scale and at any location...

There are now over 450 LBC projects worldwide. However as a philosophy and an advocacy tool, the LBC is starting to impact on the industry in a more widespread manner…

The Living Building Challenge UK was launched in 2013 through a number of collaboratives (working groups / communities) and workshops. There is much interest in the Challenge as an alternative route to sustainable building certification from clients, designers and contractors, particularly as the health aspects of sustainability gain more attention. Whilst a number of UK Living Building Challenge based workshops and biophilic design charrettes have been held, there is currently only 1 registered project seeking accreditation in the UK.

Affordable housing pilot projects

In recent years the ILFI (International Living Future Institute) has supported a number of US affordable housing pilot projects across a range of housing typologies and climates. The Institute continues to provide technical assistance to guide the pilot projects on a pathway to meet the Living Building Challenge through a Living Affordable Housing Challenge:

Energy

Affordable housing tenants spend proportionally more on energy. Through its imperative of providing 105% net-positive energy, LBC can improve both economy and resiliency:

“Low-income tenants deserve freedom from energy bills: Net Positive Energy strategy offers a realistic solution for affordable housing in an age of energy volatility and climate risk.”

Water

“As global climate change and urbanisation continues to add new stresses to our ageing infrastructure, a new and more resilient system for affordable housing is necessary to ensure that we can meet our communities’ long-term water needs.”

The Net Positive Water Imperative requires that project water use and release must work in harmony with the natural water flows of a site and its surroundings. Our traditional storm water infrastructure allows toxic chemicals to be washed into waterways, causing pollution which impacts on human and ecosystem health. Water reuse, storm water management and infiltration at the project scale can eliminate these environmental impacts while restoring a healthy hydrological cycle to a site.

Materials

“Small shifts in the standard specifications of the affordable housing industry can have ripple effects that spread across the building marketplace, transforming a materials economy and providing safe, healthy affordable housing for all.”

The Materials Petal offers a framework to ensure healthy, non-toxic affordable housing projects. The Materials Petal is one of the more challenging Petals within the Living Building Challenge requiring more than a technical or engineering solution. It requires a shift in the manufacturing industry to embrace transparency and toxic chemical avoidance. While challenging, meeting the Materials Petal is also critical to protecting occupant and environmental health. The requirements of this Petal are particularly important to meet in affordable housing projects, which have a long history of substandard materials that have a negative impact on occupant health.

Health and Happiness

“Creating environments that optimize physical and psychological health and well-being”

Operable windows and other passive ventilation strategies do not just decrease energy use, they also improve comfort by allowing control over the environment. Occupant health and comfort are at the forefront of the Healthy Interior Environment Imperative. Zero- and low-VOC materials coupled with indoor air quality testing can reduce rates of asthma and other airborne illnesses. The Health and Happiness Imperatives can significantly improve occupant health and well-being for our more vulnerable populations through intelligent design with limited additional cost.

Place

The Limits to Growth Imperative represents the chance to rejuvenate an existing site and protect ecologically sensitive areas that are often affected by sprawl. Meeting the Urban Agriculture Imperative provides amenities for residents that promote community interaction while providing access to healthy, locally grown food. Residents will also benefit greatly from being located near basic amenities and services within a pedestrian-oriented community.

Equity

The Equity Petal, 'Supporting a Just and Equitable World' is at the centre of why achieving the Living Building Challenge for affordable housing is so critical to creating a just and equitable society. True sustainability can only be achieved if the movement embraces all sectors of humanity, no matter the background, income, age, class or race.

Beauty

The Beauty Petal serves not only to elevate the spirit and beauty of a particular place, but also to highlight the necessity of designing spaces that become cherished community resources. Thoughtful consideration to how every square metre of a project will elevate the human spirit will provide residents with a sense of pride in and affection for the space. Education programs can expand the impact of the development to the broader community and turn each project into a centre for inspiration and education.

The Living Building Challenge has initiated a series of Living Affordable Housing Challenge on-demand online educational workshops. Although aimed at the US Affordable Home market, they can be adapted and made available to the Welsh (and UK) sector. Embracing the Living Building Challenge for Affordable Housing in Wales will have a positive 'ripple effect' on the wider Welsh built environment design, construction and maintenance sectors:

Design – through an increase in awareness and skills for design that is holistically healthy, socially and culturally rich, ecologically and environmentally sound.

Construction - through increased awareness of skills / construction methodologies that are low carbon, reinforce local economy, utilise non-toxic materials and are ecologically sound.

Materials –through an increase in awareness and skills for moving to a healthy, non-toxic, low carbon material manufacturing sector (through Living Product Challenge and Declare)

Operation - through an increase in awareness and skills for managing buildings based on monitoring and acting on health, air quality, energy, water usage and waste.

Recommendations:

- Initiate a Welsh LBC Collaborative to understand LBC in the context of Welsh Affordable Housing and the Wellbeing Act. Learn from an international perspective.
- Map Welsh (Building / Affordable Housing / Sustainability / Wellbeing) strategies against the LBC, LPC, Declare and Just programmes.
- Hold a LBC 'charrette' workshop for pilot affordable housing schemes.
- Initiate a pilot LBC housing project to identify opportunities, barriers and challenges

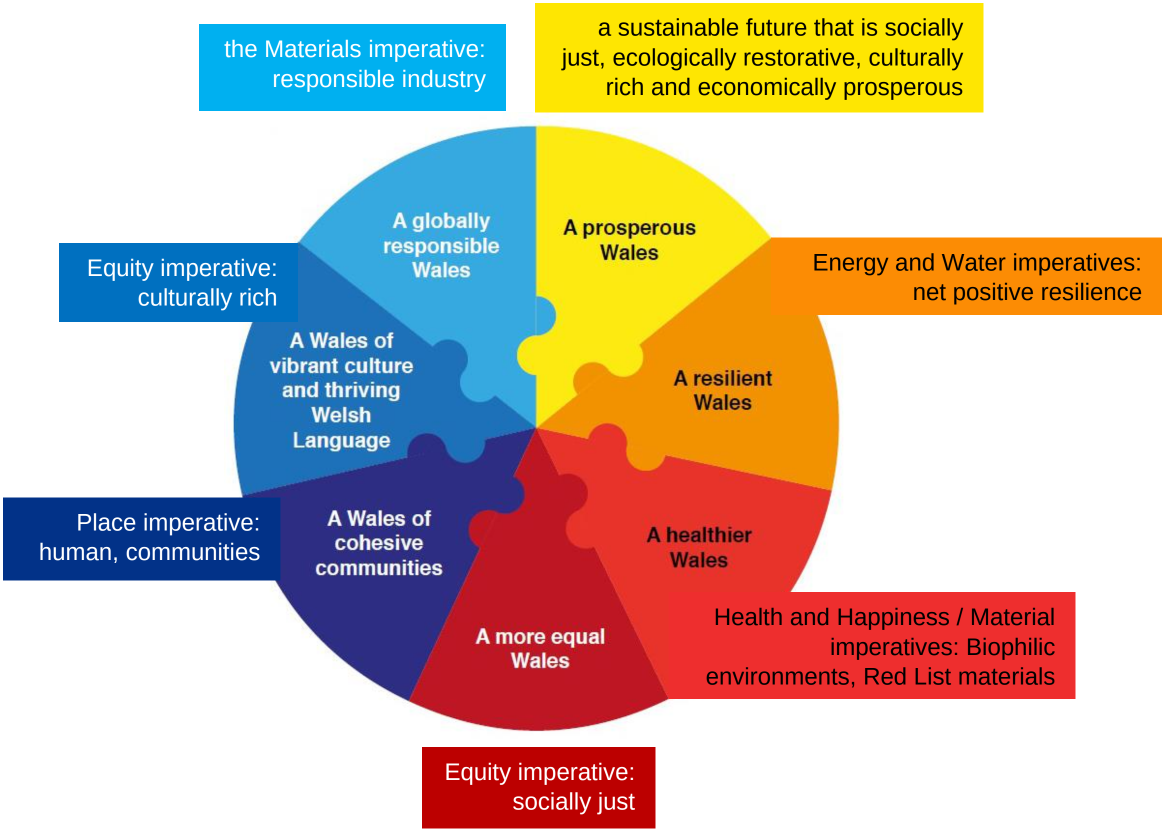


Figure 3.3B: mapping key objectives of the Living Building Challenge onto WFGAct (2015)

Essay adapted from Living Building Challenge Framework for Affordable Housing: A Pathway to Overcome Social, Regulatory and Financial Barriers to Achieving Living Building Challenge Certification in Affordable Housing. Published ILFI Nov. 2014

References:

FutuREstorative: Working Towards a New Sustainability, M Brown, Pub RIBA 2016
RIBAbookshops.com/item/futurestorative-working-towards-a-new-sustainability/85971/

Living Building Challenge Framework for Affordable Housing: A Pathway to Overcome Social, Regulatory and Financial Barriers to Achieving Living Building Challenge Certification in Affordable Housing. Published ILFI November 2014

Living Affordable Housing Challenge: On Demand online education and training modules.
http://living-future.org/affordable-housing-five-part-demand-webinar-series

Living Building Challenge 3.1 | Living Community Challenge 1.0 | Living Product Challenge | Declare | JUST | are all ILFI programmes – see www.ilfi.org

Well-being of Future Generations Act (2015)

Construction Vision (2025)

3.3 case study: **Ty Solar, Pembrokeshire**

Client Western Solar

Architect Gareth Dauncey

Location Glanrhyd, Pembrokeshire

Background

Western Solar Ltd, based in Pembrokeshire, completed the 3 bedroom TY Solar prototype dwelling on the grounds of Rhosygilwen mansion in 2013. It was inaugurated by the First Minister Carwyn Jones. They have since focussed on developing their production facilities and finding a suitable site for a showcase for rural contemporary sustainable living in the 21st century. They firmly believe that the generation of electricity from solar PV can be used to subsidise affordable homes, and that the falling cost and increasing efficiency of photo voltaic (PV) panels have begun to make this a reality. This year, they completed a six-dwelling hamlet of zero energy dwellings.

Dr Glen Peters, CEO of Western Solar said of the project, "Our six homes will produce nearly 50Kwhr over the year with current technology. In a year, that could double, given current developments in PV. It means that the income from power generation will help to subsidise the affordable rents." His intent is to develop a house design that is both sustainable and affordable, running entirely on solar energy.

Glen Peters brought together a small team comprising himself, architect Gareth Dauncey, and Jens Schroeder, a builder with sustainable construction experience and passion. Together they designed and built a three bedroom, solar-powered house as proof of the concept, and have now completed an estate of six solar houses. They plan to build 1,000 solar houses over the next ten years.

Aims

- Provision of family housing for rent at an affordable rate (20% below market)
- Maximum use of locally sourced, sustainable materials
- The houses must be comfortable, and must generate most of their own energy.

These aims led the team to focus on reduction of energy demand, rather than technology. The six houses repeat the form of the TY Solar prototype which maximizes the use of solar energy through a monopitch roof and south facing orientation. They are made of locally sourced timber at the company's eco factory in Pembrokeshire. With eleven inches of insulation and south-facing windows they use 12% of the energy of a traditional home.

The company has taken advantage of the Welsh Government's apprentice training scheme to recruit and train its workforce in the manufacture of all modular timber components. The timber frames are made from trees from a local forest, kiln-dried, processed and manufactured in the company's own factory near to the project site, supported by a growing network of local suppliers.

It takes approximately three days to erect the structural wall, first floor and roof panels, and to achieve a weatherproof envelope. This compressed programme saves considerable time on site, and results in lower overall costs.

Residents are also offered a subsidized electric car sharing scheme, powered by on-site PV, to cut the cost of short distance commuting to nearby Cardigan and Newport.

Environmental approach

Western Solar developed the first large scale PV plant in Wales, which was commissioned in 2011. The intention of the Ty Solar residential project was to create energy positive housing by maximising the impact of PV. A fabric first approach was therefore adopted, as reducing energy demand was considered an essential component of a solar-powered house. Thermal efficiency in the fabric of the building is combined with passive solar heating through large areas of south-facing glazing with appropriate shading to significantly reduce space heating requirements. Heating demand is met by a small number of electric radiators, eliminating the cost of a wet central heating system.

Construction and materials

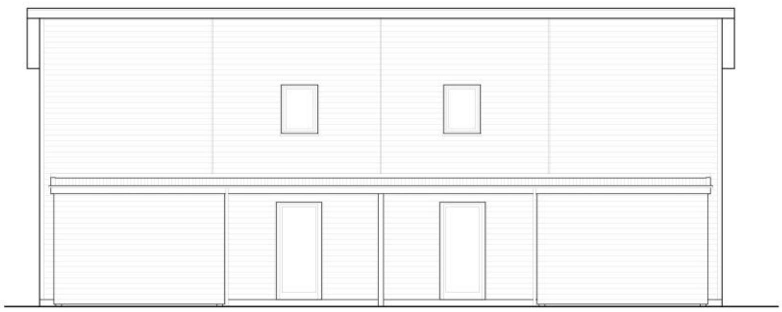
Structure	Prefabricated timber wall, first floor and roof panels			
External fabric	Breathable construction formed by factory constructed timber stud/engineered joist cassette panels, horizontally clad with larch and insulated with recycled paper			
Foundations	Simple concrete strip			
Windows / doors	Locally fabricated double glazed timber units			
Heating	passive solar gain, small standalone electric space heaters (zoned with thermostat)			
Renewables	6.5kW (semi) 10.5kW (detached) of integrated PV panels per dwelling			
U-value (W/sqm°C)	walls 0.13	roof 0.13	floor 0.14	glazing 1.34
Air tightness	target <2 $m^3/h.m^2$		as built: 1.44 $m^3/h.m^2$	

Performance as predicted *

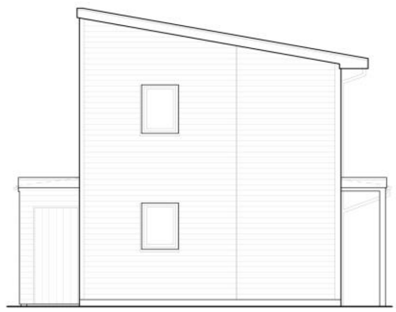
SAP	Energy efficiency 105, Environmental impact (CO_2) 104
Energy	Improvement of 16% over TFEE, Welsh Part L (2015)
Carbon	Improvement of 112% over TER, Welsh Part L (2015)
Procurement	The client, Western Solar, recognised a clear need for affordable housing in Pembrokeshire. They privately financed and project managed the development of six dwellings for affordable rental.
Current status	Completed July 2016.

Post completion

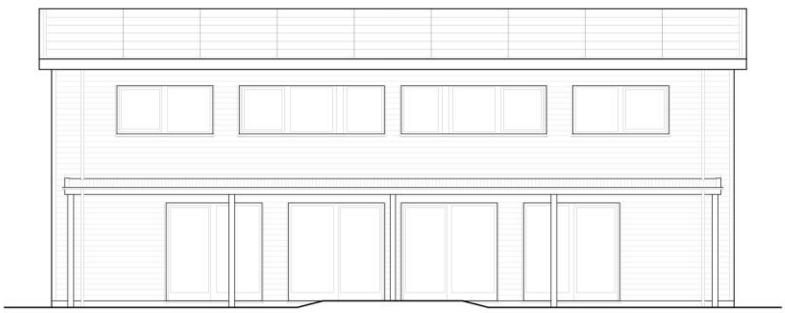
Cost data	The six dwellings were delivered for approximately £1200/sqm
Energy	space heating demand for the dwellings is around 35 $kWh/m^2/yr$.
	Integrated solar PV panels generate approximately double the energy demand of the dwellings.
Carbon	The house is predicted to be carbon negative at -230 kgCO2/annum



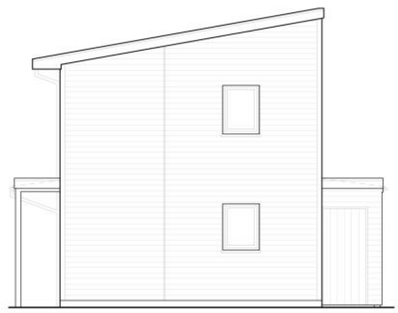
Rear (North) Elevation



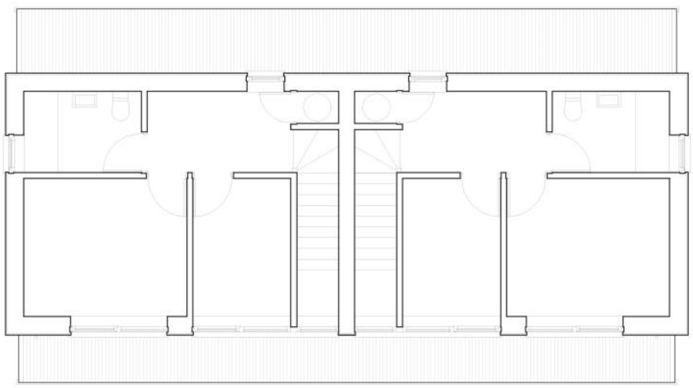
Side (West) Elevation



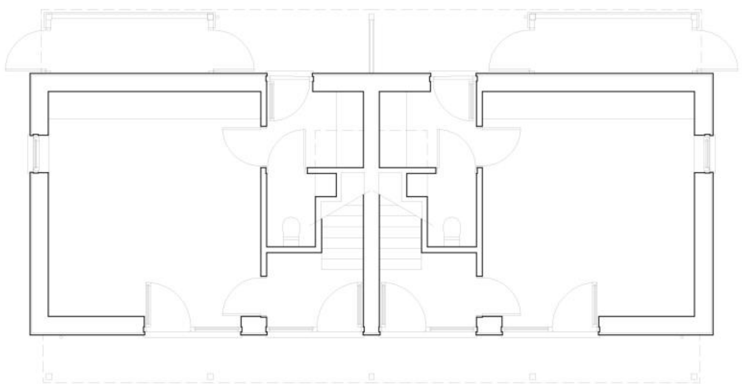
Front (South) Elevation



Side (East) Elevation



First Floor Plan



Ground Floor Plan

Figure 3.3C: Plans and elevations, semi-and inset

Figure 3.3D: Gable, as complete

Figure 3.3E: Detached pilot dwelling, complete on site

Figure 3.3F: All aspects of the design maximise the use of locally available timber

APPLICABILITY ASSESSMENT: TIMBER FRAME CONSTRUCTION

Description Simple dwelling forms constructed with timber frame and modular components using locally sourced timber and suppliers, and locally trained labour.

Benefits and limitations

Key benefits

During construction:
- System delivers healthy (permeable) buildings at an affordable cost
- Use of local resources minimises transportation costs and offers local benefit
- Off / near-site fabrication delivers high quality, reduces site time and costs

In use:
- Proven ability to achieve high levels of thermal efficiency / passive solar gain
- Offers potential for an all-Wales supply chain and minimises cement use
- Carbon negative (carbon sequestration and extensive clean energy source)

Key limitations

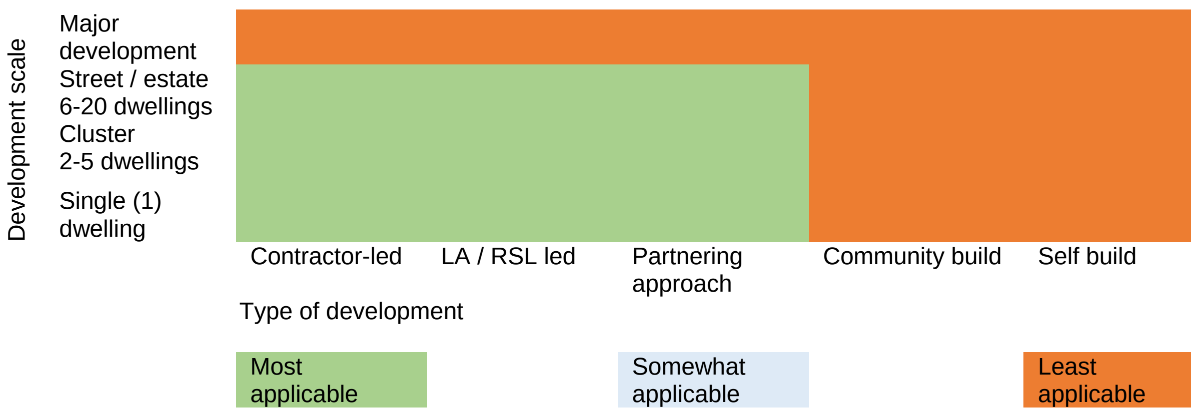
During construction:
- Relies on availability of affordable, trained carpenters and workforce
- Locally available timber weathers some microclimates better than others, and requires careful detailing to avoid maintenance issues

In use:
- Simple low-lying forms are not suited to more urban settings
- Limited palette of materials is not appropriate in all contexts
- Surplus energy must be stored or returned to the grid if it is not to be wasted.

Cross-standard analysis

Space standards	No implications, although panel limits applicability for small sites/builds
Flexibility / adapt.	Simple form and construction promote flexibility and future adaptability
Env. Performance	System relies on high thermal performance / air tightness
Resilience	Moderate thermal mass, PV energy source
Materials	Carbon capture in timber, very limited use of cement
Character	Determined by local resources & design simplification to reduce cost
Density	Low / medium density are possible
Ecology	Very low impact construction
Health	Breathable construction, low toxicity materials
Connectivity	Approach facilitates engagement of community and local trades

Applicability matrix



4.0 | thinking local

4.1 | Cooperation makes housing better

The **Wales Co-operative Centre** is a national body for co-operatives, mutuals, social enterprises and employee-owned businesses in Wales, delivering major programmes on behalf of the EU (via the Welsh European Funding Office) and Welsh Government.

David Palmer is Cooperative Housing Project Manager at the Wales Cooperative Centre, and has secured funding for the delivery of nearly two thousand affordable homes over 2012/15 period, when he managed the affordable housing programme undertaken by Persimmon Group for the HCA grant funded programme.

In 2013, the Wales Co-operative Centre commissioned research into the demand for co-operative housing in Wales. The research identified a substantial appetite for co-operative housing, particularly from those who are currently priced out of the owner-occupied sector, but are not eligible for social housing. (Link: http://wales.coop/coop-housing/) The co-operative approach offers affordable housing in a climate where mortgages are difficult to obtain, while house prices remain too high for buyers at the bottom end of the income scale. Co-operative Housing is affordable and sustainable because:

- land can be held 'in perpetuity' at less than market value by the co-op.
- the co-operative can access capital grants and/or loans, funded by the rental stream. Financial risk will be shared by members of the co-op, reducing base costs.
- the co-op is established to meet the needs of the group, and matched to means. It should be flexible enough to respond to changes in personal circumstances - maintaining long-term affordability and providing sustainable housing solutions.
- the co-operative can provide or purchase services themselves (rather than from a housing association for example), reducing costs and further improving affordability.

What is Co-operative Housing?

Housing co-operatives collectively manage, and sometimes own, their accommodation — shared houses, blocks of flats, even entire housing estates. Together they take responsibility for decisions about maintenance, rent and membership. Co-operative housing is community-led, managed in accordance with co-operative values and principles. It is different from other forms of housing because it supports community control. Its principles can be applied in many different ways to meet specific need. When Welsh Government (WG) began developing a co-operative housing approach in 2010, little experience or knowledge of the sector existed within Wales. Over just a few years, WG has worked with the Wales Co-operative Centre and the Confederation of Co-operative Housing to initiate 25 co-op housing projects. Three factors made the difference:

1 **Local enthusiasm** - people have responded enthusiastically and creatively to the opportunity to develop co-operatively. Greater community spirit, working with neighbours, and increased local autonomy all contribute to strong, local communities. Communities with

decision-making power can make a huge, positive difference. This is evidenced in the first wave of pioneer projects being developed through WG's Co-operative Housing Programme.

2 **Strong partnerships** - All of the schemes under development have come about as a result of partnerships between communities, local authorities and housing associations. Housing staff involved have learnt new skills in working with communities, and are as enthusiastic as the communities to enable them to make decisions.

3 **Flexibility** - Each scheme is shaped to fit local needs by key stakeholders. Bespoke arrangements have delivered a range of schemes for people on different income levels and in different locations. Support and funding have been flexibly designed to meet local needs. Enough has been learnt to suggest that WG was right to initiate a *"bold and ambitious co-operative housing movement".* The stage is now set for any community, local authority or housing association to develop the next wave of co-operative housing…

Sample Co-operative Rental Schemes

Home Farm Village Housing Co-operative and a developing co-operative in Carmarthen are the first two pioneer rental schemes. Founder members moved into Home Farm's 41 rented houses and flats next to Ely River, Cardiff, in Autumn 2015. The homes were developed by **Cadwyn Housing Association**, who granted a lease to the co-operative. The co-operative manages the homes in partnership with Cadwyn. With most of the incoming tenants nominated by **Cardiff City Council**, the co-operative group has been successfully developing their skills to run the co-operative since early 2014. The scheme fitted in with Cadwyn's community-based nature and led them to explore how they can incorporate co-operative principles into a small mixed residential / commercial scheme in Beechley Drive, Cardiff. They intend to start by enabling a community group to manage a garden area, with scope for them to take on more responsibility in the future. Cadwyn's Ben Hodge, who worked with the developing co-op, found it really exciting working with the group and seeing it grow. He had no doubt that they would be a successful co-operative, and enjoyed working with them as they moved into and grow in their new homes.

Old Oak Housing Co-operative is being set up to manage 27 rented family houses off Job's Well Road, Carmarthen. The scheme was originally initiated by **Carmarthenshire County Council**, who asked **Grwp Gwalia/Pobl** to develop the scheme. Grwp Gwalia/Pobl will own the homes and will have a management agreement with the co-operative. Founding members have been drawn from Carmarthen's waiting list. The group is completing its development process, with occupancy scheduled for late 2016. Grwp Gwalia's Head of Housing, Nick Read, confirms that this has been a positive experience. Staff have been really motivated by the pilot project and are looking forward to continuing the outstanding work with founder members of the co-operative.

West Rhyl Community Land Trust (CLT) are taking a different approach. Membership is open to anyone living in the area, and **West Rhyl CLT** is establishing a joint board with **North Wales Housing** to manage refurbished and new-build rental homes ('Afallon' development) and a commercial unit (community shop, bakery and training centre) in former multiple occupation homes. The overall aim is to regenerate the area, which has become run down following the loss of tourism, through provision of quality homes and other services. Homes will be allocated through the CLT according to housing need and commitment to the local community. The CLT will manage local estate management issues. Other housing services will be provided by North Wales Housing.

Ty Cyfle was set up to provide starter homes for 16 to 24 year olds who are in (or aspire to be in) education, employment, training or volunteering. Developed by **Bron Afon Community Housing**, it began life when Afon Youth asked that a derelict community centre be converted into homes. Young people have taken the lead, and provide each other with mutual support. A youth team supports them, and helps them to move on within two years. During this time, they get help with budgeting, cooking and being good neighbours. Ty Cyfle also has two community rooms where local residents can access services such as computer training job searching help. Afon Youth has set up a management committee for Ty Cyfle with tenants, to set house rules and self-manage low level issues. Following the success of Ty Cyfle, Afon Youth is now exploring further co-operative possibilities.

Loftus Village Association, a shared ownership scheme, is being developed as part of **Seren/Pobl Group's** garden village project in Newport. The co-operative (housing) association will manage 19 homes plus a shared space and garden, as well as common facilities on the rest of Loftus Village. Seren initiated the project to create a new home ownership option for people priced out of the owner occupier sector, but the co-operative aspect of the scheme is equally important. The founder members of Loftus Village moved in during summer 2016, and considered how their co-operative (housing) association would operate, with particular focus on developing an allocations policy and joint repairs and maintenance schemes. They may also use the co-operative (housing) association as a means of establishing other local co-operative businesses.

Gwynedd Community Land Trust is to be formed through a partnership between **Gwynedd Council** and **Grwp Cynefin**. It aims to provide affordable homes for sale to local people in scattered rural areas in Gwynedd, through cross subsidy from market sale homes.

Shakespeare Gardens is a **Newydd Housing** project to bring three void blocks of flats back into beneficial use. Full refurbishment of the empty blocks (eighteen flats in total) will help to rejuvenate the wider estate. The project is challenging because the local area has become stigmatised through vandalism and anti-social behaviour. The co-operative route provides a tenant–led approach, and has the support and investment of Newydd. Managed in accordance with co-operative principles, the development will support the community's control over their neighbourhood. Newydd will pre-allocate tenants to properties, and provide training to help them develop as a co-operative. This will develop skills needed to run the co-operative. It provides tennants them with the opportunity to get to know each other before they move in, and the chance to be involved in the targeted recruitment and training opportunities that will be provided. The flats completed October 2016.

Taf Fechan Co-operative developed as a joint venture between **Merthyr Valley (MV) Homes** and **Merthyr Tydfil County** Borough Council to provide homes for low income people at 90% of local market rent, in one of the most economically deprived areas of Wales. MV Homes own the homes, and the council provide borrowing. MV Homes leases the homes to the co-operative, covering financial and administrative costs. The remaining rent covers management, maintenance, and other costs, with potential for the co-operative to make a small surplus. Founder co-operators were recruited from March 2015. They moved into the 2 bed apartments during December 2015 and have held their first AGM.

Other schemes under development include a potential cohousing scheme in Mold for people with learning difficulties, a CLT in St David's, to regenerate a former swimming pool site with 100 mixed tenure homes, and a self-build-led project in Wrexham. These, and the other schemes in the co-operative housing programme, demonstrate that it is possible to adapt co-operative principles to provide a range of affordable housing solutions for people and communities in Wales.

4.1 case study: **LILAC Cohousing**

Client LILAC Society

Architect White Design

Location 1-20 LILAC Grove, Victoria Park Avenue, Leeds LS5 3AG

Background

LILAC (Low Impact Living Affordable Community) was a pioneering low carbon, affordable, sustainable mixed urban co-housing community, completed in 2013. The aspirations for LILAC were to reduce its impact on the environment, to respond to the housing crisis, and to make a positive contribution to the surrounding neighbourhood.

Co-housing communities are typically commissioned, and often created, by the residents themselves. Each LILAC household has a self-contained home, but residents come together to manage their community, share activities and dine once each day. The project consists of twenty homes plus a shared ‘common house’ and other amenities.

LILAC was delivered through the adoption of a ‘mutual home ownership scheme’ (MHOS). MHOS is a new way of owning a stake in the housing market. It is designed to bring the bottom rung of the property ladder back within reach of households on modest incomes, in areas where they are otherwise priced out of the market.

Description

The project has transformed a derelict school site in Bramley, West Leeds. The twenty homes are a mixture of 1 / 2 bedroom apartments, and 3 / 4 bedroom semi-detached and terraced houses. They have been designed to meet the clients’ requirements for character, variety and identity. Within the communal ‘house’ there is a crèche, kitchen and dining area, offices and guest rooms. These shared facilities enable the size of individual units to be reduced. On-site allotments can also be used by the general public. Residents include families of all ages, retired couples and single occupants.

The homes are built using ModCell®, one of the first products to make large-scale, carbon-negative building a commercial reality. It allows super-insulated, high-performance, low energy ‘passive’ buildings to be built using renewable, locally sourced, carbon sequestering materials that include straw bale and hemp, to create less-than-zero carbon construction.

LILAC is a Co-operative Society registered with Financial Services Authority and a member led not-for-profit. It proves that partnerships between local authorities and community-led projects can generate results. Whilst most British co-housing has been deemed socially and ecologically sustainable, LILAC claims to set new standards for affordability.

Environmental approach

LILAC achieved Level 4, Code for Sustainable Homes. The sustainable ethos underpins every aspect of the design of the scheme, from its orientation on the site, use of natural daylight and ventilation, selection of materials and landscaping design. The homes are built of ModCell panels, which consist of a timber frame filled with straw. The development meets the Code for Sustainable Homes Level 4 criteria through the use of a fabric first approach to the building envelope. Rainwater stays on site. A large pond provides on-site sustainable urban drainage, and the landscaping design increases biodiversity from within.

Residents are encouraged not to own a car. Car parking has been minimized (10 spaces only in total) and dedicated cycle storage is provided. A canal towpath provides safe routes into the city centre. Bus routes and two train stations are less than a mile from the site.

Current status	The project was completed in two phases. The first residents moved into phase I during February of 2013. Phase II completed May 2013.

Construction and materials

Structure	The ModCell system utilises the excellent thermal insulation qualities of straw bale construction to form prefabricated structural panels.
External fabric	400mm deep ModCell timber frame, filled with 400mm straw bale insulation. 12mm external breather board, 40mm wood fibre carrier, and 8mm breathable render build-up. Triple glazed windows & doors.
Heating	gas fired wet central heating / hot water (solar hot water to houses) combined with MVHR ventilation.
Renewables	Solar hot water (houses only) plus photovoltaic panels.
U-value (W/sqm°C)	walls 0.19 roof 0.15 floor 0.20 glazing 1.24
Air tightness	target <4 m3/h.m2. as built: between 1.4 and 4.3 m3/h.m2 (at 50Pa)
Performance	Fabric only improvement on Part L 2014: not known Overall Carbon Reduction on Part L 2014: 25-60% over TER
Procurement	Participatory approach adopted throughout the project. Energy advisor appointed at an early stage. Main contractor (LINDUM) successfully tendered (D&B) on the basis of detailed proposals by White Design.

Post completion data

Capital costs	The development budget was £2.4M, with a gross internal area of 2100m^2 and a site area of 7200m^2. In 2016, White Design advocate budget costs of £1150-£1250/m^2 for single dwellings, or £1050-£1150/m^2 for developments of five or more dwellings.
Carbon	The construction process is intended to be carbon negative. Materials used have low embodied energy. The flying factory approach minimises transportation. A single 3 x 3.2m ModCell panel equates to 1400kg of atmospheric CO_2 sequestered. A typical 100m^2 dwelling sequesters 43 tonnes of atmospheric CO_2.
Energy	With a mean annual primary grid energy consumption of 99.5kWh/m^2.year, LILAC's households have consumption well within the Passive House standard (maximum of 120kWh/m^2.year). LILAC's energy performance success is attributed to a combination of innovative green technologies with an engaged user. Households consume 40% - 97% of PV-generated electricity on site. PV is therefore an important part of the 'low impact living' agenga. The LILAC FIT tariff payment does not go to individual households – it is the main source of income at community level. It generates enough income to cover communal energy and maintenance costs. Residents who compared their utility bills found LILAC to be cheaper by 30-90%.

Figure 4.1A: The project was built on the site of a former Victorian primary school.

Figure 4.1B: The completed project, with rainwater harvesting and SUDs at its heart.

Figure 4.1C: Panels being assembled at a flying factory nearby in Dewsbury.

Figure 4.1D: Superinsulated, with MVHR, photovoltaics and solar hot water panels.

APPLICABILITY ASSESSMENT: PROPRIETARY PREFABRICATED PANELS

Description

Patented manufactured composite panel system for off-site/near site fabrication, incorporating timber frame and straw infill.

.Benefits and limitations

Key benefits

During construction:

- System delivers healthy (permeable) buildings at an affordable cost
- Pop up factories minimise transportation costs and facilitate local training
- System uses locally available resources in Wales and minimises cement use

In use:

- Off / near-site fabrication delivers high quality under controlled conditions
- Demonstrated ability to perform at the highest levels of energy efficiency
- Carbon negative (due to high levels of carbon sequestration in timber / straw)

Key limitations

During construction:

- Panelised approach reduces applicability on the smallest infill sites
- Implementation at scale would necessitate industry-wide re-skilling / training
- Construction relies on availability of straw (currently abundant but seasonal)

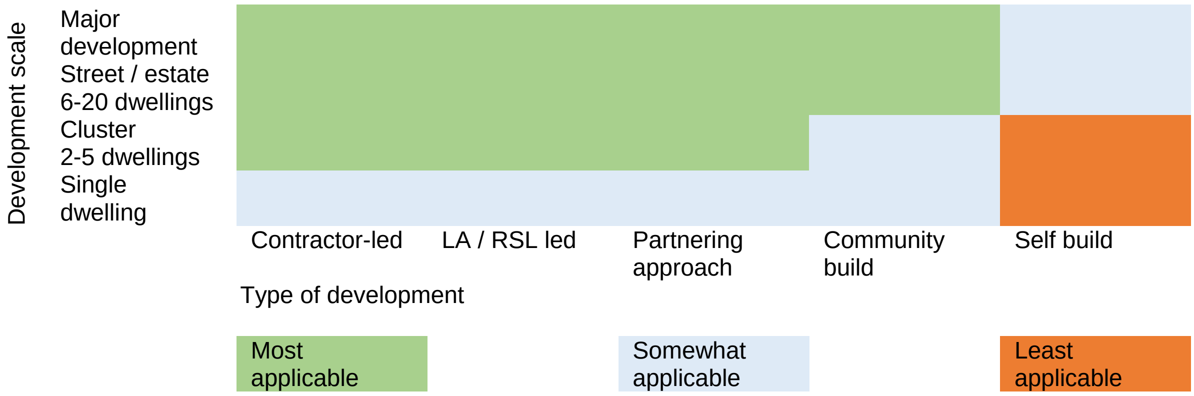
In use:

- Specialist construction reduces ease of adaptation
- Specialist construction limits applicability for self-build or for hands-on community build projects

Thematic analysis

Space standards	No implications, although panel limits applicability for small sites/builds
Flexibility / adapt.	Floor / roof panel sizes constrain future flexibility
Env. Performance	System ensures consistently high thermal performance / air tightness
Resilience	Some thermal mass, MVHR provides an option for 'cooling'
Materials	High level of carbon capture within envelope, use of local materials
Character	Panel aesthetic which can be 'wrapped' in other materials
Density	Low / medium / high density are all possible
Ecology	Low impact construction, carbon negative
Health	Breathable construction and MVHR ensure air quality
Connectivity	Flying factories facilitate community engagement / local resource use

Applicability matrix



4.2 | Better buildings, better resources

Gary Newman is Chair of the Alliance for Sustainable Building Products and of Woodknowledge Wales.

The Alliance for Sustainable Building Products is a cross **sector**, not for profit organisation, committed to accelerating the transition to a high performance, healthy and low carbon built environment.

Woodknowledge Wales champion the development of wood-based industries for increased prosperity and well-being in Wales. They work with construction clients, customers and specifiers to stimulate demand, and with industry to increase the capacity to supply timber for construction.

Context | drawing on Goodhart's Law

Market forces do not work as a mechanism to drive up quality in housing. House building is largely governed by policy and regulation. In recent years the technology of house building has been dominated by the measure of carbon in-use. Whilst a focus on carbon in-use has created a clear target for industry, it has failed to deliver quality. A fresh approach is now needed. *Goodhart's Law*, first articulated by the economist in 1975, states that measures that become targets cease to be good measures.

Accordingly, measuring carbon in-use should be regarded as a good thing. Setting a target for reduction seems inevitable, and important. But Goodhart's Law tells us to be careful, as all the focus and innovation will go into meeting that target. The recent VW emissions scandal is but one example. Goodhart's Law leads us to a simple 3-point guide for how to mitigate the problem – because it would seem impossible to escape.

Come up with a better measure. A flexible definition of 'zero carbon' should be seen as a good thing. Evolving targets are better than static ones. Business responds well to being challenged - despite what trade lobbies may indicate. I would suggest that trade associations are typically more conservative than the businesses they represent. So as a first step, let's evolve the zero carbon definition to include embodied carbon (more on this later).

Create a balanced scorecard with a more holistic approach, as intended by standards such as CfSH, BREEAM, LEED and the LBC (section 3.3). These standards require good governance, and should be tailored to the needs of the community they are serving. There is a strong argument for Wales to develop its own sustainable housing standard, one that adds value rather than cost and bureaucracy. Cambridge City Council are working towards a new aspirational standard with help from the Good Homes Alliance (www.goodhomes.org.uk).

Rely more on human discretion and focus on policies that encourage and enable better decision making. Consumers could be better served and more empowered by facilitating self build, custom build, and community housing models, creating more locally applicable solutions. Similarly, professionals could be provided with better tools, to support better choices. For this to happen, attitudes to risk must be addressed; we currently spend too much time and effort moving risk around rather than getting a job done.

This argument for a broader, more nuanced and holistic approach to deliver better quality housing in Wales can be explored using four common themes - Low Carbon, Resource Efficiency, Health and Wellbeing and Social Value:

Low Carbon

Passivhaus provides a useful target for energy in use, as it requires rigour in design and construction as well as post completion testing. But low carbon should also mean low embodied carbon. It seems perverse to attach great value to estimates of future carbon emissions in use, yet attribute no value to measurable and avoidable emissions today, caused by the types of resources and the way they are deployed. A focus on embodied carbon would be more disruptive to the status quo – but the wins could be substantial.

The use of timber in construction stands to have a profound impact on embodied energy. Increasingly, the carbon sequestering capabilities of products has been considered within planning and delivery. In 2007, the Murray Grove ten story cross-laminated timber apartment building (http://bit.ly/29J2ewX) was the tallest timber structure in the World. A derogation from the Merton Rule (requiring 10% onsite renewables) was allowed due to the quantity of carbon stored in the building. The UEA Enterprise Centre (http://bit.ly/29J33G4) sought to create an embodied carbon negative building by storing more carbon in the construction materials than is required for their extraction, manufacture and transportation and assembly.

The climate change mitigation benefits of sequestering carbon are substantial and measurable. Under IPCC rules they can be accounted for in national carbon inventories. Research in 2005 showed that two thirds of the UK's entire embodied carbon emissions in construction could be off-set by an increase in the use of timber (http://bit.ly/29NJWuv).

The first important step to valuing embodied carbon is relatively simple in policy terms. Developers of all new buildings over a certain size should be required to undertake embodied carbon measurement and enter onto the WRAP (soon to be RICS) embodied carbon database. We are starting to see embodied carbon requirements in local plans in England (e.g. Camden and Islington). A focus on embodied carbon would also favour more local production. In support of the UK steel industry, the Cabinet Office recently issued procurement guidance stating that embodied carbon and social value should be considered (http://bit.ly/29NKPmY)

Resource Efficiency

A focus on resource efficiency requires that we look beyond waste minimisation, and embrace the circular economy. In reality, the vast majority of buildings are temporary. Yet we glue them together without a thought to future adaptation or demolition. We should design for flexibility and adaptability, to avoid redundancy or costly retrofit. We could design so that resources are recoverable and can be re-deployed, rather than written-off on the day they are installed. Benefits include reduced whole life costs, reduced redundancy, reduced whole-life carbon emissions and reduced resource intensity. Employment opportunities would be liberated in product development, deconstruction and product re-use supply chains.

Projects that demonstrate how we could re-conceive buildings as a rolling-stock of reusable parts are emerging. The SEGRO building at 9 Cambridge Avenue (http://bit.ly/29J4Bjh) shows the potential for deconstruction and redeployment. The design brief for the Place / Ladywell social housing project in Lewisham (http://bit.ly/29J4OmR) included the requirement for re-deployment. The Chobham Manor marketing suite on the Olympic Park (http://bit.ly/29J505z) showcased the potential of buildings designed for deconstruction.

The first policy step is relatively simple. Require all new buildings over a certain size to be designed for deconstruction (and for adaptation). A new housing standard could be embedded with these principles.

Health and Well-being

The report *Every Breath We Take* by the Royal College of Physicians (February 2016) links 40,000 deaths each year in the UK to air pollution, with more deaths linked to indoors air pollutants. The report acknowledges a lack of focus on indoor air environment, stating that:

The construction, occupancy, and exposure profiles of newer workplaces will lead to the potential for novel inhaled hazards and risks, and vigilance will be required in order to identify the occupational lung problems attributed to the workplace of tomorrow.

With increasing knowledge about harmful VOCs including formaldehyde, there is a need to demonstrate that the right products can contribute directly to good indoor air quality (IAQ). In the absence of strong policy drivers on IAQ, voluntary standards and procurement tools are beginning to play a helpful role:

Natureplus (www.natureplus.org) is one of Europe's leading construction product eco-labels, and could be a useful tool for the UK market, as is increasingly the case in parts of Continental Europe (particularly Germany and Austria). The label takes an evidenced based and holistic approach and considers product performance and sustainability, as well as impacts on human health. Exacting VOC emission limits are set down in a product standard. The Natureplus product database can be found in the Baubook procurement tool (www.baubook.info), which provides detailed product information. Baubook also provides health-related procurement clauses for tender documents, along with links to products that meet these requirements. Sentinel Haus (www.sentinel-haus.eu) has developed a standard, building on 15 years of research, with some 500 buildings certified to date. They advise clients on procurement strategies and operate a traffic light system to ensure that every product used has evidence of test results, or they insist upon product testing. Buildings are then tested over 28 days and a certificate issued if guidelines are met.

Urgent policy opportunities exist around product testing standards and labelling (now compulsory in some European countries) and post completion monitoring of air quality. Given the known health risks, the lack of monitoring of IAQ in the UK – particularly in public buildings - is scarcely believable, and we should expect to see litigation in the future.

Social Value

Procuring to maximise social value is not a zero sum game. It is true that £1 spent locally is £1 not spent elsewhere and, in that sense, one communities gain is another's loss. However, local procurement can add to the sense of belonging and connection to production and resources, as well as to the emotional and physical well-being of individuals.

We need to develop new policies that truly support our SMEs. Our desire to value fast growth over sustainable growth has been detrimental to SME business development in the UK. It can be argued that the success of the German economy is less embodied in the large multinational companies such as Siemens and Audi, and more in the medium size, often family owned and regionally rooted businesses. Business which are small enough to care about local impact yet large enough to support professional career development.

Political statements about supporting local industry through public procurement are not followed through by civil servants who tend to hide behind European procurement rules. Herein lies a Brexit opportunity.

One clear opportunity for the development of social value is in the forestry sector. Currently 85% of construction timber is imported. There is no shortage of potential demand for homegrown timber. The European average forest cover is 37%, compared to 14% in Wales. In recognition of the environmental, economic and social benefits of woodland expansion the Welsh Government has proposed a target of planting 100,000 hectares of new forest by 2030. The current annual planting rate stands at zero. There is ambition but little strategy.

Most modern high performance offsite housing is based upon timber. As a consequence timber construction is on the rise, and there are some great examples of successful companies rooted in Wales – including Fforest Timber Engineering (www.fforest.co.uk), Williams Homes (www.williams-homes.co.uk) and PYC Construction (http://bit.ly/29JuMXk). Williams Homes are constructing houses for Wales and West Housing using homegrown timber (http://bit.ly/1qGvKew). However, to make this the norm rather than the exception a coherent policy focus is needed. Otherwise the opportunities for increased social value, improving our balance of trade and improving our environment, will continue to be missed.

There are multiple opportunities to encourage more local procurement of timber through policy, and to encourage increased forest planting… by valuing embodied carbon, through local procurement policies, by establishing a national Wood Encouragement Policy, creating a level playing field between state support for agriculture and forestry (another post Brexit opportunity), or creating a more dynamic public forest sector by putting forest management in the hands of regional authorities rather than NRW, or re-structuring forestry to attract more private investment (e.g. pension funds and private management companies).

In summary…

Taken together, the Well-being of Future Generations Act and the Environment Act are very ambitious. They require Welsh Government to be bold in action, and demand a focus upon medium term gain rather than short term expedience. Policies, standards and strategies are needed that reflect this ambition.

There is ample evidence to suggest that we can build healthy, high performance, highly sustainable housing, using home-grown timber drawn from an expanding forest industry, supplied by Welsh companies and conceived in a way that delivers wider social benefits. But all too often, we choose to do otherwise.

4.2 Case study: **Ty Unnos**

Client Blaenau Gwent CBDC

Architect Design Research Unit Wales, Welsh School of Architecture

Location Welsh Future Homes, Ebbw Vale (and other sites)

Background

Wales has 150,000 hectares of coniferous plantations which produce around a million tonnes of softwood per annum. Over 70% of current production is Sitka spruce, a native of North America. It has become the predominant species in Welsh plantations because of its liking for our mild, wet climate and its ability to establish in peaty upland soils. It has lesser structural properties than imported softwoods, and a tendency to twist during drying. As a result, its contribution to the construction industry is limited.

Ty Unnos was developed to provide low-cost, sustainable pre-fabricated housing using local materials from an 'all-Wales' supply chain. It transforms a low-cost, low value local material into an engineered product of high-value to the Welsh Timber Sector. Aims are:

- to add value to Welsh timber to encourage the maintenance and regeneration of indigenous Welsh Forests, expanding local supply chains, utilising locally sourced and readily available resources.

- to develop technology for self- or community-builds that can be adopted by the existing saw mill industry without extensive investment or reskilling

- to establish a simplified, standardised kit of components which can be prefabricated and efficiently assembled on challenging sites using variious grades and species of softwood

- An appropriate, sustainable response to the challenging demand for affordable housing in the diverse landscape and cultural context of Wales

- to embrace the challenge of zero carbon construction through the use of highly sustainable materials and construction methods, and highly efficient thermal properties.

Description

Ty Unnos 'modules' create single storey low cost, low density rural housing. The system was developed through a partnership between industry and the Welsh School of Architecture with the help of a substantial research grant from the Technology Strategy Board in 2010.[11]

Off-the-shelf Sitka spruce is used to create box section beams and columns, which are combined using simple fixings into portal frames. These portal frames are then connected using infill wall, floor and roof panels to create room modules.

The resulting frame is light but very strong and easy to erect on the simplest foundations. Filled with a locally sourced natural insulation such as hemp, sheep's wool or Warmcell insulation, this creates a fully locally sourced component system which combines low-tech manufacturing with fast build times and u-values around 0.15W/m^{2}K. Prototyping has suggested that this approach can be made more efficient through the development of a larger panel module.

[11] The SHSS House – 'Low cost sustainable hosing from Sitka Spruce'

The system was granted an ETAG Certificate (European Trade Technical Approval) for Timber Frame Building Kits. It was tested, developed and refined through a series of real projects which considered parameters such as economic and environmental performance and enabled the system to be certified. Coed Cymru, in partnership with Vintage Joinery, have also developed components such as window / door cassettes.

Pilot project, Welsh Future Homes

Technology Strategy Board (TSB) funding was secured for a two bedroom house through an open design competition conducted by the Welsh Future Homes project partners. The home was designed and built using a local supply chain, and was opened by the Welsh Minister for the Environment in 2010. The project was a partnership between BRE Wales, the Welsh Assembly Government, Blaenau Gwent Council and United Welsh Housing Association.

The system lends itself to a fabric first solution but has the added advantage that this may be achieved by using a Welsh supply chain. At Ebbw Vale the house was designed to simultaneously meet Code 5 and Passivhaus standards.

Heating	MVHR, supplemented with a small back-up gas boiler for underfloor heating on ground floor and four radiators on first floor
Renewables	The client advocate FEES (Fabric Energy Efficiency Standards) without renewables, but other approaches will be considered.
U-value (W/sqm°C)	walls 0.1 roof 0.09 floor 0.07 glazing 1.0
Renewables	MVHR, 4m^2 Solar Hot Water array with air source heat pump
Air tightness	target 1m^3/h.m^2 at 50Pa
	As built 0.3m^3/h.m^2 at 50Pa
Performance (PHPP)	Predicted specific space heating demand 41 kWh/m^{2}annum
	Predicted total primary energy demand 146 kWh/m^{2}annum
From SAP 2005:	DER 3.26 kgCO_2/m^{2}annum
	% improvement of DER over TER (2005) 88%

Post completion analysis

The completed prototypes show that local, under-utilised, low value Sitka spruce can be used in the design of contemporary and sustainable domestic scale architecture in Wales. Through re-engineering the timber provides a real alternative to importing Scandinavian or North American timbers. The frame was erected in two days, and the complete structure with infill panels erected in a week. Prefabrication of roof beams as a 'truss' greatly helped construction. The structure has since proved to be straightforward to disassemble and reassemble in different locations. However, some limitations need to be overcome to reduce cost, improve tolerances and flexibility and refine details. It was built on a raft rather than pad or strip foundations, which worked well, but used excessive amounts of concrete.

Capital costs

As the Welsh Future Homes dwelling was a one off demonstration project, it is difficult to provide a robust cost prediction for delivery of Ty Unnos dwellings at scale. The Ebbw Vale House cost £1500/m2 but this figure should reduce if produced at volume. A self-build application would yield further cost savings through a reduction in labour costs.

Figure 4.2A: First floor plan

Figure 4.2B: Ground floor plan

Figure 4.2C: Principal elevation of the 5P3B house.

The house was designed to simultaneously meet Code 5 and Passivhaus standards.

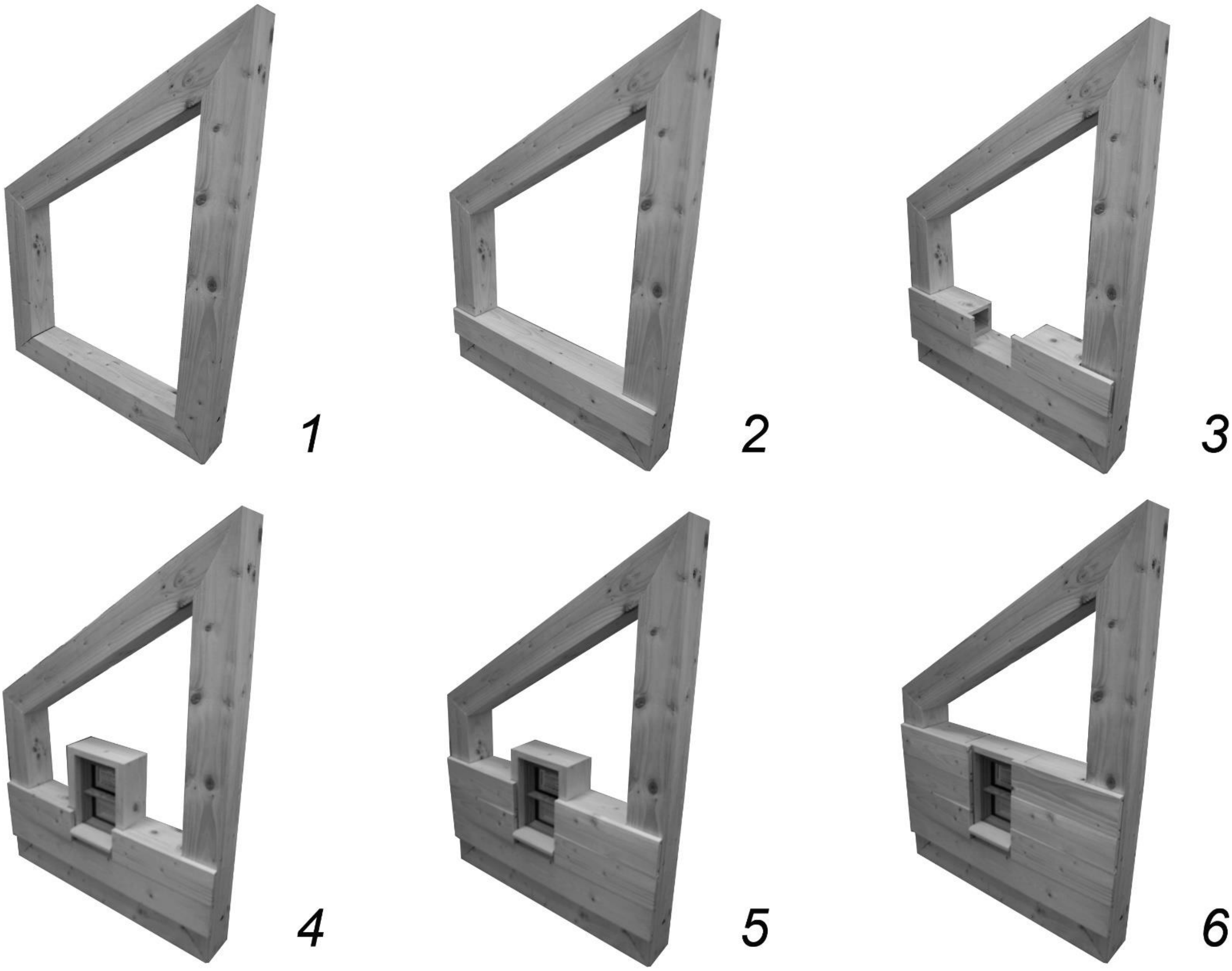


Figure 4.2D: 1. A frame is created from box beams… 2. and is infilled with lightweight, hemp filled box panels…3. which stack within the frame…4. module sized window and door units can be inserted…5+6. infill continues around and above the window.

Figure 4.2E - I: Photographs of the completed dwelling at Ebbw Vale.

APPLICABILITY ASSESSMENT: TY UNNOS SYSTEM

Description

Bespoke construction system focussed on the use of low grade locally available timber and other local, sustainable resources to meet higher performance standards.

.Benefits and limitations

Key benefits

During construction:

- use of local materials, resources and suppliers
- system utilises off site/ near site fabrication, with low skill requirements on site
- benefits to programme thru increased speed of delivery / reduced time on site

In use:

- off-site fabrication delivers improved quality
- delivers high performance with very low running costs
- Natural, breathable, healthy construction

Key limitations

During construction:

- bespoke prototype requires further refinement for mass market
- less suited to dense / urban contexts
- the industry is not yet committed to using locally sourced/low carbon materials

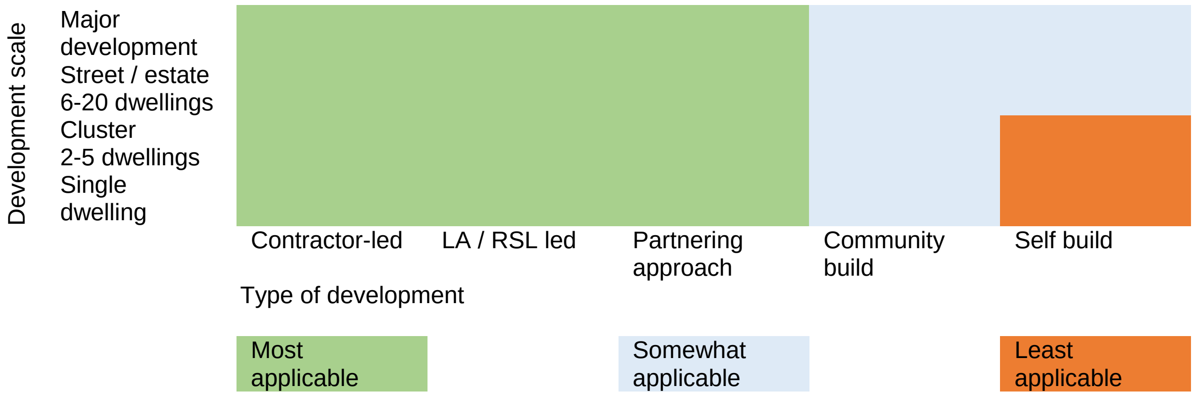
In use:

- requires good user guides to ensure residents understand operation
- different maintenance regimes for conventional social /affordable providers
- 4.8m span limits proportional constraints, influencing aesthetics

Thematic analysis

Space standards	Modular aspect and thick walls limits layouts / use for smaller sites
Flexibility / adapt.	Fabric inherently structural, limiting potential future flexibility
Env. Performance	System ensures consistently high thermal performance / air tightness
Resilience	Includes thermal mass, MVHR provides option for ‘cooling’
Materials	High level of carbon capture in fabric, locally sourced materials
Character	modular aesthetic which can be ‘wrapped’ in other materials
Density	Low / medium density are possible
Ecology	Low impact construction, low embodied energy / carbon
Health	MVHR and natural materials ensure very high internal air quality
Connectivity	self / community build and flying factory options, local resource use

Applicability matrix



5.0 | making places

5.1 | Accommodating growth

Kevin Logan has wide-ranging experience of mixed-use projects, large scale masterplans, and urban regeneration projects and has a particular interest in the dynamics of contemporary urban and rural conditions in cultural, social, political, and economic terms. He works for Maccreanor Lavington, a 60-strong practice based in Rotterdam and London.

Maccreanor Lavington have won 14 architectural competitions, and seven awards for architectural quality. In addition, the work of Maccreanor Lavington in the Netherlands was cited as a case study in the Urban Taskforce's report, and in a recent CABE publication on housing and public space.

Existing settlements have a major role to play in the delivery of new housing in Wales. There is latent capacity within both urban and suburban areas, in the form of brownfield sites, areas of low intensity use and physical infrastructure that is poorly resolved or oversupplied.

Brownfield sites – Previously developed land is a major potential resource. It is typically undeveloped due to unknown below ground conditions or contamination which requires remediation, resulting in additional complexities and cost uncertainty.

Low intensity use sites – Areas that are developed at low density, are mono-functional, or are space hungry present a negative urban condition. However, they have potential to be incorporated into new build schemes, combined with other uses, or otherwise intensified.

Physical infrastructure – Areas of physical infrastructure often blight the adjoining land, and limit potential for residential development. Land hungry infrastructure has potential to be optimised to release developable land, and produce more desirable places.

Accommodating growth within existing settlements offers wider benefits to the surrounding community. Growth within existing settlements not only offers the opportunity to deliver housing, but also to sustain existing social and cultural resources, and contribute economically to the area. Furthermore, growth within existing settlements presents an opportunity to develop wider resources which may be lacking, and to develop additional resources required to create more desirable, sustainable (sustaining) communities.

The carefully considered, co-ordinated and proactive re-shaping and intensification of existing settlements has the potential to offers the following additional advantages:

- Delivery of long term social, physical and economic regeneration, building on local qualities and resources
- The opportunity to reinforce character and distinctiveness
- Physical renewal of existing neighbourhood demonstrating a commitment to urbanity
- Improved vitality through increased population and increased viability for commercial and social resources

- Encouraging more sustainable lifestyles through better access to resources, services and social infrastructure, and supporting community life
- Contributing to sustainable development by reducing dependence on cars.

The delivery of housing in existing **urban** settlements presents specific challenges and raises different issues. Firstly, it will invariably not just concern housing; it will typically involve redevelopment, and potentially re-provision, of non-residential accommodation. In many cases, net gains in housing are a by-product of regeneration of the wider urban area. Secondly, it is more complex. Capturing such opportunities, and ensuring the optimum outcome, can necessitate land assembly and engagement with complex sites, often with sensitive contextual issues. It also involves resolving complex planning requirements, which typically include active frontages, a mix of uses, as well as affordable housing obligations.

The delivery of coordinated, intensified developments requires the creation of overarching spatial strategies. Spatial strategies enshrine a commonly shared vision, are a means to identify and formulate strategic projects, identify goals, establish overarching urban principal, formulate a development trajectory and set out mechanisms for delivery. Strategies should be tactical, informing policy and allowing it to operate as a tool to deliver the coordinated vision. Equally, the spatial strategy operates as a measure of a scheme’s success, and as a means to identify where short-term gains may undermine longer-term opportunities.

Case study 1: **The Electric Quarter, Ponders End, London**

The Electric Quarter, Ponders End is a mixed-use town-centre regeneration masterplanned by Karakusevic Carson Architects and Maccreanor Lavington. Publicly owned assets were used to unlock a greater opportunity and facilitate wider regeneration and intensification.

The masterplan seeks to deliver comprehensive regeneration, which captures the wider opportunities and creates a development which respects and contributes to Ponders End’s character and heritage assets, and social and civic life. It provides a mix of uses, including new housing of varying types, sizes and tenures aligned to local needs, new social and civic infrastructure, small-scale High Street space, live-work units and workspaces.

The 5.2 hectare site is situated in the centre of Ponders End, adjoining the High Street. It was identified in the North East Enfield Area Action Plan as a key development opportunity. The majority of the site was owned by a private developer, and predominantly landlocked, with the council owning a key site adjoining the High Street. The council owned land is occupied by the Ponders Ends Library. Presently the library is set back from the High Street and isolated, hidden behind surface car parking, lacking visual and civic presence.

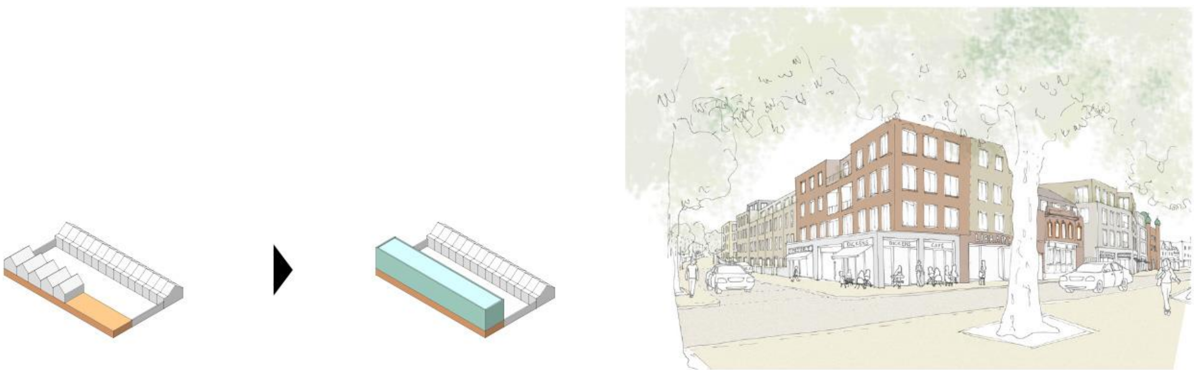


Figure 5.1A: Reprovided retail beneath new residential in a high street location.

The masterplan unlocked a latent opportunity and facilitated the creation of wider, more meaningful regeneration. Central to unlocking the opportunity was the decision to relocate the library to a prominent corner of the high street. The position of the library was considered key to rejuvenating the high street, creating a local landmark, encouraging footfall and informal social engagement. The masterplan further reinforces the nature of the existing high street by creating suitably scaled and aligned buildings which respond to their context, and delivering a fine grain of small-scale retail units aligned to the town centre use patterns.

The strategic repositioning of the library also facilitates utilisation of land in council ownership to unlock the unused centre of the site, increasing the area available for redevelopment, resulting in a net housing gain and a more cohesive urban environment.

In addition to the new high street frontage the masterplan proposes a series of courtyard perimeter blocks which define a series of new pedestrian and bike friendly streets. These blocks integrate with the retained heritage buildings and comprise houses, maisonettes and apartment buildings. The retained heritage buildings are creatively re-used as live work units, workspaces, community uses, combined with housing.

Consideration of the site holistically, combined with strategic use of council land to unlock a landlocked site, improved the overall design quality and contextual response of the scheme.

Case study 2: **Canada Water - Sites C & E**

Maccraenor Lavington worked collaboratively with David Chipperfield, Klaus en Kaan Architects and Vogt landscape to prepare a comprehensive residential-led mixed-use town centre masterplan for these sites.

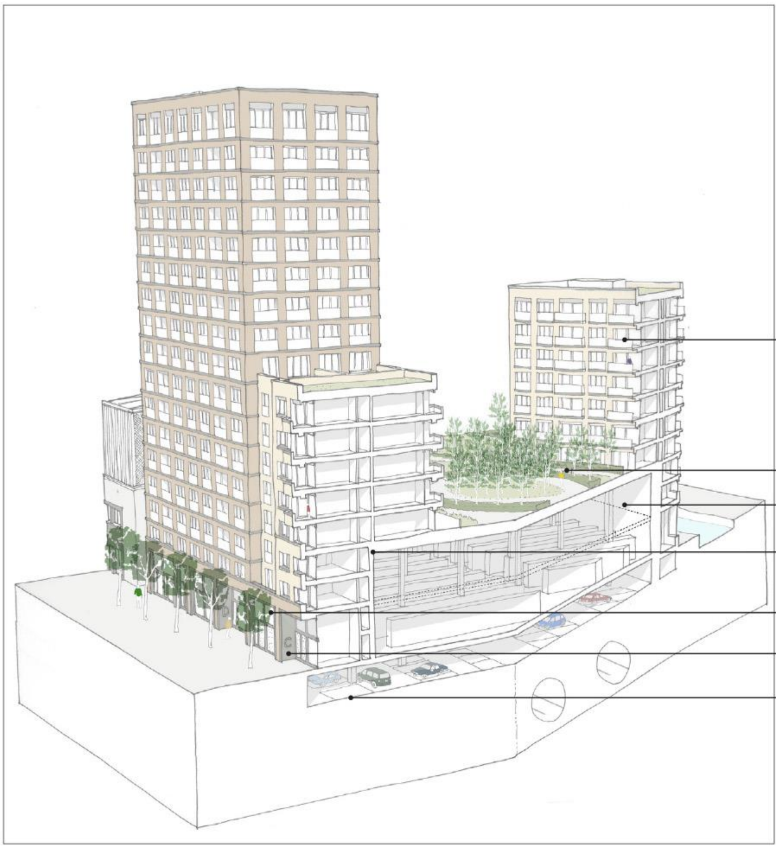
The project is located on two sites in the Canada Water Area Action Plan (AAP), adopted in March 2012, and sit either side of Surrey Quays Road, in the London Borough of Southwark.

Since closure of the docks, Canada Water has lost its sense of identity. The character of the site and the wider town centre is one of a sprawling out-of-town retail environment dominated by surface car parking and large retail stores of low architectural quality.

The sites are currently occupied by large, single storey retail sheds, reinforcing the vehicle-dominated character of the town centre. Various connections through the site are compromised by cluttered public realm and unclear distinctions between public and private space. The mono-functional nature of the current retail use, in combination with limited opening times, leads to the perception that the area is neither safe nor desirable.

Proposals comprise five mixed-use buildings and quality public space, as follows:

- Circa 1,030 new homes;
- a new flagship Decathlon store to replace the existing store;
- high quality retail stores, including a new neighbourhood foodstore;
- waterside restaurants and cafes;
- a new art-house cinema;
- a health centre;
- workspace for start-up companies;
- community sports facilities, including a tennis court;
- a significant new public green space at the heart of the development, and
- improved access to Canada Water and the Albion Channel.



Figures 5.1B and 5.1C: At Canada Water, existing ground floor large-scale retail is rebuilt and wrapped with new residential, with car parking below and housing stacked above.

Project objectives respond directly to Southwark's vision as set out in Canada Water AAP: “We are working with the local community, landowners, and developers to transform Canada Water into a town centre … Our aim is to make best use of the great opportunity to create a new destination around the Canada Water basin which combines shopping, civic and leisure, business and residential uses to create a new heart for Rotherhithe.”

The development will contribute significantly to the realisation of London Borough of Southwark's aspirations for the area. It will transform Canada Water into an active, viable town centre; a new destination for high quality local shopping, eating and leisure activities set in generous public space which engages the unique Canada Water basin water front.

See also William Street Quarter, case study 6.1

5.1 Case study: **PassivHaus, Bristol**

Client Bristol City Council

Architect Emmett Russell Architects

Location Henbury, North Bristol

Background

Henbury is predominately made up of privately owned properties (53%) and Bristol City Council housing (30%). To help diversify tenure in the ward, it would benefit from more shared ownership (currently 1%), as the level of demand for housing in the ward is high (9% of citizens on HCB).

Void turnover is just over average, but housing need in the area outstrips demand. Nearly half of the applicants in the ward need one- or two-bedroom properties. Currently, 19% of the overall stock in the ward is one bedroom accommodation, mostly house-type flats. 57% of the stock is two bedroom flats. A need for three and four bedroom properties exists, but this may achieved through downsizing, as there are a large number of under occupiers in the ward, all of which currently require one bedroom (88%) or two bedroom properties.

Description

The three projects together constitute twenty dwellings, and are being constructed to the rigorous Passivhaus energy efficiency standard, utilising timber frame construction. The three developments are in North Bristol on infill sites previously occupied by garages within blocks of post war council housing. The architect won the three projects in Henbury as a 'lot' through competitive tender. The BCC owned sites available for development are predominantly brownfield and have been split into two tender lots, smaller sites and slightly larger ones. These projects are drawn from the smaller lots, which have a typical development potential between one and fifteen dwellings of varying size per site.

As most of the existing council housing in the area is family housing, these new housing projects will provide twenty smaller units with a mix of one-bedroom flats and two-bedroom bungalows. One of the aims of the projects is to provide housing that will be suitable for existing tenants who want to downsize. It is important that the projects have a simple, deliverable and robust 'fabric-first' approach to reduce energy use and fuel bills, and to ensure that they are both easy to use and to maintain.

Three sites:	Chakeshill Drive	3 no. 2bed 3person bungalows
	Peverell Drive	1 no. 2bed 3person bungalows + 8 no. 1bed 2p.flats
	Satchfield Crescent	8 no. 1bed 2person flats

Environmental approach

In 2015 Bristol was awarded the title of European Green Capital raising both the profile and the ambition of the city's strategies for sustainability. The city aimed to achieve a "Low Carbon City with a high quality of life of all" and it was important that the new council housing produced by the city lived up to these ambitions. After comparing the relative benefits and implications of Passivhaus and Code for Sustainable Homes (CfSH), the decision was taken by BCC to develop a timber frame Passivhaus design strategy for the first 'lot' of social housing, in order to provide an exemplar future proof development that will form part of the European Green Capital legacy. Achieving Passivhaus accreditation also accords with local sustainability policy (BCS14) of reducing building energy demand by passive and energy efficient measures and then applying renewable technology to at least 20% of the residual CO_2 emissions.

The use of Passivhaus certification for these projects provides a means to reduce energy use to clearly defined levels, address issues of fuel poverty, and provide a comfortable internal environment with good air quality. The Passivhaus approach demands an attention to detail above and beyond conventional construction standards so careful coordination is needed at each stage of the design and construction process. Members of the main contractor's team have undertaken Passivhaus training to ensure that awareness of airtightness and detailing issues can be disseminated throughout the construction process.

Construction and materials

Structure	Substructure is generally traditional strip foundations with a raft on one site due to ground conditions. Superstructure is timber frame.
External fabric	Double stud timber frame wall 100/140/100 mm with mineral wool insulation between and over, to achieve very high levels of insulation, and external brickwork skin. 275mm thick EPS to floor and roof. Aluminium clad timber, triple glazed windows and doors.
Heating	Gas fired wet central heating+hot water with communal boilers to flats.
Ventilation	Due to the low air tightness requirements, each dwelling will utilise MVHR to provide continuous ventilation for moisture control.
Renewables	The aim is to employ a fabric first approach but some renewables have been provided (solar thermal and photovoltaic panels) to fulfil Bristol City Council's 20% renewables target at planning.
U-value (W/m^{2}K)	walls 0.11/0.12 roof 0.09/0.1 floor 0.13 glazing 0.85
	(more than 2x better than current building regulations, combined with thermal bridge free construction.)
Air tightness	Target is below 0.6 ach (air changes per hour) at 50Pa
Procurement	traditional, with the client (BCC) acting as Contract Administrator
Current status	All three projects are currently on site, and are due to be completed in early 2017.

Post completion data

Capital costs	tbc
Performance	Total annual primary energy will be limited to 120kWh/m2
	Total annual space heating energy will be limited to 15kWh/m2

	Satchfield	Peverell	Chakeshill
Fabric only improvement on Part L (2014):	23.4%	23.4%	19.3%
Overall Carbon Reduction on Part L (2014):	38.7%	42.2%	69.4%

For thematic analysis of timber frame to Passivhaus std. see case study 3.1, More Homes.

Figure 5.1C: projects are located on tight infill sites, increasing the density of these neighbourhoods.

Figure 5.1D: Low-lying forms sit discretely in backland infill sites, and minimise overlooking.

Figure 5.1E: forms are simple and compact, to maximise performance, with a contemporary aesthetic.

Figure 5.1F: Visualisation of another project, on completion

5.2 | Edge of settlement

Niall Maxwell moved to Wales from London in 2004 to work on the development of Cardigan's historic port on the Teifi river estuary. He established Rural Office for Architecture (ROA) in 2008. A former tutor and lecturer at The Bartlett School of Architecture Niall now tutors at the Welsh School of Architecture in Cardiff, and is an Arts Council Wales External Assessor.

ROA classify themselves as regionalists, working within rural or vernacular settings, responding to the context of each particular site. They were recently selected by the Architecture Foundation as one of the best emerging practices in the UK.

In the wilds of Wales where I live and work, conversations about architecture are few and far between. The built environment plays second fiddle to a dominant agricultural landscape and climate that has defined the development of Wales for the past three centuries. The weather saturates and corrodes, providing luscious pasture and vibrant year round colour to sustain generations of close-knit rural dwellers wedded to the land and its relentless toil.

Wales makes up only 5% of the UK's population and constitutes 8.5% of the UK's land mass, so as a region it is relatively small. Add to this statistics on household incomes, poverty, population densities, agriculture and its economic geography, and you'll better understand the profile for contemporary architecture in this small nation.

Wales is a sparsely populated country with centres historically developed around mining, prospecting or industrial growth, such as wool or steel. This type of growth connected the valleys to the coast, and reflected the importance of global trade to Wales for many centuries. Rural settlements however were established to serve the needs of agriculture, as market places for the many disparate farmers and producers or for those passing through droving their livestock to larger cities in England. It's sometimes hard to connect the brand that is Lloyds Bank to the Carmarthenshire town of Llandovery, but that is where the first 'Black Ox Bank' was established in 1799, to serve the needs of the many drovers using the town as a stopping place on their journeys to and from the cities.

For a small nation the historic architectural language of Wales is therefore quite diverse - from Victorian coastal gentrification to the impact of heavy industry, but with the majority being the vernacular of rural hinterland. The same defining features are shared by most; be it materials and modesty or a direct response to function, climate, topography, and geology.

The rural Welsh vernacular building stock was built and rebuilt over time by the same hands that worked this land; the quality was variable, but they all shared the same defining features, materials and modesty. Buildings were often sited adjacent to a small quarry, watercourse or hollow, sheltered from the prevailing wind. The builders had no design training or concern for fashion, their focus being on function and warmth. They were guided by a series of conventions developed in the locality, handed down from father to son, evolving over time. They were a direct response to climate, topography and geology, with their earth-filled solid stone or slate construction providing a high thermal mass to keep out the cold, with small windows to retain heat, and heavy overhanging pitched roofs to withstand the prevailing wind and rain. Solid walls were often limed to help the walls breath and aid evaporation of moisture, and later coated with roughcast to provide better protection from the weather. But these surfaces required regular maintenance to retain the lime coating, so over time, and with the wider use of cement, contemporary pebbledash finishes provided a more permanent weathering solution. There was no room for ornament or decadence in these buildings, but there was still beauty and pride in their simplicity.

There was no architecture, so to speak. But this rural vernacular is now perceived as having an appealing aesthetic through an appreciation of a time past, and there is still a generation of people alive who grew up in these buildings, who recount the ways of old with nostalgia, but without a desire to return to the harsh realities of childhood. Or maybe this appreciation reflects how the modern vernacular is missing the character of the old, in the same way that the character of communities has changed over the same period.

Ostensibly, the modern Welsh rural vernacular is the homes built for (or by) the masses; concrete block, pebble-dashed bungalows synonymous with Ireland's 'bungalow blitz', also found on the islands and highlands of Scotland. They reflect changing tastes, the changing dynamic of extended families and demographic shifts, as well as changes in construction methods, heating and access to services. Fundamentally, they demonstrate greater mobility; the people who live in these homes do not usually make their living from the land as their forebears did, and migration has brought with it changing tastes and consumer demands.

Figure 5.2A: Niall's 'New Barn' – a single storey office, studio and home in a rural context

Over time, countryside settlements have been transformed from the 'bwythn' to bungalows, to detached suburban homes. As development policy changed, village plots became less generous and the dwellings, as if on steroids, grew to fill these plots. Settlements have struggled to hold on to their character, and journeys through rural parts can often feel like driving through a never-ending roadside ribbon village. The sense of centre or scale within many villages has been lost, reflecting changes in living patterns, employment and mobility.

Many settlements have grown over time to serve the demands of a changing population, but this is not always supported by commercial activity. This form of zombie growth, where existing housing is abandoned due to changes in living standards, land prospecting, or town centre decline has led to a morphing of rural and surburban typologies. Perhaps it's too easy to make such sweeping generalisations, but these issues are evident in many settlements across the country and impact on the character and distinctiveness of regions across Wales.

Growth is usually focused in existing cities and urban centres with adequate infrastructure and logistical support. This is of course obvious when you consider the geographical challenges of linking the nation, or the catastrophic impact of Beeching's rail reforms in the 1960s. By road, moving East to West in the North, mid or South of Wales is fine, but movement from North to South prevents a logistical flow between service centres or an ability to redistribute growth.

With space to expand and plenty of demand to service this expansion, these centres adopt a generic form of growth, whereby volume housebuilders and commercial developers deliver their 'one style fits all' development, away from the constraints of historic context or vernacular typologies. Planning policy tries in vain to address these concerns, which in turn leads to a superficial application of traditional material and form, and the deterioration of design standards and clarity of architectural language.

The Welsh built environment is rich and varied in places, but the value of our contemporary output is low. Furthermore, beyond the odd signature project, the architectural profession' output is limited. As a profession, we are not reaching the communities we need to serve.

Perhaps the next step is to bring the quality of the occasional 'one-off' into the mainstream, to educate homeowners, developers and authorities as to the benefits of quality design. But this isn't straightforward and requires will on the part of government and the industry to change both policy and practice, and to invest in good design. It requires incentives, not just at the large scale but also for occupier developers, for cooperatives and social enterprises who are stifled by policy, land availability, financing, and a lack of collective opportunities.

Perhaps a radical rethink of the tax incentives for land use and new-build or existing redevelopment would force the market to reconsider the value of existing settlements, and encourage communities to exert more influence over their environments… I could go on, but the more you propose, the more counter arguments present themselves; surely the conundrum of policy making and governance.

But who am I to judge the quality of the rural built environment? It is easy to criticise, but much harder to provide an alternative; buildings are only part of the solution. The longer I live and work in rural South West Wales, it becomes more evident that the strength of community remains, often flourishing, and decrying that contemporary development is out of kilter with the desires of the nation. Be it through lack of choice, poorly written design guides, or prevailing tastes, the profession's outlook may be at odds with society at large.

In many ways our response has been to provide an alternative to the everyday, to reinterpret our sense of place as an observer in this beautiful country. We may be working on a small scale, but we wish to contribute to a Welsh built environment that reflects the way we live now, not a nostalgia for a time long past or a generic typology. Over the past few years we have built locally in a way that test ideas and challenge perceptions of modern architecture. Our design service is not just for the well-healed; there is no reason why standard building materials and simple construction cannot be rethought, or combined with modern technologies, to create well designed buildings that are affordable to the mainstream. Thinking modern can still embrace the old, by retaining the essence of the history of an area through its culture, by speaking the same language but with a different outlook.

Figure 5.2B: the New Barn is borne of standard building materials and simple construction

By opening our eyes to the agricultural legacy inhabiting our settlements and surrounding landscape, we recognize their importance. Rather than focusing on a few quaint or refined dwellings, we celebrate the distinct character of individual structures or farmsteads: for example, the odd scale and proportion of a peculiar extension, or their ingenious if not adhoc, method of construction. This palette informs our approach to design.

These responses are not restricted to the exterior. Family life has changed beyond recognition, and our designs need to reflect these changes in interior character, layout and function. Our battle lies with explaining this to the authorities that determine development and, by default, judge (or prejudge) taste and quality.

Working in this way, we enable a new generation of buildings to converse with the old, while responding to contemporary society's needs, and offer an alternative for consideration. It's not possible to do this on our own, but if the conversation is offered a dialogue can begin.

Wales is in a position to evolve its own architectural identity. This is something that doesn't happen overnight, but we remain positive in our belief that there is a growing awareness of the value of good architecture.

5.2 Case study: **Barnhaus**

Client Valleys to Coast HA

Architect Pentan Architects

Location Plas Morlais, Bridgend

Background

The Barnhaus system was predicated on the basis that contemporary house-building practice produces homes that are too small, inflexible, lacking in character, energy hungry and, above all, unaffordable. In the summer of 2013, Grand Designs and the National Self Build Association (NASBA) ran a competition to design an affordable family home, to be built using 'alternative' methods. Pentan Architects took this opportunity to address these concerns by developing the Barnhaus concept, which went on to win the national competition.

Description

The Barnhaus system draws from agricultural construction for inspiration. It relies on a simple portal frame structure to generate the space for a new home, manufactured to a high level of accuracy by a specialist fabricator, and then delivered to site and erected in a single day. This frame is then clad in a highly performing thermal wrap, which can also be fabricated off site or built using local materials, depending on local resources, skills and performance requirements. The envelope can be erected on site in a single week, delivering much higher standards of construction (in terms of both thermal performance and air tightness) than are typically achieved with conventional 'bricks and mortar'.

Simplicity of construction is a central theme of the design. A deep external envelope supports the use of straw bales, an affordable insulation that locks carbon in to the build, delivering carbon negative construction, and maximising the benefit of the fabric first approach. The majority of the frame is wrapped in a simple, consistent envelope with as few penetrations as possible, and requires no specialist skills or wet trades. As a result, consistently higher quality of workmanship and higher performance standards are easier to achieve, enabling performance on site to mirror design intent, and reducing programme time. Straightforward detailing means that this element of the build can be delivered by a contractor, but is also well suited to self-build and community-build projects.

The system is inherently extendable; another portal frame adds a further 3metres of 'space' onto an existing structure. The agricultural origins of the system mean that it is more suited to smaller or more low-lying dwellings, and to rural and edge-of-settlement contexts.

The primary aims are:

- Healthy (permeable) buildings at an affordable cost
- High environmental performance that maximises comfort and minimises energy use and fuel costs / heating bills for end users
- Use of locally available resources where available, and minimum cement
- Off-site fabrication to deliver high quality frame under controlled conditions
- Frame facilitates structure-free interior and maximises flexibility / adaptability
- Carbon negative (due to high levels of carbon sequestration in timber / straw)

A pilot project has been commissioned by Valleys 2 Coast Housing Association. The client has agreed to use the pilot to test the system's ability to deliver homes that meet, and hopefully exceed, public aspirations for modern housing. Perhaps most importantly, this approach has the potential to offer a significantly more affordable way to empower communities to be involved in the delivery of housing that meets their needs, satisfies emerging nearly zero-energy standards, and delivers carbon negative construction.

Construction and materials

Structure	Steel portal frame fabricated off-site by a specialist fabricator.
External fabric (Larsen Truss)	Fibre cement profiled sheeting hung via timber rails to portal frame. Breather membrane fixed back to portal frame, and larsen Trusses at 600mm centres, all sheathed with 9mm OSB board. Void filled with 440mm of blown cellulose insulation, faced with plasterboard and skim finish. U-value of 0.08 W/sqm°C
External fabric (Straw bale)	Fibre cement profiled sheeting hung via timber rails to portal frame. Breather membrane fixed back to portal frame. Straw bale insulation between portals, sheathed with 9mm OSB board. Plasterboard and skim finish to interior. U-value of 0.08 W/sqm°C
Heating	Underfloor heating supplied by gas powered solar hot water.
Renewables	Solar hot water panels, 4kW photovoltaic array
U-value (W/sqm°C)	walls 0.08/0.13 roof 0.12 floor 0.10 glazing 1.00
Airtightness	target 2.0m^3/(h.m^2) at 50 pa.
Performance target	FEEs of 56 kWh/m^2.yr, an improvement of 11% over TFEEs.
	DER of -1.51 kWh/m^2.yr, an improvement of 108% over TER (Building Regulations Part L (Wales)2015)
Carbon	SAP predicts the project to be carbon negative
Procurement	An extensive and in-depth tender process (2013-2015) led to the appointment of Wates Living Space and their design team for the HPP
Capital costs	£1350/sqm (at tender) excluding site, consultant fees and abnormals
Costs in use	predicted energy bills of £411/year, predicted PV yield of £540/year for a *net energy gain of £129/year*

Current status

The system remains at a prototyping stage.

The four dwelling social housing pilot project for Valleys 2 Coast HA has planning approval, and tenders have been returned. The site is in Plas Morlais in the county of Bridgend, and is previously undeveloped / hard standing due to significant existing site-related abnormals. The intention is to develop four DQR compliant dwellings using two different constructional approaches and insulants - blown cellulose and straw bale - to facilitate a comparison / exploration of the best approach for future projects.. At 88sqm, the dwellings are 5% larger than WG notional standards, to maximise flexibility, accessibility and adaptability.

Figure 5.2A (above left): Four stages of construction

Figure 5.2B (above right): DQR compliant three bedroom dwelling layout

Figure 5.2C: Streetview of the proposed Plas Morlais pilot project

Figure 5.2D: cut away section illustrates benefits of frame and connection with outdoors.

Figure 5.2E: agricultural roots make the dwellings more suited to rural / edge of settlement locations.

APPLICABILITY ASSESSMENT: STEEL PORTAL FRAME, TIMBER/BALE INFILL

Description

Simple agricultural-style steel portal frame supporting deep timber skin, with straw bale infill.

Benefits and limitations

Key benefits

During construction:

- Approach delivers healthy (permeable) buildings at an affordable cost
- Steel frame maximises speed and minimises impact of adverse weather etc
- Approach uses locally available resources and minimises cement use

In use:

- Frame fabricated off site by others, all other trades are low skill / accessible
- Frame facilitates structure-free interior and maximises flexibility / adaptability
- Carbon negative (due to high levels of carbon sequestration in timber / straw)

Key limitations

During construction:

- Frame / thick wall construction reduce applicability on the smallest infill sites
- Frame necessitates careful party wall detailing – fire, acoustics, etc
- Construction relies on availability of straw (currently abundant but seasonal)

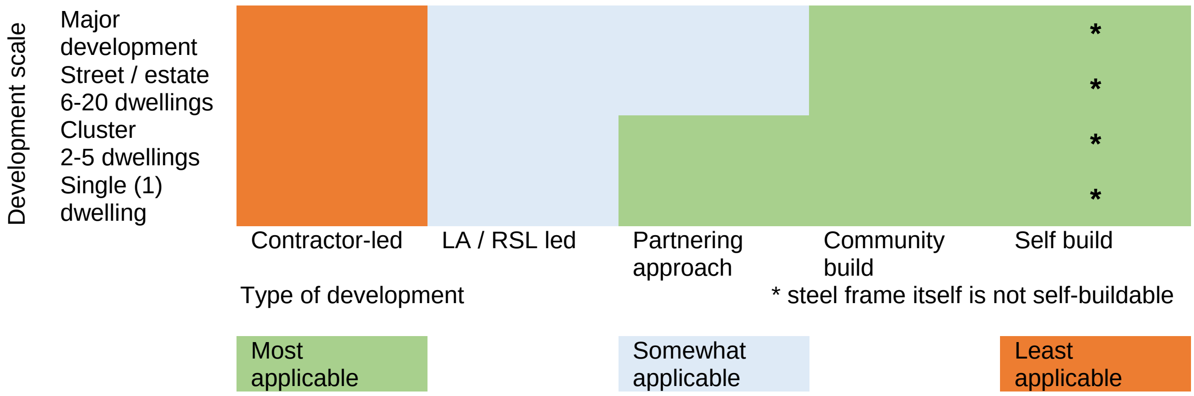
In use:

- Steel frame has high levels of embodied energy
- Frame means that the build cannot be 100% completed by self- or community build teams without specialist input – although all follow-on work can be.

Cross-standard analysis

Space standards	Thick external wall and frame module limit applicability for tighter sites
Flexibility / adapt.	Frame ensures open plan flexibility and adaptability.
Env. Performance	Approach promotes high thermal performance / air tightness
Resilience	Some thermal mass, MVHR provides option for ‘cooling’
Materials	Significant carbon storage in building fabric, embodied energy in steel
Character	Frame can be ‘wrapped’ in any materials, promotes simple forms
Density	Low / medium density are possible
Ecology	Low impact construction
Health	Breathable construction and MVHR
Connectivity	Construction facilitates community involvement / local resource use

Applicability matrix



BARNHAUS VARIANT: a locally grown, all timber alternative

During detailed design development of the Barnhaus project, it was identified that the steel frame limits potential application for true self build projects. Steel, while highly recyclable, is also energy intensive in fabrication.

To address these limitations, the designers developed an alternative approach intended specifically for self-builders, learning from the Segal Method. The steel frame is eliminated, and in its place the use of widely available timber is maximised. Timber portal frames are assembled from locally produced, untreated, off-the-shelf, small section timber components.

Background – the Segal Method

In the 1970s, architect Walter Segal devised a repetitive modular ‘system’ for building houses with timber, which came to be known as the Segal method. It was conceived to be constructed with a minimum of building experience and without employing ‘wet trades’.

Segal’s method was a rationalisation of traditional timber frame, and he made no claim to copyright. His approach, a premonition of open source design, used standard ‘off the shelf’ timber sections and boards to promote buildability without specialist skills and flexibility in design, empowering individuals and households to make their own homes.

Although only a few hundred Segal homes were built, the system and its ethos has many advocates. Modern interpretations include the WikiHouse and projects by Turner Prize-nominated design collective Assemble. In the context of today’s housing crisis and the limitations of volume housebuilding, Segal’s principle concerns - ease of construction, promotion of self-build, and flexibility in design - appear more relevant now than ever.

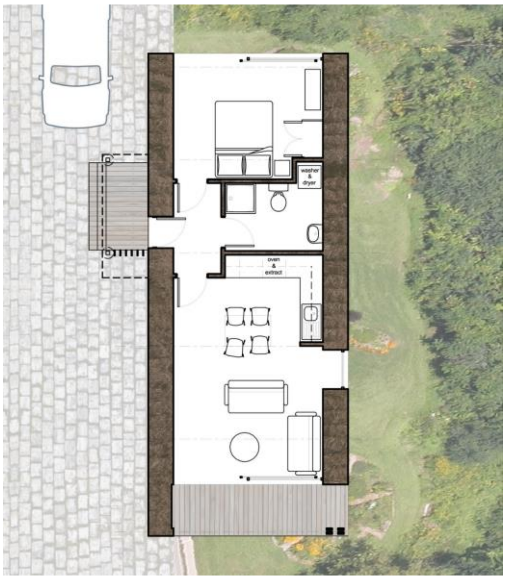
Description

Triangulated portal frame forms are by their nature simple to fabricate, which suits first-time constructors and self-builders who are working on site, without access to extensive workshops, enabling them to achieve quality without controlled working conditions.

A pilot project, two bays of a ‘house’, was built by students on site at CAT (the Centre for Alternative Technology), then dismantled and rebuilt as a demonstration project at the Glastonbury Festival in July 2016. The first full all-timber, single storey dwelling is now under development.

Construction and materials

Structure	Interlinked timber portal frames, fabricated on site from small section off-the-shelf timber, much of which can be untreated / locally sourced.			
External fabric	inside: plywood lining, service void, vapour check, straw bale insulation, permeable outer sheathing, battens, rainscreen cladding.			
Heating	For the size of dwellings to which the system is suited and the levels of insulation, heating system is expected to be a point heat source such as a wood burning stove with back boiler, feeding towel rails to bathrooms.			
U-value (W/sqm°C)	walls 0.14	roof 0.15	floor 0.15	glazing tbc
Procurement	The system is designed specifically for self-build projects			
Capital costs	Envelope-only costs (excluding all labour) from approx. £460/m^2.			



Figures 5.2F-H (above): the approach lends itself to simple forms and modest dwellings.

Figure 5.2I-J: Under construction at CAT and onsite in the Green Futures Field, Glastonbury festival.

6.0 | building alternatives

6.1 | Commercial alternatives

Mike Fleming is Director of Glosford SIPS, a Hereford-based company offering a complete service for construction using a structural timber building envelope, for both the self-build and contractor-led sectors.

Established in 2009, the company has developed a reputation for the supply of high quality, sustainable timber building solutions.

They now have one of the largest facilities in the UK, a strong commitment to the environment and an experienced management team with a pedigree in efficient manufacturing practices.

Glosford SIPS was born of the recession. In 2009, I found myself out of work (having been a Director of a national company specialising in the manufacture and distribution of building components to the largest volume house-builders. Looking for a new challenge at a more local scale, I established Glosford SIPS with a colleague. Our shared aspiration was to deliver a ‘niche’ housing product, using emerging SIPs technology, with a focus on environmental performance and better quality homes.

We now employ thirty staff in our Gloucester factory, and produce around sixty homes per year, with an annual turnover of £6M and a focus on “sustainable timber engineered products”. We are one of the larger UK SIPs manufacturers, and are unusual in that we have all the skills necessary in house to deliver a fully designed and certified SIP shell. This affords us the flexibility we need to deliver bespoke projects to individual clients, within a framework that offers a high level of environmental performance and consistent quality on site.

Despite a total absence of advertising, publicity, or marketing budget, Glosford SIPS has shown consistent growth since 2009, and today boasts a healthy order book and a busy factory floor. We attribute this success to a specialist, but growing, market; the construction of new homes for clients who know what they want, and are not satisfied by traditional house-building practice. Recently, our workload has expanded from one-off ‘self-build’ housing, to include schools and commercial projects, as well as a broader range of housing projects that include neighbourhoods of 50-100 units, and one project that promises to be significantly bigger again. While repeat business in the private one-off housing sector is unusual, we find consultants and particularly contractors returning to Glosford SIPS time and time again, because of the control that our approach provides over the manufacture and assembly process, due to the mitigation of risk, and the accelerated build programme.

What are SIPs?

SIPs (Structural Insulated Panel systems) are a Modern Method of Construction (MMC). Products are manufactured off-site to tight tolerances directly from the designer’s CAD drawings. The manufacturing system uses software that produces CNC processing data for all components, from soleplates at the base of walls to the fillets in roof valleys and gutters.

We focus on the use of Kingspan TEK, a nationally available SIP panel system. Panels of either 142mm or 172mm thickness are connected with a unique jointing system to form walls and roofs, and floors are constructed using open web joists, which suit the use of MHVR. The panel itself is a sandwich of insulation (core) and timber board outer layers. The core comprises CFC/HCFC free rigid thermoset urethane insulant, manufactured with a blowing agent that has zero Ozone Depletion Potential (ODP). The external layers are 15mm Oriented Strand Board (OSB), structurally bonded to the polyurethane.

Figure 6.1A: A SIP roof panel being installed.

Key benefits to end users:

Predictability – accurate programming and QA enable the project team to work smarter.

Minimum defects – because our panels fit precisely, staircases, doors and windows go into position with little, if any, remedial work to deliver a better quality, crack-free finish.

A solid feel – SIP panels are rigid and dense, unlike the skeleton of a timber frame house.

Less heating needed – many SIP homeowners install modern ventilation and heating systems, like Mechanical Ventilation and Heat Recovery systems (MVHR), which reuse warm air, and can make a traditional central heating system a thing of the past.

Flexibility – SIPs are used not just for new homes, but also extensions and renovations. They cope with most design needs and can be finished externally as required.

Environmental benefits:

Continuous Insulation – 96% of wall area and 99% of the roof is covered with insulation in a SIP home (compared with 88% in conventional timber frame).

Long life thermal performance – the dense rigid urethane insulation core won't sag or deteriorate over time, and can't be poorly fitted like insulation quilt, so there are no gaps through which warm air can escape.

Limited Cold Bridging – continuity of insulation provides enhanced thermal consistency compared with more traditional construction, with only 4% thermal bridging from timber elements in a typical wall and 1% through the roof.

Air tightness – SIP is ideal for the construction of an air-tight building envelope. The proprietary TEK system ensures an effective air seal. Blower door tests give results of 0.08 air changes per hour at normal air pressures or 0.91m3/hr/m2 air changes at 50Pa.

Thermal Bypass – whereby heat escapes through gaps in the thermal envelope, is a common issue in other forms of construction due to the way that insulation is manually fitted. Insulation cut by CNC to near perfect tolerances ensures continuity of the thermal fabric.

Sustainable construction – TEK panels use wood fibre that would otherwise go to waste, and use about 30% less timber than typical timber frame construction.

Less waste – panels are precision cut off-site, which means that little waste is generated.

Benefits to developers:

Speed of build –installation team are typically on-site less than two weeks for a 4 bed house.

Predictable – SIPs offer a precise building method with a precise completion date so that follow-on trades, suppliers and installers can be organised with confidence

Smoother project management – elimination of slow, messy, 'wet trades' means that sites stay cleaner and are easier to manage, helping with on-site Health and Safety obligations.

Less to organise – panels come from one source, simplifying project management.

Improved financing – purchase of a single SIPs 'package' means that costs are predictable.

Fewer on-site problems – precision cutting of panels ensures 'minimum defect building'.

Limitations:

The key stumbling blocks we encounter are around lack of knowledge and understanding when it comes to the integration of other traditional trades / constructors. Typically, groundworkers do not build to SIP tolerances – TEK relies on +/- 5mm. However, this is an example of poor quality workmanship rather than a negative to SIPs.

Another key aspect of SIPS is that the key benefits outlined above are rarely factored in at pricing / tender stage, so the SIP product is competing with the raw material costs of traditional products which are inherently cheaper.

Potential for adaption could be a key if the homeowner loses the detailed drawings which show where structural supports are etc. Generally though this has not been an issue and most extensions adaptions could be undertaken once surveyed professionally.

Capacity is the biggest limiting factor in the delivery of new homes using SIPs. The sector is new, and there are no seriously large producers. However this could change fairly quickly if demand rose significantly.

Can 'niche' construction deliver at scale?

We are currently considering expansion of the business. However, to expand considerably will test the capacity of our current operation, extending risk, and raises the question of how far an 'alternative' approach can be taken…

During the 1980's and 1990's, many medium-sized housebuilding contractors and family businesses were acquired by the largest volume house-builders, in a coordinated drive to control the market and establish regional centres for their national operations. To streamline and to maximise economies of scale, all aspects of these operations have been standardised, ranging from site selection and house design through to constructional methodology and the use of nationally standardised components.

The longer term consequence is that housing tends to be delivered at one of two very distinct scales – either piecemeal at a local level by small scale contractors, or to predominantly generic designs using standardised products and delivery mechanisms by the dominant national organisations. These large organisations are selective in their choice of projects; high overheads and on-costs mean that viability only works above a certain scale of development, and in geographic locations where land values will support profit margins.

Such large organisations have high levels of inertia, relying considerably on established practice, on their supply chain network, and on a clearly defined management and procurement structure. Within this framework, Glosford SIPS have found it difficult to instigate change.

The implementation of BIM has, to an extent, compounded this problem. While the use of BIM software facilitates highly accurate scheduling, comprehensive automated take-offs and theoretically makes the substitution of parametric elements and other design changes more straightforward, the amount of time and investment taken to develop 'model' house types and in-house components often means that developers are reluctant to revisit the design process significantly beyond master-planning. More comprehensive changes to their construction ethos, such as would be necessitated by a switch to SIP-based construction, would require a considerable commitment to change on their behalf.

Figure 6.1B: SIP-built Hillside farmhouse in South Farnham

SIP has the potential to be delivered at scale and at speed… indeed, many benefits would come from increased levels of production. The product itself is already manufactured and supplied centrally within the UK (TEK is manufactured in Leeds by national supply chain Kingspan, and there are four of five broadly comparable SIP sandwich products on the market). However, it is the route of this 'product' to market that presents much bigger challenges in terms of scaling up SIPs for housing. While it is entirely feasible for the larger national SIP suppliers to produce increasingly large quantities of SIP panels, the greater challenge is faced by the housebuilders and contractors, who must adapt to large scale offsite solutions. Specific challenges are posed by changes to current working practices and subcontractor arrangements, changes to procurement practice, and implications for project programmes that much quicker offsite construction would inevitably create.

6.1 Case study: **William Street Quarter**

Client	London Borough of Barking and Dagenham
Architect	Allford Hall Monaghan Morris and Maccreanor Lavington Architects
Location	Linton Road, Barking, IG11 8HG

Background

William Street Quarter is the first totally privately financed council housing scheme in the UK. The Local Authority-led housing project offers affordable homes (80% market rate) to people who can't afford to get on the housing ladder, on the basis of five year tenancies, without grant funding or cross-subsidy from market housing. The masterplan transformed a site previously occupied by the 1960s Lintons Estate in Barking, east London, with improved housing, new community space and a Business Centre designed to support startups.

The Lintons Estate was a great project of its time but had fallen into disrepair. The estate was constructed in 1962. Over the years the condition of the estate deteriorated and some of its design elements proved to be impractical and unpopular. In 2008, 40% of the Council's homes failed the government's Decent Home standard. The Council redeveloped the estate to address the government target of ensuring all housing meets the standard by 2010.

The two phase development replacing it comprises more than two hundred homes across a range of types. Three mews streets of three and four-bedroom family-sized brick terraced houses line and define the perimeter of the site, while a central 10-storey tower containing 76 one-bedroom apartments terminates a mansion block lined boulevard. Two six-storey mansion blocks, which face each other across a pedestrianised boulevard, provide 39 and 45 three and two-bedroom duplex apartments respectively. The ground floor flats at the rear of the mansion blocks have small gardens, which open out onto larger courtyards.

A high quality urban landscape has been created to maximise opportunities for community interaction and informal play. This has been achieved by the creation of generous and high quality outdoor amenity spaces – private gardens, balconies and terraces, communal courtyards, play-able routes and further local planted green spaces.

Description

The simple and clear block structure – which relates well to the town centre and the scale of the surrounding residential areas – reinterprets the traditional structure of terraced houses and creates proper street frontages. The layout enables a high level of passive surveillance, ensuring security for all residents. Individuality has been achieved by the use of colour and alternative finishes to the mews houses and mansion blocks, with varying colours to entrances and balconies providing an enhanced sense of place for tenants.

The mews houses have been designed to tie seamlessly into the greater masterplan, forming a defined neighbourhood. The pitched roofs of the two-storey houses balance the taller three-storey houses on the opposite side of the mews. Although the accommodation and layouts vary slightly, many of the features remain common.

The modest budget was focused on the simple application of high-quality materials and an internal generosity of scale not often experienced in local authority buildings. All houses and garden walls are built of the same high quality variegated brick – chosen for its robustness, quality and appropriateness for residential use. Parapets, deep reveals and large timber-framed windows reinforce a sense of solidity and permanence.

Individuality has been achieved by the use of colour and alternative finishes to the mews houses and mansion blocks. The entrances are recessed into the façade, providing shelter and privacy, and are lined with muted colour variations to enhance sense of place. Generous kitchen corner windows wrap around the recess to allow for overlooking the front door.

Security, safety and amenity are carefully balanced. Vehicle traffic was minimised through the site, with a series of shared surface zones encouraging pedestrian movement and allowing for cycle, play and home zones with reduced traffic ingress. All houses have enclosed private gardens, while the mews environment opens up the street for social use to maximise community interaction and informal play. Further high-quality outdoor amenity spaces are provided in the form of balconies and terraces, communal courtyards and planted green zones.

The completion of William Street Quarter has provided a catalyst for wider regeneration in the area. The scheme helps to re-stitch the existing urban grain and provide a safe, contextual living space where a mixture of tenures can live happily alongside one another.

Construction and materials

Structure	SIP construction generally (142mm Kingspan TEK) with localised steelwork. The offsite manufactured roof structure joists were assembled on the ground and lifted into place, receiving their final finish of fibre cement slates on site.			
External fabric	SIP panels, overclad in 20mm of internal high performance rigid insulation, a breather membrane and a single layer of traditional Barnsteen London weathered yellow brick.			
Windows / doors	Large double glazed timber windows and doors by Nordan, tilt and turn to the upper levels and fixed to the ground floor, provide maximum size, usability and thermal performance.			
Heating	Gas central heating			
Renewables	MVHR, with connection planned to Thames Gateway district heating			
U-value (W/sqm°C)	walls 0.15	roof 0.13	floor 0.13	glazing 1.2
Air tightness	target <10 m3/h.m2		as built: 3 m3/h.m2	
Standards	Lifecycle costs, London Housing Design Guide requirements and the Lifetime Home standard were all taken into consideration. All units are built to the Code for Sustainable Homes level 4.			
Procurement	Phase I:	JCT Design & Build (Nov 2008 to March 2011), £4.5M		
	Phase II:	PPP / PFI (May 2011 to June 2014), £35M		

Post completion analysis

Fabric Energy Efficiency: improvement of 23% over Building Regulations Part L 2010 target

CO_2 Emissions: 33% reduction over part L 2010. A future connection to the London Thames Gateway district heating network will increase it to 48%.

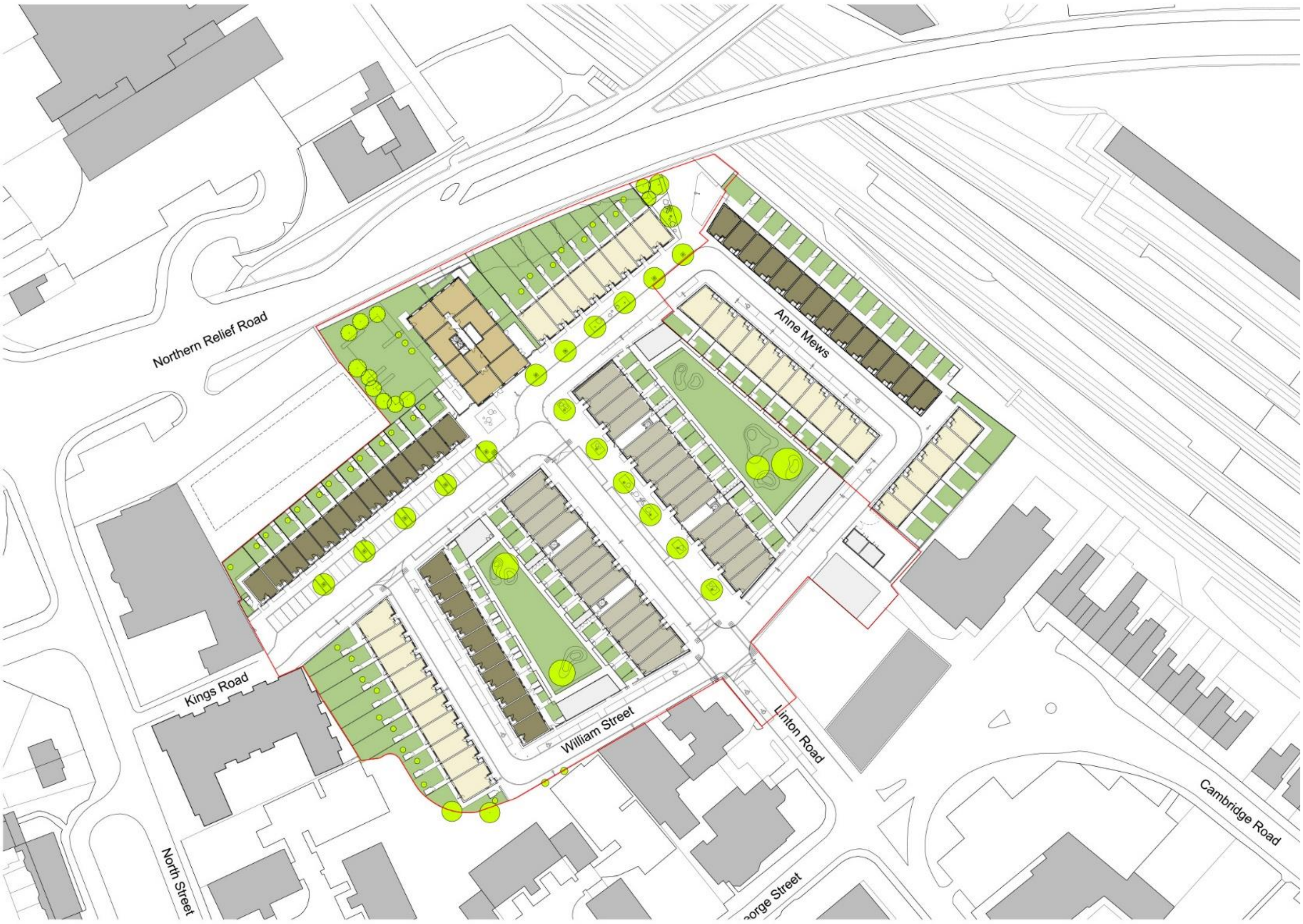


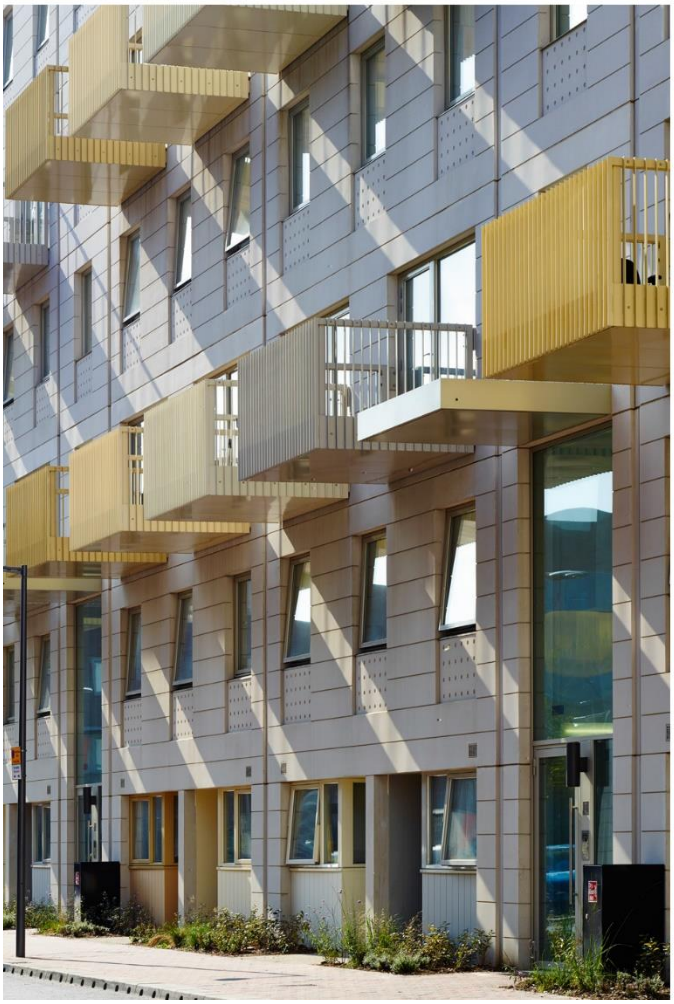
Figure 6.1C: masterplan

Figure 6.1D: Two and three storey dwelling types

KEY

- Three-storey 4 bed houses
- Two-storey three bed houses
- Mansion blocks - two and three bed masionettes
- Tower with one bed units
- Energy Centre, bin and bike stores






Clockwise from top left: Figure 6.1E: mews streets provide three- and four-bed family-sized brick terraced houses.

Figure 6.1F: a central 10-storey tower contains 76 one-bed apartments.

Figure 6.1G: streets are open for social use, creating a safer, more attractive neighbourhood.

Figure 6.1H: Two six-storey mansion blocks provide two- and three-bedroom duplex apartments.

APPLICABILITY ASSESSMENT: SIP CONSTRUCTION

Description Mass-produced market leading composite SIP (structural insulated panel) system, based in the UK

Benefits and limitations

Key benefits

During construction:
- Offsite / dry fabrication reduce time on site and dependence on site factors
- Construction is inherently more airtight – more affordable to reach higher stds
- Dry construction minimises cement use from ground level up.

In use:
- 'Shell-only' package is ideal for custom-build and partial self-build projects
- Provides a consistently high level of thermal performance, easy to upgrade
- Longer term, could be adapted to use locally available resources

Key limitations

During construction:
- Walls require continuous sole plate and larger openings necessitate steelwork
- Implementation at scale would require industry-wide re-skilling / training
- Insulants are petrochemical products with high levels of embodied energy

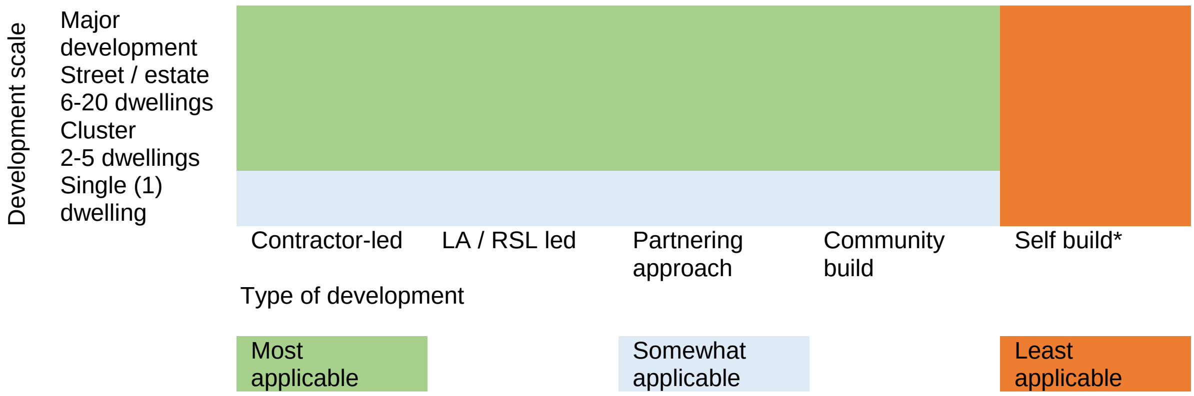
In use:
- Resulting building fabric is non-permeable and low thermal mass
- Specialist construction reduces ease of adaptation
- Requirement for approved installers limits applicability for self-build

Cross-standard analysis

Space standards	Slim construction maximises potential of smallest / infill sites
Flexibility / adapt.	Can produce large flexible spaces, but limits ease of future adaptation
Env. Performance	System ensures consistently high thermal performance / air tightness
Resilience	No thermal mass (unless provided in floor slab), MVHR cooling option
Materials	Typically glues in engineered timber, petrochemical-based insulants
Character	Flexible aesthetic – some benefits are lost when 'wrapped' in masonry
Density	Low / medium / high density are all possible
Ecology	Low to medium impact construction
Health	Airtight construction and MVHR control indoor air quality
Connectivity	Currently only a few national providers. Scope for local production.

Applicability matrix

* while SIP does not lend itself to true self build, it is ideally placed for hybrid self-build / starter homes requiring a 'shell'



6.2 | Modular construction

James Picard co-founded Cartwright Pickard with Peter Cartwright in 1997. He was the only practicing architect on the main board of Constructing Excellence between 2005-2006. He has carried out government funded research work into the design of low energy buildings, and is a visiting professor to the University of Glasgow School of Art and Architecture.

James is a steering board member of the Urban Land Institute's 'Build to Rent' best practice guide for the private rental sector. The guide seeks to be as essential to the PRS sector as the BCO Guide to Specification is to the office sector.

Modular construction (MC) involves the manufacture of highly finished building elements under factory conditions, that are transported to site and assembled to form buildings. MC is suited to buildings with cellular plan forms, and is widely used for student accommodation, hotels, schools, health care and temporary buildings. More recently MC has been used for residential developments for both sale and affordable rent. There are around a dozen significant modular manufacturers in the UK that are able to produce high-quality residential buildings, but not all of them are able to build multi story. Some manufacturers have successfully completed schemes up to 25 storeys.

Why modular?

Modular manufacturing techniques using factory controlled conditions and a skilled workforce, which generally enables higher quality construction than traditional building methods. Traditional building sites often lack sufficient quality control, which leads to the ubiquitous defects and long snagging list that creates hassle for their clients. Contractors and subcontractors working on traditional building sites tend to employ a more transient workforce who often have to work in difficult, wet, windy, muddy and sometimes dangerous conditions. The Health and Safety Executive's own statistics show that there are eight times more serious injuries and deaths on British building sites than there are in British factories.

In the winter months, traditional building sites often provide inadequate task lighting, which results in poor quality of workmanship and dangerous working environments. It is commonly observed that the traditional construction industry fails to deliver on quality. The UK construction industry is focused on completing on time whatever the impact on quality. The industry has a serious shortage of skilled labour. We have completed numerous modular residential projects with a broad range of manufacturers, and a common theme is greater emphasis on quality and predictability in the performance and quality of the product.

The manufacturing industry takes far greater pride in the product and has a vested interest in improving process to achieve better value and quality. Modular manufacturers in the UK compare well with others elsewhere in the world, and often build one or two demonstration apartments so that all design details can be rigorously reviewed prior to manufacturing the entire scheme. Modules can be fully inspected in advance so that the electrics and plumbing are all tested prior to leaving the factory. This enables modular buildings to be handed over with zero defects, which is almost unheard of in traditional construction.

Another key advantage with modular manufacturing is the speed with which the accommodation can be manufactured and delivered to site. The key benefit here is that time spent on site can be reduced significantly. In fact, most of our completed modular housing projects have reduced traditional site time by up to 50%. The speed has commercial benefits in terms of return on capital and bringing forward revenue stream. Volume house builders see little benefit in speed of delivery as they are set up to drip feed the market and build to their sales rate, which has the effect of sustaining high levels of house price inflation. Hotel companies, student accommodation providers and PRS landlords are more interested in speed to market, and have a greater interest in whole life costs, and therefore the higher quality control achieved using modular construction comes into its own.

Additional benefits of MC are reduced environmental impact caused during construction. Significantly shortening time on site is one impact, but there is also a significant reduction in construction traffic which has an additional benefit of reducing congestion to local roads, minimising the impact on neighbours. In terms of corporate social responsibility, modular construction can deliver residential accommodation with significantly lower levels of embodied carbon and significantly lower levels of waste.

Modular construction is not a panacea for all building types, but provided there is a high degree of repetition, either vertically or horizontally, and a large number of standardised units to be manufactured, MC can be a very efficient way of delivering new homes.

Figure 6.2A: Calshot Street mixed tenure housing project

(image copyright Cartwright Pickard)

Fundamental to the success of any modular housing project is the selection of the right manufacturer. It would be an advantage to have at least two or three manufacturers on a framework agreement. The framework agreement secures a commitment from the manufacturers to supply to the developer, and equally important is a commitment from the developer to place a minimum quantity of orders with each manufacturer. Manufacturers crave a continuous predictable flow of work. Less predictable large orders at short notice are less attractive. In the current London and south east construction market, inflation is achieving record levels due to shortages of skilled labour and availability of materials and products. Modular construction methods where manufacturing is done outside London and the south east of England should result in lower construction costs, or at least better value for money and better quality of product with lower whole life costs.

Constraints / limitations

Module size is one of the key constraints using MC. Most manufacturers work to maximum widths, lengths and heights. 4m is a typical module width, however some modular manufactures will go as wide as 5.7m as a non-police escorted load.

Module Lengths are typically up to 12m with a limitation generally being the length of suitable trucks. Floor-to-ceiling heights of 2.5m are easy to achieve and in some cases manufacturers have been able to achieve 3.8m floor-to-ceiling heights for luxury apartments. Low bed transport vehicles are required for taller modules.

The only restrictions on module size are the transportable dimensions. 4.5m wide and 13m in length are the largest full module external dimensions that can be easily transported. However wider modules can be transported with extra precautions. Larger rooms can be formed by joining two open sided modules.

One criticism of MC is that it is less flexible and adaptable to changes in the future and possible changes in use. However, it is possible to build into modular building the opportunity to carry out future modifications such as removing internal walls to make a two-bedroom flat into a one-bedroom flat with large living space.

Another criticism of modular buildings is that they lack design flair. On highly repetitive projects, it is not difficult to find examples where design is sadly lacking. However, there are also examples of award-winning buildings such as Murray Grove key worker apartments for the Peabody Trust (see case study), which won every design award it was submitted for, including an RIBA award. Modular construction methods can create buildings of lasting architectural merit if the right architect is appointed and the client is committed to quality.

Figure 6.2B: Bourbon Lane affordable housing, 2007 (image copyright Morley von Sternberg

Control of waste

Approximately 24% of all UK waste comes from the construction industry. Studies carried out by the BRE have shown excessive amounts of waste occur on traditional building sites. Modular manufactures minimise waste during the manufacturing process, through high levels of standardisation of components and repetition in a similar way to car manufacturers.

Traditional contractors of today don't make anything. They manage a process that brings together specialist subcontractors and suppliers. Main contractors have deskilled as organisations and are therefore no longer best placed to manage quality. Lessons learned are soon forgotten, and there is rarely continuous improvement that benefits the client.

Programme benefits

The on-site programme for modular projects can be reduced by up to 50%. The combination of speed and quality reduces the cost of site preliminaries significantly. Most cost consultants ignore the savings produced by a shortened construction time. There are also financial benefits to an earlier rental stream. We have experience of projects whereby the programme length from initial sketch proposals to handover had a duration of 14 months. A number of these projects were handed over with zero defects.

Traditional construction methods are plagued by poor workmanship that results in high maintenance costs for the user. Volume house builders sell homes quickly and have little interest in the long term costs and energy consumption of the homes they sell. PRS landlords have far more interest in ensuring whole life costs are kept to minimum and the energy consumption is kept low. In our experience modular apartments can be significantly more durable than that traditionally built counterparts. This is because any building manufactured under factory conditions should stand the test of time for a longer period.

Conclusion

Modular manufacturing has gained significant traction over the past 15 years as a viable alternative to traditional forms of construction. Advancements in computer aided design and manufacturing techniques have streamlined the process of designing for manufacture. The UK tops the global rankings for being one of the most expensive countries in the world to build, in particular in London and the South East of England. The quality and productivity gains made by using manufacturing methods will over the next 10 years produce a significant increase in the use of offsite manufacturing for housing provision in the UK. To help with this process, government, local authorities and housing associations can use their influence and buying power to encourage the UK’s construction industry to raise its game and make the necessary investment in technology and manufacturing capabilities.

6.2A Case study: **Murray Grove**

Client	Peabody Trust
Architect	Cartwright Pickard
Location	Murray Grove, Hackney, London

Background

Cartwright Picard's first built project, Murray Grove in Hackney, demonstrated that modular construction can halve time on site and really can improve standards, with quality of design. Transferring highly skilled construction tasks to a controlled factory environment raised build quality, and reduced both programme timescale and risks inherent in site work.

Description

Thirty spacious rental dwellings were created for key workers in Hackney, north east London. Living spaces look south-east and south-west into a secure, communal landscaped courtyard. All flats have dedicated south-facing exterior private space. The flats are well-insulated and economical to heat, with residents spending as little as £250 a year on fuel. To provide long-term adaptability, removable sections of walls were designed in, to enable a one bedroom apartment to be turned into a large studio, or a two bedroom apartment to be turned into a one bedroom apartment with a larger living room.

This housing project was completed in 1999, and was the first to use innovative steel framed modular construction to improve quality of affordable homes to rent, and radically reduce time on site. The high quality steel framed modules were manufactured and fully fitted out by Yorkon in a British factory. The project was handed over with zero defects, and was on site for just six months, half the predicted programme time for traditional construction methods.

Murray Grove was constructed without any scaffolding and with no wet trades on site. Balconies, cladding, external walkways, lift-shaft, staircases, and roofing elements were all fully prefabricated, enabling the project to be completed from start to finish within 6 months. Modular construction enabled most of the construction activities to take place in a factory and therefore reduced waste and minimised health and safety risks.

Construction and materials

Structure	Steel framed volumetric modular construction
External fabric	Terracotta tiles to the street facades and western red cedar to the courtyard facades
Windows / doors	Aluminium/timber composite
Heating	Electric
U-value	Approx. 0.2 W/sqm°C to all elements of building fabric
Procurement	Negotiated Design & Build
Capital costs	Approx. £1000/m^2 excluding land or consultant fees. The BRE estimated costs to be approximately 5% higher than for a more traditional form of construction.

Post completion

In 1999, Murray Grove was a radical step change in the design and production of affordable housing. The site is adjacent to a conservation area which required careful negotiation with planners and conservation officers, and a high quality design. The evidence we have about the success of the project is based on feedback from Peabody and residents themselves.

When Building magazine revisited the scheme after five years of occupation, they found it to be exceeding all expectations of both client and end-users. The building manager reported "In this financial year, with two months still to run, the total repairs and maintenance cost, along with redecorating and replacing white goods… is £7,000"; just 20% of the typical maintenance bill for a scheme of this size. (Source: Building Cost Information Service)

One criticism of modular buildings is that they lack design fair. Modular buildings are used for student accommodation, prisons, and hotels, and it is not difficult to find examples where design is lacking. However Murray Grove went on to win every design award it was submitted for, including a National RIBA award. Modular construction can create buildings of lasting architectural merit if the right architect is appointed and the client is committed to design quality. Peabody have confirmed that the development continues to be very popular and has a very low tenant churn rate. In Building magazine's revisit to the scheme in 2006, a resident was quoted as saying "let's face it they could charge the earth for these flats".

Lessons learnt from this project have informed many other modular / offsite construction schemes designed by Cartwright Pickard, including the following:

Sixth Avenue in York, completed 2 years after Murray Grove, consisted of 24 modular keyworker apartments for Yorkshire Housing. The key innovation that added most value and reduced overall development costs was the successful use of modular construction. It halved the overall project development programme, from initial appointment to hand-over, from 28 months to 14 months, saving the client 14 months of loan interest and enabling the client to start to receive rental income many months earlier than expected.

The dramatic reduction in programme time was achieved through an open book partnering arrangement between the architect, the manufacturer Yorkon (who also acted as main contractor) and the client Yorkshire Housing. The entire project was also handed over with zero defects. Allowing for inflation of construction costs, the Sixth Avenue apartments were built for 20% lower costs than Murray Grove in real terms.

Bourbon Lane for Octavia was won in a design competition run by Cabe to develop best practice in affordable, inner city family housing. It has gathered many accolades and awards from the RIBA, Civic Trust and Housing Design awards amongst others.

The scheme occupies a site between a retail development to the north and a conservation area to the south, and comprised 27 houses and 51 flats and maisonettes for rent or shared ownership. Cost and value were critical to project viability. Despite designing on a very constrained site, planning permission was obtained for a scheme which created a 70% increase in density of dwellings compared with the original competition brief.

During a value engineering process, whole life cycle costing was taken into consideration. The innovative design required no scaffolding, saving £350k. This money was then reinvested into the provision of CHP plant with a 15-year payback, meaning that the residents' electricity, heating and domestic hot water costs them about 25% less as a result. After 15 years, the CHP plant will generate that will be used to carry out ongoing maintenance of the public realm areas and the homes.

Figure 6.2C and D: 30 keyworker apartments in the London Borough of Hackney - total construction cost £2 million

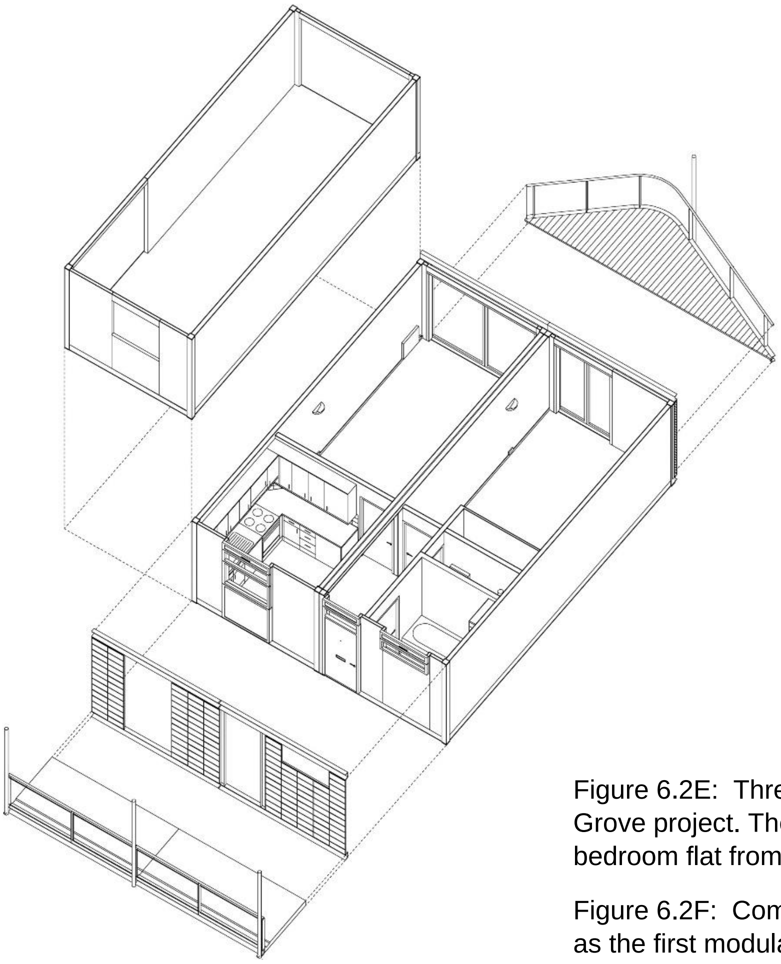


Figure 6.2E: Three standardised modules were used for the Murray Grove project. The addition of a bedroom module would create a two bedroom flat from a one bedroom flat.

Figure 6.2F: Completed November 1999,Murray Grove is regarded as the first modular apartment building of its kind in the UK.

APPLICABILITY ASSESSMENT: VOLUMETRIC CONSTRUCTION

Description Bespoke steel frame volumetric building modules, fabricated and fully fitted out off-site by a market leading manufacturer.

Benefits and limitations

Key benefits

During construction:
- Offsite fabrication reduces time on site and vulnerability to site factors
- Better working conditions in factory, and higher standards more affordable
- Dry construction minimises cement use from ground level up

In use:
- High quality of workmanship (and few defects) due to off-site fabrication
- Consistently high level of thermal performance
- Low levels of maintenance / repair

Key limitations

During construction:
- Large modules are not suited to small / awkward sites
- Implementation at scale would require industry-wide re-skilling / training
- Party wall, acoustic and fire-related issues require careful resolution

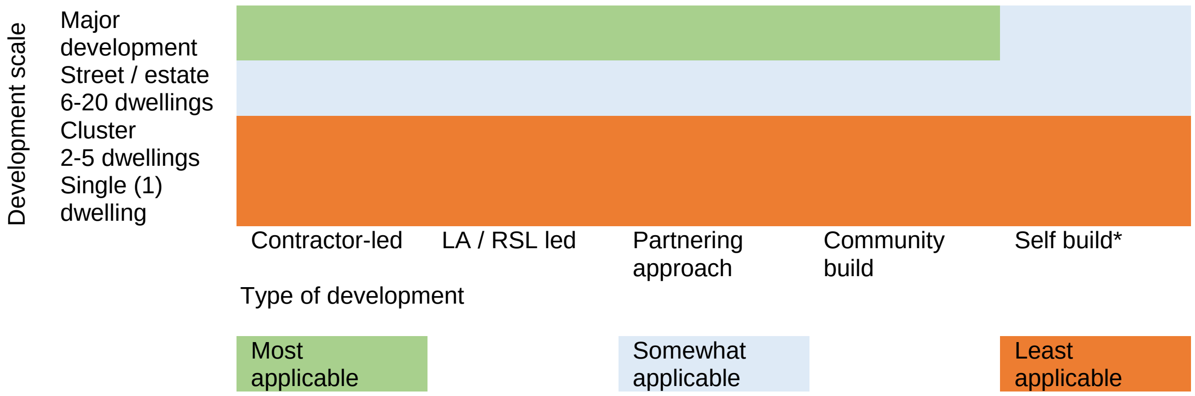
In use:
- Requires meaningful numbers to be cost effective
- building fabric is typically non-permeable with low thermal mass
- Specialist construction, if employed, can limit future adaptability

Cross-standard analysis

Space standards	Modules limit room layout options. Not suited to small / infill sites
Flexibility / adapt.	Can produce larger spaces, but reduced scope for future adaptation
Env. Performance	System ensures consistently high thermal performance / air tightness
Resilience	No thermal mass, unless provided in floor slab, MVHR cooling option
Materials	Low cement/carbon, (frame may have high embodied energy)
Character	somewhat flexible aesthetic, but driven by modules
Density	Low / medium / high density are all possible
Ecology	Low impact construction, low carbon, low waste
Health	Airtight construction and MVHR control indoor air quality
Connectivity	Limited number of national providers, but scope for local production

Applicability matrix

* while volumetric approach does not lend itself to true self build, it has potential for hybrid self-build / starter homes requiring a 'shell'



6.2B case study: **CLT volumetric housing**

Developer Legal and General Homes

Architect various

Location Sherburn Enterprise Park, nr Leeds

Background

In 2016, Legal & General Capital announced the launch of a modular housing business, Legal & General Homes, which seeks to modernise the house-building industry by providing precision engineered houses, manufactured using cross-laminated timber (CLT) from a factory in the North of England. In January 2017, the first prototype housing was produced in the 550,000 sq ft warehouse in Sherburn. Located fifteen miles east of Leeds, it is the largest modular housing factory in the world, and the only one intending to produce volumetric housing using CLT at scale. The first finished homes are anticipated to come off the production line later in 2017.

Description

"CLT is an engineered timber product with good structural properties and low environmental impact (where sustainably sourced timber is used). It can provide dry, fast onsite construction, with good potential for airtightness and a robust wall and floor structure suitable for most finishes internally and externally. It requires only limited new site skills, and its low weight means that a high degree of offsite manufacture is possible." (BRE, IP 17/11)

CLT is formed in a similar fashion to glulam, but the timber components are pressed and permanently adhered into panels rather than beams, resulting in considerable structural strength across two dimensions, rather than one. These thin panels can then be used to make the floor, walls and roof of dwelling-sized 'boxes'. While CLT can in theory be produced in any size (so long as the press is big enough), a key constraint to overall size of each module is transportability. Modules up to 3.5m wide can be transported without an escort. Beyond 3.5m wide, they require a private escort. Beyond 5m wide, police escorts are required throughout the journey, and costs become prohibitive. This 5m wide constraint provides a dimension for a one module dwelling, or for a dwelling to be made by pairing modules, and / or stacking them.

For L+G Homes, internal walls as well as external walls are made of CLT. This means that fabrication of all elements of the building fabric can be automated using CNC routers. It also means that all elements have a solid, robust feel to them. While most of the modules are rectangular, there is also scope for the fabrication of storey-and-a-half / inhabited roof space units, allowing for greater flexibility in design. CLT construction has been built to nine storeys in the UK (Murray Grove, Hackney) and has potential to go significantly higher.

The focus of L+G Homes has been on affordability and speed of construction. Modules are assembled in twelve work stages, with each stage completed over a single 12hour period. With 100 work stations in the factory, it is anticipated that the current facility could produce up to 4000homes per year. Wiring routes are pre-routed, and along with push-fit electrical fittings virtually eliminate the need for skilled specialists. Most factory employees are trained as generalists, and are able to complete all tasks on most of the twelve work stages. Modules are produced almost entirely finished in the factory, with only making good of junctions to be completed on site.

Environmental approach

Very high tolerances mean that openings for doors, windows and services can be machined to the nearest millimetre. As a result, it is anticipated that an airtightness lower than 1 m3/h.m2 (at 50Pa) will be achieved as standard. These construction tolerances, combined with high levels of insulation and MVHR, dramatically reduce heating loads and result in savings in the heating system itself. The volumetric CLT approach is intended to provide a robust, reliable means of delivering mass produced dwellings with very low fuel bills as affordably as possible.

The CLT panels are currently only manufactured overseas (Austria, Germany, Switzerland). However, L+G Homes intend to begin manufacture of CLT panels on or near site this year. At present, timber would have to come from overseas, but improvements in the moisture content of UK timber would mean that local timber resources could be utilised.

CLT offcuts are not wasted. Cuts from new panels can be broken down and recombined to make non-structural CTL. Cuts from non-structural CLT and sawdust are to be fed to a biomass boiler, dramatically reducing waste production.

Current status Four prototype modules were completed in the factory using European CLT in January 2017. The intention is to commence work on live projects later in the year. For broad market appeal, L+G Homes have focused on producing prototypes that replicate ‘typical’ market and social housing. However, through characteristics including its facility for wide spans and exposed materials, there are also opportunities to deliver housing that is overtly ‘new’ in its nature.

L+G Homes anticipate developing an extensive catalog of patterns or templates, with a “pick, fit and click” customer methodology.

Construction and materials

Structure	CLT panels provide a flexible, monolithic structural envelope.
External fabric	80mm thick CLT generally to walls and roof (floor typically 140mm thick, to suit span), insulation, breather membrane and exterior cladding. Internally, CLT can be lined or left exposed.
Heating	CLT construction is particularly suited to underfloor heating, with facility to apply a semi-wet screed directly to the CLT structural floor.
Renewables	any possible, depending on performance targets and site constraints.
U-value (W/sqm°C)	walls 0.13 roof 0.13 floor 0.13 glazing 1.24
Air tightness	anticipated <1 m3/h.m2 (at 50Pa)
Performance	not yet modelled or measured.
Procurement	L+G Homes have private developers already engaged in their prototyping process, and developing planning-ready schemes for trial. The long term success of this venture depends upon the widespread acceptance of alternative approaches, and sufficient appetite from the market to keep the factory busy. These are both necessary steps if we are to meet current and future housing need, and also deliver on the many additional potential benefits identified within this report.

APPLICABILITY ASSESSMENT: CLT VOLUMETRIC

Description

Off-site fabrication of volumetric construction at scale, using CLT (cross laminated timber) panels for floor, roof and walls (external and internal).

.Benefits and limitations

Key benefits

During construction:

- Off site fabrication proposes to reduce build programme by 50%
- System delivers healthy (permeable) buildings at an affordable cost
- Almost all aspects of construction are de-skilled

In use:

- Off-site fabrication delivers quality, to very high tolerances
- Inherently airtight fabric provides a predictable route to very low fuel bills
- Construction ensures solidity (no studwork) and ease of adaptation

Key limitations

During construction:

- Volumetric form reduces applicability in character-sensitive contexts
- Currently CLT material is only manufactured overseas
- Requires good level of coordination pre-site for factory fabrication

In use:

- Limited thermal mass (although better than timber frame)
- Factory fabrication means that it is not suited for traditional self-build or for hands-on community build projects

Thematic analysis

Space standards	No implications
Flexibility / adapt.	System is inherently adaptable, with limited need for internal structure
Env. Performance	tolerance ensures air tightness, materials limit cold bridges
Resilience	Limited thermal mass, MVHR provides an option for ‘cooling’
Materials	non-UK timber at this time, but quantity ensures good carbon capture
Character	Form is limited by volumetrics, but can be clad in any materials
Density	Low / medium / high density are all possible
Ecology	Low impact, minimum site disruption, potential for carbon negative
Health	CLT is vapour permeable and can produce breathing construction
Connectivity	As a low skill technique, CLT ‘shell’ could facilitate user engagement

Applicability matrix

Development scale

Major development
Street / estate 6-20 dwellings
Cluster 2-5 dwellings
Single dwelling

* while volumetric CLT does not lend itself to true self build, it is well placed for custom build

Contractor-led | LA / RSL led | Partnering approach | Community build | Self build*

Type of development

Most applicable | Somewhat applicable | Least applicable

6.3 | Open source and DDM

Alex Whitcroft is a designer and architect. His work focuses on environmentally and socio-economically sustainable design. This includes innovative technologies, community empowerment and ownership, and product and material lifecycles.

Alex works on Passivhaus projects as an associate director at bere:architects alongside acting as designer-developer for sustainable housing projects with KIN Architects, and has been developing digitally fabricatable building systems at the WikiHouse Foundation. He is a certified Passivhaus Designer, member of LBC UK Collaborative, RSA Fellow, and advises on the collaborative economy.

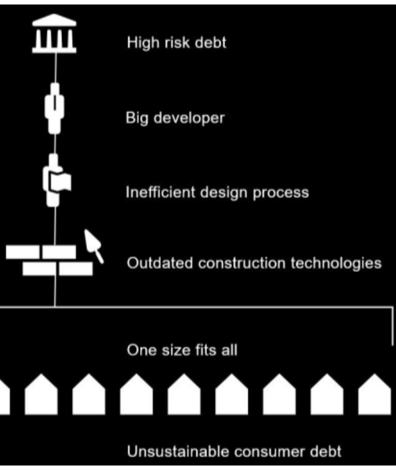
Over the last couple of decades, the internet has radically changed how we create and access information (e.g. Wikipedia, YouTube), and more recently a similar change in how we interact with infrastructure (e.g. AirBnB, Uber). Over the coming decades, this shift will affect how we create physical things - how we commission them, design them, interact with regulations, manufacturer them, deliver them, use them, and decommission them. From consumer electronics to furniture. From vehicles to buildings. Even our cities.

This 'Third Industrial Revolution' is poised to radically change the construction industry. But what will a construction industry for the 21C look like? One built for digital fabrication (eg: CNC cutting and 3D printing); open source; data driven generative parametrics; distributed manufacture; and user-led on-demand manufacturing? How does it help new and existing businesses? What might the benefits to government be?

The Third Industrial Revolution

Over last few centuries we have seen a steady shift in manufacturing from many relatively small, distributed points of production to more centralised production. By the late 20th century, the competitive advantages leveraged by a few large companies led to this model becoming an overwhelming norm. Today in the UK, most housing is built by a handful of very large developers. Most building materials come from just a few huge multinationals.

Figure 6.3A: The current centralised model in housing production. Source: WikiHouse Foundation



We are now seeing the emergence of a new model. This new change in industrial paradigm is called the 'Third Industrial Revolution' (TIR). We can see it as characterised by a series of sequential shifts:

- Affordable digital manufacturing - The emergence of more affordable ('lower order') digital manufacturing technologies.
- Distribution of manufacturing - This results in more and smaller distributed points of manufacturing and putting precision manufacturing into the hands of small businesses and individuals. It also makes designs, once recorded digitally, much more reliably transportable globally as digital fabrication machines will reliably produce the same components - be they in Romania, Canada, or the Philippines.
- Prosumers - This diffusion of manufacturing capability in turn results in a blurring of the distinction between the established roles of 'producers' and 'consumers'.
- Open IP - With less centralisation, IP is generated and held in an increasingly large number of places. The benefits of pooling resources and sharing IP mean the next shift is one towards open IP ('Commons'). This is made far easier by existing open licenses like Creative Commons.
- Collaborative tools - Improvements in collaborative tools (many running online) make it much easier for teams made up of multiple companies to work effectively and to share learning with other teams.
- Parametrics - Alongside the above, maturation of parametrics software tools and the explosion in available, machine readable data (eg from Internet of Things (IOT) devices) enables process to be automated and design choices to be driven directly from data.

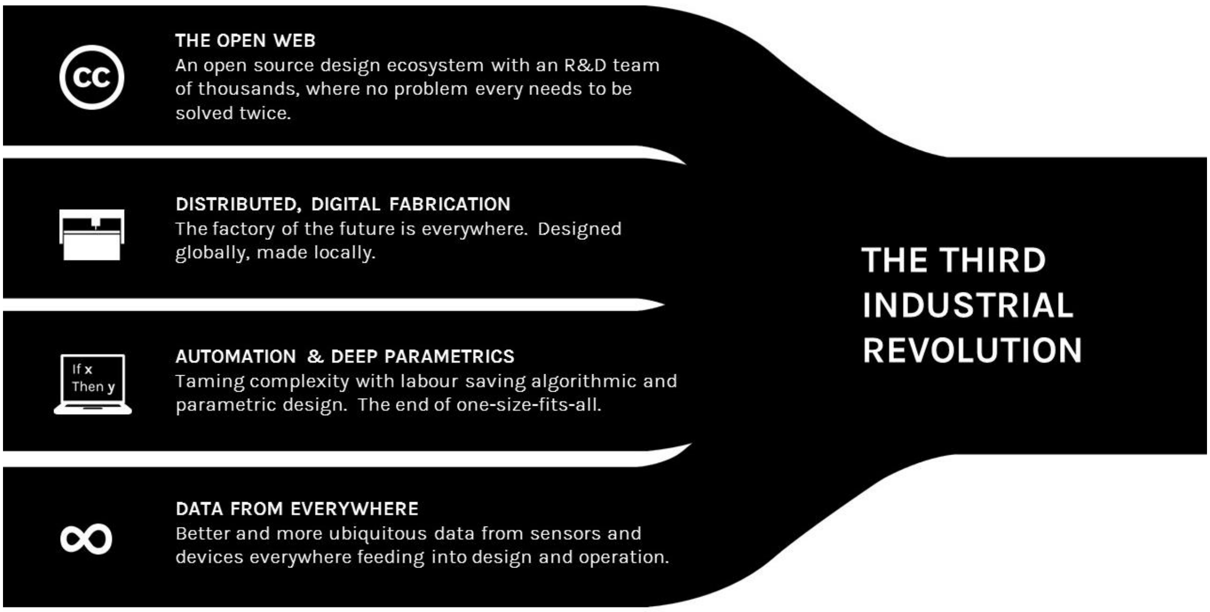


Figure 6.3B: The drivers of the Third Industrial Revolution. Source: WikiHouse Foundation.

Distributed, digital manufacturing (DDM)

'Digital fabrication' is an umbrella term. It refers to manufacturing technologies that are controlled by computer with little or no direct handling input from people once the machine has been told what to do (eg: 3D printing, CNC routing, laser sintering). The designer/maker builds an accurate 3D digital model of the object to be manufactured. The 3D model is then sent to a fabrication machine which cuts, routes, burns, prints, bends, or grows the actual object.

The use of digital fabrication technologies has been growing in many industries for years. In the construction industry product manufacturers have been using digital fabrication for a while. However production is almost exclusively through expensive, centralised factories. And then, on site, buildings are largely put together manually, reading off of printed drawings - completely non-digital.

A key driver for change is increasingly cost effective / 'low order', digital manufacturing technologies. Where previously a prefabrication facility needed a large factory with a high setup cost, one can now be set up locally for a few thousand pounds. This enables a shift from centralised to distributed digital manufacturing (DDM). DDM has a number of advantages, including more ability to scale incrementally and resilience to low demand periods (by producing other products for a while).

Figure 6.3C: Digital fabrication facilities can be located anywhere. Here one is located in a shipping container on the construction, site to reduce costs. Source: Facit Homes.

At present very low order tools are limited to CNC routers and small 3D plastic printers. However there are a number of projects around the world advancing high-end new technologies including 3D printing very large components and even whole buildings in concrete and other materials. These include D-Shape, a team at Loughborough University, and Win Sun in China. These will, over time, make it to market and then become affordable, broadening the range of viable DDM technologies.

Parametrics, workflows, and data driven design

Parametric software makes it possible to design products based on given inputs. We are able to use a simple few parameters to adjust predefined geometries but we are also able use deep parametrics to generate the geometries of whole structures from scratch. In truth, any information (eg: structural or insulative properties, costs, maintenance information) can be input or determined based on other data sources.

As this technology matures we will see more and more information in industries move from human readable information (eg PDF), to digitally readable information (eg spreadsheets), to parametric data. This will enable more and more processes to move from requiring extensive human input, to being automated. First, it allows each product to be customised for close to zero marginal cost, ending ‘one size fits all’. Second we can tame complexity & uncertainty by automating workflows from outline design to costed, factory-ready manufacturing information in seconds; a task which previously required weeks or months. Third, it enables design decisions to be driven by data rather than intuition or costly and slow modelling / manual calculations. Even things like building regulations (at present just human readable) could quite easily be embedded parametrically. This kind of functionality is well beyond the currently defined BIM Levels 1 to 3.

The need for seamless end-to-end workflows from initial design to finished components (and ideally beyond into site management and use) is an underpinning requirement to leverage the true potential of DDM. This incentive for a vertically streamlined process, although patently logical, runs counter to the way most buildings are procured, with distinct stages of work and information transitioning from one form to another and often degrading as the project progresses (eg: 3D model to 2D drawings to PDFs to paper printouts). Various software platforms are being explored, from very specialised online product customisers to professional grade (and price) BIM software like Autodesk’s Revit. Some emerging software intended for product design (eg: open source FreeCAD, OnShape, AutoDesk’s Fusion 360) also offer great promise.

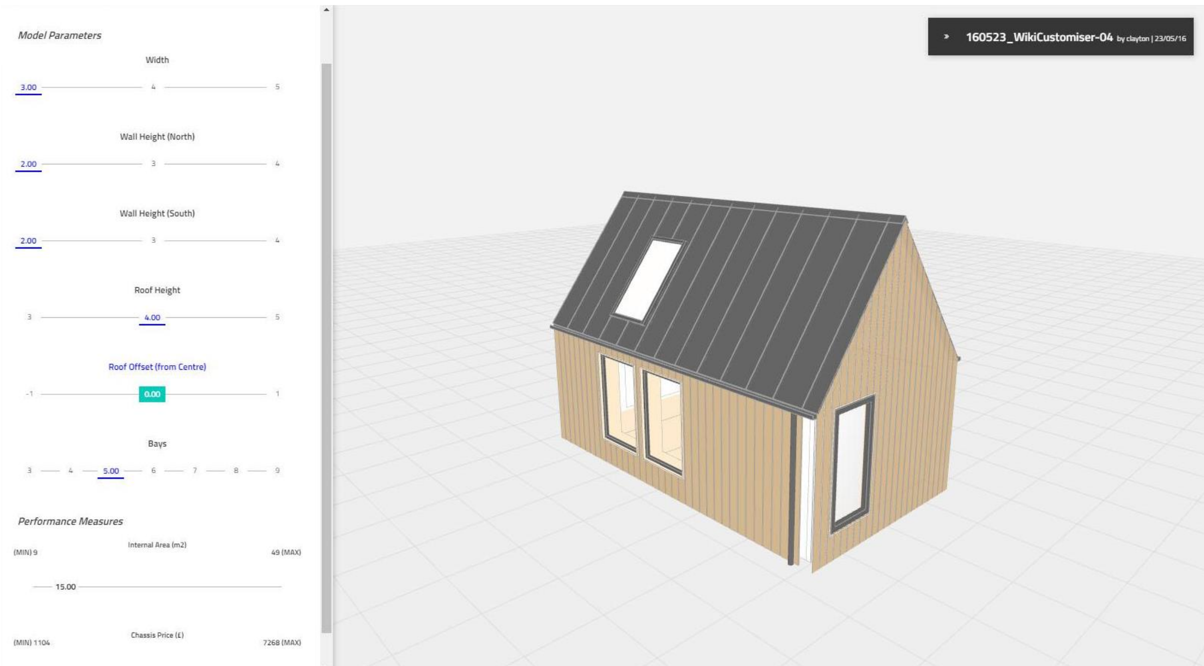


Figure 6.3D: The prototype online customiser the WikiHouse Foundation are developing. Source: WikiHouse Foundation.

Open source and collaboration

Tesla, the electric car maker, has released huge swathes of its patented technologies for people to innovate on. General Electric (GE) open sourced thousands of patents related to consumer products. Sun Microsystems has an extensive portfolio of software that it has open sourced, including some of the key technologies for the internet (eg: Java, MySQL). So big is this phenomena that last year, tech magazine Wired said that 'open source is now mainstream, and the mainstream is open source'. But why? Because open source accelerates innovation and helps ease the burden of maintenance and testing. Not to mention being good PR.

The core tenet of open source is letting users of a technology adapt it to their needs or improve it. The choice of license used to release the original innovation will determine how subsequent iterations of the technology must be re-released. Often the license will stipulate that all future iterations must use the same license, ie: it must remain open in perpetuity.

However, open source need not put professionals out of business. Open source end-users are given the opportunity to deploy the technology themselves. However, there is also the ability to add a service layer, whereby companies can provide paid services using the open source technology. In the build environment, this might mean innovating new components, architectural design, structural engineering signoff, manufacture, delivery to site, or site assembly. Many open source software projects already do this. And, as it turns out, a lot of people will still pay for assistance.

Benefits

The potential for these new manufacturing processes is huge. Even in its infancy, DDM technologies have a broad range of benefits:

Sustainability

One of the key challenges in achieving sustainable buildings is how to get the required tolerances reliably and affordably. Traditionally this required a high skill site work force. With digital fabricated building systems care and attention is still required, but precision manufacturing and refined assembly systems can significantly reduce these challenges.

Because the details of a digital building systems are encoded digitally, 'bad' details can be identified and remedied, driving iterative improvement and closing the performance gap. Applied to open source systems, these improvements are then globally disseminated.

Customisation and local responsiveness

The use of parametrics in CAD software, customer-facing customisers, and the nature of DDM dramatically reduces the cost for individually customising buildings. This is a boon for both end users (who get bespoke products cheaper) and professionals (who save time). It also enables building systems to be adapted to local climate or site conditions more easily.

Checks and Compliance

Tasks such as engineering calculations and energy performance modelling can be built in and streamlined using parametrics. Similarly, requirements such as Building Regulations and space standards can be encoded parametrically, meaning that building designers (be they self-builders or professionals) simply can't design a non-compliant building.

Cost certainty and cost savings

One of the aspirations for BIM is cost and time certainty. However, using manual procurement and fabrication processes means that, with the best will in the world, there are still unpredictable factors. With digital fabrication, more of the process can be controlled and predicted. In addition, the building system approach means that information can be recorded and transferred from one project to the next, improving knowledge and allowing more certainty earlier in projects.

Multiplier effect

By distributing rather than centralising production, many more companies can participate, spreading increased benefits (including jobs, investment, and skills) across local communities.

The self build / citizen sector

DDM can help enable the development of small sites by self-builders and small developers. DDM works efficiently and affordably when producing one-off products and small batches in a way manual and/or centralised production do not. It also lowers other barriers to entry such as skills and cost uncertainty, while actually improving the performance of the buildings delivered. The public sector, housing associations or private owners own vast areas of land on which development has been previously unviable, due to marginal costs. Unlocking the citizen sector through DDM could significantly contribute to solving the housing shortage in the UK.

Benefits in public procurement

Currently, when the public sector procures buildings, IP and learning generated typically disappears into the hands of the companies commissioned to deliver the projects. Public bodies and housing associations use framework agreements to build relationships with companies so that they can benefit from that IP, which they paid for, on future projects. The application of open source to public production could change this, with public bodies stipulating that open source technologies should be used preferentially and that project outcomes should remain open source. Public money would, then, not be funding proprietary IP but paying for a growing catalogue of publicly available technologies, design solutions, and open standards.

A growing community of pioneers are already developing and providing services around digitally fabricatable and open source technologies. Many of these technologies are beyond concept stage, and are starting to be put into use on real projects.

6.3 Case study: **A Wiki farmhouse**

Client Martin and Janet (private homeowners)

Architect Architecture00

Location near Rugby, Warwickshire

Background

This case study gives an overview of the current status of the WikiHouse ‘chassis’ system (the structural frame). WikiHouse is not just a chassis, but a building system incorporating many products and services. The system is developing globally through the work of the WikiHouse community (3000 people, including nearly 300 businesses, around the world).

Description

More than 300 structures have now been built using the WikiHouse chassis system, ranging from pavilions to complete homes. Variations continue to be developed for local and project specific requirements, for example hack houses in the US that were occupied for six months. The farmhouse is the first complete, habitable dwelling in the UK, and is close to completion.

WikiHouse builds exploit the benefits of parametric design (generating fabrication-ready components direct from a 3D design model) and digital fabrication (cutting all components on a CNC machine rather than laboriously by hand) for the whole of the building's superstructure. This makes the costing and programming of projects highly predictable. Teams are then free to use conventional trades to complete the project, or some of the other WikiHouse products currently in development. For these reasons, WikiHouse buildings are effective self-build and/or community-build projects. The system limits the need to work at height by making the structure self-supporting. Each part of the process is easily understood and can be taken off by sub-teams to work on autonomously. This reduces the requirement for oversight, so teams can self-manage and self-organise.

Environmental approach

Digital fabrication is an extremely material efficient process compared to conventional fabrication and on-site-assembly processed. There are few to no mistakes in machining. There is some material wastage during the CNC cutting process, but it is relatively small, a known amount, and produced at the workshop rather than on site (so the material stays clean and dry and can therefore more readily be recycled). On site there is virtually no wastage at all as all the components arrive cut and ready to assemble.

Current status Current projects include a teaching space up in Liverpool with non-profit group Friends of the Flyover, a retreat space near Vienna, a bus shelter, a barn and two community spaces in Scotland, and a 3-bed family home near Rugby, in Warwickshire, due to be completed soon. This domestic project provides the focus for this case study.

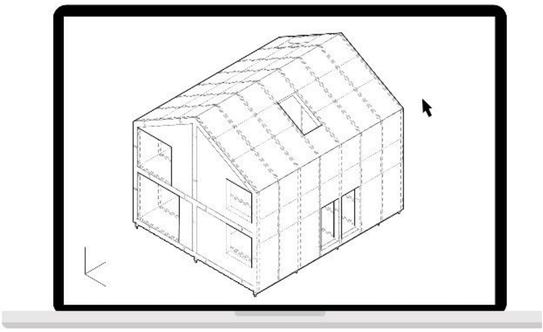
Construction and materials

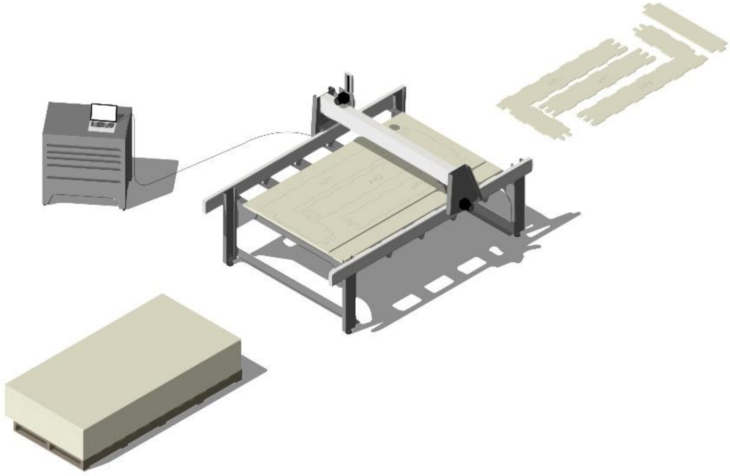
Structure High performance timber frame made of spacer-studs. The innovation is in how the parts are cut and that the ply/OSB webs connect directly to the sheathing rather than requiring solid wood battening, saving on labour and material.

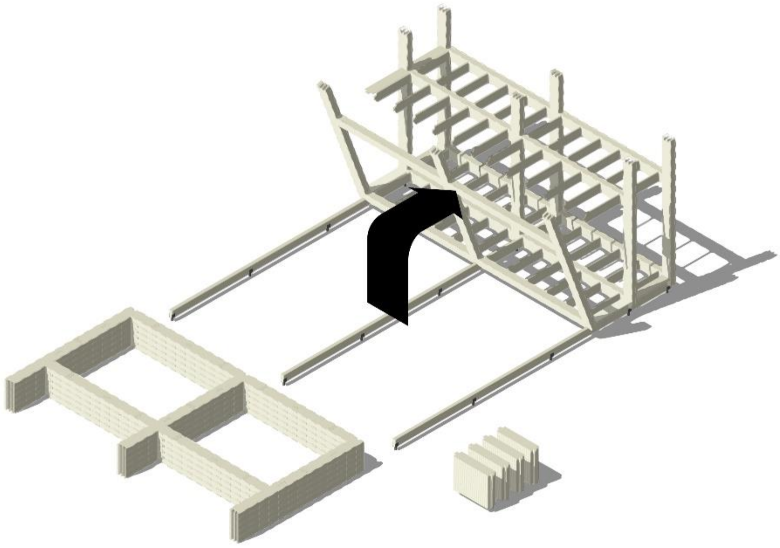
Foundations	WikiHouses have been built on a wide range of foundations to suit design requirements and local ground conditions. Foundation costs need not be any higher than with other types of construction. In this case, foundations are simple concrete strips.
External fabric	The exterior walls, floors, and roofs are, by default, 300mm thick, so they are ready to take Passivhaus levels of insulation, in this case 300mm of foam insulation. A continuous interior sheathing facilitates air tightness, while the accuracy of the process means that glazing and other penetrations are fitted snugly and easy to seal around. The chassis also performs well from a cold-bridging point of view, including typically problematic locations such as the foundation-to-wall junction.
Windows / doors	Double glazed.
Heating	Wet central heating with MVHR.
Programme	The house chassis was CNC cut from 512 sheets of plywood in 3 weeks by a small workshop (Chop Shop in Sheffield). To produce a large number of units, an organisation could set up a CNC workshop of their own. This would speed up the process (and save money). The chassis took a little over a week to erect and another week to fully enclose. This was with a team of amateurs, including training time for people who just turned up for a day. After erection of the chassis, the process of fitting glazing, services, finishes, etc is made faster and easier as the structure is absolutely square and level (finished structures are consistently within 5mm of the digital model even when built by unskilled people). When working with professional constructors there is a cost saving in time saved levelling, packing out, measuring, and waiting for things to be built before ordering the next set of products to be installed etc.
Procurement	The house was almost entirely self-built (with limited construction assistance from plumbers and electricians), which provided a cost saving, but also slowed down the construction.

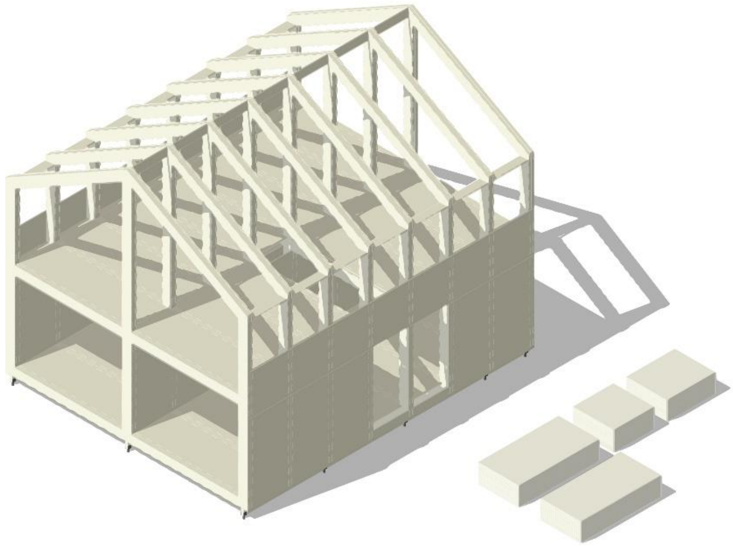
Post completion data

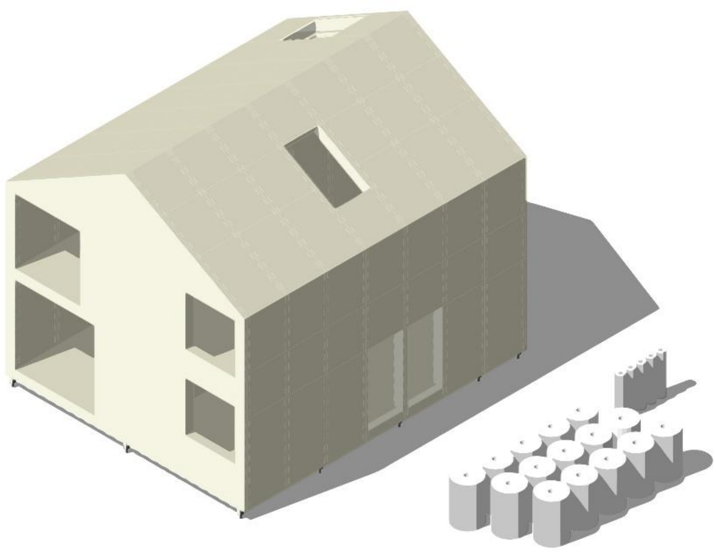
Capital costs	The plywood frame cost around £215/sqm including materials and CNC cutting, but excluding site or labour; the project was built by family and friends. The construction costs were a little over £700/m^2 (including foundations, superstructure, services, finishes, etc), or £850/m^2 including all consultants' fees and contingencies. This project was a one-off house so there were no economies of scale. Based on conventional construction a saving of up to 30% might be expected across a small to medium sized housing project.
Footprint	The chassis is made entirely from timber board products (which are available FSC-mixed certified and with zero added formaldehyde) so the chassis has low embodied energy and good material health.
Energy in use	WikiHouses tend to be very energy efficient. More detailed information on fuel bills will be published once the Warwickshire house has been inhabited and monitored for a time.











Figures 6.3E to Figure 6.3I:

WikiHouse does not need to have a single structural grid, but in most countries, sheet materials come in 1200mmx2400mm sheets, so the basic structural grid is based on that to achieve the maximum efficiency. The system is based on a sequence of framed placed at 900mm and 300mm (alternating) intervals.

The length of a WikiHouse is, in theory unlimited, and the roof profile can take almost any shape within reason, but the maximum room span is 4.5m at present. Spans can be combined horizontally...

Figure 6.3J and Figure 6.3K: The project is now nearing completion, and was assembled by a team of volunteers. The chassis took three weeks to fabricate, and a further two weeks to assemble.

APPLICABILITY ASSESSMENT: CNC CONSTRUCTION

Description

Digitally fabricated timber frame and envelope, parametrically designed using open source software, built by volunteers and filled with polyurethane foam insulation.

Benefits and limitations

Key benefits

During construction:

- Low skill constructional approach maximises self- and community-build
- Parametric design and CNC cutting deliver high quality to small tolerances
- Uses off-the-shelf materials. Minimal cement use and minimal waste

In use:

- Constructional approach delivers high quality under controlled conditions
- Frame facilitates structure-free interior and maximises flexibility / adaptability
- High performance, potential for carbon negative (subject to insulants)

Key limitations

During construction:

- Material-intensive construction
- Constructional approach (currently) limits applicability to non-complex forms
- Lowest cost approach relies on insulants which are petrochemical products

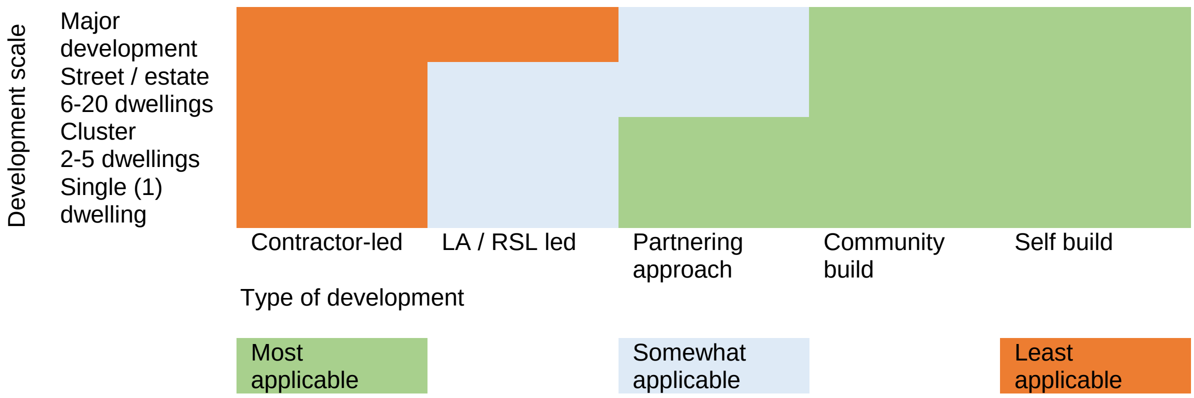
In use:

- Low thermal mass limits resilience / resistance to overheating
- Construction is vulnerable to damage from moisture, esp. at ground level
- Party wall arrangements / multi-storey details are still under development

Cross-standard analysis

Space standards	constructional module limits internal layouts somewhat
Flexibility / adapt.	System ensures open plan flexibility and maximum adaptability
Env. Performance	Approach promotes consistent thermal performance / air tightness
Resilience	Low thermal mass, MVHR provides option for ‘cooling’
Materials	Low cement, low carbon building envelope but petrochemical insulant
Character	Frame can be ‘wrapped’ in any materials (limited to simple forms)
Density	Low / medium densities are possible
Ecology	Low impact construction
Health	Airtight construction and MVHR control indoor air quality
Connectivity	Construction facilitates community involvement / local resource use

Applicability matrix



7.0 | findings

This chapter summarises key findings. The findings are a combination of observations drawn from the thirteen themed essays that structure the report, supported by findings relating to the case studies. Findings are broken down under the following ‘headlines’:

7.1 | performance: what works
This section describes the key factors affecting the specification and environmental performance of the case studies, and identifies where approaches converge in a way that might inform new standards for housing. Key recommendations reinforce the need to ensure that buildings perform as designed. A series of diagrams compare technical performance across the case studies.

7.2 | delivery pathways
This section describes the various alternative delivery pathways to more housing that have been identified by the report. Figure 7.2A identifies key considerations and benefits impacting on selection of pathway. Figure 7.2B describes conceptually the potential impact of a step change promoting alternative pathways.

7.3 | construction techniques
This section summarises key benefits associated with alternative construction techniques and provides an overview of the obstacles currently limiting uptake. Figure 7.3A identifies specific benefits associated with each construction technique investigated. Figure 7.3B describes conceptually the potential impact on housing delivery of a step change that promotes alternative construction techniques. Figure 7.3C identifies recurring client incentives and concerns.

7.4 | local leadership
This section outlines ways in which local authorities could play a part in the delivery of more | better housing. Recommendations relate to the promotion of alternative pathways to housing, a number of which are already being exploited outside of Wales.

7.5 | cost versus value
This section highlights key findings in relation to the cost of more | better housing. This includes the identification of options for reducing the cost of housing, as well as a discussion of the importance of attributing value to non-cost related benefits.

7.6 | initiating a step change
This section identifies a series of steps that Welsh Government could take to promote more | better housing in Wales, with the principle aims of meeting current and future housing need in Wales, delivering truly affordable new housing (including affordable warmth) and addressing the emerging implications of the WFG (Wales) Act 2015.

7.7 | promoting more | better
This section identifies a number of ways in which Welsh Government and other organisations could contribute to the promotion of more | better housing, principally through coordinated and accelerated learning, through the commissioning, delivery and long-term evaluation of a range of ‘exemplar’ affordable housing pilot projects.

the case studies: in summary

The table below provides a thematic comparison of the construction techniques exploited by each of the case studies. The ten themes were drawn from the prior discussion of existing and emerging housing standards (section 3.0). The findings are as described in the analysis that follows each individual case study. Indicative figures are also provided for construction costs (£/m^2) and costs in use (heating bills, £/annum), where available. However, as has previously been stated, projects are not like for like, and costs are not directly comparable.

	case study	space standards	Flexibility/ adaptation	Environmental performance	Resilience	Materials	Character	Density	Ecology	Health	Connectivity	Typical annual heating bills £/annum	capital cost £/sqm
2.3	porth teigr	green	light blue	green	green	orange	light blue	green	orange	light blue	orange	£172 estimate	n/a
2.1	Cardiff HPP	green	light blue	green	green	orange	light blue	green	orange	light blue	orange	£279-£296 estimate	£1450*
6.2A	Murray Grove	orange	light blue	green	orange	light blue	light blue	green	green	green	light blue	£300 actual	1050*
6.2B	L&G Homes	green	green	green	light blue	light blue	light blue	green	green	green	light blue	n/a	n/a
2.2	Graven Hill	green	light blue	green	light blue	orange	light blue	green	light blue	green	light blue	n/a	£810**
3.2	SOLCER	green	light blue	green	light blue	orange	light blue	green	light blue	green	light blue	n/a	£1200*
6.1	William Street Qtr	green	light blue	green	orange	orange	light blue	green	light blue	green	light blue	n/a	n/a
4.1	LILAC co-housing	light blue	orange	green	light blue	green	light blue	green	green	green	green	£145 estimate	£1143*
3.3	Ty Solar	light blue	green	green	light blue	green	light blue	light blue	green	green	green	£140-260 estimate	£1200*
3.1	More homes, SCC	green	light blue	green	light blue	green	green	green	green	green	light blue	£34 estimate	n/a
5.1	BCC passivhaus	green	light blue	green	orange	green	green	light blue	green	green	green	n/a	n/a
4.2	Ty Unnos	light blue	light blue	green	green	green	green	light blue	green	green	green	n/a	£1500*
5.2	Barnhaus	orange	green	green	light blue	light blue	green	light blue	green	green	green		£1350***
6.3	Wiki farmhouse	light blue	green	green	light blue	light blue	light blue	light blue	green	green	green	n/a	£710****

Figure 7.0A: thematic comparison of case study construction techniques

Load bearing masonry

Volumetric construction

Sandwich, eg SIP

Panelised system

Timber frame

Portal frame

DDM

Notes:
The above thematic analysis pertains to the construction technique adopted by each case study, and is not a critique of the case study project itself.

*	capital costs exclude land and consultant fees
**	capital costs exclude land, abnormals (piling), fitout, and internal finishes
***	capital costs exlclude site, consultant fees, abnormals
****	capital costs exclude site, consultant fees, labour

7.1 | performance: what works

FABRIC FIRST: All case studies adopted a fabric first strategy, but to differing degrees. Performance is represented in the diagrams overleaf. The Murray Grove case study, completed in 1999, demonstrates the extent of improvements in ‘best practice’ that have taken place over the last decade or so.

PASSIVHAUS levels of fabric performance are generally achieved by the case studies, so long as capital costs are affordable. Simple, compact building forms make this target more affordable. Case studies typically achieved equivalent levels of thermal performance for walls and roofs, while floors were more varied. Glazing performance is the most varied, primarily due to the higher cost of better performing glazing products.

AIR LEAKAGE is a major source of heat loss. Since 2002, Building Regulations have stipulated an air tightness ($10m^3/h.m^2$ at 50Pa), but this target is no better than the average airtightness of Victorian housing. The case studies all achieved, or propose to achieve, air tightness of at least 4, but with a considerable range in the values achieved on site. Some construction techniques (SIP, CLT volumetric) guarantee very low air leakage rates.

MVHR (mechanical ventilation and heat recovery) is mandatory for buildings with air tightness better than $3m^3/h.sqm$ at 50Pa, to maintain indoor air quality. In hot conditions, MVHR can work in reverse so that unwanted heat is transferred to the exhaust air. This technology has potential to **future proof** housing that is prone to overheating.

HEALTH: The impermeability of contemporary construction is cited as a cause of building-related health issues. Natural, permeable insulation tends to be less effective and required in greater quantities, increasing cost and adding to the thickness of the building envelope.

PASSIVE SOLAR DESIGN is considered to be good practice in conjunction with *fabric first*. Studies have identified that simply orienting a ‘typical’ housing estate for solar gains can reduce primary energy consumption by 5%. Further reductions in energy consumption (and fuel bills) are obtained by adjusting the size and position of openings. To maximise these benefits, we must move from standardised house ‘types’, towards more site-specific designs.

WATER HEATING can use more energy than space heating in highly efficient homes. Losses due to heating, storage and distribution of hot water should be minimised.

RENEWABLES represent the biggest variable within the case studies. A number of the case studies avoided renewables altogether, due to payback periods and maintenance implications. Renewables must be assessed on a project-by-project basis.

NET ENERGY POSITIVE case studies demonstrated how carefully selected, integrated renewable energy sources can be incorporated into affordable housing.

PERFORMANCE GAP remains an unknown quantity for some of the case studies, but others benfitted from detailed energy modelling. For buildings to perform as intended, we must model performance accurately, select forms of construction that suit the skills and experience of the constructors, and spend sufficient time and resources educating constructors around expected outcomes.

POST CONSTRUCTION MONITORING is also needed, to correct mistakes that are inevitably made, and reward performance that meets or exceeds expectations. We must be better at sharing lessons learnt, so that mistakes are not repeated over and over again.

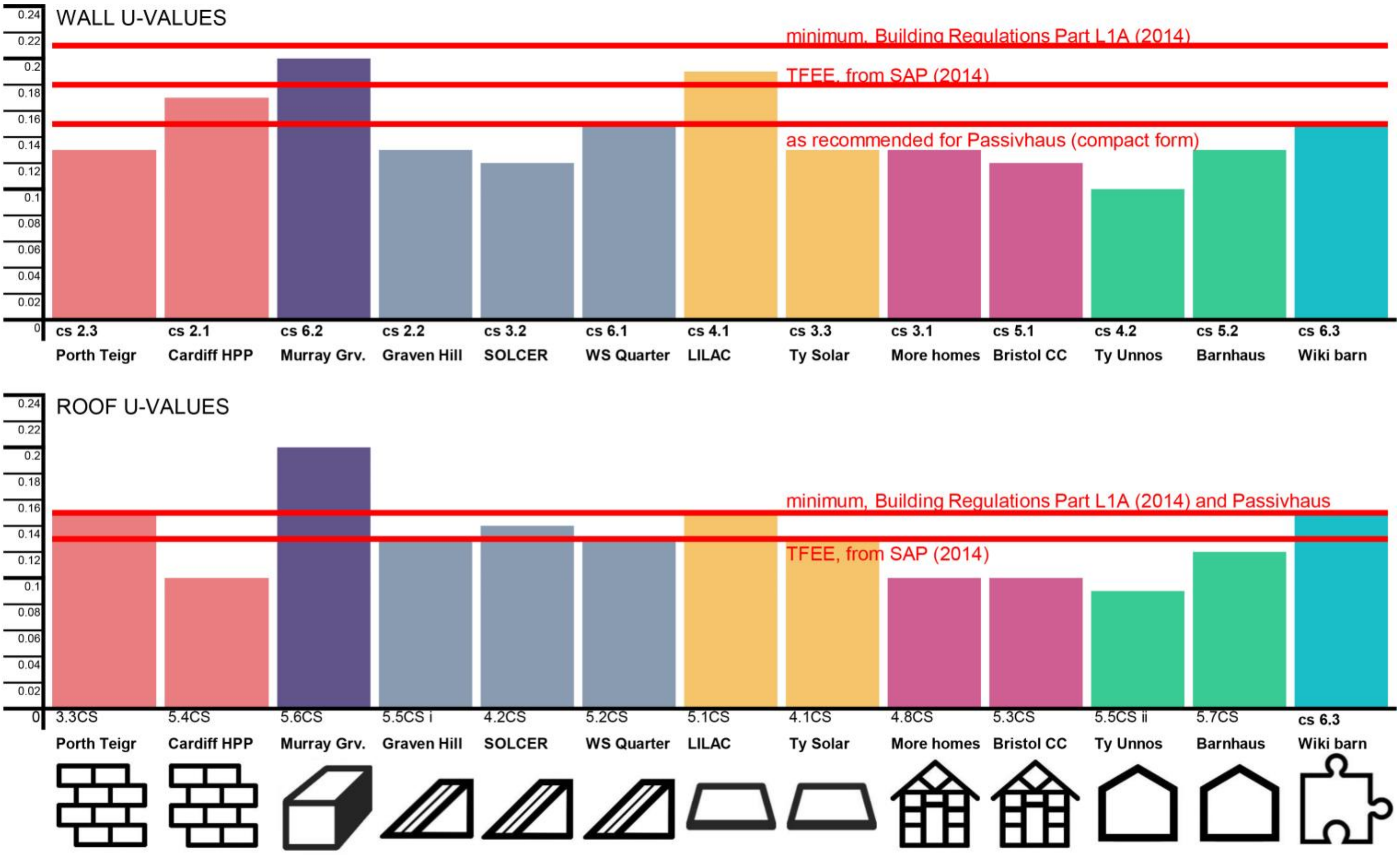
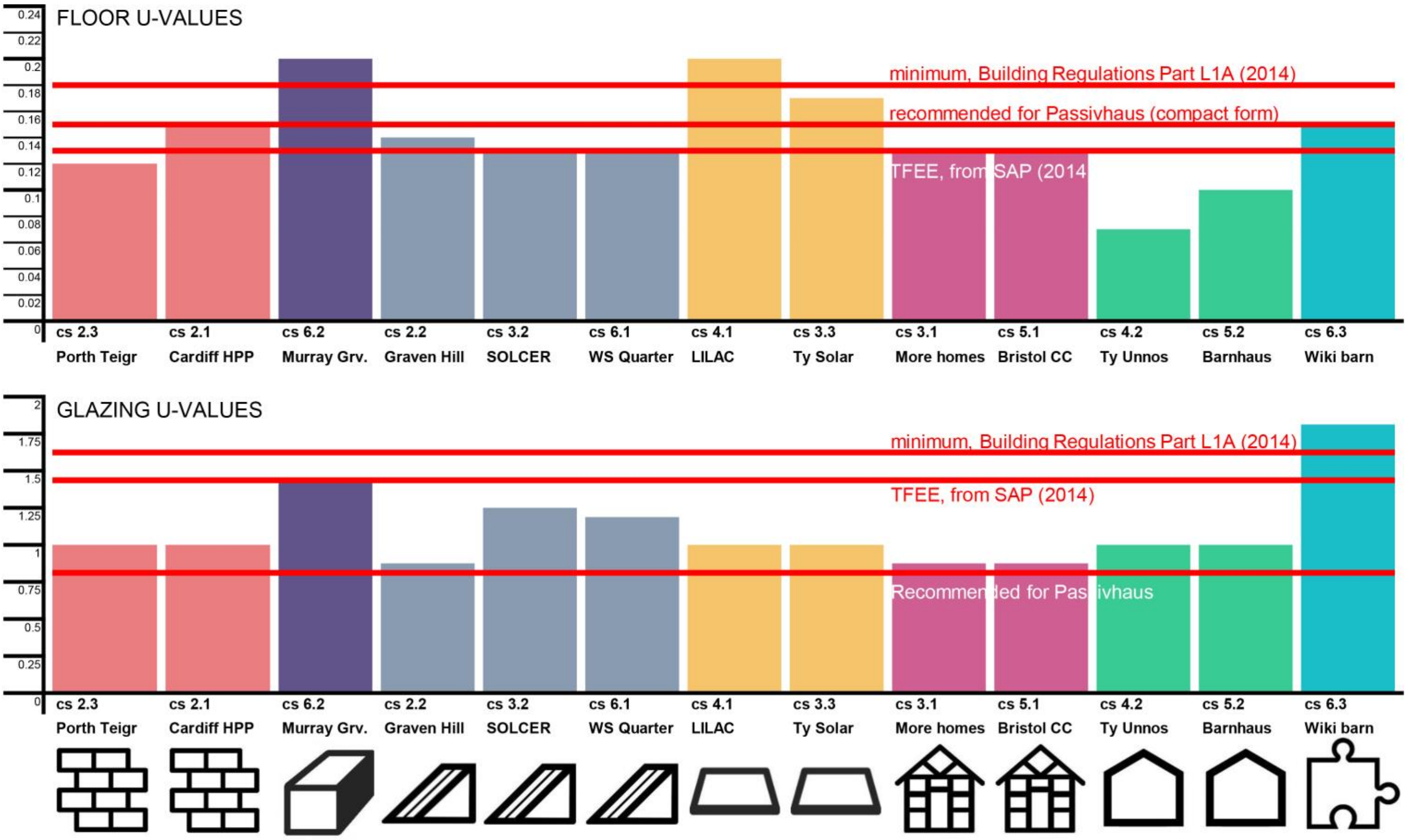


Figure 7.1A (above): cross case study comparison of wall and roof u-values

Figure 7.1B (below): cross case study comparison of floor and glazing u-values



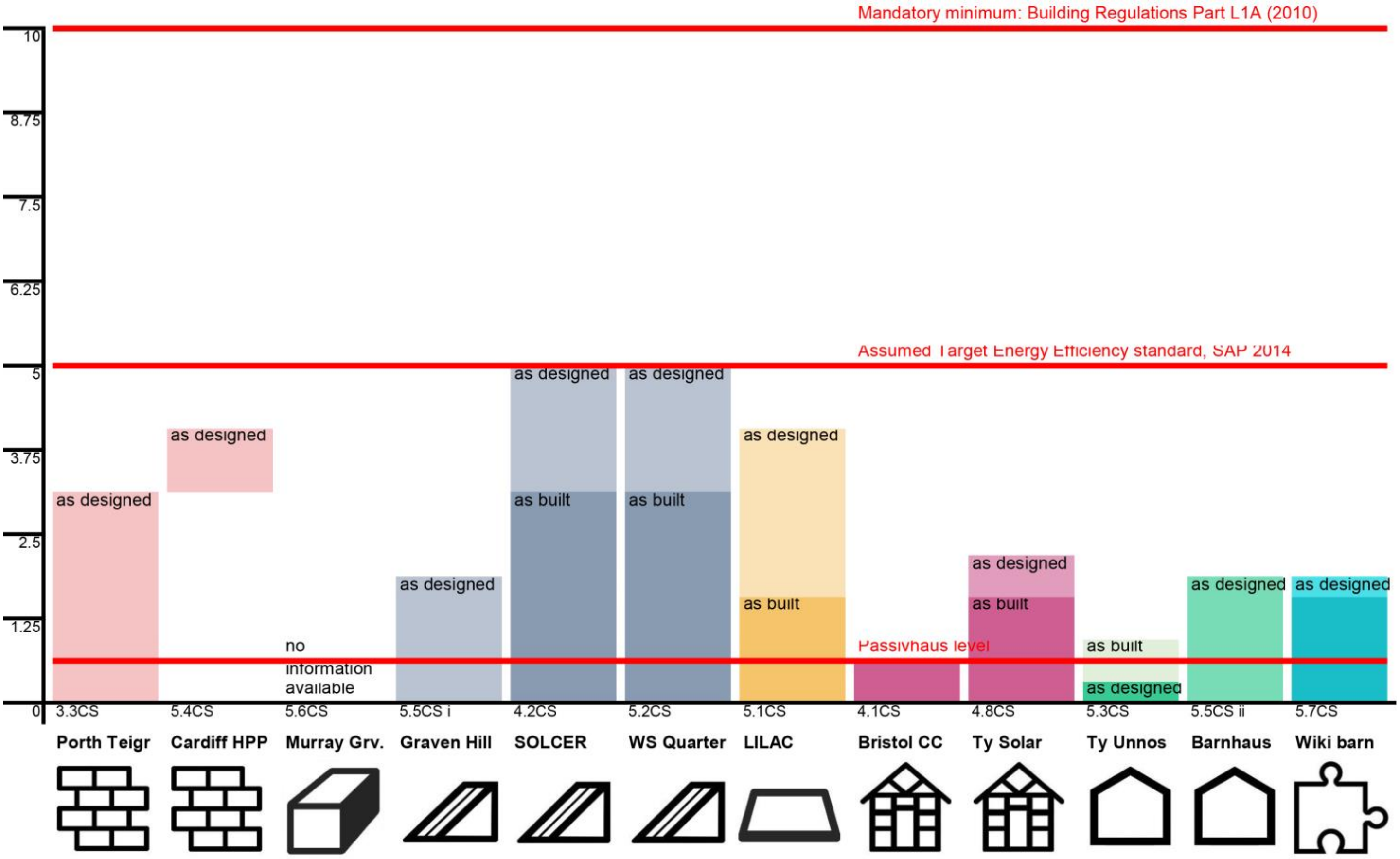
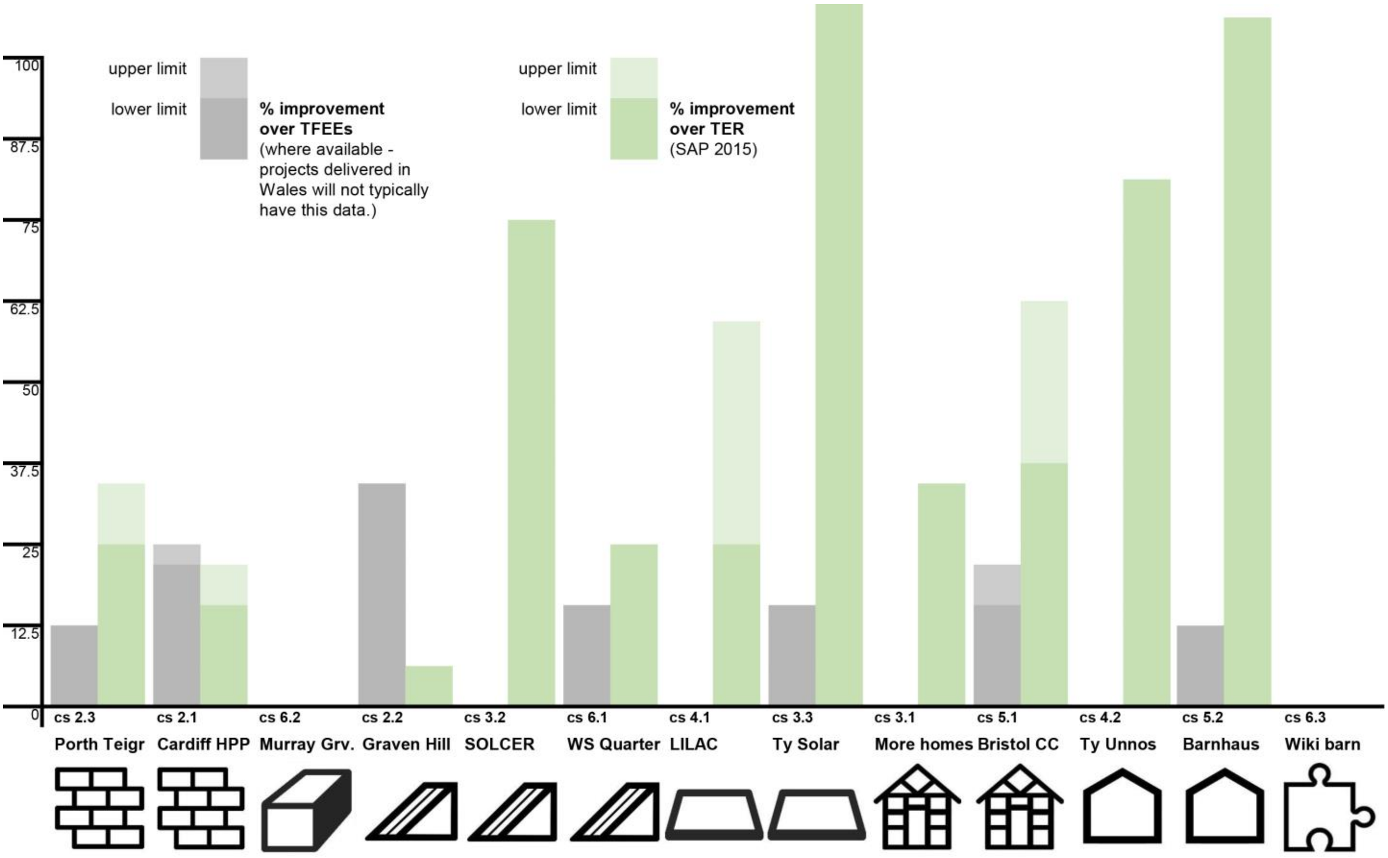


Figure 7.1C (above): cross case study comparison of air tightness as designed / built

Figure 7.1D (below): predicted improvement of case studies over target performance (SAP)



Percent improvement over TER (and TFEEs where available) from SAP (2015)

7.2 | delivery pathways

A great deal of time and energy has been expended on the search for a 'solution' to the housing crisis. It would appear that there is no *single* silver bullet.

People value difference in housing. Qualities such as character, site specificity and adaptability are intrinsically valuable. It is difficult to imagine a single standardised approach that meets all of these aspirations in equal measure.

A wide range of factors contribute to selection of the 'best fit' approach to delivery for any given project. Most can be summed up as relating to project delivery, in-use, or contextual benefits – see figure 7.2A, overleaf. More focus on design is also needed, to ensure that homes are fit for future generations, along with a more consumer-oriented housing market.

PRIVATE SECTOR does finance affordable housing, but mostly in higher value urban centres. Build to Rent has proven competitive on sites with abnormals, infrastructure costs or depressed sales, and incentivises developers to think longer term. However, longer term, land hoarding by investors creates impediments to joined-up, sustainable development.

CUSTOM BUILD, whereby residents have some choice in the design of their future homes, amounts to around half of housing delivery in some European nations. In England, the appetite for Custom Build is growing, and the Government has implemented initiatives including changes to NPPF (requiring LA's to ascertain and respond to demand for self- and custom-build plots), dedicated funding, pilot sites, and tax exemptions to drive more housing. In Wales, the scope for Custom Build to deliver more housing is not yet established (the first Welsh custom build development, 27 plots in Blaina, was announced in August 2016).

COOPERATIVE HOUSING offers affordable housing in a climate where mortgages are difficult to obtain, when the average house price is too high for low income home buyers. Recent research (2013) identified a substantial appetite for co-operative housing in Wales, particularly from groups and individuals priced out of the owner-occupied sector but without access to social housing. Co-operative principles can be adapted to provide affordable housing solutions for a range of people and communities in Wales.

SELF BUILD could provide housing for more than 400,000 people in Wales. Around 60,000 of these households would like to start building in the next 12 months. Most are either:

- Older homeowners, looking to build their retirement home. Most have financial resources / own a home. Many opt for 'green' features to minimise running costs, or
- Younger families on modest incomes who are trying to finance their first home. For them the main priority is affordability. These families are generally more likely to be keen on working collectively a group/community self-build project.

Savings on self-built / self-organised homes are typically between 25% and 45% of total capital costs, depending on the degree to which the occupants carry out labour themselves.

RECOMMENDATIONS

Pathways that encourage households or communities to build their own homes result in new homes being delivered *in addition* to homes delivered through more conventional routes, not in place of them. They could make a meaningful contribution to housing supply, and should be promoted. Wales is already exploring related pathways through community-centred initiatives. It is crucial that those involved in the commissioning, procurement and delivery of such housing understand the benefits and limitations of different approaches.

Selection of approach / pathway:

Key considerations

delivery

Who is delivering the project?

How will it be delivered?

What is the capital budget?

What are the timescales?

What relevant expertise exists?

in-use

Who is the housing for?

How will the homes be used?

How might user needs change?

How likely is future adaptation?

What is the long term intention?

site / context

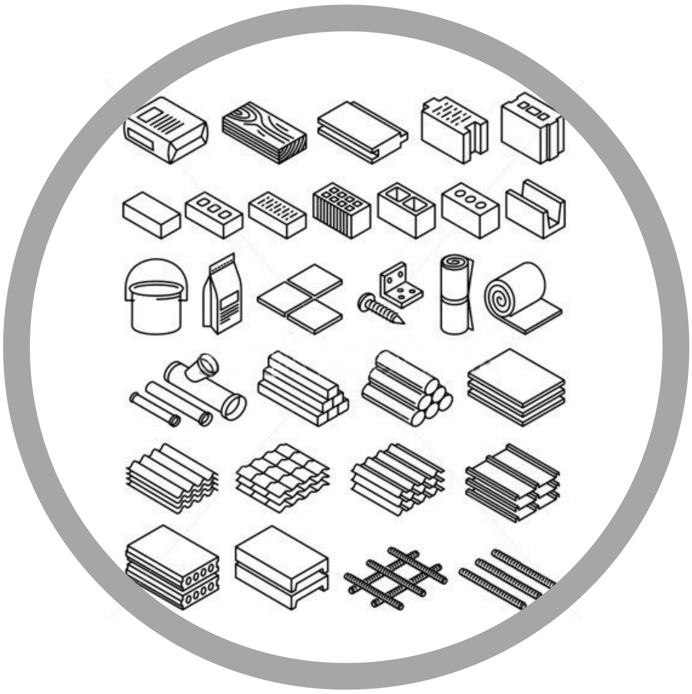
What is the physical context?

What is the local climate?

What materials are available?

What skills are available?

What resources are needed?



delivery

More affordable construction

Improved timescales

Reduced embodied energy

Low impact, carbon storing

Improved ecology

in-use

Lower primary energy demand

Reduced heating bills

Reduced CO_2 production

Energy production and storage

Future source of revenue

site / context

Less pressure on local systems

Community training / skills

Revitalising existing community

Supporting local supply chain

Contributing to local economy

Potential benefits

Figure 7.2A: Summary of key factors to be considered in selection of approach / pathway

alternative pathways: impact of a step change

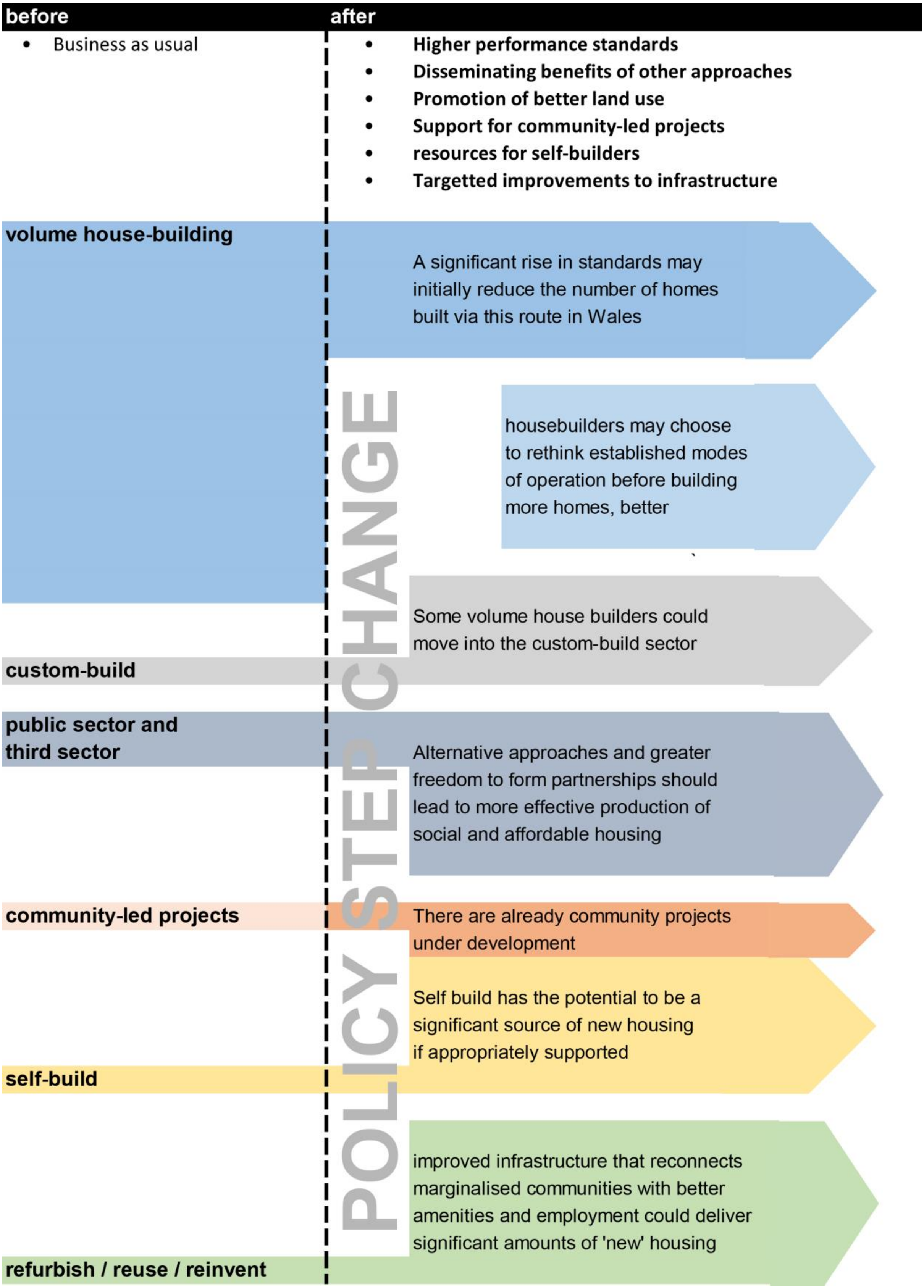


Figure 7.2B: Impact of a targeted step change on housing delivery, pathways

7.3 | construction techniques

Most housing is built by a few nationally operating housebuilders using established construction techniques, predominantly bricks and mortar. There are disincentives for these organisations to embrace alternative forms of construction, including established supply chains and procurement practices, and standardised designs. Incentives for smaller ‘alternative’ operators to up-scale are limited, as large residential developments are not commonplace, and by expanding in scale, smaller contractors and fabricators would expose themselves to greater risk through a lack of consistent demand.

The use of most alternative construction techniques at a national level would necessitate widespread reskilling and retooling. However, unless these approaches are implemented at scale, we will not access their full benefit.

All construction techniques have applicability criteria which must be assessed on a project-by-project basis, as they are influenced by a wide range of factors- see overleaf, figure 7.3A.

Alternative construction techniques do not necessarily deliver capital cost savings. Short term capital costs must be balanced against costs in use, and due consideration given to other, non-financial, benefits that alternative approaches offer (see section 7.5, cost versus value). Benefits can include higher quality, less performance gap, more predictability, better working conditions, reductions in waste / resource consumption, and reduced time on site.

This, in turn, can lead to smaller overheads and reduced costs, fewer defects, shorter snagging periods, and less adversarial contractual relationships. As a result, homes can be delivered with dramatically reduced heating bills and a healthier internal environment.

7% of global CO_2 emissions arise as a result of cement use. Generally, alternative forms of construction use less cement than ‘bricks and mortar’. Most are timber-based systems, a sustainable resource that exists widely in Wales. Timber ‘locks’ carbon into buildings, improving carbon footprints. However, 85% of construction timber is currently imported into Wales, missing an opportunity for home-grown resource use and related economic benefit.

Some construction techniques reduce the specialist skills required, reducing costs and increasing their applicability. This, in turn, suggests that it should be possible to build with these approaches to higher standards with less expertise, and increases opportunities for self-build and community-build development.

Some approaches lend themselves to densification of existing neighbourhoods, through infill of lower density sites or through the ability to work in constrained or challenging sites.

For larger developments, pop-up factories become viable, on-site or near-site. This provides opportunities to train people locally, and to use local materials and resources.

Some construction techniques deliver more flexibility and adaptability long term, which are important if we are to build neighbourhoods that will be relevant for future generations.

Modular construction can deliver higher quality, even zero-defect, building and can reduce traditional on-site programmes by up to 50%. Provided there is a high degree of repetition and a reasonably large order, modular construction can be both effective and affordable.

Distributed digital manufacturing and open source design put construction into the hands of communities. Improvements in collaborative tools, pooled resources and shared intellectual property will continue to make it easier for groups of people to live, work and build together.

Comparison, seven construction techniques:

Category	target	bricks+ mortar	timber frame	SIP panel	straw-fill panel	portal frame	CNC routed	CLT volumetric	benefits
Performance	best practice building fabric*	Potential	Potential	Potential	Potential	Potential	Potential	Potential	very low energy in use / heating bills, more comfort
Performance	air tightness <1	Potential	Potential	Delivered	Delivered	Potential	Potential	Delivered	very low energy in use / heating bills, more comfort
Performance	carbon negative		Potential		Delivered	Potential	Potential	Potential	Carbon sequestration, lower impact construction
Design	Customisable form	Delivered	Delivered	Delivered	Potential		Potential		character can be adapted to suit different places, contexts
Design	Suited to tight sites	Delivered	Delivered	Delivered	Potential	Potential	Potential	Potential	Opportunities for densification, intensification
Design	Capable of height (3+ storeys)	Delivered	Delivered	Delivered	Delivered		Potential	Delivered	More effective use of land, denser development options
Design	flexibility / adaptability	Potential	Potential	Potential	Potential	Delivered	Potential	Potential	ensures functionality and suitability for life of building
Materials	thermal mass	Delivered	Potential	Potential	Potential	Potential		Potential	Reduced risk of overheating, stable internal conditions
Materials	Natural, breathable		Potential		Delivered	Delivered	Potential	Potential	Healthier buildings, lower risk of failure
Materials	Locally sourced resources		Potential		Potential	Potential			Local / national supply chain, reduced transportation
Fabrication	No wet trades**		Potential	Potential	Potential	Potential	Delivered	Potential	Less time on site, less sequencing / specialist skills, lower carbon
Fabrication	Off-site fabrication			Delivered	Delivered	Potential	Delivered	Delivered	Better working conditions, higher quality control
Fabrication	Self-build friendly		Potential		Potential	Delivered	Delivered		Reaching a different market, client engagement / skilling, reduced cost
Fabrication	Production at scale	Potential	Potential	Potential	Potential	Potential		Delivered	Economies of scale, suited to largest developments

target benefits
bricks+ mortar timber frame SIP panel straw-fill panel portal frame CNC routed CLT volumetric

* facility to achieve thermal performance equivalent to Passivhaus standard
** excluding foundations

Potential benefit   Delivered benefit

Fig 7.3A: comparison of 'potential' and 'delivered' benefits, by construction technique

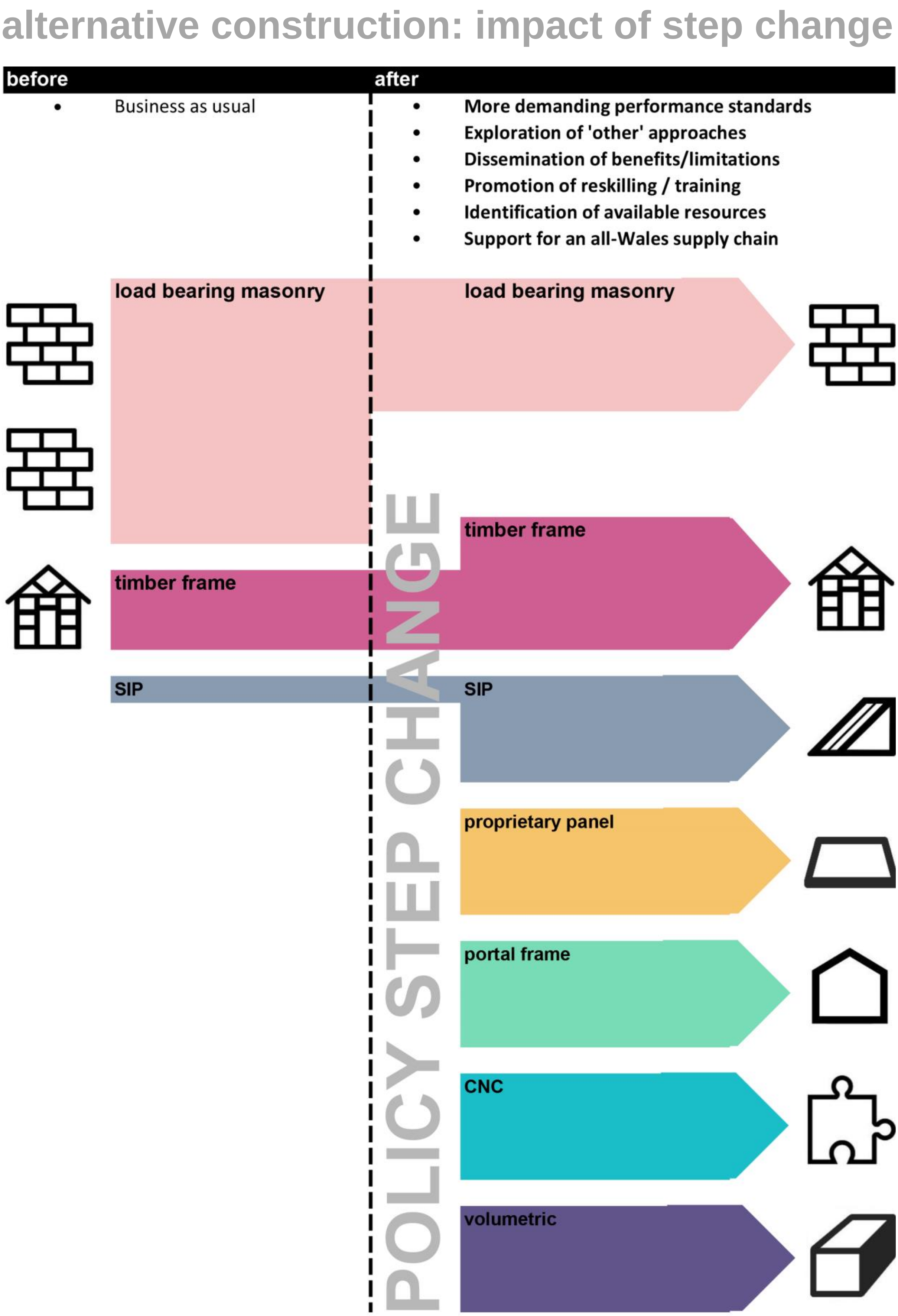


Figure 7.3B: Impact of a targeted step change on housing delivery, forms of construction

Alternative approaches: incentives + concerns

Figure 7.3C: Perceived issues were identified during a survey of occupants, homeowners and prospective self-builders, and were prioritised by two experienced industry consultants:

during construction

incentive

- Reduced capital costs
- Ease of construction
- Reduced programme time
- Use of sustainable materials
- Reduced waste / resource use
- Facility to build bigger
- Lesser environmental impact

concern

bigger issue

- Higher capital costs / good value
- Unpredictable costs / programme
- Ability to obtain planning / building regs
- Track record / post occupancy evaluation
- Ability to obtain mortgage / insurance
- Aesthetics that do not fit in
- Availability of constructors / materials

Lesser issue

in use

incentive

- Improved quality of build
- Reduced running costs
- Ability to adapt / extend
- Improved functionality (flexibility)
- More comfort (warmth, light, acoustic)
- Improved health
- Lesser environmental impact
- As a legacy for future generations
- Self sufficient (autonomous)

concern

bigger issue

- Ease of maintenance
- Replacement of specialist products
- Impact on future value
- Impact on resale / marketability
- Lifespan of materials / construction
- Ability to adapt / extend
- Complexity of controls
- Impact on air quality
- Facility to open windows

Lesser issue

"I strongly believe that we need to embrace new, sustainable approaches for housing, but there are challenges ahead. Negative views abound, brought about by the mistakes of the past. We need buildings that can deliver real benefits, not just for developers but for the wider public, and that meet a rigorous set of standards. The time has come to rethink materials that have previously been seen in a negative light by developers and purchasers alike. We need to develop the products and skills that are required to deliver these homes successfully. Wales must become the land of innovation, and create solutions that can be promoted across the world… underpinned by a consistent, green building standard –something we all come to recognise as a benchmark for quality."

Wynn Prichard is Director of Construction Skills and Business Strategy at NPTC group of Colleges.

"Alternative construction excites me for a number of reasons. It provides the possibility of more affordable housing, but it also aligns with some core beliefs that are ubiquitous amongst housing associations: customer focus, community benefits and sustainability. Innovative solutions open the door to opportunities that traditional build methods do not provide. For us, this might mean developing rapidly deployable or adaptable units to meet the changing needs of our customers. For the communities it could provide real opportunities to involve end users in the supply chain and in construction itself – creating jobs literally on people's doorsteps. Lastly, controlled and repeatable manufacturing techniques would allow us to better measure the environmental impact of the entire process, and look at ways to improve our performance."

Robert Panou is Development Manager for Bron Afon Community Housing.

7.4 | local leadership

The planning system focusses on larger parcels of land as candidate sites for housing, and Local Development Plans remain dominated by zoning of uses which limits the degree to which infill / pocket sites, exception sites or retrofit opportunities are identified.

A more creative mapping of existing settlement cores and edges would identify opportunities for development that consolidates settlements rather than encouraging sprawl. Greater Manchester is going a step further, and asking the public to assist in the identification of possible sites for housing, which are then added to a publicly accessible database.

Local authority land banks offer one of the more obvious pathways to delivering more housing. Elsewhere in Europe, land earmarked for housing is valued and then sold at a fixed price to the developer with the best scheme, rather than tendered to the highest bidder.

Some Welsh LA's are already working with private funders and developers to deliver social and affordable housing – see Cardiff HPP, case study 2.1. This approach can be fruitful, so long as packages can be put together that balance the delivery of affordable housing with for-sale market housing. Used to advantage, package developments that include desirable sites can facilitate the development of more challenging sites. However, for this approach to work more widely across Wales, land values would need to be re-appraised, greater value attributed to *better* homes, and isolated communities become more connected.

In Europe, many councils reserve a portion of land on all major developments, for community-led housing projects. Such developments consistently deliver savings and build homes to much higher standards, as well as delivering homes that people actively desire.

RECOMMENDATIONS

Local Authority-administered registers should be established to assess local appetite for self-build, and to connect communities that have a greater chance of success by working together.

LAs could facilitate self-and community-build projects, as well as other delivery pathways, by providing serviced building plots with 'principles of development' in place. If land can be provided at an affordable price, the two biggest barriers to self-build are removed.

There is scope for public infrastructure projects such as the South Wales Metro to 'find' new homes. There are around 23,000 empty properties in Wales. Well placed infrastructure projects could unlock significant quantities of housing without building a single home, by transforming isolated, deprived or undesirable communities into desirable places to live.

Infrastructure and investment should be used to transform marginal settlements into vital communities. Local authorities should have a role in this, ensuring that national policy is translated into locally appropriate planning, and that any new development is sympathetic to the nature, character and opportunities of the place.

Powers that enable Local Authorities to tackle derelict or empty infill sites, unoccupied buildings and land-hoarding by investors should be exploited.[12]

---

[12] Since new powers were provided by WG in March 2016 to tackle the issue of vacant properties, two Local Authorities (Anglesey and Pembrokeshire) have increased Council tax rates for long-term empty homes, and Newport City Council (2,500 vacant properties) are currently considering proposals to double the tax.

7.5 | cost versus value

The UK is among the most expensive countries in the world to build. (According to BCIS data, the 'typical' cost of new housing in the UK is around £1050 per m^2, plus the considerable costs associated with land, consultant / statutory fees and abnormals[13].) Changes to Building Regulations Part L1 (Wales 2015) have improved the target thermal performance of dwellings by around 8% on prior standards, but have also added cost. On top of these costs, accessibility adds to the cost of new housing by making homes bigger and more complex, particularly in locations where topography is challenging. The recent introduction of sprinklers into new homes has added further cost to housing delivery.

WG is committed to the delivery of more homes to better performance standards. However, Wales includes some of the most deprived areas in Europe. In the past, pilot affordable housing projects have attempted to attain higher standards (for example CfSH level 5/6) by adding 'bolt-ons' to established approaches rather than considering alternatives holistically. In many cases, this has resulted in untenable cost increases: "…the Code Pilot programme supported the emerging trends and understanding that the cost of delivering zero carbon on site was prohibitive, and could offer serious challenges in both cost and design principles." (BRE, WG Code Pilot Programme Technical Report ref. 285-001, 2013) For lower income communities, the prospect of purchasing housing outright at these costs is unrealistic. Approaches are needed that deliver more, better housing without untenable cost increases.

None of the case studies, all of which outperform Building Regulations Part L1, were delivered for costs in excess of £1500/m^2. Capital costs on some case studies are elevated because approaches and techniques are at an early stage of development. Few employ approaches that are being delivered at scale, suggesting scope for costs to reduce.

Self-build case studies do deliver housing below the 'typical' costs of around £1050/m^2. The shell and fit-out case study (Graven Hill) proposes to deliver a habitable shell for £810/m^2. Self-build is becoming viable for more households as a result of some emerging approaches, and capital costs for very basic self-build projects start as low as £460/m^2 (shell only). However, self-build is limited in its applicability and does not provide a panacea.

Another means of reducing capital costs is to reduce the size of houses, combining the benefits of lower cost per unit with higher densities (ie. more homes on the same land). However, studies have drawn connections between lower space standards and issues with functional performance / perceptions of quality. Approaches of this kind should only be targeted at specific housing types, e.g. starter housing, where there is a clear longer term intent to adapt / extend. Some construction techniques make this approach more feasible.

It is important to distinguish between cost and value. Irrespective of capital costs and costs in-use, wider increases in quality, performance and productivity mean that alternative approaches can deliver better value than traditional approaches. A number of the schemes propose to deliver significantly 'better' homes in terms of energy conservation and reductions in heating bills, without considerably increasing capital cost beyond the UK mean. The financial implications of these approaches are difficult to report without complex, in-depth cost analysis, because impacts are potentially so wide ranging. All approaches reduced primary energy consumption and heating bills for residents. Three case studies generate significant income through renewables (PV) as well as offsetting energy costs. Wider

[13] According to BCIS data for a sample of 1079 builds in the third quarter of 2016, mean house build costs were £1046/sqm, with the lower quartile range down to £922/sqm and the upper quartile up to £1191/sqm.

implications include reduced pressure on local systems (including environmental systems and healthcare), increased local employment, and increased local economic activity.

A number of the approaches adopted by the case studies would be increasingly affordable if developed at scale. Welsh Government, local authorities and housing associations could use their influence and buying power to encourage the construction industry to reduce the cost of alternative approaches, by investing in technological and manufacturing capabilities. Developing appropriate technologies in Wales would build new capacity for local construction. Facilitating an all-Wales supply chain would keep much of the expenditure related to housing delivery within Wales, reduce development costs, reinvest expenditure in Welsh industries and, longer term, develop Welsh expertise and products for export.

Two of the case studies demonstrate that, in the right context, renewables provide a means by which housing delivery can be re-considered as an income stream, and the costs of living offset, to deliver more affordable housing. A number of housing providers are actively exploring this concept. However, to be successful, energy generation must be properly integrated – in terms of both construction and ongoing operational / maintenance regimes.

Negative impact | Marginal impact | Positive impact

'what works' (see section 7.1)	Short term capital cost	Short term value	Long term cost in use	Long term value	notes:
Fabric first	Negative	Marginal	Positive	Positive	Improvements in fabric efficiency are not adequately 'valued' by the market, but deliver real long term value
Airtightness	Marginal	Marginal	Positive	Positive	With the right approach, airtightness has as much to do with quality on site as cost. Energy savings are considerable.
MVHR	Marginal	Positive	Positive	Positive	Combined with fabric first approach, initial cost can be offset against heating system costs. Long term savings.
Permeable fabric	Positive	Marginal	Marginal	Positive	Typically demands more expensive products, but delivers health benefits. Could be linked to local supply of materials.
Passive solar	Positive	Positive	Positive	Positive	Good design at outset has low cost implications, delivers higher quality internal environment and reduces energy used.
Water heating	Marginal	Positive	Positive	Positive	Modest initial costs combined with good practice design produce modest long term savings.
Renewables	Negative	Positive	Positive	Positive	Payback periods for different technologies now well known. Potential source of income for developer / providers.
Other targets / aspirations:					
local resource use	Negative	Positive	Marginal	Positive	Local resources often cost more today, but wider use would develop economies of scale and support wider Welsh growth
'green' materials	Negative	Marginal	Marginal	Positive	'Green' materials typically come at a premium, but reduce long term impact and may improve potential for reuse
prototype system	Negative	Positive	Marginal	Positive	Use of prototype systems will increase capital costs, but provides immediate learning and supports long term gains
Self-buildable	Positive	Positive	Marginal	Positive	Self build market relies on low labour costs to increase affordability but also delivers greater long term appreciation
Carbon storing	Marginal	Positive	Marginal	Positive	Some approaches facilitate carbon storing at little / no cost. Key benefit is short and long term carbon sequestration.
Fewer specialists	Marginal	Positive	Marginal	Positive	Less use of 'trades' increases applicability. Involvement of client/community leads to ownership of build / long term care

Figure 7.5A: Impact on cost and value of key factors associated with alternative approaches

7.6 | initiating a step change

A step change is needed. Wales should lead the way by placing affordable housing and affordable warmth for all at the centre of national policy, with homes and places that meet our needs, now and in the future. The creation and maintenance of sustainable communities could provide a new focus for post-industrial Wales, facilitating joined-up development that works at a local level, with all of the benefits of a Wales-based supply chain.

To facilitate a step change in the quality and quantity of housing, Welsh Government should:

- Initiate a working group tasked with understanding housing within the context of current and future housing need in Wales, truly affordable housing (including affordable warmth) and the emerging implications of the WFG(Wales) Act.
- Map existing and emerging housing standards including Building Regulations, DQR, Sustainable Development and Wellbeing strategies and policy against existing and emerging performance standards, including Passivhaus and FEEs, Lifetime Homes and the Living Building Challenge, using cost- and performance-based metrics.
- Liaise at an international level with policy makers, housing commissioners and industry practitioners, participating openly in an international innovators network.
- Establish an open-access Welsh house-builders’ forum, to provide anyone interested in building homes with relevant resources including a database of other users and prospective sites, and links to emerging best practice, whether they be a house-building consortium, co-operative, collective or a motivated single person.
- Map housing need (including specific types of need, such as self-build), supply and development opportunities (both new and existing) in a transparent, joined-up way that encourages public engagement, and supports community initiatives.
- Nurture industry that is located in Wales, using resources found in Wales, with potential to contribute to a Wales-based supply chain, and engage with suppliers, fabricators and manufacturers who are considering doing the same.
- Explore the densification of existing communities (targeting lower density areas), through a combination of new build in-fill and inventive re-use of existing, underused neighbourhoods.
- Translate this learning into a clear, concise, flexible, adaptable housing standard.

This new Welsh Housing Standard should promote quality, diversity, sustainability, shared learning and equality. It should be capable of adapting to emerging best practice. It should demand excellence in the built environment, to ensure that Wales has a clear pathway to Zero Carbon, and a means of developing sustainably for the future, in line with the Wellbeing of Future Generations (Wales) Act (2015). Above all, it should encourage more | better housing delivery from *all* appropriate pathways.

7.7 | promoting more | better

The perspectives gathered within this report suggest that by exploiting alternative delivery pathways and construction techniques, we could be constructing new homes and neighbourhoods in a more contextually appropriate way, with greater long term value.

Together, these approaches provide a range of different pathways that could lead to more diverse housing being built, and a better quality of housing that is more fit-for-purpose, more affordable and more sustainable. These approaches have the potential to deliver new homes *in parallel* with more established delivery mechanisms, so long as knowledge is shared, to enable informed decisions to be made by commissioners and constructors.

'Exemplar' affordable housing projects should be supported and, if possible, commissioned by WG. The location, site, brief, project team and procurement route adopted for these pilots should be considered carefully, in order to:

- Test emerging Welsh Housing Standards against a range of different dwelling 'types', to identify weaknesses, limitations (in terms of cost or performance) or other potential to improve or refine the standards.
- Identify, through live comparative projects, the relative benefits and limitations of a range of different construction techniques. Criteria to include energy use (embodied and in-use), carbon (embodied and in-use) and detailed cost comparisons (capital costs and running costs).
- Explore, using the same comparative projects, more qualitative implications of each technique including neighbourhood, sense of place, and kerb appeal, along with the facility of each technique to deliver housing that offers flexibility, adaptability, ease of maintenance and eventual re-use through disposal.
- Target approaches with potential to deliver particular types of housing, for example young persons' single bedroom apartments, or that suit alternative pathways to housing delivery, for example community-built projects, or that offer wider ongoing benefit, for example skills training.
- Incorporate, where appropriate, local resources, materials or products, that might be developed into a Welsh supply chain in support of the aspiration for house-building and the development of sustainable communities to form a basis for new 'industry'.
- Generate wider learning opportunities through an open-access methodology, a broad interdisciplinary team of stakeholders, and a focus on continually identifying and nurturing opportunities for further research and dissemination.

If Wales is to rise to the challenge of the housing crisis by constructing a legacy of homes that future generations consider to be a blessing and not a burden, the correct standards, incentives and monitoring must be put in place to encourage *all* existing pathways, along with some that do not yet exist, to produce more, better housing

8.0 | useful links

Section 2.0

Wellbeing of Future Generations (Wales) Act (2015) https://goo.gl/sQTRfv

Building better places (report), House of Lords (2016) https://goo.gl/yGBLH7

Section 2.1

PPIW publications:

Future Need and Demand for Housing in Wales (2015) https://goo.gl/pSCb9x

Meeting the Housing Needs of an Ageing Population in Wales (2015) https://goo.gl/FMeUdV

Section 2.2

NaCSBA website and updates http://www.nacsba.org.uk/pressandnews

The Way we Live now (report), RIBA with IPSOS MORI (2012) https://goo.gl/ShOjid

Survey of self build intentions, IPSOS MORI / NaCSBA (2014) https://goo.gl/dJjOww

Section 2.3

Footprint policy http://www.blueprintregeneration.com/wp-content/uploads/2015/07/footprint-pdf.pdf

Section 3.0

London Housing Design Guide, London Development Agency (2010) https://goo.gl/jzU0wG

Homes for Wales: A White Paper for Better Lives and Communities, WG (2012) https://goo.gl/guI70e

Section 3.1

UK Passive House organisation http://www.passivhaustrust.org.uk/what_is_passivhaus.php

Passivhaus, BRE http://www.passivhaus.org.uk/

Section 3.2

Zero Carbon Hub (closed for business March 2016) definitions and policy http://www.zerocarbonhub.org/

Closing the Gap - between Design and Performance (report), Zero Carbon Hub (2014) https://goo.gl/gc9DLo

SOLCER house, WSA http://sites.cardiff.ac.uk/architecture/news-items/solcer-house/

Section 3.3

Living Building Challenge: Framework for affordable housing (report) ILFI, 2014 https://goo.gl/2QCVwv

Western Solar website http://westernsolar.org.uk/ty-solar/

Section 4.1

Research into the potential demand for co-operative housing in Wales http://wales.coop/coop-housing/

Section 4.2

Every Breath We Take (report), Royal College of Physicians (2016) https://goo.gl/Na9NN0

Dwelling: design of low/zero carbon buildings (report), LCRI / WSA (2011) http://orca.cf.ac.uk/27168/

Section 5.1

Accommodating Growth in Town Centres (report), Maccreanor Lavington Architects, Peter Brett Associates, Graham Harrington Planning Advice (2014) https://goo.gl/UcwCNO

Section 5.2

Design Commission for Wales' 'LandMarks' conference publication – a collection of essays: https://goo.gl/lFxf9e

Section 6.1

Decent homes standard: beyond decent homes, DCLG (2010) https://goo.gl/jQX4Bj

9.0 | List of collaborators

This report was funded by Welsh Government's *Homes and Places* division. The views expressed do not represent Welsh Government policy. The report was written collaboratively, with the involvement of a wide range of practitioners, academics and industry advisors. Collaborators are listed in the order in which their contribution appears:

Lauren Carter-Davies, PPIW

Cardiff City Council

Ted Stevens, NAcSBA

Graven Hill Village Development Company

Glen Howells architects

Chris Brown, IGLOO

Loyn and Co. architects

Jonathan Hines, Architype

Rob Pannell, the Building Hub

Welsh School of Architecture, Cardiff University

Pobl Grwp

Martin Brown, Fairsnape

Western Solar and Gareth Dauncey architects

David Palmer, Wales Co-operative Centre

White Design

Gary Newman, Wood Knowledge Wales

Kevin Logan, Maccreanor Lavington

Emmett Russell Architects

Niall Maxwell, Rural Office for Architecture (ROA)

Pentan architects

Mike Fleming, Glosford SIPS

Alford Hall Monaghan Morris (AHMM)

James Picard, Cartwright Pickard

Legal and General Homes

Alex Whitcroft, KIN architects

Architecture 00

WikiHouse Foundation

Robert Panou, Bron Afon Community Housing

Wyn Prichard, NPTC Group