IDEAhaus:
A Comfortable Home for the UK's Future Climate

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ABSTRACT: This paper describes the result of a project to develop climate adaptation design strategies funded by the UK's Technology Strategy Board. The aim of the project was to look at the threats and opportunities presented by industrialised and lightweight housebuilding techniques in the light of predicted increases in flooding and overheating. This case study presents detailed concept designs for a future systemised housing product which can be Industrialised, Delightful, Efficient and Adaptable; an IDEAhaus.
Keywords: climate change adaptation, thermal comfort, passive cooling, industrialised housing, mass customisation

INTRODUCTION

There is a great need for mass affordable housing production in the UK and greater industrialisation of the process could bring better quality, speed and predictability to it's delivery. However, factory made housing has not been able to provide the variety and flexibility necessary to respond to different site context and programme requirements. Much recently built highly insulated, air-tight, timber frame housing is suffering overheating and is highly susceptible to flood damage. Supertight houses requiring MVHR systems to provide suitable air quality, present landlords with risks in terms of resident mis-use and lifestyle issues, maintenance burden and health factors.

The project took a proposed social housing development in Liverpool designed to current regulations and modelled energy and thermal performance with UK Met Office climate projections up to 2080 [1]. Analysis showed significant risks of overheating now and cooling demand outstripping heating demand within 20-30 years.

The case study developed designs for a building system which would be more resilient to flood damage and resist overheating through passive cooling techniques, including shading, thermal mass and natural ventilation strategies. The system is based around a limited number of components which can be assembled to provide different sized homes, a modular service/circulation core and a range of cladding and double skin options. The designs illustrate how spatial flexibility, customiseable facades, thermal improvements and future adaptability could revolutionise UK housing production.

FUTURE CLIMATE IN THE UK

Climate change forecasting is an uncertain science. In the UK the Department of Environment, Food and Rural Affairs have produced a range of Climate Projection scenarios known as UKCP09. These cover a range of years (2030, 2050, 2080), emissions scenarios (low medium high) and probability (33, 50, 66 and 90 percentiles). The probabilities here are the likelihood of a certain climate being not exceeded, so the 90th percentile model is the most extreme with only a 1 in 10 chance being exceeded. From these scenarios, the Prometheus Project [2] at the University of Exeter have projected climate as a yearlong set of results that mimic the CIBSE dsy (design summer year) and try (test reference year) data. The scenarios are in the form of hourly data, in Energy Plus format (epw) for use in most energy modelling software. In general the anticipated pattern of change is towards hotter dryer summers, milder wetter winters, stronger winds and more frequent, more extreme events such as heatwaves and storms.

Psychrometric analysis was carried out to identify potential passive cooling strategies.

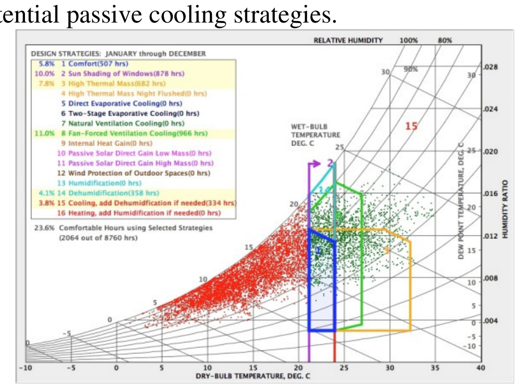

Figure 1. Liverpool Pyschrometric chart. Baseline climatic data. 2080 Hi-Em 90th Percentile.

The current DSY shows very little need for any environmental control other than solar control. By 2030 there is a need for a co-ordinated cooling strategy –

thermal mass. By 2050 there is increased humidity over 2030 - more ventilation with high thermal mass. In 2080 there is increased temperature and humidity, making passive solutions difficult – ground cooling is one option. Average increase in summer temperatures is an astounding 9degC by 2080. The maximum temperature will also increase by over 11 degC.

TIMBER BUILDING SYSTEMS REVIEW

A desktop appraisal studied different types of timber frame systems. In summary, the study found that full volumetric systems were too limited by transportation constraints and could not offer sufficient variety in the end product. Open panel systems were economic but could not offer the speed and quality benefits of more industrialised options. Cross laminated timber was uneconomic and over engineered for simple low rise housing. The team concluded that a hybrid approach of closed panel and partial volumetric construction for repetitive elements eg. bathrooms, could provide a fast watertight shell using large standardised components in a variety of configurations whilst allowing customised cladding and fit out options.

BASELINE SCHEME

An existing scheme for the site was selected to act as a ‘baseline’ for comparative thermal and energy modelling. The baseline site layout adopted a diagonal solar orientation with houses facing SW, SE, NW and NE in square urban block arrangements.

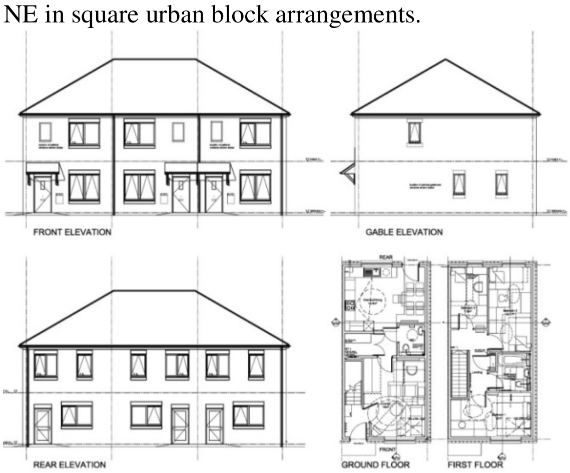

Figure 2: Baseline 3B5P Housetype

A typical 3 bedroom 5 person, 2 storey, semi-detached/end terraced house with traditional elevations was selected. The assumed construction specification was for a high performance closed panel timber frame system. The fabric was therefore highly insulated (wall, floor and roof U-values at approx. 0.1W/m2K) and reasonably airtight (5m3/h/m2) but not requiring whole house Mechanical Ventilation with Heat Recovery (MVHR) systems.

Thermal modelling was carried out with IES software for each possible orientation of the property, but this made very little difference to the thermal modelling results, probably because the front and rear elevations had similar amounts of glazing and the diagonal solar aspect tended to equalise the exposure to sunlight.

SE facing bedroom 1

			peak temp	hours> 25degC		hours> 28degC	
			degC	hours	%	hours	%
CIBSE guide					5		1
timber frame	2010 DSY	annual	35	573	19.6	192	6.6
	2010 DSY	jul/aug	35	310	62.5	141	28.4
	2080*	annual	39	2605	89.2	1474	50.5
	2080*	jul/aug	39	496	100.0	370	74.6
brick/block	2010 DSY	annual	29	396	13.6	81	2.8
	2010 DSY	jul/aug	29	286	57.7	42	8.5
	2080*	annual	33	1391	47.6	934	32.0
	2080*	jul/aug	33	496	100.0	262	52.8

Table 1: summary of internal overheating modelling (IES) on baseline housetype for 2010 &.2080 Hi-em 90th%tile*

The table illustrates overheating in a typical SE facing double bedroom. CIBSE guidance is for internal temperatures not to exceed 25degC for >5% of annual habitable hours and 28degC for >1%. This is not applied to domestic housing in the UK but is used in other residential buildings. The modelling used 2010 DSY data and a high emissions scenario 2080 90th%tile projected weather set from the Prometheus database to look at a ‘worst case’ future year. Findings showed 6.6% >28degC in 2010 rising to 50.5% in 2080. If only summer month Jul/Aug are considered, this equates to 28.4% in 2010 and 74.6% in 2080. Peak temperatures are 35degC in 2010 and 39degC in 2080. The table then compares results for a brick & block ‘traditional’ construction. This shows a significant reduction in overheating with 2.8% >28degC in 2010, and 32.0% in 2080. Jul/Aug results show 8.5% in 2010 and 52.8% in 2080. Peak temperatures are also significantly reduced at 29degC and 33degC respectively.

Energy modelling of the timber frame house was also carried out using Sefaira Concept software [3].

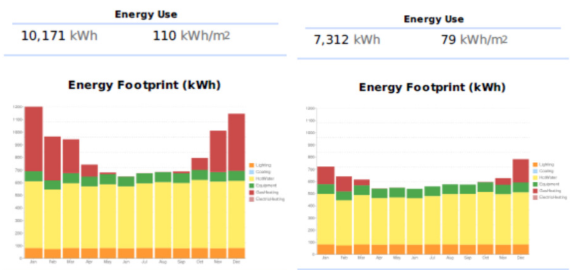

Figure 3: energy analysis for 2010 and 2080 high emissions scenario 90th%tile energy analysis

This analysis shows the space heating demand (red) reducing to a minimal level by 2080. Hot water, lighting and appliances (yellow, orange & green) are constant

The modelling was then repeated with the addition of air-conditioning.

Figure 4: energy analysis with air-conditioning at 25degC set point for 2010and 2080 high emissions scenario 90th%tile

This analysis shows that reduced heating demand is counteracted by increasing cooling demand (blue). and the overall energy demand would actually increase. Further IES analysis shows that energy demand for cooling could overtake heating demand before 2040 in a 90th%tile year

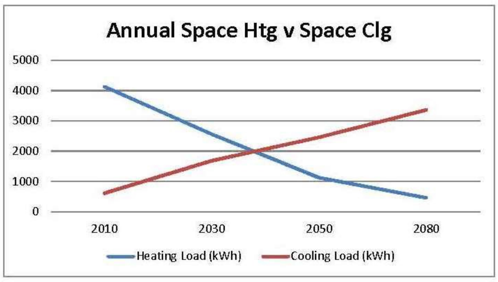

Figure 5: Timber frame - Space Heating v Cooling energy demand using high emission scenario 90th%tile projections

The 'carbon crossover' would arrive even sooner as cooling energy is more carbon intensive (from electricity) than space heating (from gas central heating) in the typical UK situation. The team therefore concluded that the importance of heat loss will diminish and that more attention must be paid to overheating and reducing the demand for summer energy use.

CLIMATE CHANGE RISK ASSESSMENT

A detailed Climate Change Risk Assessment (CCRA) was carried out considering weather data and projections for 2010, 2030, 2050 and 2080. This identified 103 risks arising from increased frequency and intensity of extreme wind speeds, rainfall events and heatwaves as well as considering general increases in these. The question arose 'are we designing for the ride or the crash?'

CCRA - summary of risks identified by 2080

	low	medium	high	total
rain	34	35	0	69
wind	3	6	2	11
temperature	8	10	5	23

Table 2: CCRA summary of number & severity of risksidentifid

The highest number of risks were identified for flooding but the greatest severity of risk was for overheating. The flood risks for this site were generally low due to topography but there are high risks for timber frame's vulnerability to permanent water damage.

Future flood return intervals are difficult to assess since they are based on historic data. For example a current 100 year flood event is projected to become a 50 year event by 2080 within a widening probability band [4]. However, there is no new projected 100 year flood data for 2080.

Future extreme wind events were also lacking in the data which projected general wind increases but not extreme gusts. Timber frame performs well in wind and the engineers felt current safety factors were adequate.

Prolonged overheating presents a danger to health. Death rates amongst elderly people rise sharply above roughly 28degC. Overheating also raises the likelihood of carbon intensive cooling systems being retrofitted.

IDEAHAUS CONCEPT

The final stage in the project was the design development of an idealised future housing product which could be mass produced, flexible in design and include passive design strategies for flooding and overheating. Branded the IDEAhaus, this would be: Industrialised, Delightful, Efficient, & Adaptable

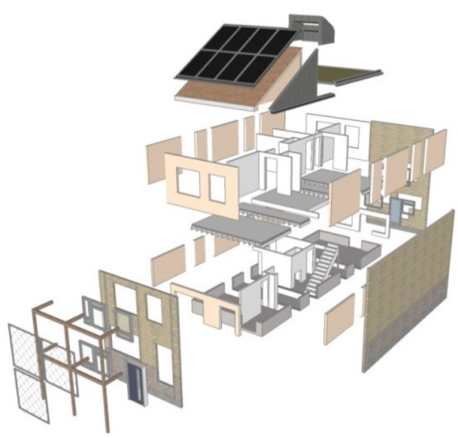

Figure 7: Exploded view highlighting component kit

INDUSTRIALISED

- **Standardisation** – mass production of regular core components for the superstructure
- **Manufacturing quality** – enhanced quality achieved by production under factory conditions
- **Predictable cost & delivery** – through repetitive design, specifications and construction methods
- **Economies of scale** – through bulk purchasing power and availability of stock items

DELIGHTFUL

- **Spacious** – designs based on detailed furniture layouts and activity spaces, good ceiling heights and central light well

Figure 8: Elevational options – brick, timber, render/panel

- **Individualised** – different possible room layouts, fenestration, cladding and finishing options
- **Comfortable** – through use of thermal mass, good ventilation, shading options and radiant heating systems
- **Quality** – high quality products with finishing options

EFFICIENT

- **Passive design** – highly insulated fabric with thermal mass, good controllable natural ventilation and shading options.

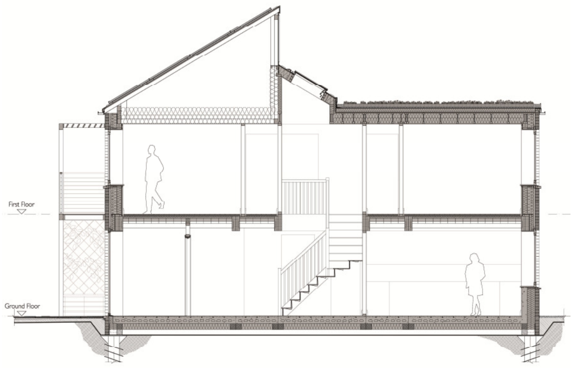

Figure 9: Long section

- **Renewable energy options** - ability to incorporate renewable energy systems
- **Low impact materials** – sustainably sourced materials, engineered to minimise waste
- **Fast construction** – predictable design time and quick to erect watertight shell construction

ADAPTABLE

- **Flexible layout** – designed to UK's Lifetime Homes generous space and accessibility standards

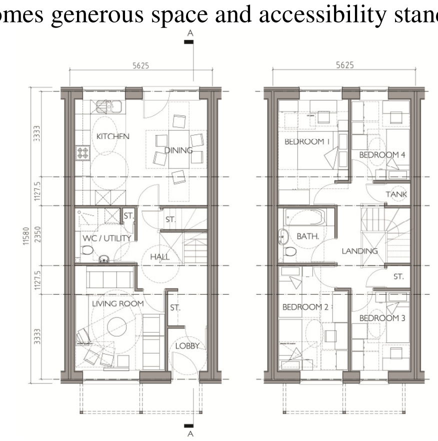

Figure 10: 4 bed 6 person house floor plans

- **Climate resilient** – flood resilient and overheating resistant construction
- **Additive features** – construction allows for exo-structure options and vertical extension
- **Upgradable performance** – allowing for replaceable cladding, solar panels and services

IDEAHAUS CONSTRUCTION

Following the philosophy of mass customisation the construction is considered as: Core construction, Additive components, Adaptable services.

CORE CONSTRUCTION

Foundations – helical steel screw piles are proposed to suit virtually any site conditions (eg. urban housing on filled brownfield sites) with minimal disruption and preparation. They can reduce site excavation and minimise cost of landfill taxes. They allow large shading trees to be located closer to buildings without root damage to foundations.

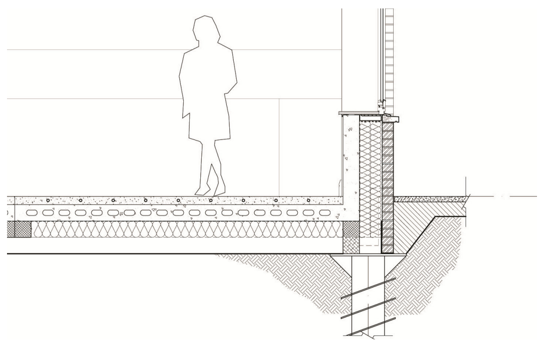

Figure 11: Ground floor to External wall detail, highlighting flood resilient floor slab upstand

Ground floor – large precast concrete units with flood resilient upstand edges, bonded damp membrane and closed cell insulation to the outer faces giving a dpc level 750mm above floor level and a high thermal mass. The units span between pile caps on insulated blocks with reinforced upstand edge beam. Units are designed to a standard house width of 5.6m to suit 2, 3 & 4 bedroom house types. A standard position is given for front and rear doors within two large 3.3m units. A central 2.4m unit is designed to suit a WC/utility & stairwell and 1.1m infill units are used to extend the housetype to suit the number of bedrooms required.

Wall cassettes – pre-insulated timber frame wall cassettes with 120mm pre-cast 'Hemcrete' insulation and 200mm of hemp fibre insulation quilt [5]. The hemcrete product provides excellent thermal mass and phase change properties which enhance its performance. The cassette has a breathable construction and good humidity control performance. Window openings can be individually designed and proposals shown are set out to suit standard brick dimensions.

Upper floor cassettes – open panel cassettes over main living spaces are of exposed engineered timber edge beams and joists. These are infilled on site with hollow clay blocks based on the Ibstock 'Coolvault' system [6] which provides thermal mass and a self-finished vaulted ceiling to ground floor rooms and a timber boarded finish above. The central area around bathrooms and stairs are closed panel with plasterboard ceilings to allow service distribution.

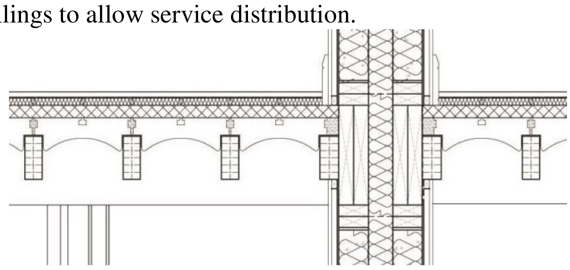

Figure 12: party wall/upper floor detail

Central volumetrics – the highly serviced central area with bathrooms, stairs and main heating system is standardised for all the house types and would suit off-site volumetric construction and could even be stock items. Finishes and fittings could be completed to standard or individual order. The upper volume has a pre-assembled roof cassette to match the main flat roofs.

Roof – the south facing roof is proposed with a 30deg pitch for optimum solar collection potential. This can be pre-assembled (on or off-site) in trussed rafter and purlins spanning between party walls. With plywood boarded finish to provide racking and suit different cladding options. North facing roofs are proposed in pre-insulated closed panel cassettes.

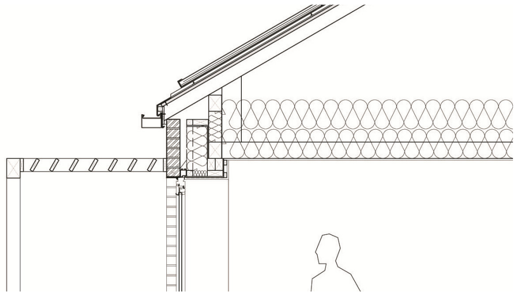

Figure 13: Eaves detail

ADDITIVE COMPONENTS

External cladding – the proposals shows cavity wall brickwork cladding and zinc clad roofs with solar panels over the pitched roof. Other finishes are equally viable.

Green roof/roof garden – the north facing flat roofs lend themselves to a green roof/garden finish to aid in bio-diversity, rainwater attenuation and cooling micro-climate through evapo-transpiration.

Fit out – the layouts shown are based on highly specified UK social housing standards. This gives the flexibility to vary room sizes and shapes or go more open plan depending on the overall size of house.

Exo-structure & components – a grid of thermally broken fixing points is built into the façade for an optional 1.2m deep timber framed exo-structure with a range of porches, shading devices, balconies, trelliswork etc.

Figure 14: Exo-structure variations

Extra floors – the structure will support additional floors with a second staircase added for vertical extension. Roof cassettes can be demounted and reused.

ADAPTABLE SERVICES

PV-Thermal – composite PV-T panels are proposed to the south facing roof combining solar hot water collectors under photovoltaic cells. PV-T's can give a 40% greater energy yield for equivalent areas of roof than separate panel systems. A large hot water tank is provided at first floor level.

Underfloor heating & cooling – both floors are shown with underfloor heating pipework for comfortable radiant heat at low temperatures and allows heat exchangers to operate efficiently. The pipework can also be used for summer cooling to disperse heat from the structure. A gas fired boiler provides heating and hot water in combination with renewable energy sources.

Ventilation – the design has focussed on a natural ventilation strategy rather than whole house MVHR. Window patterns open top and bottom to enhance single sided ventilation airflow in rooms and the rooflight increases the options for cross ventilation. Windows can be securely restrained and insect blinds can be added in the reveals. Opening sizes shown allow a nightime purge ventilation rate of 6 air changes/hour at a modest air speed of 0.5m/s. Individual extract fans with heat recovery are proposed for kitchens and bathrooms.

Services distribution – external and party walls are dry-lined to allow a service zone for cables and pipework - all above 750mm for flood resilience. Wiring for the ground floor lighting runs in the top of the 'coolvault' units and drops through where required.

PERFORMANCE MODELLING

Overheating modelling was carried out on the IDEAhaus.

SE facing bedroom 1

			peak temp	hours> 25degC		hours> 28degC	
			degC	hours	%	hours	%
CIBSE guide					5		1
IDEAhaus	2010 DSY	annual	28	41	1.4	5	0.2
	2010 DSY	jul/aug		34	6.9	5	1.0
	2080*	annual	34	990	33.9	352	12.1
	2080*	jul/aug		496	100.0	200	40.3

Table 3: summary of internal overheating modelling (IES) on IDEAhaus. for 2010 & .2080 Hi-em 90th%tile dataset.*

The findings show the IDEAhaus proposal reduces the overheating problem significantly more than the brick/block option. Annual habitable hours >28degC are 0.2% in 2010 and 12.1% in 2080. In July/Aug this is also reduced to just 1.0% in 2010 and 40.3% in 2080. This is a 76% improvement over timber frame for 2080.

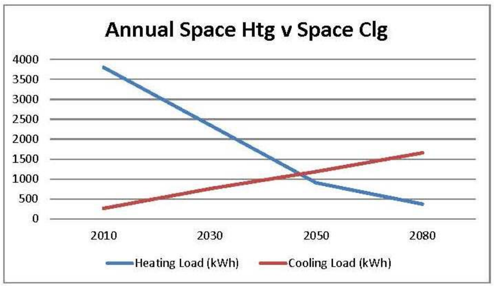

Figure 15: IDEAhaus - Space Heating v Cooling energy demand – Hi-em 90th%tile projections

IES analysis of the IDEAhaus heating and cooling demand shows a lower demand than the timber frame baseline house (half the energy requirement in 2080). It also moves the crossover point back 10 years.

CONCLUSIONS

There is a need for increasing cooling demand to be recognised in housing design. Appropriate passive cooling strategies can provide more comfortable and energy efficient houses. Timber frame structures can be flood resistant if adequately protected. Thermal mass can be incorporated into lightweight structures. Mass customisation can provide an industrialised but attractive choice of products. Adaptable construction can allow for future uncertainty.

Figure 16: Typical IDEA-Haus

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