AIMCH

TRANSFORMING HOW WE BUILD HOMES

Future Casting

July 2022

mtc Manufacturing Technology Centre

L&Q

Built Environment – Smarter Transformation

FORSTER GROUP

STEWART Milne GROUP

BARRATT DEVELOPMENTS PLC BUILDING EXCELLENCE SINCE 1958

INDUSTRIAL STRATEGY

UKRI UK Research and Innovation

EXECUTIVE SUMMARY

The UK's Net Zero Strategy: Build Back Greener is set to be achieved by 2035. The construction sector accounts for a third of UK carbon emissions so transforming construction, using greener practices, reducing emissions, zero carbon homes and integrating biodiversity and electrification are an essential part of this strategy.

The UK must achieve this to tackle climate change and reduce the warming of the planet, which is arguably the greatest challenge faced on this planet.

The AIMCH project (Advanced Industrialised Methods of Construction for Homes), funded through UKRI via the InnovateUK Transforming Construction programme, pushed the innovation boundaries for the housing sector, introducing applications that can truly transform the sector into something, greener, more efficient, more productive, safer and low and zero carbon. Further projects must follow on and build on the findings of AIMCH to create further solutions in the key areas of electrification, Whole Life Value, Zero Carbon and Assured Performance, to provide the housing sector with solutions to achieving the ambitious government targets and going beyond these.

"Future Casting" takes some of the learnings from AIMCH and presents a researched opinion piece, proposing areas for further development, which are not necessarily aligned with any particular partner in AIMCH and could form the basis for future projects with other interested parties and funders, whether in the UK or overseas. Hence, this report is framed as a discussion document, with recommendations for interested parties including funders.

Several innovations themes are presented and discussed in section 3, suggesting the potential for further activity and future projects. It is expected that each of sub-sections within section 3 would form the basis for further innovation, R&D and pilot projects, ultimately leading to deployment into mainstream housing developments or retrofit.

It is concluded that:

- "Fabric first" remains critical to enabling effective and efficient heating solutions for homes
- Advanced MMC methods can deliver improved fabric efficiency and productivity improvements at scale for volume house builders and suppliers. The approach can be adopted for further transformations in the sector
- Demonstrating effective, multifaceted energy balancing and storage solutions, whilst reducing the demand on the grid, is critical as we transition towards a 100% electric society
- Whilst delivering effective solutions for new homes is a key objective, the scale of the retrofit challenge is huge and must be tackled for there to be a broader impact on carbon reduction and fuel poverty across society
- There should be greater awareness of fuel poverty and the part that improved fabric can play in addressing this, as well as the benefits of renewable energy solutions

It is recommended that:

- There should be funding for projects that demonstrate a community solution to energy storage including SMART home integration applications
- There should be funding for projects that deliver retrofit solutions to energy generation and storage, including SMART home integration applications
- There should be funding for projects that demonstrate viable retrofit fabric improvements
- The industry should use standard KPIs to drive the required improvements in green energy and carbon reduction, as well as Social Value and Biodiversity
- There should be incentivisation from government and local authorities, including financial assistance, to drive the uptake of renewable energy solutions
- There needs to be increased training and awareness across the sector to improve the skills and knowledge base in terms of whole life value, whole life carbon, fabric efficiency, energy solutions, social value and biodiversity if the government is to achieve its net zero targets

TABLE OF CONTENTS

Title **Page**

1. Scope..... 6
2. Overview..... 7
2.1 Future Casting vs Exploitation..... 7
2.2 Structure of the report..... 7
3. Innovation Themes..... 8
3.1 Electrification & Integration..... 8
3.2 Whole Life Value..... 15
3.3 Assured Performance..... 17
3.4 Accelerating Net Zero Carbon Living..... 19
4.Conclusions..... 21
5. Recommendations..... 21
6. References..... 22
7. Appendices..... 23

Table

Table 1: Glossary of Term.....5

GLOSSARY

Term	Meaning
The Project	The AIMCH project as described in the Project Application
AIMCH	Advanced Industrialised Methods of Construction for Homes
Partners	Members of the consortium who have signed the Consortium Agreement
Lead Party	The party with overall responsibility for project
SMG	Stewart Milne Group (Lead Party)
Barratt or BDW	Barratt David Wilson Trading Ltd
CS-IC	Construction Scotland Innovation Centre (Re-branded as BE-ST)
BE-ST	Built Environment – Smarter Transformation (Formerly CS-IC)
Forster or FRS	Forster Roofing Services Ltd
L&Q	London & Quadrant Housing Trust Ltd
MTC	The Manufacturing Technology Centre Ltd
DfMA	Design for Manufacture and Assembly
EPD	Environment Product Declaration
EV	Electric Vehicle
HSE	Health and Safety and Executive
LiDAR	Laser imaging, detection and ranging
MMC	Modern Methods of Construction
NHBC	National House-Building Council
NZC	Net Zero Carbon
PMV	Pre-Manufactured Value -the proportion of manufactured components within an overall construction cost, i.e. manufactured off-site, e.g. in a factory
PMO	Project Management Office
PV	Photo Voltaic, e.g. cells used in solar panels
R&D	Research and Development
SAP	Standard Assessment Procedure

1. SCOPE

The UK's Net Zero Strategy: Build Back Greener is set to be achieved by 2035. The construction sector accounts for a third of UK carbon emissions so transforming construction, using greener practices, reducing emissions, zero carbon homes and integrating biodiversity and electrification are an essential part of this strategy.

The UK must achieve this to tackle climate change and reduce the warming of the planet, which is arguably the greatest challenge faced on this planet.

The AIMCH project (Advanced Industrialised Methods of Construction for Homes), funded through UKRI via the InnovateUK Transforming Construction programme, pushed the innovation boundaries for the housing sector, introducing applications that can truly transform the sector into something, greener, more efficient, more productive, safer and low and zero carbon. Further projects must follow on and build on the findings of AIMCH to create further solutions in the key areas of electrification, Whole Life Value, Zero Carbon and Assured Performance, to provide the housing sector with solutions to achieving the ambitious government targets and going beyond these.

This report discusses key outcomes of the AIMCH project, explores some learnings and challenges, and provides suggestions for further focus areas to help tackle the key issues that the sector is facing.

2. OVERVIEW

Throughout the 39 months of the AIMCH project, which was launched in February 2019, the project has pushed the boundaries in the application of innovative solutions for the house building sector, many of which are being taken forward by the partners into Business as Usual (BaU).

This makes this project an exemplar in terms of successful exploitation and Return on Investment (ROI) for a centrally funded R&D project. The separate Exploitation Plan delivered at the end of the project summarises the innovations and exploitation outcomes for each of the six partners involved.

This "Future Casting" report resulted from the desire of the Project Lead (Stewart Dalgarno of SMG) and Project Manager (Tim Limberger of Limberger Associates) to create an output from the project that presents some suggestions for areas of further development. This was discussed with Mike Pitts of InnovateUK, who fully supported this and suggested the title and context of this report being "Future Casting".

The lead author for this report is Hannah Limberger, AIMCH Project Coordinator/employee of Limberger Associates Ltd, with input from Tim Limberger, AIMCH Project Manager/Director of Limberger Associates Ltd. Material included is based on learnings from the AIMCH project and partners.

2.1 Future Casting vs Exploitation

The AIMCH Exploitation Plan, in its several up-issued versions, describes the strategy for establishing exploitation potential, the commercial and other benefits that could be realised through implementation and a summary from each partner of the several examples where they will or could exploit into their business processes.

"Future Casting" takes some of the learning from AIMCH and presents a researched opinion piece with areas of further development, which are not necessarily aligned with any particular partner in AIMCH and could form the basis for future projects with other interested parties and funders, whether in the UK or overseas. Hence, this report is framed as a discussion document, with recommendations for interested parties including funders.

2.2. Structure of the report

Several innovations themes are presented and discussed in section 3, suggesting the potential for further activity and future projects. It is expected that each of sub-sections within section 3 would form the basis for further innovation, R&D and pilot projects, ultimately leading to deployment into mainstream housing developments or retrofit.

3. INNOVATION THEMES

3.1. Electrification & Integration

Electrification and integration are key to addressing climate change, reducing carbon emissions and meeting the UK's Net Zero Strategy: Build Back Greener. Removing fossil fuels and replacing with cheap, clean energy, made in Britain, is the ultimate goal, set to be achieved by 2035 (1). Of course, reducing the carbon impact of industry, including the construction sector, along with how buildings and homes are heated, which account for almost a third of UK carbon emissions, are among the 10 Point Plan for a Green Industrial Revolution (1).

Developers are already designing homes that are "heat pump ready", but with the advent of increased utilisation of electrical solutions there is also the need to integrate the controls for these. Suppliers of electrical systems are providing software applications (apps) to control them, and some of these can be integrated through smart home control systems such as Google Home©, Alexa© and Apple Home©, but with the plethora of new suppliers entering the market, there is a danger of home- owners, landlords and tenants having a vast array of apps to control the various systems in a home, in a sub-optimal way, not always integrated to make to make the best use of the available energy vs the varying demands throughout the day.

The increasing utilisation of electrical energy is also placing demands on the electrical supply to the home that would require significant upgrading of the grid network unless mitigation solutions are implemented. The cost and disruption of upgrading the supply network is seen as very undesirable, and district network operators (DNO's) are seeking to mitigate this requirement by encouraging the development of solutions that include local energy generation, storage, high efficiency heating and the balancing of grid-supplied energy with that produced locally. Locally supplied energy could be provided by solar panels, heat pumps, wind turbines, hydrogen fuel cells, hydro, battery storage, electric vehicles, etc and could include balancing of energy needs across several homes and businesses in an integrated energy network.

A key innovation in the area of electrification and integration evaluated as part of the AIMCH project, was the Z House, 'a home of the future', led by Barratt Developments. The ultimate aim, as stated by Barratt Chief Executive David Thomas, was "to show what was achievable for mainstream volume housebuilders and find solutions that enable industry to build high-quality zero-carbon homes that customers love, at scale." (2)

The electrification and integration technologies demonstrated on the AIMCH Z-House included the following:

- Smart Home Monitoring Equipment
  - o Monitors energy usage at appliance and circuit level through the use of CT clamps and smart plugs/sockets
  - o Uses algorithms to define when and where energy generated from PV is best to be used or stored

- Photo-Voltaic (PV) solar panels, battery storage and Electric Vehicle (EV) inverter
  - o Estimated annual energy outcome of PVs is 4600kwh – enough electricity for a family home for four or five people
  - o 10kwh of battery storage could provide enough energy to run a laptop for 200 hours

- Air Source Heat Pump
  - o Combined with the hot water cylinder, provides both hot water and heating to the home
  - o Works with external temperatures as low as -20degrees
  - o Smart-enabled and any issues can be diagnosed remotely via technical support centre

- Heated skirting boards
  - o Combines skirting board and heating emitters in one package, saving space and cost
  - o Furniture in front of heat emitter does not affect performance
  - o Minimum coverage needed for maximum effect

- Low Water Sanitary Ware
  - o Turns off instantly if motion isn't detected, so reduces waste from taps being left running

- Magnetic heating flooring systems
  - o Easy to install as well as to retrofit
  - o Can be controlled remotely via app

- Lightweight roof tiles
  - o 86% lighter than equivalent clay or slate roof tiles
  - o Up to 25% recycled steel used in the manufacture – steel is more easily recycled than concrete
  - o Lighter weight reduces carbon footprint of material as well as transportation – reduced embodied carbon (3)\

There are some key learning points and challenges that need to be addressed to achieve successful implementation of innovative solutions to the challenge of net zero carbon:

- Skills shortages

  RICS reported that the labour shortage of skilled trades has increased throughout 2021 despite increasing workloads caused by new infrastructure projects. Sourcing materials was a big challenge on the back of the pandemic and post Brexit but finding labourers with the necessary skills is a key rising concern. Shortages were noted predominantly with bricklayers but were also seen with carpenters, plasterers, electricians and plumbers (4).

- Capacity in the supply chain and of adequate skills

  Along with skills shortages, a big concern is the lack of knowledge amongst labourers in the more 'future focused' space. A reluctance from investors to adopt green building designs or carbon neutral construction practices was noted at COP-26. RICS reports that "Around 22% said they'd seen no shift in support and nearly 40% said only niche investors had shown an interest in building more sustainably. Added to this, 56% of respondents confirmed that biodiversity was not considered at all or in fewer than half of the schemes on their books." This shows there is a real challenge in getting those in the sector to adopt these crucial green, MMC practices and is really concerning for the impact on sustainability and the impact on climate change, let alone the ability to meet government goals (4).

  The pandemic has undoubtedly had a big impact on the construction sector: the construction supply chain was one of the hardest-hit areas and this, coupled with the impact of Brexit, highlights the need for the supply chain to bounce back for the success of our economic recovery. The tragedy of Grenfell Tower highlighted the challenge of ensuring cost is not pursued at the expense of safety and risk, since such highprofile outcomes will result in long term impact on the sector. Reference (5) highlights the need for increased focus on outcomes rather than up-front cost.

  It is notable that the Construction Leadership Council has developed a 'Roadmap to Recovery', having 3 phases to be delivered over 2 years.

  - o Restart: increase output, maximise employment and minimise disruption (0-3 months);
  - o Reset: drive demand, increase productivity, strengthen capability in the supply chain (3-12 months); and
  - o Reinvent: transform the industry, deliver better value, collaboration and partnership (12-24 months) (6).

- Over Heating

  There have been several studies that suggest that new homes built to higher air tightness and insulation standards may be prone to overheating (7). This further highlights the importance of ongoing monitoring of occupants living in new homes constructed against new standards to ensure new homes support the wellbeing of occupants. A value-based approach to new developments could help reduce such problems.

Unfortunately, with the impact of climate change there is no doubt certain parts of the UK will suffer the effects of the predicted warmer climate, and this should be taken into consideration with new developments, along with retrofit solutions.

This could be seen as more reason to consider biodiversity at residential properties and developments, as it is well known that trees and vegetation cover are very effective in reducing localised surface and air temperatures.

- Indoor Air Quality
  Similar to overheating, indoor air quality has been noted as a concern due to the increased performance of new build homes. A study was completed in 2019 which showed poor quality in some homes that were monitored but these cases were due to not fully complying to ADF ventilation standards (8). Monitoring of new homes should continue with measures that ensure new homes are built to the correct standards. It should be noted that green walls and house plants can significantly improve air quality and the wellbeing of occupiers.

- Grid Capacity
  As renewable energy is an intermittent form of energy, the concern is that, as we turn fully electric, using heat pumps and electric cars, that the grid will not have capacity to deliver without the stability that coal, gas and nuclear provides. Clever balancing, battery storage, and reducing the waste of energy are going to become critical. Other developments are in heat recovery, hydrogen storage and carbon capture technology. These are all likely have a part to play in the future but a culture shift is certainly needed.

- Impact of Electric Vehicles
  Electric vehicle usage is expected to increase significantly over the coming years and, whilst this is a positive move towards a net zero society, there are several ways that EVs can negatively impact some industries and stakeholders:
    - o EVs will require a huge shift in the Automotive sector;
    - o The grid will have to cater for the increased demand caused by EVs;
    - o The production of batteries has a large environmental impact and the volumes of batteries needed could cause material shortages.

  It could be argued that moving to EVs is just shifting emissions from one sector to another (9). Therefore, in order to demonstrate a positive net impact and to convince society as a whole, the development of EVs as part of the zero carbon solution will have to be done very intelligently, with careful consideration for the impact on other industries and the environment.

- Other considerations:
    - o The Standard Assessment Procedure (SAP) tool will need to be updated to take into account new processes and solutions so that energy performance can be calculated correctly
    - o Integration of products and processes will be key to maximising efficiency gains and driving up customer satisfaction
    - o The sector and government should launch campaigns to increase sector and customer awareness of the opportunities and benefits from electrification and integration – it is suggested that customer awareness of this area is currently less than 20%.

Discussion

There is a clear need and market for lots more development in this area, this would more likely be seen as several projects, focusing on separate solutions but with the overall aim of compiling findings to achieve the wider, greater aim of zero carbon, electrified housing, running on renewables, which consider social value and focus on the environmental impact including biodiversity whilst tackling key issues of grid capacity, materials, skills etc.

With such a large aim, and with government goals to meet, it would be sensible to explore several solutions that meet the objectives and to deploy a range of solutions to work together and meet the overall aim. For example, looking at battery storage there are two main angles to consider: a community perspective, and an individual level.

A community perspective would look at a battery storage solution that serves a community, with homeowners making power through roof top solar to feed into a 'community power supply'. This would allow energy to be available at peak times through the energy stored when surplus is being made. However, this sort of system does mean that the homeowner would not own their own solar panels and would not be able to sell surplus energy back to the grid, which for those who can afford such systems is a significant financial incentive. The SCENe (Sustainable Community Energy Networks) project is a good example of this, and seeks to: "accelerate the adoption Community Energy Systems, a different way of generating and supplying locally generated heat and electricity to homes and commercial buildings. The benefits are reduced cost and more efficient use of distributed renewables to reduce the overall carbon emissions from the energy system. In addition, the utilisation of energy storage provides additional services to help keep the UK power networks more robust and stable. Most of the necessary technologies are available but they are too expensive for consumers to invest in themselves, and there is currently no business model in place to show companies how they will make a return, so they do not invest." (10).

There is also the individual perspective, setting each individual home with its own energy generation and storage. The homeowner would own their solar and batteries and could use their own stored energy when needed from the battery, with battery systems scaled to suit the energy demands of the household. These homes could benefit from selling surplus energy to the grid and could in theory make homes 'off-grid'. However, this approach would be less cost efficient and would arguably take longer to achieve than the community approach (8). There have been notably more developments in this area but offering solutions that are affordable to homeowners as well as incentivising them to adopt these solutions are challenges that need to be addressed.

There are also developments using hydrogen and hydrogen stores. There are a few current trials, the first of which is in Wales, using hydrogen-ready boilers to power homes as a replacement for gas. Other developments are evaluating hydrogen stores in a similar way to community energy storage. The benefits of hydrogen are that it heats a home just like gas: the system could step in, in very cold climates, to warm the home at a higher level of heat without having to wait for a heat pump to warm up. As boilers now can be hydrogen-ready, they can use gas but easily switch to hydrogen when the infrastructure is in place. However, due to high price of hydrogen this would not solve the 'affordability' issue (11).

There are 2 main ‘colours’ of hydrogen: green Hydrogen being the zero-carbon solution and ‘blue’ hydrogen being a relatively low carbon solution that would rely on carbon capture technology. So, while green hydrogen would be the only option for meeting net zero there are developments in blue hydrogen from those that see the transition to hydrogen occurring through the colours, ending on green. Green hydrogen is currently 2 – 3 times more expensive than blue hydrogen and to use hydrogen widely, offshore windfarms need to be scaled up by 30 times [(12) The first hydrogen town is predicted to be achieved by 2030, and promises to offer affordable hydrogen as well as supporting many new jobs (13). Hydrogen certainly has a place in the energy transition, but there is a strong argument for leaving it to areas that are not so easily electrified, such as energy-intensive industrial processes and heavy transport, due to green hydrogen being a more limited and costly form of energy (14).

Biodiversity: The UK has committed to reverse biodiversity loss by 2030 (15), which is a huge target. The construction sector in general has a poor understanding on biodiversity but is picking up momentum with focus on natural capital and net positive gain being seen. More needs to be done to get this goal into mainstream developments and there are a variety of ways to introduce biodiversity targets into housing developments, to not only support the diversity of species but improve the wellbeing of residents and occupiers (16). Social Value is a broad phrase but an important framework that should be embedded in all new projects . Monitoring against social value KPIs would ensure some focus and is imperative to successfully delivering against all goals and issues. The construction sector is still delivering on a cost-based approach, where other sectors have already shifted to a value-based approach, suggesting that the construction sector is lagging behind other sectors. With the development of the value toolkit and much more visibility in this space, the construction sector should be shifting to this approach more actively and widely.

Taking into account the lessons learned to date and the discussion presented above, it is proposed that areas for further innovation are as follows:

In the area of “All electric/zero carbon homes", not using gas for heating, hot water or cooking:

- Home electric energy systems
- Community electric energy systems
- SMART grid balancing
- PV electricity generation and storage
- EV charging and community use
- Connected energy eco-systems
- Vehicle to grid systems
- Zero carbon heating
- Low water usage

In order to drive integration of technologies and control systems, to create SMART integrated homes with one integrated digital platform:

- SMART metering and billing
- SMART home energy control
- Digital home connectivity
- Single user integrated application control solutions
- Home Technology integration
- Heating, security, lighting and energy
- Black and white goods integration

All Electric Developments

Transforming construction towards a greener, more environmentally conscious industry is key to meeting government targets. Positive shifts have started, with projects such as AIMCH and other InnovateUK TC projects building greater momentum, whilst the Construction Playbook shows how government policy and guidelines can be sued to influence the sector to minimise greenhouse gases and drive efficiency.

The impact of construction and the associated emissions begin with materials selection, before any building work commences. Materials used in construction are very carbon intensive, so consideration of the impact of every material at every stage, focusing on green, recycled materials where possible, cutting waste and thinking about sourcing and delivery of materials is an important part of reducing the impact of the sector.

Consideration of the circular economy is gathering pace and several industries are implementing such approaches, but the pace of engagement within the construction sector could be significantly increased.

It is critical that the sector takes into account the carbon cost of the “end of life” of products, to prioritise the use of renewable solutions and the sourcing of sustainable, recyclable materials. A strategy that covers all aspects from carbon, to environmental impact, end of life, waste and social value would be extremely advantageous but it is likely that this would have to be developed and implemented in staged approach with the aim of bringing all elements together once the processes are sufficiently mature, as long as this can be done quickly.

HS2 have trialled the ‘EasyCabin EcoSmart ZERO’, which is the world’s first solar and hydrogen powered welfare unit, combining solar and hydrogen power to eliminate carbon emissions from construction sites, with more of these to be rolled out across HS2 sites. Data gathered across 16 EcoSmart ZERO cabins over a 21-week period on HS2 sites showed that 112 tonnes of carbon were saved – the equivalent of what would be absorbed by over 3,367 trees over a whole year. In comparison, a standard diesel generator running over the same period would have used 40,000 itres of diesel fuel (17).

Construction organisations should be considering the use of hydrogen to power their heavy machinery, as well as turning to fully electric fleets, using renewables and MMC to reduce carbon across their sites.

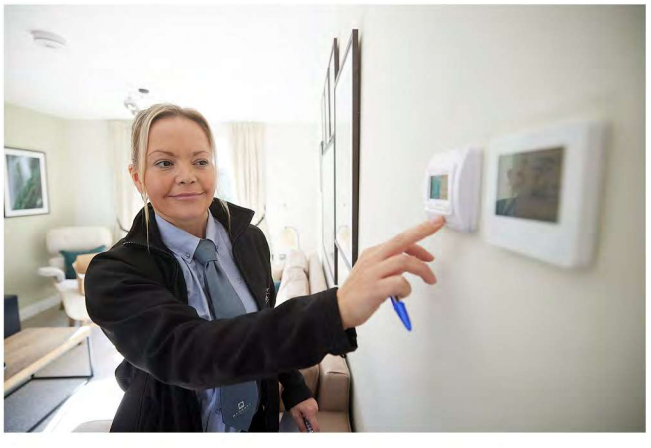
Semi and fully automated MMC methods are proving to increase efficiency and reduce carbon in the construction of homes. The use of automation and robotics in the new Stewart Milne Timber Systems (now Donaldson Timber Systems) factories and Forster’s work with MTC in designing an app-based approach to roof tiling are revolutionary achievements in the field. Both approaches are expected to result in hugely significant productivity benefits, as well as reducing waste and therefore carbon.

Further developing the mobile app technology, which can incorporate LIDAR technology, could be used to scan houses to assess the carbon and environmental impact and provide the best design and solutions to improve energy efficiency and reduce carbon footprint. This would enable a more systems-based approach to the sector by way of improving the existing stock of houses in terms of efficiency, carbon impact and even biodiversity.

SMART Integrated Homes

A Smart Home Operating system is an integrated platform that simplifies all the technology in a home. The Z-House designed by Barratt Developments within the AIMCH project demonstrated several electrical, technological products that can efficient heat, create and store electrical energy, and save water in the home. All these separate systems showcased the importance and efficiency of a SMART integrated home, which could control all these technology solutions, including but not limited to, being able to switch on lights, control the oven and check there is sufficient hot water, in one neat, easy to use app platform. Along with the convenience of such a system another key benefit would be the ability to monitor the home, from security systems to monitoring energy usage and battery levels.

Whilst there are some products on the market, there is a need to enable integration and to make the systems easy to use for the homeowner/occupier without needing to be highly IT-savvy.



3.2. Whole Life Value

Whole life value in construction relates to the process of assessing the long-term value and social impact of a project or development: it links to sustainability and the environmental impact that the project has, considering things such as the energy costs and long-term value to society.

Whole life cost is different and considers the costs associated with the whole life of the project from construction to disposal.

As the sector shifts towards a focus of reducing its impact on the environment and being more aware of the impact on social value, the consideration of the whole life value of projects and the assessment of whole life cost is becoming increasingly important. The Construction Innovation Hub Value Toolkit provides a framework for construction that enables users to assess many of the issues in this context.

AIMCH completed whole life carbon (WLCarbon) assessments across 4 house types and 3 construction methods assuming a 60-year occupancy, as well as an embodied carbon assessment of the timber MMC Panelised Wall System produced by Stewart Milne Timber Systems. The construction of the Z House used more of a value-based approach, considering the materials used and the end of life of products (monitoring of the Z House continues post AIMCH).

Areas for further innovation

In the context of whole life value, it is proposed that future projects should address the challenge of both new and retrofit, with the ultimate aim of working towards zero rework or at least minimal disruption, through the following:

- Energy system & home retrofit solutions
- Affordable homes asset strategies
- Low carbon heat solutions
- Boilers v Heat Pumps
- Return on Investment
- Maintenance & Repair
- Replacement & Waste
- Current and future state forecasts
- ROI New v Retrofitting
- Energy Systems - Whole life costs

To support this, a focus on whole carbon, to transition towards zero emissions and minimal impact should explore the following areas:

- Whole life cost assessment of energy systems & homes
- Impact on Networks & Grid reinforcement
- Supply chain readiness
- Measurement and protocols
- Accelerating Environmental Product Declarations
- Evaluating embodied carbon
- Investigating material circularity

There has already been a significant shift to using a whole life approach in similar infrastructure projects, but the challenge still remains of accelerating this approach, and encouraging suppliers to get on board.

A fundamental and critical step forward would be to integrate all the elements of electrification, net zero and whole life, whilst also considering the homeowner/occupier and demonstrating the value in benefits. Using the findings, building on these and taking the outcomes to others within the sector, and forcing suppliers to get involved is critically important.

The ambition of transforming construction to a whole life shift has been around for a while and there has been a lot of progress already but there is a significant challenge to improve sector knowledge and deliver the required training: everyone within the sector has their part to play in developing the skills and knowledge required, not just in thesupply chain but also for the homeowner/occupier.

Monitoring users in new developments through a value focus would also be a valuable step towards tackling the issue of fuel poverty. The big push for heat pumps is positive but not many homes are fit for them, although many could be improved with improvements to insulation. Monitoring heat pump effectiveness across a variety of installations could provide useful data for tackling how to deliver cleaner forms of energy, particularly in rural communities.

With the huge increase in oil and gas prices the issue of affordable warmth is becoming increasingly relevant and the provision of clean, affordable energy to everyone is critical. Rolling out solutions on a wider scale will typically result in improved affordability but incentives such as grants and tax cuts along with evidence that supports a switch to these solutions will improve energy bills, as well as wellbeing, is really important right now.

New v Retrofit

The government still has ambitious plans for the number of new homes needed to be built in the coming years, and with regulations changing, the standard of these homes from an energy and environmental standpoint will be greatly improved, with new regulations addressing concerns over things like ventilation and overheating which have been a concern to-date.

The future homes standard aims to reduce emissions by at least 75% compared with previous standards and will address energy efficiency and the use of materials, ensuring new homes are ready for the full transition to net zero by 2050. The future homes standard should also reduce the need for retrofit in the future, likely making new build homes a more cost-effective approach considering the cost of retrofit solutions and the amount of homes that need retrofitting. There is a heavy focus on new build for good reason, however there is a large existing stock of housing accounting for significant carbon emissions. Adapting our existing homes to further their lifespan, improvinginsulation, and introducing renewables can be a far lower carbon pathway than the production of new materials and the emissions and destruction caused by new developments.

Thus, a deeper focus on retrofit is required - the main challenge here lies with the vast array of retrofit options and their affordability for the homeowner. In fact, retrofit solutions are not affordable for many homeowners, having often struggled to get on to the property ladder in the first place.

“Retrofit first” is the circular economy approach to house building: re-using and extending the life of existing materials Many argue that older properties provide owners with some significant benefits compared with new homes, and our older properties are favoured by many in society.

Passivhaus and other such approaches, whilst very successful in making a building energy efficient are not affordable to the average homeowner, so developing methods that work for different environments and incentivising such changes are important. Plus, the skills needed to design and implement such solutions are lacking, there is not great awareness or understanding of such ‘future’ methods for the average trade, and the training of trades is another hugely challenging task. The benefit of new builds is that they can be designed for the future and can include design for ease of retrofit.

With the use of LIDAR and similar technology and the greater ability to capture and interpret important data, it is possible to scan existing homes to assess the impact on emissions and environment. Such data could provide information that enables the design of solutions to improve energy efficiency, carbon impact and biodiversity of the property. This can be achieved by developing new solutions as well drawing on existing products and providing a catalogue of solutions that work for different environments and for a variety of budgets. Such a system could tackle the transition from “fuel poverty” to “affordable warmth” and onwards to “energy wealth”.

3.3. Assured Performance

There has been a significant acceleration in the adoption of industrialised and standardised processes for the building of homes and large components. This is, in part, driven by the need to meet demand for increased numbers of new homes, as well as benefiting from the transfer of skills and learning from the automotive sector, where high volumes and low margins have driven high levels of automation, standardisation and consistent quality of output.

For some, there is an assumption that offsite manufacturing and standardisation means “modular” housing in the context of fully assembled, “volumetric1” units. However, these account for only 7.5% of new homes (18) and the uptake is probably held back by a combination of customer perception, supplier capacity and lack of uptake by established house builders.

More popular, is the supply of pre-manufactured components, such as timber frames, partition walls, concrete floors, intermediate floors, roof components and facades, as demonstrated by the AIMCH project. Some of these components have been supplied for many years by Stewart Milne Timber Systems (now Donaldson Timber Systems) and other suppliers, with Donaldson having significantly enhanced their manufacturing capability to upscale their capacity and efficiency to deliver to meet increased demand and fabric efficiency requirements.

The AIMCH project has verified the performance of its demonstrated solutions through analysis of Embodied Carbon and Whole Life Cost, assessing these against the requirements of the new regulations coming into effect in 2022 (see Appendix 1).

The increase in volumes of pre-manufactured components supplied to house builders is consistent with government incentives to increase pre-manufactured value (PMV), with analytical tools being made available to assist the calculation of PMV. Higher PMV is expected to drive improved productivity and quality, reduced costs, reduced onsite risk exposure and several other aspects as reported in AIMCH published reports. The NHBC, HSE and other regulatory bodies will assess both on-site and factory processes to ensure the delivery of product that complies with required standards. This, along with the proven performance of standardised manufacturing processes to deliver consistent output, will provide greater confidence in delivering assured performance against applicable regulations.

Mainstreaming AIMCH Build Methods

Improved build methods have been demonstrated in the AIMCH project by SMH, BDW, L&Q and FRS, with several homes built using Advanced MMC systems developed within the project. This has led to the design of new housing ranges, and the implementation of improved manufacturing and assembly methods, incorporating key outcomes from the project. This has required significant investment, which indicates the confidence that the partners have in the potential benefits for their businesses. Further evidence is provided in the recent sale of Stewart Milne Timber Systems (SMTS): significant factory improvements were developed for SMTS, incorporating automated and robotic workstations for the manufacture of timber frames, with automated insulation filling and the fitting of windows. This made SMTS highly attractive to new owners, with Donaldson Group completing its purchase of SMTS and rebranding this as Donaldson Timber Systems.

The AIMCH partners and other companies are therefore implementing AIMCH learnings in the sector, which will accelerate exploitation and sector change. Furthermore, these same partners are well-placed to lead the additional

[1] Volumetric modular units are large building elements that can be linked together to form complete buildings without the need for an additional superstructure (www.offsitehub.co.uk/offsite-technologies/volumetricmodular)

changes required to meet the Future Housing Standards from 2025, having gained considerable expertise in the manufacturing of thermally efficient, low carbon solutions in preparation for this next upgrade in building regulations.

It is suggested that future projects should target zero construction productivity loss through the following:

- Accelerating AIMCH NZC build solutions
- Scaling near to market MMC solutions
- Increasing site labour productivity
- Offsite construction systems
- Lean assembly techniques
- Energy efficient building fabric
- Thermal design & detailing

Validating Performance

It is clear that all homes need to comply with the current building regulations, and that builders and contractors must also comply with applicable regulations to ensure compliance in all activities. However, validation of performance against the applicable standards can be improved and there are opportunities to reduce the real vs theoretical performance gap through evaluation of the following:

- Building Fabric & Services Performance
- Energy Systems Performance
- Evaluation and testing of Design vs As-Built performance and Post-Occupancy Evaluation
- On site monitoring

The conclusions of these evaluations would be a gap analysis and a set of improvement recommendations, designed to ensure compliance with current and future regulations [2].

[2] Note that the building regulations coming into force in June 2022 are designed to achieve a 31% reduction in emissions compared to current regulations, whilst the future homes regulations from 2025 will target a 75% reduction compared to current.

3.4. Accelerating Net-Zero Carbon Living

The AIMCH project is a good example of developing and demonstrating near-to-market solutions, which can be subsequently exploited by partners to implement solutions into business-as-usual (BaU) at scale. Several partners within the AIMCH consortium have made or are committed to make investment decisions to take AIMCH solutions forwards. These solutions will deliver improvements in productivity, safety, whole life cost and carbon reduction

The housing market is being driven by several factors to take a next significant step towards net-zero carbon, these being through government policy, regulation, market pressures, financial incentives, and customer expectations.

There are many areas of opportunity that can all contribute to reducing carbon, whilst maintaining or enhancing the customer experience. The challenge is to balance the opportunity vs the cost, in order to achieve viable outcomes for all stakeholders.

The Future Homes Standard, coming into force from 2025, will mandate “zero gas” for new homes, driving all new homes to use alternative energy sources for heating, hot water and cooking.

The energy suppliers and owners of electrical supply grid infrastructure are faced with the challenge of providing domestic and commercial customers with only electrical and other non-fossil fuel energy. This will place massive demands on the supply system, which requires innovative solutions to enable customer requirements to be met, whilst upgrading the infrastructure with minimum disruption.

The technologies required to enable a transition to net-zero are achievable but need considered development and implementation to ensure effective and affordable solutions can be implemented.

Taking into account the learning from AIMCH, and the near-term requirements and opportunities, it is recommended that follow-on projects focus on the areas suggested in this report, prioritising in light of benefits vs challenge, but with a focus on whole life and whole system outcomes, i.e. house builders, developers, suppliers and investors should take a long term view rather than near-term/point of sale profits.

Funding is available for R&D projects, from energy suppliers, funding authorities, government departments and the EU to drive towards net-zero across many sectors, with house building a key area.

To accelerate the transition to net-zero, it is suggested that demonstrator homes be built, incorporating the following technologies:

- High thermal efficiency and air-tight fabric design, utilising advanced MMC solutions
- Integrated energy systems, utilising heat pumps in conjunction with solar PV, energy storage and automated control to manage energy utilisation
- Electrical vehicle charging & vehicle to grid energy sharing
- Use of recycled and recyclable materials

The high thermal efficiency fabric design and advanced MMC solutions should include the use of:

- Cat 2 MMC systems
- Lean assembly methods
- DfMA
- Standardised solutions
- Productivity improvements
- Non masonry cladding systems
- Pre tiled roofs with integrated solar
- Scaffold-less erect

Improvements to energy infrastructure, systems and supply will require the following to be considered:

- Balancing of energy generation, consumption and storage, including energy from and for electric vehicles
- Level of dependency on the energy supply grid and whether the grid infrastructure requires reinforcement or upgrade
- Private wire systems, i.e. localised electricity grids connected to the local distribution networks but linked to privately-owned central plant that produces electricity
- Metering and billing
- Key roles, e.g. Grid energy supplier, District Network Operator, Independent District Network Operator, developer & homeowner
- Contracts and long term deals
- Small- and large-scale demonstrator sites
- Private, Affordable & SME markets
- Demonstrator sites and deployment by region and country, recognising and variations in compliance requirements

4. CONCLUSIONS

1. Fabric first remains critical to enabling effective and efficient heating solutions for homes

2. AIMCH demonstrated that advanced MMC methods can deliver improved fabric efficiency and productivity improvements at scale for volume house builders and suppliers. The approach can be adopted for further transformations in the sector

3. Demonstrating effective, multifaceted energy balancing and storage solutions, whilst reducing the demand on the grid, is critical as we transition towards a 100% electric society

4. Whilst delivering effective solutions for new homes is a key objective, the scale of the retrofit challenge is huge and must be tackled for there to be a broader impact on carbon reduction and fuel poverty across society

5. There should be greater awareness of fuel poverty and the part that improved fabric can play in addressing this, as well as the benefits of renewable energy solutions

5. RECOMMENDATIONS

1. There should be funding for projects that demonstrate a community solution to energy storage including SMART home integration applications

2. There should be funding for projects that deliver retrofit solutions to energy generation and storage, including SMART home integration applications

3. There should be funding for projects that demonstrate viable retrofit fabric improvements

4. The industry should use standard KPIs to drive the required improvements in green energy and carbon reduction, as well as Social Value and Biodiversity

5. There should be incentivisation from government and local authorities, including financial assistance, to drive the uptake of renewable energy solutions

6. There needs to be increased training and awareness across the sector to improve the skills and knowledge base in terms of whole life value, whole life carbon, fabric efficiency, energy solutions, social value and biodiversity if the government is to achieve its net zero targets

6. REFERENCES

1. HM Government. Net Zero Strategy: Build Back Greener. London : Crown Copyright 2021, October 2021.

2. CS-IC. AIMCH Partner Builds Zero-Carbon Home of the Future. 2021.

3. Barratt Developments. Z House Technologies. 15/02/2022.

4. RICS. UK construction works strong despite price inflation and labour shortages. s.l. : RICS, 2021.

5. Chartered Institute of Procurement & Supply. Building supply chain resilience in the construction sector. s.l. : CIPS.

6. Construction Leadership Council. Roadmap to Recovery. s.l. : CLC, 2020.

7. Department for Communities and Local Government. Investigation into Overheating in Homes. 2012.

8. Ministry of Housing, Communities & Local Government. Ventilation and Indoor Air quality in New Homes. 2019.

9. Power Technology Research. Electric Vehicle Impact Report.

10. SCENe. Welcome. [Online] 2016-2022. https://www.projectscene.uk/.

11. Housebuilding and Renovating. Hydrogen Heating: 'World-First' Trial Begins in Wales. [Online] 2022. https://www.homebuilding.co.uk/news/hydrogen-heating.

12. Petrofac. The difference between green hydrogen and blue hydrogen. [Online] https://www.petrofac.com/media/stories-and-opinion/the-difference-between-green-hydrogen-and-bluehydrogen/.
13. RYZE Hydrogen. [Online] https://ryzehydrogen.com/about/.

14. The role of hydrogen in heavy transport to operate within planetary boundaries. Antonio Valente, Victor Tulus, Ángel Galán-Martín, Mark A. J. Huijbregts and Gonzalo Guillén-Gosálbez. 2021, Sustainable Energy Fuels, Vol. 5, pp. 4637-4649.

15. DEFRA. Government sets out commitments to biodiversity and sustainability in G7 Nature Compact. [Online] 2021. https://www.gov.uk/government/news/government-sets-out-commitments-to-biodiversity-andsustainability-in-g7-nature-compact.

16. IEMA. How construction is enhancing biodiversity. [Online] 2019. https://www.iema.net/articles/howconstruction-is-enhancing-biodiversity.

17. HS2. World's first solar and hydrogen powered cabins to dramatically cut carbon on HS2 construction sites. [Online] https://mediacentre.hs2.org.uk/news/worlds-first-solar-and-hydrogen-powered-cabins-to-dramaticallycut-carbon-on-hs2-construction-sites.

18. Leah McCabe, Verco, SMG, BDW, L&Q. Whole Life Carbon Assessment of 4 house types and 3 construction methods. s.l. : AIMCH, 2022.

19. The Guardian. Can modular homes solve the UK's housing crisis? [Online] 6 August 2019. https://www.theguardian.com/music/2019/aug/06/flatpacked-homes-can-modular-buildings-solve-the-ukshousing-crisis.

7. APPENDICES

Appendix 1. Changes to Part L of the Building Regulations (Dwellings) Regulations for Part L, Conservation of Fuel and Power, coming into force on 15-Jun-2022, include changes to Part L, Part F (Ventilation), and addition of new regulations pertaining to overheating entitled Part O, designed to achieve reduction in emissions for new homes by 31% compared to the previous regulations.

The changes focus on the fabric performance of the building, with standards for U-Values, thermal bridging calculations, and air-testing all being tightened. Sections have also been added to future proof homes.
The changes will bridge the gap between 2022 and the introduction of the Future Homes Standard, due for release in 2025.

Enhanced U-Value Standards

Building Element	Part L1 2013 U-Value (W/m2K)	Part L1 2021 U-Value (W/m2K)
Wall	0.30	0.26
Floor	0.25	0.18
Roof(s)	0.18 – All Roof Types	0.16 – All Roof Types
Glazing	1.60 – Windows 2.20 – Rooflights	1.60 – Windows 2.20 – Rooflights
Doors	1.80	1.60 – incl. glazed doors
Other requirements		Mains gas boiler minimum 88%efficiency, and minimum 75% L.E.L in all outlets Waste Water Heat Recovery (WWHR) as standard

Air-Testing: every dwelling to be air tested

Thermal Bridging: new methods of calculating thermal bridging, replacing Approved Construction Details (ACD's), which were published in 2002. Details will be available from Local Authority Building Control (LABC)

Thermal Mass Parameters (TMP's): thermal mass of buildings was previously assessed, in most cases, by selecting a level of low, medium or high, depending on the construction, but rarely precisely calculated. SAP10 now requires accurate information about the construction of all internal partitions and intermediate floors, including area measurements of both sides of all these internal elements, for a thermal mass (or 'kappa') value to be assigned. Buildings with high thermal mass construction (e.g., solid masonry) will take longer to warm up when the heating is turned on from cold than those with low thermal mass construction (e.g., timber frame). High thermal mass building will also take longer to warm up on a very hot summer's day. Manipulating thermal mass at design stage will not solve energy use or summer overheating problems on its own, since external fabric, fuel type and heating efficiency will still determine the outcome of a SAP calculation.

Carbon Factors: these are updated, addressing the anomaly whereby the carbon factor for grid electricity had not been updated since its historical reliance on coal-fired power stations, resulting in a carbon factor significantly higher than gas. With the carbon factors now updated to reflect the current emissions from grid electricity, heat pumps are now a far more attractive option for new build homes.

Extensions: Previously, for an over-glazed extension to be passed, the total CO2 emission was the only metric from the 'as designed' dwelling required. The new regulations introduce a primary energy metric to the whole house calculation method for extensions. This metric will assess the energy sources, its production and delivery to the home. As grid electricity is progressively decarbonised, the CO2 emission rate becomes a less useful metric to drive. down the energy demand of buildings, and the primary energy rate has been selected under the Energy Performance of Buildings Directive (EPBS) as the more appropriate metric to achieve this aim.

Future Proofing: Part S is an all-new building regulation document that requires all new homes to have facilities for electric vehicle charging, whether this be charging points, or by making it easy to have future connections installed.

Heating and hot water: Gas and oil boilers will be phased out, being banned for new build homes from 2025, in favour of low-carbon technologies such as heat pumps.

The latter two changes aim to ensure that homes suit the needs of future occupants, as well as addressing environmental concerns.

In conclusion, the updates to Part L and the introduction of SAP10 will improve the environmental performance of all new dwellings in the UK, through driving a 31% reduction in emissions compared to the standards in the previous regulations. This reduction is set to be achieved by the enhanced standards used in the calculation of TER, TFEE and the inclusion of the new primary energy metric. Changes to air-testing, now to be carried out for all new dwellings rather than samples, and the method of calculating thermal bridging, will encourage better building standards across all new builds as well as make clients and builders more aware of schemes relating to good practice in environmentally friendly construction.

AIMCH

TRANSFORMING HOW WE BUILD HOMES

Future Casting

July 2022

mtc Manufacturing Technology Centre

L&Q

Built Environment – Smarter Transformation

FORSTER GROUP

STEWART Milne GROUP

BARRATT DEVELOPMENTS PLC BUILDING EXCELLENCE SINCE 1958

INDUSTRIAL STRATEGY

UKRI UK Research and Innovation