# Low carbon housing: Lessons from Elm Tree Mews

Findings
Informing change

November 2010

Meeting the Government's zero carbon housing targets by 2016 will not be easy. Exemplar low carbon housing schemes are now being built. But do they meet energy and carbon expectations and what lessons can be learned? This research evaluated one such scheme, Elm Tree Mews, York.

## Key points

- Elm Tree Mews sought to achieve a standard equivalent to the Government's carbon target for 2013. It adopted high levels of insulation, solar thermal panels and a communal ground source heat pump.
- Performance measurements revealed that:
  - dwelling heat loss was 54 per cent higher than designed;
  - solar systems provided hot water but suffered numerous operational problems; and
  - the performance of the heat pump system was significantly less than designed.
- The net effect was dwelling carbon emission rates only marginally in advance of current regulations.
- Despite the underperformance, residents were comfortable and pleased with their heating bills. However, hot water systems were problematic and controls confusing.
- Many processes and cultures within the industry and its supply chain need to change if zero carbon housing is to become a reality.
  - Design needs to be improved to give greater priority to as-constructed performance and to supporting low carbon lifestyles.
  - Services design should focus on whole system performance.
  - The planning and control of construction needs to be improved and include in-production testing.
  - Improvements are required in services commissioning, testing and monitoring to ensure effective performance.
- More support and guidance is required across the house-building industry.
- Policy aspirations will not be achieved without rigorous evaluation of low carbon schemes and ensuring that lessons are embedded in all parts of the industry.

**The research**
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# Background

## The Elm Tree Mews scheme was conceived in 2005 by the Joseph Rowntree Housing Trust (JRHT) as an exemplar for "21st Century Suburban Homes".

The aim was to build a small housing development, which would provide affordable, high-quality houses and flats for sale and rent. The dwellings were to meet the requirements of lifetime homes and reflect the "Arts and Crafts" vernacular of New Earswick village. Also, the development was intended to address the emerging low carbon housing agenda by achieving an energy and carbon standard broadly in line with that currently proposed for the Building Regulations in 2013.

The aims of this research were to:

- evaluate the extent to which the energy/carbon performance of schemes such as Elm Tree Mews meets design predictions;
- evaluate the impact on performance of the design and construction processes used; and
- understand the influence on performance of the interactions between residents and their homes.

The conclusions are relevant to policy-makers, regulators, housing developers, social landlords and technical leaders within housing and the house-building industry.

## Government policy

The Government has set ambitious targets for incremental changes to building regulatory standards, which are intended to achieve zero carbon new housing by 2016. However, despite the fact that prototype designs have been produced for very low and zero carbon housing, there is concern that many of these solutions are untried and untested. It is clear also that many schemes do not undergo comprehensive monitoring and evaluation to check whether they have achieved their designed performance in reality. The Elm Tree Mews field trial was intended to explore the issues involved in the development of low carbon housing and the extent to which performance expectations are realised.

## Design performance

The design was based on a panelised, timber frame construction with recycled cellulose insulation, a timber clad/rendered façade and a tiled roof. Heating and hot water was provided by a communal ground source heat pump in combination with solar thermal panels and immersion heater. The expected carbon emission rate was about 14 kg($CO_2$)/$m^2$, broadly equivalent to the Level 4 carbon standard in the Code for Sustainable Homes. The design relied on three key elements:

- **high levels of fabric insulation** to minimise space heating demand;
- **a communal ground source heat pump system** to achieve very high levels of efficiency in supplying space heating and hot water;
- **solar water heating**, providing carbon-free energy for about 30 per cent of hot water needs.

## Actual performance

Energy and carbon characteristics were measured prior to occupation to establish performance, free from resident impacts. Following occupation, the dwellings were monitored over a year to assess in-use performance and evaluate the resident experience.

### *Fabric performance*

Whole-house heat loss is a combination of conduction, convection and radiation through the dwelling fabric (fabric loss) and via air leakage (background ventilation loss). Whole-house heat loss was much higher than predicted at the design stage. Instead of a predicted heat loss coefficient of 127 W/K, the real loss was just over 196 W/K, an overall increase of 54 per cent (70W/K). Almost all of the additional loss was attributable to fabric losses, which were 70 per cent higher than predicted.

This discrepancy was the result of design and construction process factors that:

- underestimated the amount of timber in the walls and roof (23 per cent of the difference);
- did not account fully for thermal bridging at junctions and openings etc. (25 per cent);
- did not account for heat loss via a thermal bypass within the party walls (30 per cent); and
- did not maintain window performance when a change of supplier occurred (21 per cent).

### *Airtightness*

Pressurisation testing showed that airtightness was typical of current UK practice for mass housing, with a mean air permeability of 7 $m^3/h.m^2$ (the lower the value the less heat loss). However, the measured values were significantly above the original target of 3 $m^3/h.m^2$ contained in the outline design submission. Airtightness was well above that normally expected for low energy housing. Had the original target been achieved, heat loss due to air leakage would have been some 50 per cent lower than in the completed scheme.

### *Heating and hot water services*

The communal ground source heat pump did not achieve its expected performance, with the measured annual Coefficient of Performance (CoP) of the pump (2.7) being significantly lower than the nominal design of between 3.2 and 3.5 (a higher CoP denotes greater efficiency). The CoP of the whole system, heat pump unit, circulation pump, distribution and control devices, was 2.15. A number of interventions were made during the monitoring period. These included modifying pumping arrangements to optimise the load/power match for the system and altering system controls, all of which had a positive impact on system efficiency.

The energy delivered by some of the solar thermal systems met expectations. However, all but one system had installation difficulties, which included leaks, control issues, incorrectly positioned sensors and kinks in the pipework. Hot water storage temperatures were lower than in a conventional system and a weekly immersion heater cycle had to be introduced to control the risk of legionella. The various problems identified with the heat pump and hot water systems were related to the extent of design integration and the robustness of commissioning and installation processes. In some cases problems would have gone undetected had it not been for the monitoring programme.

### *In-use energy consumption and carbon emissions*

The total annual electricity used by all the Elm Tree Mews dwellings for heating and hot water was around 15,000 kWh, equivalent to 6.4 tonnes $CO_2$/annum, based on the 2006 carbon coefficient for grid electricity (0.422 $kgCO_2$/kWh). It is estimated that, had fabric and systems performed as expected, electricity consumption would have been nearer 6,300 kWh, only 2.7 tonnes $CO_2$/annum. The extra carbon emitted as a result of underperformance was therefore about 3.7 tonnes $CO_2$/annum. This would rise to 4.55 tonnes $CO_2$/annum under an updated national electricity carbon coefficient (0.517 $kgCO_2$/kWh), due to come into force in October 2010.

The decision to use an electric heating system rather than gas placed considerable reliance on the performance of the communal heat pump. At the time the decision was made, calculations supported the use of a heat pump. However, the increased carbon coefficient of electricity coupled with lower than anticipated energy efficiency meant that estimated emissions from a gas system would have been about 1 tonne $CO_2$/annum less over the whole scheme. This illustrates how difficult it is for designers and developers who are often operating in the face of considerable uncertainty, having to contend with shifts in national carbon coefficients, the complex interplay between services and fabric and uncertainties about as-constructed performance. In order to address these issues it is important that:

- the Government provides a stable carbon coefficient platform rooted in robust long term energy and carbon policy; and
- the house-building industry tackles the considerable variability in as-constructed performance.

### *The resident experience*

Resident interviews revealed a mixed experience, which was often related to individual circumstances and expectations.

- **Affordability** – residents were generally pleased with the lower heating bills compared with their previous accommodation.
- **Design and resident needs** – some important interactions between living needs and energy consumption emerged. For example, one resident was considering using fan heaters to heat the "winter garden" (a conservatory with no heating) to provide additional dining space. This could result in a significant increase in carbon emissions.
- **Engaging with new technologies** – controlling heating and hot water was complex. Four different controllers were used (space heating, water heating, solar system and immersion heater), each with a different arrangement. Also, thermostat dials were difficult to understand. This complexity caused considerable confusion among residents and led, in some cases, to less efficient use.
- **Knowledge and confidence** – The complexity of the systems meant that residents did not understand how they worked and did not have the confidence to make appropriate adjustments to improve effectiveness.

## Implications for the house building industry

Evidence of significant energy/carbon underperformance in UK house building is increasing. The underlying causes are related to the cultures and processes that pervade mainstream housing development. The lessons from Elm Tree Mews support this position.

### *Key lessons*

Closing the performance gap will require significant improvements in the way that homes are procured, designed and constructed so that they provide households with homes that meet their needs while enabling low carbon lifestyles. The following important lessons emerge:

- **Procurement** – Housing providers need to take more interest in the energy and carbon performance of homes and in ensuring that claims made by designers, contractors/developers and suppliers are supported by robust evidence.
- **Design** – Design processes should be improved to:
  - increase the robustness of detailed design, including thermal calculations;
  - focus on as-constructed performance, taking into account component interactions in both fabric and services systems;

– give more consideration to the needs of householders and provide resident-friendly controls.
- **Construction** – Construction processes need to be improved so that:
  – construction operations and sequences are planned in more detail and include in-production testing;
  – changes during construction are closely controlled to ensure that performance is not compromised;
  – the commissioning of services is more robust, ensuring that expected efficiencies and other operational parameters are realised.
- **The supply chain** – Performance information and guidance provided by suppliers should reflect as-constructed performance rather than laboratory performance and the supply chain should take more responsibility for product performance as-constructed.
- **Resident support** – Developers and landlords should give more attention to the provision of meaningful guidance and support for residents.

### *Feedback for continuous improvement*

Performance feedback is vital if improvements are to take place. This study should be seen as part of a programme of feedback from real schemes that provide guidance for government and the industry in the pursuit of national zero carbon housing goals. An excellent example of feedback is provided by a follow-up scheme developed by JRHT - at Temple Avenue, York - which demonstrated a vast improvement in measured fabric performance following feedback from Elm Tree Mews.

## Implications for government

If national zero carbon housing goals are to be achieved, the performance gap must be closed. There are encouraging signs that this is being taken seriously by sections of industry and government.

We propose a ten-year programme of radical change to be steered through a government, industry and stakeholder partnership, which includes:

- **a clear regulatory framework** that establishes a robust system of incentives and penalties to ensure the achievement of standards, on the ground;
- **a programme of research, education and training** consisting of:
  – pilot studies to enable the industry to generate effective process blueprints;
  – research and development that addresses issues of production testing, as-constructed performance and resident/dwelling interactions:
  – education and training to improve skills throughout the industry;
- **a national feedback loop** to collect and analyse data on completed dwellings and their energy use, charting the performance of dwelling cohorts as regulations are modified;

Elm Tree Mews has demonstrated many of the issues that need to be tackled and lessons to be learned. It is crucial that learning continues through further evaluative research. However, successful learning will depend on the cooperation of forward-thinking designers and developers and of residents.

## About the project

The research project ran from 2007 to the end of 2009 and adopted an action research approach. It included retrospective and concurrent observations of design and construction processes, post-construction measurement of performance and monitoring of the dwellings in occupation. The resident experience was captured through post-occupancy interviews and other data collected during the monitoring period.

## Further information

The full report, **Low carbon housing: Lessons from Elm Tree Mews** by Malcolm Bell, Jez Wingfield, Dominic Miles-Shenton and Jenny Seavers is published by the Joseph Rowntree Foundation. It is available as a free download from www.jrf.org.uk. A technical report is available from the research team at http://www.leedsmet.ac.uk/as/cebe/projects/elmtree/index.htm. For further information please contact the authors: m.bell@leedsmet.ac.uk, j.wingfield@leedsmet.ac.uk, d.miles-shenton@leedsmet.ac.uk, j.seavers@leedsmet.ac.uk

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