State of the Nation review: Performance evaluation of housing

An accessible review of new-build housing performance studies in the UK, their objectives, main findings and key conclusions.

Introduction

The UK has committed to a net zero emissions target by 2050 and to five-year carbon budgets in the interim. By 2050, the UK will also likely need to fully decarbonise heating of homes through installation of heat pumps, use low carbon gases (such as hydrogen) in the existing gas grid and install district heat networks. These carbon budgets have driven the need for new dwellings to be built with high standards of insulation with mechanical ventilation, high efficiency heating systems, and renewables.

Building performance evaluation (BPE) studies have shown that low/zero energy dwellings often underperform as compared to the design specifications, due to discrepancy in building fabric thermal performance, performance of heating and ventilation systems, and resident behaviour. Past studies have demonstrated that in-use energy use can be up to three-five times more than design predictions. However, many of these studies are not widely publicised and limited to a small audience. Moreover, national policy targets for carbon reduction cannot be met without understanding, quantifying and minimising this ***performance gap between design intent and reality***.

The State of the Nation study has produced a comprehensive report that provides an accessible review of key studies on new-build housing performance and BPE methods, analysis of meta-data as well as a look at the future of housing performance evaluation.

The report covers the following aspects:

- Rationale and objectives of housing performance studies
- Review of key findings of studies and meta-studies of housing performance
- Key data, benchmarks and how they impact residents
- The future of building performance studies to guide methodologies for future studies

Key findings

Current landscape of housing performance evaluation (HPE) studies in the UK

Using a combination of desk research and online survey with experts, the State of the Nation study identified the following resources on housing performance:

- Six research programmes on housing performance
- Five repositories and eight meta-studies that store and compile data from the individual housing performance evaluation studies which originate from the research programmes.
- Ninety-one HPE studies of new housing.

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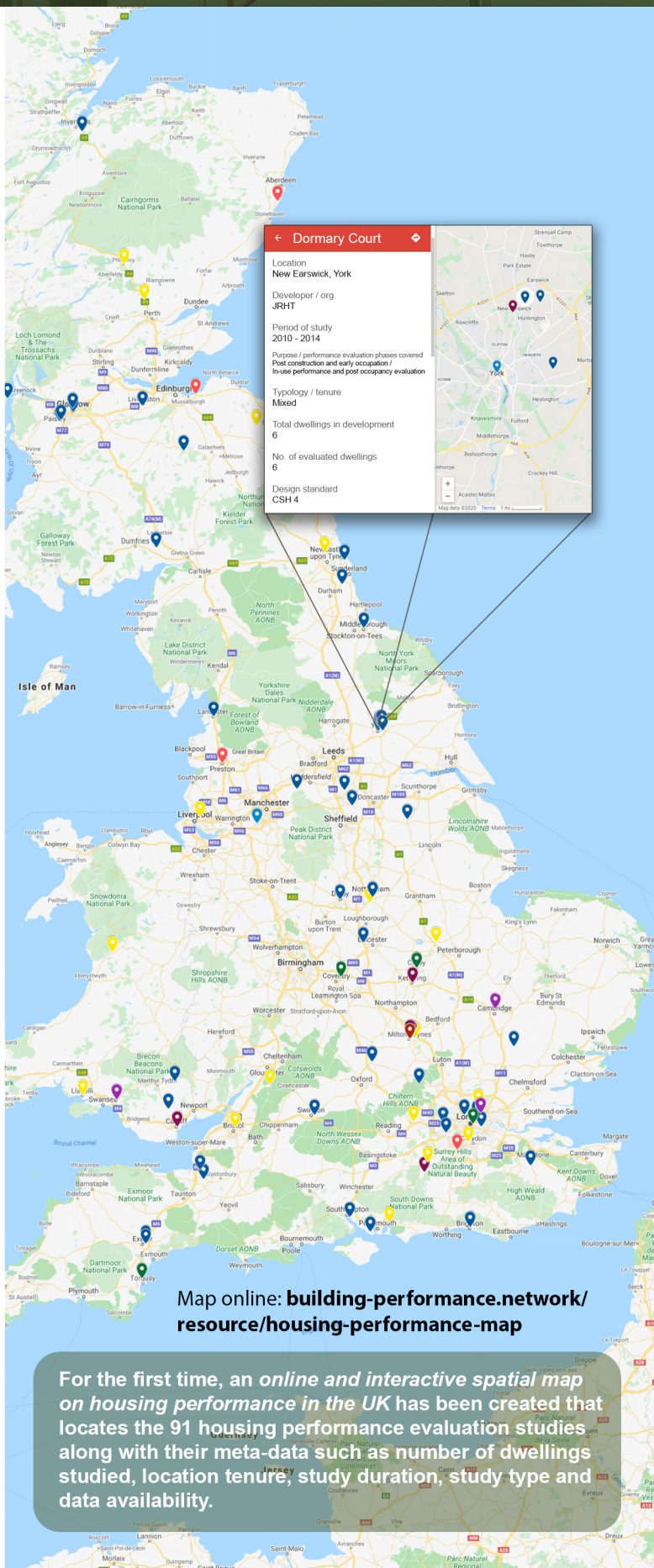
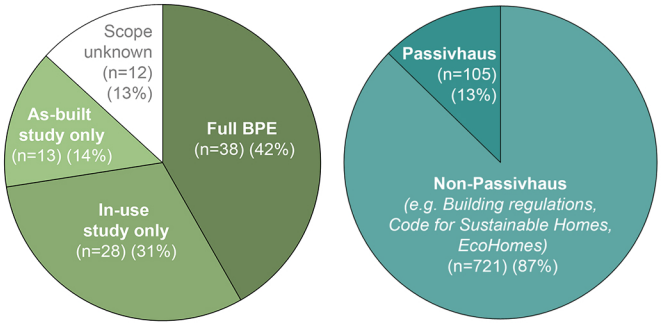


The 91 HPE studies cover 826 dwellings, of which 105 are Passivhaus and 721 Non-Passivhaus dwellings (low energy). About 43 studies were funded by the Innovate UK BPE programme which ran from 2010 to 2014.



Building performance evaluation methods

A range of tools and methods that have been used for assessing the as-built performance (design intent compared against as-built, performance of the building fabric and installed equipment, and how residents react to it as well as effectiveness of the handover process) and in-use performance (energy use, indoor environment, resident experiences) of new-build housing.

Most common methods (for which data were available) were air-permeability testing, thermal imaging, measuring performance of mechanical ventilation with heat recovery (MVHR) systems, monitoring of energy use, indoor temperature and relative humidity, and Building Use Studies (BUS) questionnaire survey.

Meta-analysis of housing performance data

Meta-analysis of housing performance data provided insight into housing performance at scale. The meta-analysis covered building fabric thermal performance, energy assessment, indoor environment and resident satisfaction for Passivhaus and Non-Passivhaus dwellings (low energy), as shown in the table below.

Sample size of housing performance data analysed (no. of dwellings)

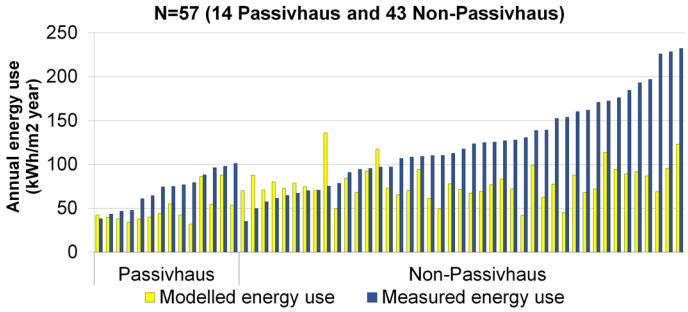
As built performance: Building fabric thermal performance analysis			
	Passivhaus	Non-Passivhaus	Total
Air permeability	50	138	188
External wall U-value	14	48	62
Roof U-value	5	15	20
Whole house heat loss	6	23	29
Thermal imaging	10	34	44
In-use performance: Energy assessment			
	Passivhaus	Non-Passivhaus	Total
In-use energy data	30	62	92
Energy performance gap	19	49	68
Space heating energy use	12	56	68
In-use performance: Indoor environment			
	Passivhaus	Non-Passivhaus	Total
Temperatures & RH	12	38	50
CO_2 concentrations	12	28	40
In-use performance: Resident satisfaction and perception			
	Passivhaus	Non-Passivhaus	Total
BUS survey (responses)	80	438	518

Building fabric thermal performance

Average difference between design and measured air permeability was found to be negligible amongst Passivhaus (PH) dwellings at 0.5 $m^3/h/m^2$@50Pa, but considerable at 1.9 $m^3/h/m^2$@50Pa amongst Non-Passivhaus (NPH) dwellings. Masonry dwellings presented the highest gap in terms of airtightness, external wall U-value and whole building heat loss. Thermal weakness at openings seemed to be endemic across the sector as issues with doors and/or windows were identified in 84% of the project sites, demonstrating a need to improve detailing, specification and workmanship. “Junctions and joints” and “roof, eaves and loft space” are also highlighted as areas requiring attention, as thermal bridging issues were pinpointed in nearly half the project sites.

In-use energy performance

Mean energy consumption in NPH dwellings was found to be 117 kWh/m^2/year while PH dwellings use 62% less energy - 73 kWh/m^2/year. Energy used for space heating was 2.4 times higher in NPH dwellings. The energy performance gap (as compared to SAP) in NPH dwellings was nearly twice that of PH dwellings.



Indoor environment and resident experiences

Despite the differences in energy use, indoor temperature profiles in the heating and non-heating season were similar in PH and NPH dwellings, with mean indoor temperature ranging from 20.1°C - 24.6°C. However consistently higher mean monthly CO_2 concentrations were observed in NPH dwellings than in PH dwellings, with the difference being more significant in bedrooms.

Resident comfort and satisfaction with indoor temperature are found to be higher in winter than in summer across PH and NPH dwellings. Indoor temperature were perceived to be hot.

Future landscape of housing performance

With decarbonisation of heating and electricity, it will become important to assess not only the thermal performance of the building fabric but also energy demand profiles and resident health and wellbeing. Future technological trends that could guide HPE studies include:

- Building Information Modelling (BIM)
- Low-cost non-invasive building fabric performance tests
- Smart metering and smart home energy management systems
- Internet of Things (IoT) based low cost sensors
- Personal monitoring devices / wearable technology

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