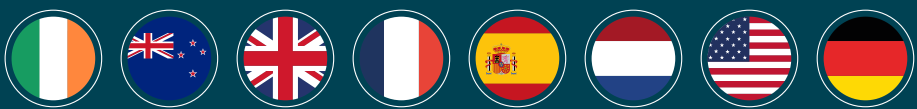
Wales Centre for Public Policy
Canolfan Polisi Cyhoeddus Cymru

Lessons from retrofit programmes to cut residential emissions

Eight international case studies



Josh Coles-Riley, Greg Notman and Dr Helen Tilley

www.wcpp.org.uk

Contents

Wales Centre for Public Policy
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Cardiff University, sbarc|spark, Maindy Road, Cardiff CF24 4HQ

www.wcpp.org.uk
info@wcpp.org.uk
029 2087 5345
@WCfPP
/company/wcfpp

Economic and Social Research Council

Llywodraeth Cymru Welsh Government

Cardiff University Prifysgol Caerdydd

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Introduction

There is no pathway to decarbonising residential buildings in Wales without rapid uptake of retrofit measures, on a scale not previously seen anywhere in the UK or in many comparable countries worldwide.

As we make clear in our background paper (Notman et al., 2024), residential emissions are not falling at the rate needed to meet Wales' carbon targets, reflecting the sluggish pace of heat pump and energy efficiency retrofit installations. Meeting existing emissions targets will require a decisive departure from these trends, through fast and massive deployment of retrofit measures.

In the UK CCC's balanced pathway scenario for net zero by 2050, heat pump installations in Wales increase to 21,000 a year by 2025 and 68,000 a year by 2035, with 400,000 existing homes receiving roof or wall insulation by that date (UK CCC (2020)); Wales-specific data on actual uptake is patchy, but the best available data suggests that there were around 3,400 installations of heat pumps in Wales in 2022, increasing the estimated total number of heat pumps in the country to just under 15,000 (Welsh Government, 2023).

As there is currently a gap between actual uptake and levels of uptake required to meet the existing net zero target, this gap only widens if the target is brought forward from 2050 to 2035 – as Wales' Net Zero 2035 Challenge Group has been tasked with exploring by the Welsh Government, under the terms of the cooperation agreement between the Welsh Government and Plaid Cymru (Welsh Government, 2021). Reaching net zero by 2035 would therefore require significant, ambitious and potentially unprecedented policy innovation to tackle existing barriers to large-scale retrofit uptake.

This is the context in which WCPP has been asked by the Net Zero 2035 Challenge Group to produce case studies of residential retrofit programmes elsewhere in the UK and internationally, with the aim of identifying lessons and implications for decarbonising residential buildings in Wales.

The remainder of this report includes:

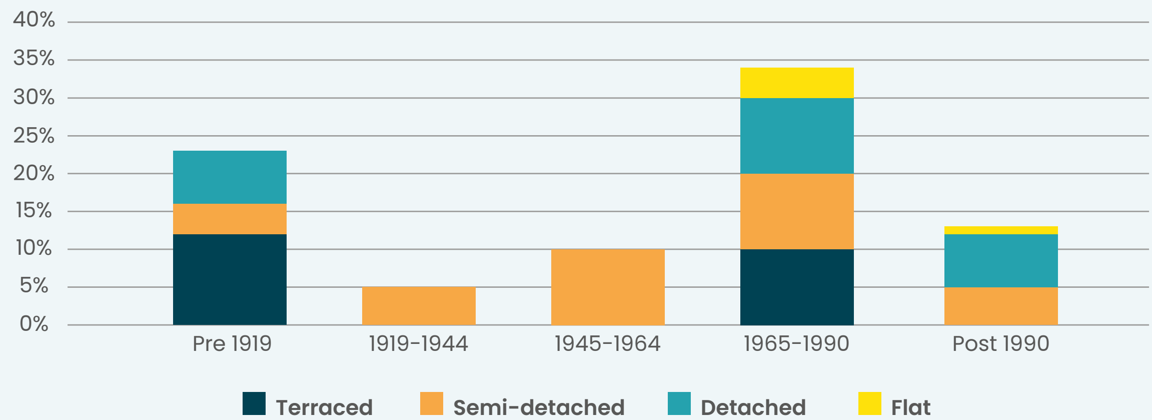
- A snapshot of key contextual data and the policy background for retrofit delivery in Wales, intended to support an assessment of the transferability of lessons from international retrofit programmes;
- Eight case studies of international retrofit programmes at a range of different scales, from Ireland, Germany, the Netherlands, France, and New Zealand, along with two programmes from elsewhere in the UK, drawing out:
    - Evaluated programme outcomes in terms of reductions in energy demand and/or emissions, as well as wider co-benefits (e.g. health and economic impacts);
    - Key programme features and delivery mechanisms; and
    - Insight into contextual factors, enablers and barriers, in order to highlight lessons for Wales.

Decarbonising housing in Wales – a snapshot

Age, type and condition

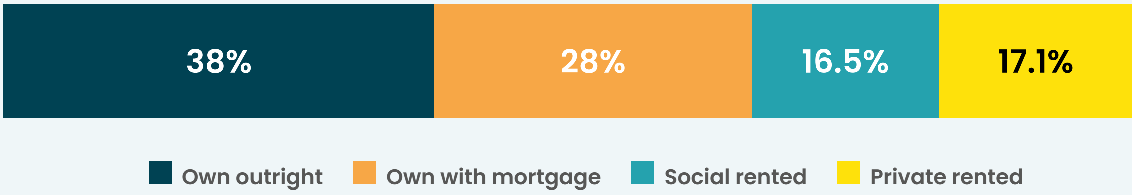
- **Wales has some of the oldest and least efficient housing stock** in both the UK and Western Europe (Decarbonisation of Homes in Wales Advisory Group, 2019).
- **More than one in five homes in Wales were built before 1919,** and only around 13% were built after 1990 (Figure 1; Lannon and Green, 2019). Most homes built before 1919 were terraced, whereas detached houses are the type built most commonly since 1990.
- **Only one in eight homes in Wales is a flat or apartment.** The remainder are predominantly whole houses which are split somewhat evenly between terraced houses and bungalows (27% of the total housing stock), detached houses (29%) and semi-detached houses (32%). The majority of flats are purpose built, with converted buildings only comprising around 3% of the total Welsh housing stock (Office for National Statistics, 2023).
- **Of all UK nations, the Welsh housing stock has the highest prevalence of Category 1 hazards** (those which risk causing the most serious forms of harm, up to loss of life) (Piddington et al., 2020). These are more common in older housing stock, of which Wales has significantly more.
- **The median EPC energy efficiency score for houses in Wales in 2023 was 66, equivalent to a Band D.** Homes in urban areas were found to have typically higher EPC scores than rural areas (Guggisberg and Smith, 2023).
- **In 2017, around 81% of homes in Wales with solid walls (typical of older homes) were uninsulated.** In comparison, only 32% of Welsh homes with cavity walls were uninsulated (Piddington et al., 2020).

Figure 1: Dwellings in Wales by age and type



Source: Lannon and Green (2019)

Figure 2: Dwellings in Wales by tenure



Source: Office for National Statistics (2023)

Tenure

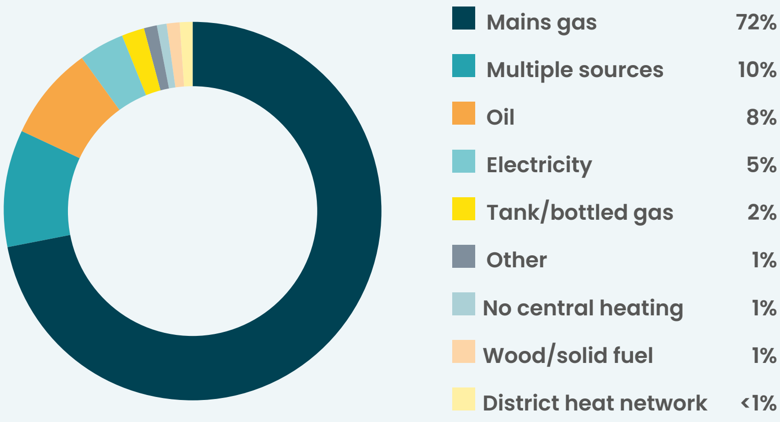
Figure 2 shows the Welsh housing stock split by tenure.

- **Two thirds of occupied dwellings in Wales are owner-occupied.** Of those which are owner-occupied, 57% are owned outright, 42% are owned with a mortgage and less than 1% are under shared ownership (Office for National Statistics, 2023).
- **Those which are not owner-occupied (34% of occupied dwellings in Wales) are split almost evenly between those which are social rented and private rented** (Office for National Statistics, 2023).
- **Social housing in Wales is typically more energy efficient than owner-occupied and private rented homes** (Decarbonisation of Homes in Wales Advisory Group, 2019).
- **Approximately 16% of all properties in Wales are leasehold,** mostly concentrated in densely populated urban areas such as Cardiff and Swansea (Welsh Government, 2021). In leasehold properties it is often necessary to gain permission from the freeholder to have significant work carried out to the property, including making changes to the heating system (Climate Citizens, 2022).

Fuel source

- **Over 70% of homes in Wales are estimated to use mains gas as their sole source of heating** (Office for National Statistics, 2023).
- **Around one in five homes in Wales are estimated to not be connected to the gas grid** (Department for Business Energy and Industrial Strategy, 2022).
- As such, there are a significant proportion of properties in Wales which use forms of heating other than mains gas. **Around 8% of properties in Wales use oil as their sole source of heat,** which is the most common single fuel source after mains gas (Office for National Statistics, 2023). Figure 3 shows houses in Wales by fuel source.
- **There is significant regional variation, with properties in rural parts of Mid and North Wales less likely to be connected to the gas grid.** It is estimated that only 26% of domestic properties in Ceredigion and 45% of those in Powys are connected to the gas grid. Across the whole of the UK, the areas with the highest proportion of properties using oil, tank or bottled gas, solid fuel and wood, are all located in Wales (Stewart and Bolton, 2023).

Figure 3: Dwellings in Wales by fuel source



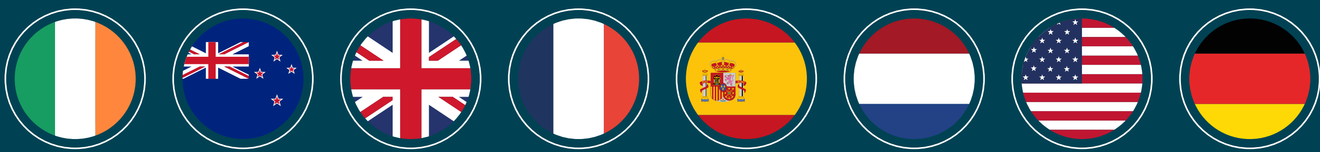
Source: Office for National Statistics (2023)

- **Houses using tank or bottled gas, oil, solid fuel and wood are Disproportionally more likely to be owner-occupied.** For example, 81% of homes using oil central heating are owner-occupied, despite this applying to only 66% of all homes (Office for National Statistics, 2023). Similarly, homes which use electricity or a district heat network as their sole source of heating, are significantly less likely to be owner-occupied.

Powers

- **'Most of the powers required to deliver the decarbonisation of buildings are reserved to the UK Government'** (UK CCC, 2023: 60). However, it is widely acknowledged that the Welsh Government has some of the requisite powers to influence home decarbonisation, and can also influence the UK Government on reserved matters (Welsh Government, 2023a)
- **Powers relating to both housing and fuel poverty are devolved to Wales.** The Welsh Government has commenced the Optimised Retrofit Programme, to retrofit 1,700 socially owned homes and to trial and refine digital tools which can support wider decarbonisation (UK CCC, 2023). The Warm Homes Nest scheme provides free advice and support to all households, and funds packages of energy efficiency measures to those on low incomes or struggling to meet the cost of their domestic energy bills (Welsh Government, 2023b).
- **Wales also has powers in the devolved planning system and in its control over building regulations, to enable low-carbon heating in new homes:** an update to Part L of the building regulations requires a reduction in emissions from new homes (Welsh Government, 2020; UK CCC, 2023)
- **While the Welsh Government can encourage energy efficiency measures,** including through the Nest programme, **it cannot make regulations on energy efficiency standards,** such as those implemented at a UK level for private rental properties (Welsh Affairs Committee, 2021).
- **The Welsh Government can provide loans and grants for improvements to buildings** but the regulation of financial products is a power reserved to Westminster (UK CCC, 2023).

Eight international case studies



Case Study 1

Better Energy Homes: Ireland (2008-)

Programme characteristics

Better Energy Homes is a nationwide residential retrofit grant programme administered by the Sustainable Energy Authority of Ireland (SEAI).

The programme provides direct grants to homeowners (including landlords renting dwellings), covering c. 30% of total investment costs, to upgrade their dwellings with energy efficiency actions that must be installed by contractors registered with SEAI, with a bonus grant available in case of multiple actions. Eligible actions each have minimum performance criteria and technical requirements and include:

- Ceiling/attic and wall insulation (inner and outer)
- Heating controls
- High efficiency boiler upgrades (subsequently revised to apply to heat pump installation only)
- Solar heating systems

A Building Energy Rating assessment must be carried out after the works are completed.

Programme aims:

- Improve energy efficiency of dwellings
- Reduce heating bills
- Reduce GHG and air pollutant emissions

Programme costs (2008-2010): €62.8 million. CBA estimates net benefits of €106 million-€518 million

Total dwellings receiving retrofits: 376,218 from 2008-2019 (18% of total national housing stock)

Evaluation characteristics

- **Scheer & Motherway (2011)** – Cost-Benefit Analysis (CBA), using data on investment costs and modelled energy savings over the action lifetime (based on pilot scheme data), using a standard scenario about energy prices' forecast and a 4% discount rate. Also provided Net Present Value (NPV) estimates using different sets of costs and benefits for government, participants and whole society (e.g. by monetizing modelled reductions in CO_2 and other air pollutant emissions).
- **Scheer et al. (2013)** – ex-post billing analysis of metered gas data for 210 households who had received energy efficiency improvements through the programme in 2008 and a control group of 153,928 households with similar dwellings but who did not participate in the programme. Study uses a difference-in-difference method to compare pre- and post-intervention gas consumption for both groups.
- **Coyne & Denny (2021)** – ex-post billing analysis of whole-home energy data (gas and electricity) for 8,572 homes with bimonthly observations over a two-year period to 2017. Sample includes a control group of 6,725 homes that never receive a retrofit, a subsample of already treated households who have a recorded retrofit before the period of observed energy use, and the treatment group of 571 households that undergo a retrofit under the programme during the observation period.

Impact on energy use

- Scheer et al. (2013) found a mean reduction in gas demand of 21% (c. 3,600 kWh) between 2008 and 2010 for homes that received energy efficiency upgrades through the programme.
- Coyne & Denny (2021) found a mean reduction in whole home energy use of 1,091 kWh per year (2015-17), with substantial variation depending on the measures installed. Some measures resulted in more significant reductions in energy use, while others resulted in increases.

Emissions impacts

- For their CBA, Scheer & Motherway (2011) estimate 2.4 $MtCO_2$ avoided emissions over the action lifetime for actions carried out between 2008-2010 (using modelled energy savings and official direct emissions factors weighted for the different fuels saved. adjusted for predicted change in fuel mix and efficiency of electricity generation).

Economic impacts

- Scheer & Motherway (2011) estimate that 60% of total expenditure on installations is on labour. Using statistics about average industrial wages, the programme turnover is converted into full-time jobs supported by the scheme. For 2010, turnover was estimated at €72 million, representing c. 2,000 FTE jobs directly supported.

Lessons for Wales

As with other retrofit programme evaluations, ex post evaluation of energy savings in the Better Energy Homes programme reveals a significant difference between actual savings and the technical reduction potential indicated by engineering estimates. Scheer et al. (2013) find this shortfall to include both the effects of direct and indirect 'take-back' effects (sometimes known as 'rebound effects') and variations in actual achieved efficiencies for upgraded dwellings, though point to features of the sample (such as self-selection bias) that are likely to underestimate the population wide potential.

A more recent ex post evaluation of whole home energy savings (Coyne & Denny, 2021) from the programme finds that savings vary significantly depending on the measures installed. Only retrofits with external wall insulation, high efficiency boiler upgrades or solar heating are associated with significant reductions in actual energy use. Indeed, some combinations of measures are associated with increases in energy use (e.g. internal dry lining and gas boiler upgrade plus roof insulation), highlighting the vital role of occupant behaviour and pointing to the need for further research to understand the determinants of higher energy use, so that subsidy levels can be calibrated accurately for specific measures.

Neither ex post evaluation of energy savings from Better Energy Homes included observations involving installation of heat pumps (both studies took place before the programme was revised to no longer include subsidy for gas boiler upgrades). It remains to be determined whether Better Energy Homes retrofits that involve fuel switching from gas or oil boilers to heat pumps achieve greater reductions in whole home energy use than seen with gas boiler upgrade retrofits. (Greater reductions in gas demand can be safely assumed.)

Case Study 2

Warm Up New Zealand: Heat Smart (2009–2013)

Programme characteristics

Warm Up New Zealand: Heat Smart (WUNZ:HS) was a nationwide programme designed to susbsidise improved energy efficiency in residential buildings.

Subsidies were available for a range of measures for all houses built before 2000:

- Retrofitted ceiling and/or underfloor insulation and a range of other measures including draught proofing
- Funding for a 'clean heating device' (if floor and ceiling insulation requirements met), most typically a heat pump.

Without income restriction, the programme provided households with one third of the costs of retrofitting insulation (up to NZ$1,300), and NZ$500 towards the costs of heating retrofit from approved suppliers. Lower-income households were eligible for up to 60% of the costs of insulation and NZ$1,200 towards a heating retrofit (landlords whose tenants were low earners could also receive this subsidy). The programme worked with additional partners (including energy retailers and local government) to provide co-funding, with third party funding generally applied to low-income households to cover remaining insulation costs. For those not eligible for additional funding, upfront costs were addressed by offering simple repayment options for costs not covered by grants, including repayment through property tax bills.

Programme aims:

- Helping New Zealanders have warm, dry, more comfortable homes
- Improving the health of New Zealanders
- Saving energy
- Stimulating employment and delivering capability in the insulation and construction industries

Programme costs:
NZ$330 million (CBA central estimated gross benefit of NZ$1.3 billion)

Total retrofits delivered:
241,000 (26% of pre-2000 housing stock – exceeding the original aim to reach 20% of pre-2000 homes)

Evaluation characteristics

- **Energy savings** – 2009/10, sample size 46,655 households (insulation and heating retrofits) plus a matched control group; uses difference-in-differences approach to analyse retrofit impacts on monthly household electricity and total metered energy use.
- **Health impacts** – 2009/10, sample and control group as above. Used anonymised National Health Index records data and a 'difference-in-differences' approach to analyse household hospitalisation and pharmaceutical costs before and after the intervention; and a sub-cohort of those aged 65 and over who had been hospitalised prior to the treatment date for a mortality rates analysis.
- **Economic impacts** – 2009/10, sample size 51,600 households (insulation) and 12, 658 households (heating retrofits). Uses building consents data and number of houses subsidized to predict insulation consumption and an estimate of how much of this was additional; then uses these calculations to estimate additional employment and national producer surplus resulting from the programme.

Impact on energy use

- Insulation retrofits – 0.9% reduction in average annual household electricity use and 0.7% reduction in annual total metered energy used.
- Heat pump installation – 1.9% increase in average annual household electricity use and 0.8% increase in total metered energy used.

Health impacts

- For inhabitants of households that received **insulation retrofits**, key health benefits were:
  - Significantly reduced hospitalisation and pharmaceutical costs.
  - Reduced mortality, particularly among those who had previously been hospitalised with circulatory conditions.
  - Receiving a **heat pump installation** did not result in statistically significant changes to any of the health outcomes measured.

Economic impacts

- Evaluation of year 1 found that the programme resulted in:
  - Additional consumption of 6.6 million m2 of insulation and 10, 700 heating units; generating.
  - An additional 64-431 FTE jobs.
  - An additional producer surplus of NZ$44-62 million.

Lessons for Wales

According to the energy savings evaluation, while it achieved high take-up the programme failed to deliver deep reductions in average energy demand. However, total metered energy savings from heat pump installation were significantly higher for households on the gas grid, particularly at the lowest outdoor temperatures. (Just 14% of households in New Zealand are on the gas grid compared to 81% of households in Wales.)

Among households that received heat pump installation, energy use increased significantly during warmer months (and this effect was strongest in warmer areas), resulting from the use of heat pumps for air conditioning. Air-to-water heat pumps may be preferable from this perspective (compared to air-to-air heat pumps which can be used for cooling purposes).

For both heat pump installations and insulation retrofits, impacts on energy use were mediated by a take-back effect at the coldest outdoor temperatures, whereby households took back some of the potential savings from increased energy efficiency via increased indoor temperatures/increased thermal comfort. There was also evidence of a take-back effect at milder outdoor temperatures, whereby houses used more energy than without treatment as households became accustomed to warmer houses.

It may be that the flipside of lower-than-expected impacts of insulation retrofit on energy use is greater health benefits for insulated households. The evaluation also found that energy use and health benefits were more pronounced for lower income households – the successor programme reflects this by narrowing eligibility to low income homes.

It should also be noted that energy savings are not a perfect proxy for emissions reductions – particularly for heat pump installations in the WUNZ:HS evaluation, especially where the previous heating device did not use metered energy, meaning that differences in energy use could not be accurately evaluated (and would only be captured as an increase in electricity use). Generally, the emissions impact of heating retrofit reflects the difference between the emissions intensity of the source of heating being replaced and the emissions intensity of the replacement source, mediated by changes in energy demand.

Case Study 3

Kirklees Warm Zone: West Yorkshire (2007–2010)

Programme characteristics

Kirklees Warm Zone (KWZ) was an area-based retrofit programme designed to systematically reduce fuel poverty on an area basis in the Metropolitan Borough of Kirklees (total population 440,000), initially prioritising the need for a single point of contact for practical support and advice for householders (one stop shop approach) and the simplification of existing grant schemes for home energy efficiency and heating.

A significant increase in investment from Kirklees Council (made possible by the sale of their stake in a local airport) and leveraged investment from co-funders (including Scottish Power, investing £11m as a means to meet carbon emissions reduction target, CERT, obligations) enabled the programme to offer:

- Free energy assessments and surveys for all households
- Free cavity wall and loft insulation where technically feasible
- Free improvements to heating systems (for households in fuel poverty)
- Competitive prices for replacement boilers and interest free loans for renewable technologies for able to pay households

The programme had a highly localised delivery model, involving a ward-by-ward approach with dedicated local branches of the installation contractor, with single streets or neighbourhoods saturated with retrofits at the same time. High participation rates were achieved through community engagement, sustained marketing, and repeated household visits by a trusted provider.

Programme aims:

- Tackle fuel poverty
- Deliver a low carbon Kirklees
- Improve the uptake of state benefit support by residents
- Create jobs

Programme costs: £21m

Total dwellings receiving retrofits: 51,000 (from 176,000 total dwellings in the area, of which 133,000 received a preliminary assessment and 111,000 went on to have a full survey)

Evaluation characteristics

- **Webber et al. (2015)** – ex-post analysis of actual energy savings for 49,436 participating households, examining correlations between actual reductions in energy demand and modelled impacts to separate background trends from the effects of the programme.
- **Liddell et al. (2011)** – CBA monetising modelled impacts on health and wellbeing over a lifespan of likely impacts for all participating households.
- **Butterworth et al. (2011)** - economic impact assessment/CBA using data on investment costs and modelled impacts on energy bills, carbon emissions, job creation and economic output.
- **Kirklees Council (2011)** - process evaluation drawing on in-depth interviews and focus groups to explore stakeholders' perceptions of the delivery of the programme.

Impact on energy use

- **Webber et al. (2015)** identify an aggregate reduction of 4.2% space and water heating energy demand that can be attributed to the programme, amounting to an average reduction of 2,655 kWh per participating household from 2007-2011.
- The results suggest that the actual impacts of the scheme have been higher than predicted, with the scale of performance gaps and take back effects significantly lower than assumed (on average the measures installed achieved 64% of their full technical energy savings potential, compared to the 50% assumed in the predictive modellling).

Energy bills and emissions impacts pacts

- **Webber et al. (2015)** identify reductions in energy bills totaling £6.2m a year (2011 energy prices), equivalent to an average annual reduction of 10.6% per participating household. Total savings over a 25 year period are calculated at £148-214m.
- Average carbon savings for participating households are estimated as 507.9 $kgCO_2$/yr (an 11.7% reduction), based on 2011 emissions factors for gas and electricity. Across the whole programme total carbon savings are calculated as 47.7 $ktCO_2$ a year.

Economic impacts

- The KWZ programme directly employed 126 FTE posts and resulted in a further additional 117 jobs via multiplier effects through the supply chain, the majority based locally.
- The programme's invested costs of £21m are calculated to have resulted in an increase of spending in the economy of £39.1m (not accounting for the value of household savings from reduced energy bills).

Lessons for Wales

One of the key insights from the ex-post energy savings evaluation (Webber et al. 2015) is that the scale of performance gaps and take-back effects was significantly lower than assumed in key predictive methodologies (such as the one used in the UK Government's CERT scheme), meaning that installations through the programme achieved a significantly higher proportion of their technical energy saving potential than predicted (62% compared to the 50% assumed in the CERT model). The accuracy of modelling assumptions also varied significantly when the results were broken down by area deprivation, with 49% of technical energy savings potential achieved by installations in the lowest income areas, compared to 70-71% in middle and higher income areas. This indicates that existing modelling of the impact of retrofit activities is accurate for lower income areas, where there is likely to be greater fuel poverty and therefore thermal comfort take-back effects at a greater scale, but may significantly underestimate the impact in middle and higher income areas. In other words, the results show that the KWZ programme was at least as effective as predicted at reducing energy use (and alleviating fuel poverty) in lower income areas, but more effective at reducing energy use than predicted in middle and higher income areas – suggesting that as these households were already adequately heated, more of the technical energy saving potential of insulation measures was able to be 'cashed in' rather than 'taken back' as increased thermal comfort.

Process evaluations of KWZ also highlight key insights into implementing area-based retrofit programmes and delivering insulation measures to communities at a large scale:

- The method of street-by-street saturation was effective at encouraging take up – leveraging powerful peer influences on behaviour – and enabled the programme to deliver large numbers of retrofits in a short timeframe. Alternating between more deprived and less deprived wards helped ensure coverage across the borough and meant that wards with higher needs didn't overwhelm the programme too early. Households that initially declined to participate were given multiple opt-in points and a high proportion joined the programme in this way.

- An early challenge was the problem of 'gate-crashing' by unauthorised contractors, which risked lowering trust in the programme and deterring households from participating. (This was exacerbated by the initial plan for a low key launch of the programme to avoid being inundated with requests.) This identified the need for ward-targeted marketing campaigns to make households aware of approved contractors and what to expect from the programme, supplemented by hyper-local community engagement.
- The programme involved coordination of multiple partners and stakeholders. Partnership approaches were especially beneficial in relation to marketing and local engagement, procurement (particularly the procurement of the programme funding and programme contractors, and in partnership support and involvement with contract management) and in providing bolt-on services (such as fire safety or benefits advice) to maximise the programme's offer to households and communities.

Case Study 4

Turnkey Retrofit: France, Ireland and Spain (2019–22)

Programme characteristics

The Turnkey retrofit programme developed an integrated home renovation service, or one stop shop, which can be accessed through a user-friendly online platform called 'Solutions4Renovation.'

It involved expanding existing models from France into Ireland and Spain and was funded in its entirety by the European Union. Each scheme was comprised of several replicable tools to guide users through the retrofit process and link to other sites.

The service covers all aspects of the retrofit journey including initial assessment, the offer of retrofit measures, contract development, the provision of financial support, on-site coordination, and quality control, offering tailor made solutions for each home.

Programme aims:

- Increase awareness and access to local and national financial support schemes
- Decrease total renovation costs by providing integrated renovation solutions
- Provide additional benefits beyond energy efficiency, including comfort, security and quality of life
- Build partnerships with important stakeholders in order to develop a service which would be replicable in other European countries at the end of the project.

Programme costs: €1.5 billion

Evaluation characteristics

In the cross-country report each country's evaluation reports were analysed to identify instructive points of comparison: common difficulties, success factors and lessons for replication. Two tools, explained in detail below were evaluated as part of the online platform. There is also a wider report on lessons for implementation of one-stop shops as a whole, of which the online platform forms only a part.

- **In France:** A baseline evaluation allowed for measuring qualitative impacts compared to existing services and was drawn from the existing evaluation processes for these services. Interviews and surveys were then conducted to determine the results of the project.
- **In Spain:** Eighteen interviews, of which eight were with experts, seven were with homeowners, and three were with property managers of multifamily buildings. Tools had not been developed for the entirety of the renovation process, meaning the evaluation focused on the tools and functions that were available at the time.
- **In Ireland:** Two households were surveyed and thirteen experts were interviewed. The Irish platform was not live at the time of the evaluation, meaning no households had completed a retrofit journey. Interviews therefore focused on householders who had completed their retrofits through other services.
- **In all countries:** Homeowners complete a common survey and interviews are conducted using a common framework to make the local evaluation process as similar, feasible and comparable as possible.

Punch Diag (awareness raising)

- In this feature, the homeowner is prompted to describe their house by answering multiple choice questions.
- After answering the questions, the user is then given a ranking for each element of their house and the potential for progress on four metrics: energy saving, thermal comfort, acoustic comfort and air quality.
- The user is then redirected towards a separate energy assessment feature (the Roadmap tool) to develop a retrofit plan.

Roadmap (starting the journey)

- The roadmap tool allows the homeowner to answer further questions about their home, receiving basic, intermediate and advanced roadmaps for their home.
- They are provided with the estimated EPC improvement for each solution, as well as other metrics including, projected savings on bills and improvements in comfort.
- The homeowner can then personalise their plan, looking at finance options, cost estimations and visualise it step-by-step – prompting a visit from an assessor.

Evaluation of the online platform

- Homeowners in Spain indicated that the online tools allowed them to develop their knowledge on what measures could be taken up in their homes to both increase energy efficiency and deliver other benefits, such as increased comfort and reduced energy bills. They indicated a need for more information on financing, noting that, despite future bill savings, they would be unlikely to retrofit their home if there was no additional support.
- In Ireland, homeowners felt improvements to the website could be made in several areas, including further technical information on retrofit options, transparency about finance options and the experiences of previous homeowners. They stated that if the tool recommends homeowners contact professionals for further information, there needs to be oversight to ensure those professionals are suitably qualified.
- Experts in both countries stated that the two different tools were good concepts that could assist homeowners new to understanding retrofit, but needed tweaks in design and phrasing to suit the country context. The platform would also need maintaining on a regular basis to update estimated costs and available finance options. Given that the Irish platform aimed to nudge the customer towards contacting a retrofit advisor, there were also concerns about ensuring there are sufficient numbers of these if the one stop shop were to be deployed at scale.

Lessons for Wales

The Turnkey project highlights that one stop shops ought to only form one part of a comprehensive policy package which need to include regulatory measures, energy performance standards, training and accreditation programmes, technical support and communications campaigns. Wales does not have policy competence on energy efficiency standards, but many of these potential policies are devolved to Wales.

One stop shops also have a role in signposting homeowners to different sources of finance, with the online platform developed as a template within the Turnkey project providing homeowners the option to personalise their retrofit journey based on available finance. One stop shops which offer innovative financing options are likely to result in greater uptake, meaning it is important to involve and encourage lenders. Electronic buildings passports are also seen to be effective in convincing homeowners to undertake deeper retrofits, and one stop shops should aim to drive consumers to undertake these.

The success of one stop shop models is predicated on having the local capacity and skills to deliver retrofit at scale: upskilling will be required in a number of areas. Accreditation of workers carrying out retrofit measures provides credibility and increases trust for homeowners and lenders, harmonising training programmes across different regions and nations, for example through a UK-wide accreditation scheme, could increase perceptions of quality.

Effective one stop shops also rely on building capacity in monitoring and verifying results from the retrofit. This helps both provide quality assurance for homeowners and signal confidence in the retrofit scheme, but also can provide data on the uptake of retrofit measures and the success of the scheme. If implemented at a local level, data will need to be transferable across different schemes to obtain a reliable national picture of the uptake of home decarbonisation measures: templates and toolkits can ensure that both national government can coordinate the retrofit mission, but that it is adapted successfully to suit the local context.

There are existing replicable elements of one stop shops, including the online tools created through the Turnkey project. Digital elements can be easier to recreate but templates can also be used for the physical activities, including site visits. Any replication needs to be adapted to the local context; the Turnkey project highlights that this process needs to be iterative and often takes more time and resources than initially envisaged.

Case Study 5

Social Housing Decarbonisation Fund Demonstrator: UK (2020-22)

Programme characteristics

The Social Housing Decarbonisation Fund (SHDF) is a 10-year, £3.8bn UK Government funding programme intended to kickstart retrofitting activity in social housing across England, develop a whole house retrofit approach at lower cost, and stimulate the retrofit market and local authority retrofit capabilities.

In the initial Demonstrator (SHDF(D)) phase of the programme (originally intended to run to 2021 but extended as a result of significant delays to delivery), the Fund awarded grants totalling £62m to 19 pilot projects across England, encompassing 2, 273 households, targeting EPC improvements to at least EPC C, a 5-30% reduction in costs and energy performance of 50 kWh/m2 a year. As of the end of June 2022, just 255 of these initial properties had been completed (14% of the target), with a further 39% underway and 47% not yet started. A final outcome and economic evaluation report for the Demonstrator phase of programme is not yet available, but a process evaluation conducted by Ipsos and the Energy Saving Trust highlights some valuable learning for future phases of the programme and grant-funded retrofit programmes more widely.

Lessons for Wales

The SHD(D) programme attracted substantial interest from local authorities and registered social landlords and was able to award grants to a wide variety of projects at different scales and types and levels of innovation. However, the programme faced significant challenges during its implementation, including but not limited to the impacts of the Covid-19 pandemic on the supply of materials, availability of labour and access to targeted households, meaning that almost all the funded projects had to downgrade original ambitions on building performance, cost reduction and clean heat technologies in response to these challenging market conditions and to align with grant spending timeframes. Unavoidable challenges and delays created by the impacts of the pandemic were also compounded by unintended consequences of the programme design and delivery:

- SHDF(D) was the first UK government retrofit grant programme to include mandatory compliance with the British Standards Institute's publicly available standard for domestic retrofit (PAS 2035), introduced with the intention of supporting consistency and quality across SHDF(D) retrofit projects. However, while some providers regarded PAS 2035 as beneficial to installation quality and their understanding of whole house retrofit requirements, almost all projects reported that the PAS 2035 standard added complexity and generated delays and delivery challenges. In many cases a lack of awareness and preparedness (e.g. of PAS 2035 certification requirements for window installation) in existing supply chains prevented these from automatically transitioning to the new market created by the programme, leading to unexpected initial shortages in energy efficiency measures which had previously been deployed at scale. Several projects also saw costs increase due to preparatory work to meet PAS 2035 requirements.
- SHDF(D) was deployed as part of a package of pandemic recovery measures, with a focus on short-term economic stimulus objectives which also drove very short timescales for grant applications and project delivery. The reduced time for project design and set up resulted in implementation setbacks, such as delays in procuring materials and labour, leading to costs increasing in line with price rises. In some cases, properties had been included in the original SHDF(D) funding

submissions on the basis of historic or inaccurate energy and property data, with the result that some properties could not be technically delivered, proved too complex or costly or turned out to fall outside of programme requirements.

- Another consequence of the short programme timescales was that the SHDF(D) cohort made concurrent demands on the supply chain, with the result that demand for specialist materials and products often outstripped supply (an advantage of longer timescales is increased opportunities for flexibility and sequencing in the supply chain). Indeed, the main criticism of the programme design is that the 12 to 18-month timeframe failed to take sufficient account of the time required to deliver retrofit projects and was inconsistent with the programme aims of encouraging innovation and generating learning about how best to implement deep retrofit at scale.

However, despite these implementation challenges and the programme's delayed delivery, there is evidence of success across SHDF(D) in driving technological, process and business model innovation, including considerable innovation in heating systems technologies and the use of permitted development design arrangements with local authority partners to circumvent planning permission requirements. While the outcome evaluation report is not yet available, the process evaluation highlights emerging, but so far unsubstantiated indications of positive impacts on jobs, business growth and supply chains, as well as evidence that projects are having the desired effect on home energy efficiency and healthier homes.

Case Study 6

Energiesprong: the Netherlands and the UK (2013-)

Programme characteristics

Energiesprong is a whole-home deep retrofit business model, initially developed through funding from the Dutch government for a large-scale market-led initiative to achieve net zero energy homes (a home that generates enough energy for heating itself, providing hot water and powering household appliances).

The business model was explicitly designed to overcome key barriers and drawbacks with traditional retrofit delivery (see Table 1).

Having completed a pilot phase in the Netherlands, the initiative has since undergone a period of expansion to other national contexts, with Energiesprong teams being established in France, the UK and the US. 5,000 net zero energy homes have been delivered to date in the Netherlands, with a handful of pilot homes in France and the UK.

Picture credit: EnergiesprongUK

Table 1: Traditional retrofit delivery versus Energiesprong business model

Traditional retrofit delivery	Energiesprong business model
'Atomised' market model involving single measures delivered by separate contractors, typically requiring multiple points of contact, and tending to be funded by multiple separate subsidies.	Delivered by a market development team acting as a market 'intermediary', the model involves a net-zero energy performance contract, an integrated and industrialised supply chain, a single customer interface, a financial model based on the performance contract, and coordinated governance of these elements via the Energiesprong team.
Traditional offer to customers framed in terms of energy cost savings, which are typically based on estimated rather than actual or guaranteed performance. This approach is seen as resulting in poor-quality installations, with limited liability or recourse potential.	Customers offered a comprehensive whole-house retrofit, with a 30-year energy performance guarantee for net-zero annual energy consumption. This typically involves offsite manufactured, insulated facades and modules integrated with renewable heat sources and PV panels. Homes are given a visual upgrade and the retrofit typically includes some non-energy based maintenance measures.
Typical supply chain consisting of multiple disconnected installers, suppliers and consultants. This supply chain fragmentation (alongside lack of performance guarantee, measurement and verification) seen to contribute to low quality retrofits.	An integrated supply chain, typically with a single 'solution provider' taking a performance-based approach to procurement based on a fixed price. This model is also driving a move to industrialization and offsite manufacture with integrated energy modules that can be minituarised and mass produced, with the intention for process innovation to drive down costs and installation times through economies of scale.

Traditional retrofit delivery	Energiesprong business model
Household engagement has typically involved single measures, leaving customers themselves to procure and project manage more comprehensive work – requiring them to engage multiple consultants and contractors, each with their own marketing channels and points of sale (increasing complexity and seen as likely to deter all but the most committed households).	The customer interface involves a single product offering, rather than separate sales, audit, measures and financing from different providers. There is also an intensive consumer engagement process, with householders involved in developing the design brief.
Current model seen as synonymous with government grant and supplier obligation schemes, typified by stop-start funding for single measures – resulting in a grant dependent marketplace and potentially contributing to the piecemeal nature of installations and limited diffusion of whole-house retrofits.	As with other forms of energy performance contract, the financial model relies on realised energy savings to fund the cost of measures (a net zero energy retrofit meaning that the whole energy bill can be used to recover costs). However, currently the model is heavily reliant on government subsidy; making the business model self-sustaining is reliant on achieving economies of scale and learning rates to bring costs down to c. £40,000 a unit (compared to around £90,000 a unit currently).

Lessons for Wales

While the Energiesprong model has many potential advantages compared to traditional retrofit delivery (see Table 1), there is little evidence so far to determine if it is successful on a large scale. Energiesprong's own modelling points to impressive expected energy savings (an average Energiesprong retrofit is estimated to reduce a home's total energy demand by 80%), but there is very little information on post project evaluation, to verify if actual retrofit results match projected savings.

In both the Netherlands and the UK, Energiesprong teams have so far solely focused on the social housing sector as a target market, because achieving scale is easier (multiple households can be reached by a single deal with a housing provider) and because social housing tends to be more uniform (the model requires scalable products that can be produced offsite and applied to homes with uniform characteristics). The financial model has also been designed for the social housing sector: housing associations provide the upfront capital to pay the building companies that provide the retrofits and then recoup the costs through an energy services charge equivalent to savings on tenants' energy bills, with no net additional cost to tenants.

For tenants/participating households, one of the key potential advantages of the model is the minimal disruption and installation time compared to traditional retrofit delivery, with offsite modular construction enabling some Energiesprong retrofits to be installed in just 24 hours. The model also deliberately emphasises visual appeal and wider home improvement beyond energy savings as part of its offer to customers.

A recent report by the Green Alliance sets out a proposal for scaling up the Energiesprong model via a government commitment to funding 5,000 retrofits, conditional on industry progress in achieving economies of scale and further innovation and learning rates to bring down costs. For the social housing sector, costs of £50,000 per Energiesprong retrofit would enable them to be self-financing; a goal of £35,000 would need to be reached for the model to be viable in the wider housing market.

Case Study 7

Zero Energy Now: Vermont, USA (2016–)

Programme characteristics

Zero Energy Now (ZEN) is a whole-home retrofit programme initially funded as a pilot by Green Mountain Power (the largest utility company in Vermont) and administered and delivered by the Building Performance Professionals Association of Vermont (BPPA-VT).

ZEN whole-home retrofits are designed to drastically reduce household emissions by combining energy efficiency, heat electrification and renewable energy generation into a single package of measures.

In the initial, pilot phase in 2016 and 2017, whole-home retrofits were delivered to 35 households, at an average cost of US$54,500 per home. The pilot targeted the able-to-pay market with a mix of grant subsidies and low interest loans; some participating households were able to complete projects without long-term financing and made immediate savings on energy bills, while others met non-subsidised investment costs with 20- to 30-year loans (with loan repayment costs mitigated by guaranteed energy bill savings as described above).

Key features of ZEN include:

- Programmatic use of decarbonisation metrics including: an energy and fossil fuel reduction standard based on a minimum 50% reduction in combined fossil fuel and grid electricity use; a minimum 10% reduction in energy use via insulation and building envelope measures; and at least 50% of the home's energy portfolio post-project to be drawn from renewables;
- A 'one-stop shop' delivery approach that integrates financing, project design support by programme staff, a network of approved contractors, and ongoing maintenance and support into a single service offer to households;
- Building simulation modelling to define optimum strategies for individual properties; and
- The use of energy savings guarantees to provide confidence to homeowners that measures will be cash flow neutral (or in some instances even cash flow positive), with reductions in energy bills compensating for the cost of loan repayments.

Emissions, energy use and energy bills impacts

An evaluation study of the pilot programme, using actual pre- and post-project fuel usage and metered gas and electricity data, found:

- Average annual fossil fuel and grid electric savings of 64%. Two of the participating homes became 100% fossil fuel free and a further eight achieved fossil fuel savings of >90%
- Average annual energy cost savings of 60% - amounting to an average US$1,878 per year for participating households

Lessons for Wales

It's interesting to compare ZEN Vermont with the Energiesprong initiative: both are whole-home retrofit approaches combining electrification of heat, insulation measures and renewable energy generation, with an energy savings guarantee as part of the financing model to address upfront cost barriers. The key difference (aside from the different target markets of the two initiatives) is that where Energiesprong takes a 'superinsulation' approach, with extensive insulation measures including prefabricated panelised envelope upgrades, ZEN Vermont can be considered as part of a broader trend of US colder climate retrofit programmes targeting substantial energy and emissions reductions via more moderate, lower cost envelope upgrades in combination with equipment electrification and solar PV. ZEN projects were generally limited to more conventional, if still comprehensive envelope upgrades with high levels of industry familiarity (with the advantage of an adequate workforce and training already in place, as well as lower material and labour costs), combined with cold climate heat pumps and a rooftop solar array. The ZEN approach therefore represents a shift away from heavy investments in building envelopes to reduce energy loads, towards decarbonisation through the combination of end-use electrification and solar PV. On average, about US$12,000 was spent on building envelope upgrades for each ZEN retrofit, contributing to significantly lower overall project costs than have been reported for 'deeper' whole home retrofits.

While reported results are encouraging and based on actual fuel and energy use data, there is no independent or peer-reviewed evaluation study of the programme to date. The pilot evaluation sample size is small and there are limitations to its approach to measuring differences in fuel and energy use as well as disentangling the effects of the programme intervention from broader trends in fuel and energy use. On the other hand, it should be noted that because ZEN retrofits involve fuel switching away from fossil fuels to electrified heat sources, residual use of grid electricity will become increasingly less problematic for emissions reduction as the grid itself reduces its reliance on fossil fuel generation. As with Energiesprong, there is currently limited evidence to indicate how and whether the ZEN Vermont approach could be applied at scale, though the programme model is now expanding to other communities and US states.

Case Study 8

CO_2-Building Rehabilitation Programme: Germany (2001-)

Programme characteristics

The CO_2-Building Rehabilitation Programme (CBRP) is a home energy retrofit financing initiative administered by *KfW Bankengruppe* (KfW), Germany's state-owned investment and development bank.

Since 2001, the CBRP has been funded directly by the German Federal Government and enables KfW to issue low interest loans of up to €75,000 per household (significantly below market rates) for retrofit measures to achieve an energy performance benchmark (based on Energy Savings Ordinance (EnEV) regulations for new buildings).

Homeowners, housing companies and public bodies can apply for CBRP loans at an intermediary bank, which conducts initial credit checks before forwarding the application to be assessed by KfW against programme-specific criteria; if approved, the applicant signs a contract with the intermediary bank, enabling KfW to transfer the money to the intermediary bank which assumes legal responsibility for the agreed loan.

To qualify for the programme, packages of measures must achieve modelled reductions that meet or exceed the energy performance benchmark for that category of building, with reductions in loan repayment for cases that achieve higher percentages. From 2009 onwards, the programme was expanded to include support for single measures such as wall and loft insulation or heating system replacements, though the majority of CBRP funding is still allocated to multiple measure retrofits (in 2011, 74% of CBRP retrofits achieved new build standard or better). From 2007, around 5% of the programme budget has been allocated for performance-linked (rather than unconditional) subsidies.

Between 2006 and 2009, 1.4 million existing homes received retrofit measures through the CBRP, with total loan commitments of €26bn made in this three-year period. The programme is widely regarded as an international exemplar and has been subject to multiple (German-language) evaluations over its lifetime (the results of some of which are highlighted below).

Carbon and energy savings

- From 2006-2009, estimated average annual energy demand reductions of 40kWh/m^2 for participating households (a 33% reduction), amounting to total energy bill reductions of €1bn a year (Schörnborn, 2010).
- For the same period, total emissions reduction of 3.9 MtCO_2 and average *lifetime* carbon savings calculated

at 19 $MtCO_2$ per year (the evaluations did not consider free rider or other reduction effects which may mean the actual number is slightly lower) (Rosenow et al., 2013).

Economic impacts

- From 2006-2009, 894,000 new jobs lasting at least one year directly supported by the programme (Schröder et al., 2019).
- Estimated €9 in loans and private investment leveraged for each €1 in public subsidy (ibid).

Lessons for Wales

The high uptake and delivery rates of the CBRP have been attributed to several factors, some of which are unique to the German context and others of which point to lessons for Wales. Key to the CBRP's success is a wider policy and regulatory environment which acts in concert to stimulate a robust 'retrofit economy':

- The German approach deliberately links (and coordinates across) the 'three pillars' of a clear legal framework for home energy retrofit via EnEV regulations; strong subsidy and low interest loan programmes to address upfront investment barriers; and statutory provision of promotional information, advice and support for homeowners via the German Energy Agency (DENA). In this way, energy efficiency provisions are integrated into a clear framework of regulation, information and support, with policy stability, clear and consistent messaging to industry and the public, and a strong, enforceable legal standard to underpin change.
- In KfW, the German federal government has a funding investment tool with a powerful reach in all regions of Germany, enabling the CBRP loan and subsidy programme to operate on a very large scale. The involvement of the state investment bank also gives weight to the programme, increasing efficiency and leverage, and inspiring private-sector confidence.

- The approach of using performance-linked investment subsidies and low interest loans (as opposed to unconditional subsidies or tax concessions) creates a reliable funding mechanism tied to ambitious standards, with eligibility for and levels of support provided by CBRP loans and subsidies determined by building standards and requirements for energy efficiency, and much more support for more expensive retrofit measures than is currently available in a Wales/UK context. This combines with an explicit but flexible "whole house approach" to energy saving (allowing for measures to be applied sequentially), providing energy suppliers and builders with clarity about the overall ambition for energy efficiency improvement – translating into an average investment of €36,000 per household in retrofit measures.
- The aggressive energy savings targets for new and existing homes have inspired innovation in energy technologies and building practices. This is bolstered by direct policy support for experimentation and innovation, with pilot projects coordinated by DENA to develop and trial individual measures, which can then be incorporated into KfW's loan and subsidy provision as well as informing and strengthening the legal framework, which has seen periodic updates over the last two decades. This has led to a virtuous circle in which the CBRP is not only underpinned by the EnEV regulatory framework but also improves it: because the CBRP funds measures which go beyond EnEV standards, driving technology development and commercialization and thus enabling policy-makers to tighten the standards.

Discussion

In the evaluation case studies presented above, we have endeavoured to highlight lessons and implications from individual retrofit programmes within the UK and internationally for decarbonising residential buildings in Wales.

As we draw conclusions from these case studies collectively, it is important to acknowledge some challenges and limitations encountered in synthesising lessons across the diverse retrofit programme case studies in this manner.

Firstly, due to the rapid timeframe required to complete this work for the Challenge Group, a systematic approach to identifying evaluation case studies was not feasible. Instead, we relied on initial scoping desk research, existing reviews of international retrofit programmes, and discussions with experts to select case studies. In finalising these, our aim was to include a variety of programmes of different scales. Although our initial intention was to focus exclusively on programmes that incorporated heat pump installations alongside energy efficiency measures, we found no published English-language evaluations of programmes where heat pump retrofits were implemented at scale. This is notable since several large-scale heat pump retrofit programmes have recently been undertaken, but published evaluations for these are not yet available. Given the significant anticipated role of heat pump adoption in the decarbonisation of residential buildings in Wales, this constitutes a key limitation of the review. It makes drawing definitive conclusions about the potential impacts of future retrofit programmes on reducing residential emissions challenging, as we detail further below.

An additional challenge arises from the relative variety and diversity of the retrofit programmes covered in our case studies, their varying implementation contexts, and their evaluations, all of which complicate comparisons. Not all programmes included have undergone peer-review or independent evaluations, particularly the newer and potentially more innovative ones. The diversity in evaluation approaches complicates comparisons since different evaluations do not measure programme outcomes in the same way. For instance, they adopt varied methods for measuring changes in energy use or attributing these changes to programme interventions; often, they do not even focus on the same outcomes of interest. There is also significant variation in the degree to which evaluations provide data on programme features, delivery mechanisms, and contextual factors, which are crucial for informing the implementation of future retrofit programmes.

With the caveats mentioned above in mind, the following points are offered more as potential implications of the case study findings for retrofit policy in Wales rather than definitive conclusions:

1 While evaluations of retrofit programmes do not consistently demonstrate deep reductions in energy demand across the board, it is crucial not to draw hasty conclusions regarding retrofit policy.

With the exception of Zero Energy Now Vermont and Energiesprong (both smaller scale pilot programmes without independent or peer-reviewed evaluation studies), none of the case study retrofit programmes included in this report achieved deep (>50%) reductions in energy demand. Although this may seem disheartening at first, the implications for retrofit policy are not straightforward for several reasons.

Firstly, the majority of programmes reviewed in this report were not designed as 'deep' retrofit programmes and, as such, were not expected to achieve >50% reductions in energy use. We found no examples of 'deep' retrofit programmes delivered at a significant scale, making the feasibility of delivering deep retrofit at scale difficult to determine from the available evaluation evidence.

Another perspective on the effectiveness of retrofit is to consider the extent to which the retrofit measures installed through a programme achieved their technical potential to reduce energy demand. When viewed through this lens, the findings are mixed: some programmes delivered energy savings significantly below the technical potential of the installed measures, while others achieved a much higher proportion of their technical reduction potential than modelling estimates had indicated.

2 Impacts on energy demand across retrofit programme evaluation studies are moderated by performance gaps and 'take back' effects. However, where 'take back' effects are higher, this may indicate greater impacts in addressing fuel poverty.

Two factors influence whether retrofit installations achieve the expected proportion of their technical reduction potential: performance gaps (for example due to poor quality installation) and 'take back' effects, where householders 'take back' some of the potential energy savings from installed measures to increase thermal comfort.

Evaluation evidence included in this report suggests that the scale of 'take back' effects may be influenced by socioeconomic factors. One study found that measures installed in higher-income areas achieved a significantly higher proportion of their technical reduction potential than ex-ante modelling estimates had suggested. This implies that as these households were already adequately heated, they were able to 'cash in' more of the potential energy savings of the installed measures than the modelling had predicted.

Evidence indicates that 'take back' effects are likely to be greater in lower-income areas, where fuel poverty is likely to be more prevalent. This suggests that, in lower-income areas, the weaker impacts of retrofit measures on reducing energy use could be viewed as being offset by stronger impacts on alleviating fuel poverty, with associated benefits for health and wellbeing.

It is not possible to draw conclusions about the extent to which impacts on energy demand were weakened by performance gaps for any of the evaluation studies included in this report.

3 For retrofits involving fuel switching to low-carbon heat sources, impacts on energy demand do not directly correlate with emissions impacts. For instance, installing a heat pump might result in a slight decrease or even an increase in household energy demand while simultaneously delivering a significant reduction in emissions.

Although most evaluations in this report measure energy use reduction as the primary outcome of retrofit installation, it should not be interpreted as a direct proxy for emissions reduction. This is especially true for retrofits that involve a switch from fossil fuel to low-carbon heat sources, such as replacing a gas boiler with a heat pump, which could, theoretically, lead to an overall increase in household energy use while achieving a drastic reduction in emissions. In the Warm Up New Zealand: Heat Smart (WUNZHS) programme, for example, heat pump retrofits resulted in average increases in household energy use. However, the majority of these involved a fuel switch from a non-metered source (such as oil or non-reticulated gas), so the impacts on energy use could only be captured as an increase in metered electricity use, as there was no reliable data on non-metered energy use. It's worth noting that none of the programme evaluations included in this report involve fuel switching from gas boilers to heat pumps at a significant scale. While it's difficult to determine this from the available evidence, logic dictates that a retrofit involving a complete fuel switch from fossil fuels to electricity can be considered to have achieved a 100% reduction in direct household emissions (direct household emissions are those produced on site, typically from burning fossil fuels such as natural gas for cooking and heating). Additionally, indirect emissions from household grid electricity use will also decrease as power generation shifts towards renewable sources and the grid decarbonises. This underlines the importance of distinguishing between retrofit impacts on energy use and impacts on emissions reduction.

4 Many of the retrofit programmes featured in this report were successful in enabling and encouraging the uptake of retrofit measures, notably because each involves key features to address upfront cost barriers.

Addressing behavioural barriers to encourage the uptake of heat pumps and insulation retrofits at a significant pace and scale remains a key challenge in decarbonising residential buildings. Despite a mixed picture in terms of energy reduction impacts, many programmes in this report are deemed successful in achieving retrofit measure uptake, largely because they address upfront costs, which are consistently identified as the most significant barrier.

Without exception, programmes included in this study address upfront cost barriers through direct grant subsidies and/or low-cost loans, typically utilising a combination of these strategies. These cover varying proportions of the upfront costs, including grant-funded programmes that address these costs in their entirety. Programmes adopt a range of approaches to targeting direct subsidies, for instance, focusing on low-income households or those in fuel poverty. Across several programmes, government support with financing to address upfront costs also provides powerful levers for influencing outcomes through conditionality. Different programmes achieve this by, for example, tying eligibility for grants and low-cost loans to the use of approved contractors or adherence to quality standards, or by linking the extent and terms of financial support for different combinations of retrofit measures to their modelled or actual impact on energy use or emissions. When delivered at scale, this also creates levers for developing and shaping the retrofit market nationally, potentially resulting in a 'virtuous circle' where subsidy-supported innovation and commercialisation elevate standards and enhance the broader regulatory framework for building decarbonisation and energy efficiency.

5 While most of the programmes included in this report address upfront costs through grants to homeowners, two programmes stand out because they feature low-cost loans made viable through the use of an energy savings guarantee.

In these two programmes, retrofits are primarily or solely funded through various forms of low-cost loans. This approach is rendered viable by ensuring the loan repayments become cash flow neutral for borrowers through the use of an energy savings guarantee (essentially guaranteeing that energy bill savings will match or exceed loan repayments). Both programmes encompass a combination of heat pump installation, fabric measures to reduce energy demand, and rooftop solar PV. In both cases, solar PV is integral to the energy savings guarantee, ensuring any increase in electricity demand from heat pump installation is offset by household-level electricity generation, aiming for minimal use of grid electricity. The concept is to achieve a 'net zero energy' household — one that generates enough energy for heating, hot water, and powering appliances.

These programmes also differ significantly in their focus on fabric insulation. The Energiesprong model employs a 'superinsulation' approach, incorporating extensive insulation measures and prefabricated panelised envelope upgrades. In contrast, Zero Energy Now (ZEN) Vermont represents a shift in retrofit programmes in colder climates in the US, moving away from significant investments in building envelopes. Instead, it focuses on decarbonisation through a mix of end-use electrification and solar PV, alongside more moderate, cost-effective envelope upgrades. This method aims to lower overall costs and address skills and supply chain issues, making it viable for the homeowner market. The Energiesprong model is specifically designed for social housing providers and tenants. While both programmes report notable impacts on reducing energy demand and emissions, they lack robust external evaluations. It's also challenging to determine from the available evidence whether either model could be delivered at significant scale.

6 Addressing upfront costs is essential but not the sole factor for significant uptake of retrofit measures.

Policymakers in the UK are likely to be familiar with some cautionary examples of retrofit programmes that failed to meet their goals despite including measures to address upfront cost barriers (lessons from one of which are included in this report). Other barriers to uptake noted in our linked overview report on buildings decarbonisation include concerns about the running costs for heat pumps (exacerbated by the higher retail cost of electricity compared to gas), skills gaps, difficulties in obtaining clear information and quotes, and the complexity and duration of installation processes.

7 The report also highlights the potential benefits of a one-stop shop approach as part of a broader package to support retrofit delivery.

Existing online tools could initiate homeowners on their retrofit journey but would need continuous adaptation to fit the Welsh context and consumer feedback. A coordinated approach could help collate pre- and post-retrofit data that would prove useful for a wide variety of stakeholders, as well as boosting consumer confidence. These tools could link to finance options and approved contractors or retrofit coordinators, both of which would need to be developed simultaneously. If a platform for encouraging the uptake of retrofit options is developed, it is important that efforts are also made to develop a wider 'retrofit system' with one-stop shop approaches potentially enhanced by segmentation and data insight approaches to provide bespoke retrofit advice to households more systematically (Mulgan and Williams, 2023).

8 This report includes a programme that underscores the benefits of place-based approaches to retrofit delivery.

This indicates that place-based approaches may be particularly effective in encouraging uptake through partnership working, locally focused promotion, and door-to-door delivery, leveraging peer influence and community pride.

Finally, it is pertinent to consider these observations within the context of the scale and urgency of the net zero challenge facing Wales. This context is crucial, for instance, when discussing the lack of robust evaluation evidence for more recent (and potentially more innovative) retrofit programmes. While there are lessons to learn from the success of countries like France, which saw 600,000 domestic heat pumps installed in 2023 compared to the UK's 55,000 (Russon, 2023), the smaller market for key low carbon technologies in the UK also means that Wales is starting from a comparatively low base. Consequently, the actions required to decarbonise residential buildings in Wales may now have to be implemented at an unprecedented pace and scale to meet even our current net zero targets. Thus, while comparable countries worldwide are each tackling the challenge of decarbonising residential buildings in various ways, policy and technological innovation in retrofit delivery seem to be advancing faster than the ability of evaluation research to offer timely insights into the comparative impacts and benefits of different approaches. Indeed, as Carmichael (2019) notes regarding interventions to encourage the uptake of retrofit measures, this represents a policy issue where the required pace and scale of change can be considered 'uncharted territory beyond the available evidence base'. The upshot is that policymakers are tasked with making critical policy decisions on buildings decarbonisation amidst significant uncertainty.

References

Broc, J. (2017). **Better Energy Homes scheme (Ireland): Case study prepared by IEECP for the EPATEE project.** Retrieved from: https://epatee.eu/sites/default/files/epatee_case_study_ireland_better_energy_homes_ok.pdf

Brown, D. et al. (2019). **An energy leap? Business model innovation and intermediation in the 'Energiesprong' retrofit initiative.** Energy Research and Social Science, 58.

Bouteloup, C., et al. (2022). **D4.2 Evaluation Report.** Turnkey Retrofit. Retrieved from: https://www.turnkey-retrofit.eu/wp-content/uploads/TURNKEY-RETROFIT_EvaluationReport_D4.2.pdf

Butterworth et al. (2011). **Kirklees Warm Zone Economic Impact Assessment.** Carbon Descent.

Carmichael, R. (2019). **Behaviour change, public engagement and Net Zero: A report for the Committee on Climate Change.** Retrieved from: https://www.theccc.org.uk/publication/behaviour-change-public-engagement-and-net-zero-imperial-college-london/

Coyne, B. & Denny, E. (2021). **Retrofit effectiveness: Evidence from a nationwide residential energy efficiency programme.** Energy Policy 159, 112576.

Department for Energy Security & Net Zero (UK Government) (2023). **Whole House Retrofit (WHR) and Social Housing Decarbonization Fund Demonstrator (SHDF(D)) Joint Process Evaluation Report.** BEIS/DESNZ Research Paper Series Number 2023/008

Desmaris, R., and Decorme, R. (2022). **D4.3 Lessons learnt to inform future-large scale uptake.** Turnkey Retrofit. Retrieved from: https://www.turnkey-retrofit.eu/wp-content/uploads/TRD4.3_R2M_2022-03-15_Revised1708.pdf

England, R. (2023). **What SHDF projects have taught us about housing retrofit.** Blogpost. Retrieved from: https://www.elementaldigital.co.uk/what-shdf-projects-have-taught-us-about-housing-retrofit/

European Construction Sector Observatory (2017). **Policy measure fact sheet: Netherlands Energiesprong (Energy Leap).** Retrieved from: https://ec.europa.eu/docsroom/documents/30290/attachments/3/translations/en/renditions/pdf

Friedler, C. & Kumar, C. (2019). **Reinventing retrofit: How to scale up home energy efficiency in the UK.** Green Alliance.

Grimes, A. et al. (2012). **Cost benefit analysis of Warm Up New Zealand: Heat Smart Programme.** New Zealand, Ministry of Economic Development.

Grimes, A. et al. (2011a). **Warming up New Zealand: The impacts of the New Zealand Insulation Fund on metered household energy use.** New Zealand, Ministry of Economic Development.

Grimes, A. et al. (2011b). **The impact of retrofitted insulation and new heaters on health services utilisation and costs, pharmaceutical costs and mortality.** New Zealand, Ministry of Economic Development.

Grimes, A. et al. (2011c). **Impacts of the NZ Insulation Fund on Industry and Employment.** New Zealand, Ministry of Economic Development.

Kirklees Council (2011). **Kirklees Warm Zone: End of project process evaluation.** Retrieved from: https://www.kirklees.gov.uk/beta/delivering-services/pdf/warmzone-process-executive-summary.pdf

Less, B. et al. (2022). **Home energy upgrades as a pathway to home decarbonization in the US:** A literature review. *Energies* 22, 15.

Liddell et al. (2011). **Kirklees Warm Zone: The project and its health impacts: A cost benefit analysis.** Retrieved from: https://www.researchgate.net/publication/278000500_Kirklees_Warm_Zone_The_Project_and_its_health_impacts_A_Cost-Benefit_Analysis

Parsons, H., Robertson, N., and Hurren, K. (2023). **Overseas programmes for improving the operational carbon emissions from existing buildings – lessons for Aotearoa New Zealand.** Branz. Retrieved from: https://d39d3mj7qio96p.cloudfront.net/media/documents/ER79_Overseas_programmes_for_impr oving_the_operational_carbon_emissions_LR14413.pdf

Perry, T. & Young, L. (2020). **BPPA-VT Zero Energy Now Pilot Programs 2016 & 2017 Project Study Report. Efficiency Vermont.** Retrieved from: https://energyfuturesgroup.com/wp-content/uploads/2020/05/ZEN-BPPA-Past-Projects-Study-Final-Report-200505.pdf

Rosenow, J. et al. (2013). **Overcoming the upfront investment barrier – comparing the German CO_2 Building Rehabilitation Programme and the Green New Deal.** Energy & Environment 24 (1-2).

Russon, J. (2023). **Heat pump rollout in France and the UK: A comparative analysis.** Retrieved from: https://solaris-energy.co.uk/assets/main/news/mcscf---heat-pump-report-2023.pdf

Sawin, E. et al. (2018). **Multisolving at the intersection of health and climate: Lessons from success stories.** Retrieved from: https://img.climateinteractive.org/2018/01/Multisolving-at-the-Intersection-of-Health-and-Climate.pdf

Scheer, J. et al. (2013). **Quantification of energy savings Ireland's Home Energy Saving scheme: An ex post billing analysis.** Energy Efficiency 6, 35-48.

Scheer, J. & Motherway, B. (2011). **Economic analysis of residential and small-business energy efficiency improvements.** Report of the SEAI.

Schröder, M. et al. (2011). **The KfW experience in the reduction of energy use in and CO_2 emissions from buildings: Operation, impacts and lessons for the UK.** UCL Energy Institute, UCL and LSE Housing and Communities, LSE, London.

Torres, J., et al. (2022). **D3.4 Lessons learnt from the local implementation.** Turnkey Retrofit. Retrieved from: https://www.turnkey-retrofit.eu/wp-content/uploads/TURNKEYRETROFIT_Lessons-learned-from-the-local-implementations.pdf

UK CCC (2020). **Advice Report: The path to a Net Zero Wales.** Retrieved from: https://www.theccc.org.uk/wp-content/uploads/2020/12/Advice-Report-The-path-to-a-Net-Zero-Wales.pdf

Volt, J., et al. (2021). U**nderpinning the role of One-Stop Shops in the EU Renovation Wave: First lessons learned from the Turnkey retrofit replication.** Retrieved from: https://www.turnkeyretrofit.eu/wp-content/uploads/06536-Turnkey-Retrofit-report_RenovationWave.pdf

Welsh Government (2021). **The cooperation agreement: 2021.** Retrieved from: https://www.gov.wales/sites/default/files/publications/2021-11/cooperation-agreement-2021.pdf

Webber, P. et al. (2011). **The impacts of household retrofit and domestic energy efficiency schemes: A large scale, ex post evaluation.** Energy Policy, 84, pp. 35-43.

Winslow, A. (2022). **From then to now: A look at Vermont's Zero Energy Now Program through the years.** (Blogpost.) Retrieved from: https://neep.org/blog/then-now-look-vermonts-zero-energy-now-program-through-years

Wales Centre for Public Policy
Canolfan Polisi Cyhoeddus Cymru

Cardiff University, Sbarc | Spark,
Maindy Road, Cardiff CF24 4HQ

www.wcpp.org.uk
029 2087 5345
info@wcpp.org.uk
@WCfPP

Cardiff University
Prifysgol Caerdydd
Economic and Social Research Council
Llywodraeth Cymru
Welsh Government