Decarbonising heat in residential homes

Which technologies are the most viable to deliver the decarbonisation of heating, and what would be the most appropriate mix of technologies across the UK?

REMOURBAN project

REMOURBAN a major Smart Cities demonstrator project, where Nottingham Trent University was a leading partner, was funded through the Lighthouse project scheme of the European Union's Horizon 2020 research and innovation programme. It aims to support the design, testing and validation of new models of urban regeneration in the cities of Nottingham (UK), Valladolid (Spain) and Tepebasi / Eskisehir (Turkey). Lessons and good practice are shared between these cities and with the two follower cities of Seraing (Belgium) and Miskolc (Hungary). The project places an emphasis on the need to develop innovative and holistic regeneration models that maximise the convergence of energy, mobility and ICTS. By working closely with local communities, REMOURBAN is reducing greenhouse gas emissions and energy consumption to help reduce fuel poverty and improve the urban environment.

Developing Sneinton, Nottingham as a smart energy community. Sneinton is a residential area in the City of Nottingham with a typical mix of property types ranging from one-bedroom flats to three bedroom terraced houses, which were built from 1900 to the 70s. While a large number of the properties (65%) in the area are social housing, owned by Nottingham City Council (NCC) and managed on their behalf by Nottingham City Homes (NCH), retrofitting is being offered to all households, regardless of ownership. Despite the variations in age and construction type, the common characteristic of most of the selected properties in the area is the lack of insulation in the walls, whether these are constructed from solid brick, solid concrete or various types of infill cladding on timber studs between solid cross-walls. This variety of property types requires different types of solid wall insulation. Over 400 social and private homes are being supported through the REMOURBAN project grant.

In order to achieve high level of decarbonisation in residential homes, a combination of two strategies are required:

- **retrofitting existing homes to reduce energy demand;**
- **decarbonising heat sources through the use energy systems utilising renewable sources of energy**.

In the REMOURBAN project we have retrofitted **416 properties** with additional **47** for lighting only. The retrofitting for **Architypes A, B and E** was solid wall insulation, which deliver between average **41%** energy reduction.

In **Architype F2 and C2** in addition to solid wall retrofitting (Energysprong type) we have created a Hybrid Energy system with ground source heat pumps (water with 11C is taken from 135 m boreholes and heated to 42C by heat pumps), PV panels on the roof of 39 (initially 9 properties) residential properties, electrical storage and $12m^3$ (initially $4m^3$) hot water thermal store

Retrofitting of **Architype G** apart from solid wall retrofitting is innovative heating system. We have replaced the gas boiler in 94 flats in 4 blocks with Low Temperature District Heating (LTDH). The source of the heat of LTDH system is from the return pipe (60C) of the existing district heating system in Nottingham. In this way we extract unused heat from Nottingham district heating network. In this way 94 flats gas heating is replaced by non-fossil sustainable heat from waste.

Retrofitting	Property type	Archetype	No. Buildings	No. Dwellings
Solid wall insulation+ lighting	Victorian Properties	A - 1900s brick house	24	24
	Windmill Lane Solid brick 1930	B - 1930s brick house	147	147
	Newark Crescent flats	E - Wimpey No Fines	14	141
Solid wall insulation + Hybrid Energy system +lighting	**2050 Homes**	**C2 - William Moss Bungalow**	**3**	**3**
	2050 Homes	**F2 - William Moss Cross Wall House**	**7**	**7**
LTDH+PV	**Sneinton Courts**	**G - Maisonettes**	**4**	**94**
				416

2050 Homes retrofitting part of the REMOURBAN project

Introduction the need for this research

Domestic space heating represents the most significant part of the 37% of UK emissions from heat. At present, gas is the dominant source of heat as it is cost optimal. The proposed project will research an opportunity to move away from fossil fuel sources by utilising a hybrid decentralised heating system, integrating the electrical and the heating system at residential homes. The proposed system aims to achieve near Passive house level of performance at reasonable cost by offsetting the energy consumption with local energy microgeneration. The pilot 2050 homes deep retrofitting intervention, part of the EU Horizon 2020 REMOURBAN project started with 10 residential homes and later upgraded to 39 homes. With this project, we have optimised the design of a hybrid energy system, to achieve optimal utilization of the energy generated. The new system presents a decentralized, scalable energy system, where the heating is supplied by the micro energy grid operating at low temperature, with economically sustainable model for the development with minimum CO_2 impact on environment.

Deficiencies in existing studies

The main barriers for development of big district heating systems is substantial investment required and the general lack of high temperature heat sources. Heat networks are more or less absent in UK due to historic development of gas networks. Gas was too good and too cheap. To eliminate fossil fuel and move to low carbon heat represent a major national challenge to the UK over the coming years. It will require major strengthening of the electricity grid. At present there is insufficient electricity generation to supply al electric domestic heat. The gas grid delivers more than twice the energy of the electricity grid. At the same time the sustainable “green” sources of electricity are volatile, seasonal and depends on environmental conditions. This means electricity need to be generated locally and stored in an appropriate way to maximise the economic efficiency. Heat network are more or less absent from most of UK cities and to change this will require substantial and long-term investment. In general, central/district heating is effective when heat is by product of electricity generation. More practical and effective solution is to decentralise the heat networks. New technologies to provide heat from alternative sources like hydrogen are emerging but are still too expensive for real life and for widespread implementation, particularly transmission and storage. New more efficient houses are built but at present they account only to 1.5% of the housing stock, which require massive retrofit to

meet fossil free targets. Innovative and the same time practical solutions need to be developed for the existing housing stock, which in its majority is poorly isolated. Also, solutions need to work also for rural areas with lower density fuel poor homes.

The basis for 2050 homes development

The future of district heating is economy at scale – the introduction of decentralised hybrid heat local networks, integrating electrical and heat networks, supplying heat to between 10 to 100 houses, which is suitable for both urban and rural solutions. In many small villages where there is no gas supply, oil-burning boilers are used and can be replaced by local hybrid heating networks. In Hybrid systems the interconnection between PV, electrical and heating networks is used to achieve electrification of the heat in order to meet peaks and deliver flexibility by using energy storage technologies. Fundamental component in the hybrid heat networks is the introduction of heat pumps (HP). In order to have HP working at high efficiency (Coefficient Of Performance) the heat source should not be bellow 10C, which can be satisfied by ground source heat pump.

As part of the REMOURBAN Smart Cities and Communities H2020 project, deep retrofitting and integrated local energy system was introduced to existing buildings (39 terrace houses in Sneinton, Nottingham). This research aims to introduce economically sustainable intervention (Zero Energy type) aiming to maximum utilize the energy generated on site and achieve maximum offset of the energy consumed from the network. The new energy/heating system comprises a photovoltaic (PV) plant, ground sourced heat pumps (GSHP), a thermal energy storage (TES) and an electric energy storage (EES), this is a centralized, scalable energy system, the heating in the apartments is now supplied by a micro energy grid operating at low temperature

Originally in all the houses the Space Heating (SH) and the Domestic Hot Water (DHW) was provided by a combi-boiler (24kW) combined with a radiator system. The radiators in the retrofitted houses have not been changed, it is assumed that by improving the building fabric after the refurbishment work, the energy consumption will be substantially reduced, and the old heating elements will be able to provide necessary heat.

The heating system has been completely changed, the gas boilers has been removed and replaced by completely new, low temperature heating system. The cluster of houses now is configured as a micro Low Temperature District Heating (LTDH) network.

The heat in the system is generated by three GSHPs with a total power of 144 kW (3 x 46) to heat the water up to 40°C and to heat the hot water over 50°C. The GSHPs are connected to 9 boreholes 135m deep. The thermal storage is formed by four hot water tanks with a total capacity of 12 m^3. The electrical storage is 40kWt. The hot water is supplied to the radiators at about 42°C, whereas the DHW is supplied to the users at 50°C.

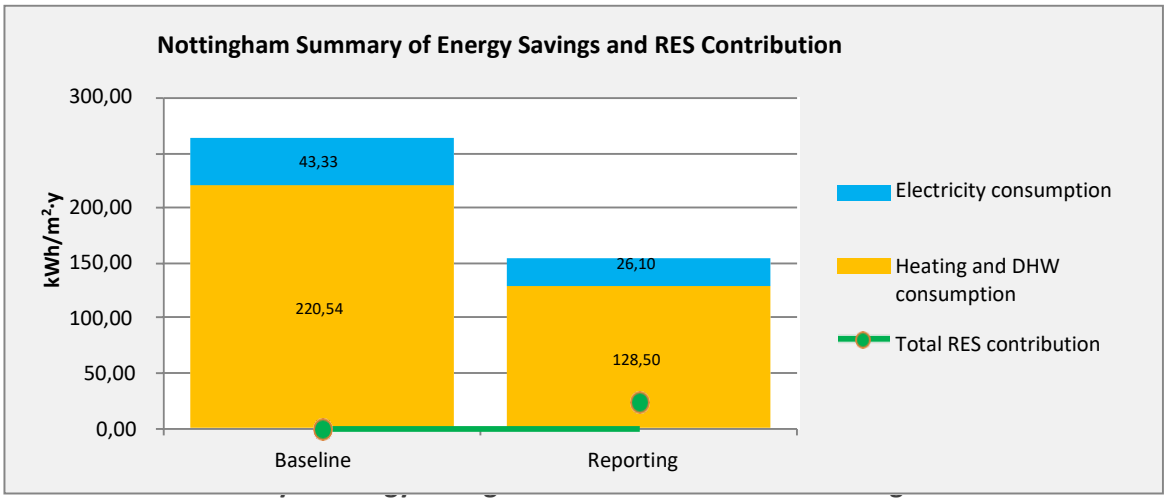
Sneinton Courts - Low temperature district heating retrofitting (LTDH)

Nottingham has the largest district heating network in the UK. The Nottingham district energy network has 68 km insulated pipework carrying pressurised hot water around Nottingham City Centre and a residential suburb to the north of the city. This is used to satisfy the space and hot water heating requirements of approximately 4900 dwellings and over a hundred commercial premises. The district heating system uses combined heat and power plant supplied by steam from a waste incineration facility processing around 170,000 tons of municipal waste per annum. Gas boilers provide backup, but these are only operational 5% to 10% of the time. As well as generating hot water, the plant produces 60 GWh of electricity annually.

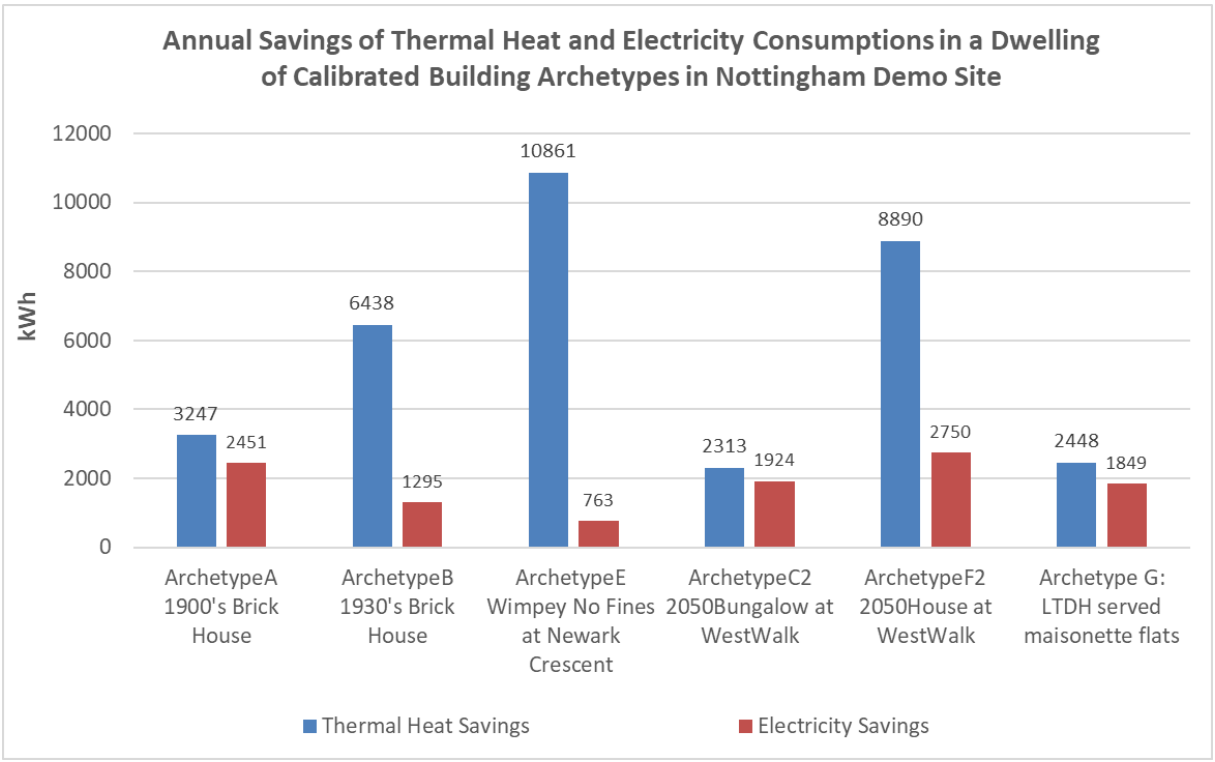
REMOURBAN (**Archetype G - maisonettes**) retrofitting connects Nottingham existing extensive district heating to a secondary network of 94 dwellings via the return pipe of the existing system. This new secondary system has a lower feeding temperature of 60 C to 65 C, developing in this way a new 4th generation Low Temperature District Heating (LTDH) for the first time in such scale in UK. This new lower cost, low carbon alternative of district heating replaced the expensive and inefficient heating within the 94 dwellings. The LTDH system extracts unused heat from the existing system making it more efficient. Upgrading the maisonettes with external wall insulation and new windows and doors means a much lower energy demand for heating. This makes the installation of a low-temperature district heating system more effective. The LTDH system takes water in at 60 C to 65 C, extracts the heat and returns it at about 35 C. As well as providing heating for the four blocks; a high-efficiency plate heat exchanger converts mains cold water into instantaneous hot water for each property. Because it operates at a lower temperature, costs are reduced, heat losses in the system are lower and efficiency higher. The system successfully provides low-carbon space and water heating to a significant number of properties, taking advantage of heat which would otherwise go to waste.

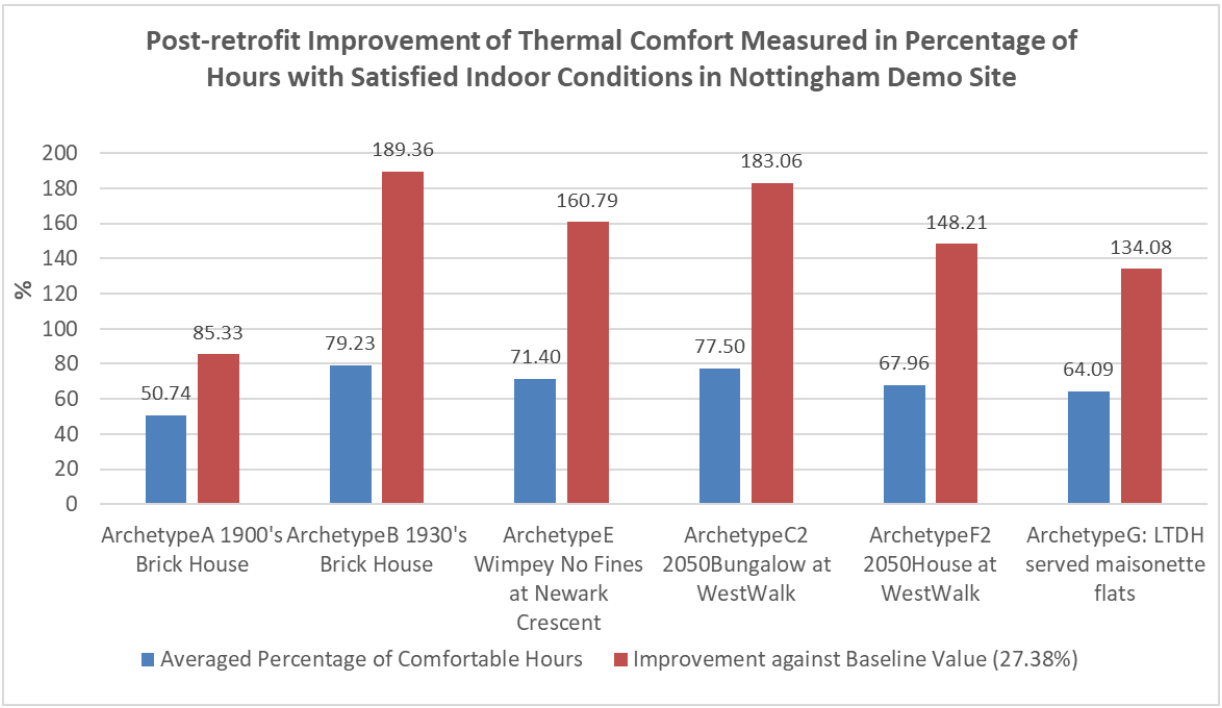
Summary: Total energy consumption savings in Nottingham demo site achieved 41 percent and total energy use saving 3GWh/yr. and **CO_2** (eq.) saving of approximately 550 tonnes.

RES Contribution mainly sourced from innovative applications of the LTDH in Archetype G, the heat pump-based energy centre in Archetypes C2 and F2, and the PV and battery equipped private wire systems. Thermal heat demand in these Archetypes was fully met by RES. PV production of 129,671.71 kWh/y from the PV and battery based private wire systems commissioned in **Archetypes C2, F2 and G** were not only covering most of on-site usage by homes and energy centre but also exporting around 25 percent of PV generation as surplus amount of electricity to the grid. The energy savings in **Archetypes C2, F2** is up to 72%. Energy simulations show that these properties with appropriate settings can be energy self-contained (not to consume energy from the grid) between middle of March to end of September while exporting electrical energy to the grid.



In addition to energy savings, thermal comfort levels and indoor air quality levels were generally improved in all retrofitted Archetypes.





<u>The impacts of this local low temperature heating systems are:</u>

- **reduced energy consumption from the main network,**
- **use of renewable energy sources,**
- **reduced heat losses,**
- **improved living comfort,**
- **electrification of heating networks,**
- **minimum CO_2 impact on environment.**

Building Archetype	Pre-retrofit	Post-retrofit
Archetype F2: 2050 Homes (houses)		
Archetype G: LTDH served maisonette		
Archetype E: 'Wimpey No Fines' flats		
Archetype B: Solid Brick 1930s		

Improvement in Property Appearance After the Retrofit

What are the barriers to scaling up low carbon heating technologies? What is needed to overcome these barriers?

Technical solutions for retrofitting existing homes exist, but they are not being deployed widely enough or rapidly enough. The primary reasons are:

- Lack of demand - Retrofit for energy efficiency is not attractive enough to homeowners, landlords or tenants. All buyers worry about the risks. They are not confident that the promised benefits will arrive, and worry about poor quality installation, defective equipment and uncontrolled costs.
- No clear and consistent Government policy driving retrofit. - Government is not demanding deep retrofit of existing homes as part of the journey to net-zero. It is not being given priority. Experience of changing Government policies, such as the Code for Sustainable Homes and the Green Deal, makes both buyers and sellers reluctant to commit
- Current high costs of retrofitting - With only a few properties undergoing deep retrofit, cost per unit is still high. This makes it difficult for an owner to create an economic case to invest. A small number of retrofitted homes mean no economies of scale; keeping costs high and suppressing demand.
- A lack of both capability and capacity throughout the supply chain - Buyers lack the knowledge and understanding to specify, select and manage retrofit projects. There is a skills gap throughout the construction sector, but specifically in the new technologies required for deep retrofits. There are few integrators; businesses that can design and deliver successful retrofits.
- Difficulty in financing - There is a lack of low-cost financing in the UK to stimulate this market. Retrofit programmes have not been packaged to be attractive to large investors. They compare poorly in risk and return with more established green infrastructure projects such as wind farms

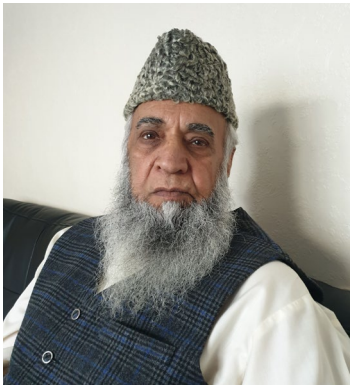
Social landlords look after 17% of the total UK housing stock and have a crucial role to play in achieving net-zero. They face some specific barriers:

- Risk - confidence in both the solutions and the providers
- Business case - something that fits their strategic objectives, investment criteria and other priorities.
- Information and knowledge - access to independent and trusted advice, and the supply chain that can deliver.

Working with the community

The REMOURBAN project encourages pro-active inclusion of the citizens, who are presently excluded from day to day energy reduction and resourcing processes, to be deliberately included in the future. It is a platform by which the "have-not" citizens learn from each other and join in the decision making for their community and city through better awareness and information. This leads to citizen-led influences on social reform within the cities.

CASE STUDY: Mr Hussein, living in 1930s house with Solid Wall Insulation (type B)



Mr Hussein is an elderly, retired male who lives alone in his home. The solid wall insulation was completed 18 months prior to the interview. Mr Hussein described the benefits to him, his quality of life and wellbeing:

"Before the solid wall insulation, there was cold in the house, particularly the bedroom. It didn't help my knees" (Mr Hussein has arthritis). "If I got out of bed in the night, the bedroom was cold, and I found it hard to get up and out of bed" (Mr Hussein has mobility difficulties and has to use a walking stick). "Going to the toilet or the bathroom at night is so much easier now."

"My body is so much more relaxed because I'm not cold anymore. I'm free to walk around the whole home which is warm. I sleep better, before it was freezing but now it's much warmer."

"Before the retrofit, I had the gas heater (in the front room) and the central heating on all day and central heating on all night. The house was freezing. Now I have the heating on only one and a half hours a day and it stays warm all night too. I'm much happier because I can wear less layers of clothing. I don't have to wear a coat (in the home) anymore in autumn, winter and I don't have to wear three layers of trousers. Now I can sit comfortably in my pyjamas watching tv which I do a lot "(Mr Hussein is retired). "Now it's quicker to heat the house and it stays warm. 30 minutes to warm the home. It's not cold at night anymore and it's warm in the mornings too, when I come downstairs. The whole house is warmer."

"It costs 10-15% less now each month. I used to use a gas heater (in the living room) and the central heating on and high all the time. Now I don't use the gas heater when I'm in the living room and the central heating is on less too."

Presented by:

Dr Anton Ianakiev

Professor in Sustainable Energy Systems,
Civil Engineering Department,
Nottingham Trent University,
50 Shakespeare Street, Nottingham, NG1 4FQ