Low Carbon Heat in Wallacetown Transcript

Title Slide

Hello and welcome everyone. We are the Strathclyde team working on the regeneration of Wallacetown District in Ayr to low carbon. Myself Ihsane, and on behalf of my colleagues: Chimwemwe, Isaac and Hodari, I would like to introduce our Project.

Our project is a leap towards sustainability, where community, education and technology are involved to create a greener future.

Slide 2

These points will be discussed further in the upcoming slides.

Slide 3

As you can see from the map, the outlined Area in red represents our focus Area within Wallacetown.

Slide 4

Wallacetown within south Ayrshire, has an estimated population of 2600 people. According to the Scottish Index of multiple deprivation (SIMD), Wallacetown is in the lower decile. As shown in the map above. The area has over 1311 domestic properties…

Slide 5

…where most of the construction type is cavity walls and less than two percent have solid walls. Wallacetown, has a diversity of housing, for example: some houses are occupied by their owners, others are rented or social housing. As we can see from the histogram, Wallacetown has a higher number of mixed tenure properties compared to other cities within south Ayrshire.

Slide 6

One of the main and serious challenges facing the area is fuel poverty. And one of the contributing factors to it is the lower income of people in Wallacetown as we can see from the Median household incomes graph. Unfortunately, only 19% of the homes have energy performance certificate (EPC) higher than C, with 14% F or G.

Slide 7

To fully appreciate the context of our initiatives, let me take you through our aims and objectives. We aim to transition Wallacetown's heating system to lower carbon, of course with a focus on tackling the main issue: fuel poverty. We will do this by assessing the integration of renewable energy sources like hydrothermal, geothermal, and solar thermal into a 5th generation district heating network (5GDHN). More on this later.

Slide 8

The next slide shows the project outputs. We started by background research of the area and an in-depth analysis of the current heating system to develop a 5GDHN model. We then did the network modelling and the numerical calculations for more viability and energy efficiency. Both financial and environmental analysis were assessed. The project findings were then well documented and presented. And we aim to launch our website very soon.

Slide 9

The three main Key performance Metrics are levelized cost of heat (LCOH), Carbon equivalent (CO_2eq) and the capital cost (£).

As we proceed further, I will let my colleague explain to you more about the current heating system in Wallacetown.

Slide 10

Thanks, Ihsane. The daily demand of Wallacetown is depicted and as expected there is not much of heating needed in summer.

Currently, the conventional gas boiler system is used for space and water heating in Wallacetown. Therefore, heating in Wallacetown contributes to the emissions of GHGs into the atmosphere. This is not environmentally sustainable. There is need to decarbonise heating to lower the GHG emissions from district heating which constitute 15% of all GHG emissions in the UK. The Scottish Government through local authorities has put in place measures to achieve net zero by 2045.

Slide 11

Some of the solutions as elaborated in the local heat and energy efficiency strategy report by south Ayrshire include fabric improvements- which potentially lower the energy needed to heat the homes - and the incorporation of heat pumps in district heating networks. As a group, we analysed the integration of all these for our Wallacetown scope to see how they would reduce fuel poverty and emissions.

Slide 13

District heating is of huge significance in the UK due to its cold climate. However, as recently as 2018, due to global warming, temperatures of 40C were experienced in the UK for the first time ever and projections show that these hot temperatures will be more frequent. Therefore, we need to incorporate cooling in our district heating networks. This is where 4th and 5th generation district heating networks come in.

Slide 14

But what do we mean when we say 4th or 5th generation district heating? District heating dates to the late 1800s when the first generation was implemented. The heat transfer fluid was steam at temperatures of approximately 200°C. So, as you would imagine, it was a very inefficient system. But with advancements in knowledge and technology, UK is now popularised with 3rd generation networks pushing for 4th and 5th generations. They can use low temperature renewable sources and boost the temperature using heat pumps to match the needs of the consumers.

Let's look at the 4th generation characteristics:

They have a centralised plant which is responsible for suppling the heat to the buildings. The supply temperatures are no more than 70°C. Because of the high temperatures and one central HP, the pipes need to be properly insulated to minimise losses. However, cooling needs to be a whole new setup altogether which comes with higher costs.

Slide 15

How about 5th generation? The one we have analysed for Wallacetown.

Unlike in 4th gen, 5th gen does both cooling and heating within the same setup which is the reason we have chosen this for Wallacetown. This is possible because 5th gen has decentralised heat pumps and is bidirectional. This means that consumers can get heat or give heat to the network. And are now called prosumers.

For instance, a data centre may require cooling most of the times and so would eject the heat to the network. This heat would be used by a home in need of heating simultaneously and hence balancing out the demand. To illustrate this, in heating mode for the house: heat transfer fluid goes to the evaporator of the HP where heat is transferred to the refrigerant, and then the lower temperature fluid goes to the lower temperature line. The refrigerant which we assume is ammonia, is then compressed to the condenser where heat is transferred to the hydraulic system in the home at 60°C. In cooling mode for the data centre: heat transfer fluid goes now to the condenser where it takes heat from the refrigerant and goes back to the high temperature line. The refrigerant then expands through the expansion valve and goes to the evaporator where it absorbs heat from the hydraulic system at end user, there by cooling the data centre.

The main loop runs on ambient temperatures according to location which in our case we have a range of 5(minimum return)-16C(supply) throughout the year according to the soil temperatures in Wallacetown. As a result, network pipes are plastic and need little to no insulation due to minimal losses.

Slide 16

This is the proposed piping across our area of interest in Wallacetown. The system stretches up to 10km and this is one of the disadvantages of 5th gen (and 4th gen) because they need large pipe works which means more digging and high initial costs. The availability of a heat pump at each end user adds to the piping costs and to the electrical load as well.

My friend will continue to talk about the thermal sources we analysed for Wallacetown.

Slide 18

Thanks, Chimz. First was wastewater. Amount of wastewater that is generated per person at 15°C in winter to 25°C in summer. And it can be, with a flow rate of 4.6 litres per second. The map with blue dots shows the buildings in Wallacetown as the sources of wastewater. And the picture shows how the wastewater is collected and how it is treated to be used for heating.

Slide 19

The second source is, water source heat pumps (WSHPs) that have a very good efficiency between 300 to 600 percent, and they can provide water up to 85°C. And the heat pumps operate on a closed loop that will be extracting water from water sources.

Slide 20

The river Ayr is the main target of the WSHP as highlighted on the map. So here are the properties of the river Ayr. We have the river Ayr flow, and you have the water temperature in the river that ranges from 7°C to 16°C. And also, the river Ayr has a catchment area of 575 km^2.

Slide 21

We go to our third source, which is solar thermal. As you can see in Wallacetown from the graph in summer, there is higher direct solar. The annual global horizontal irradiance in Ayr is an average of 1000 kilowatt hours per square meter. Literature suggests that 50 houses will need an area of 1000 m^2 for feasibility. And the blue area on the map is where the solar collectors will be installed…

Slide 22

…, and the excess heat will then be stored in the storage; that is the global seasonal storage, that will be storing the excess heat, and will be used to balance the supply and the demand. Normally they can have the temperature up to 40°C at the depth of one kilometre. And the soil type in Wallacetown is carboniferous with a thermal conductivity from one to 2.5 watts per meter kelvin. Also, the boreholes will be installed in the blue-highlighted site on the map. And we have a closed loop for our system.

Slide 23

Our last source is mine water heat pumps. Wallacetown has flooded mines which cover about 100000 m^3 of the volume. And they, this water also, this water also maintains a temperature between 10 to 40°C, and they can be used as a very good source for both supply of energy and heat.

They can be used for both storage and supply. The blue shadow on the map highlights where the mines are in Wallacetown, and the other figure shows how the water can be extracted using ground source heat pumps.

Slide 24

Now, after analysing all the sources, three of them were suggested because they are compatible with the system. They are feasible and they have good energy potential. Sources that were selected are solar thermal, water source heat pumps, and the storage to balance the demand and the supply. Mines were not selected because we did not have much data and there is a risk of failure. And, wastewater was not chosen because they did not provide enough energy to the system and the treatment site is not in our scope.

Slide 26

Now, let us go to the model results. I will start by the thermal storage. We have designed in our model a thermal storage. Storage that has 413 boreholes that will be 110 meter deep and they can maintain a temperature of up to 80°C. They can store 7.3 gigawatts-hours. We have arranged them a six by seven array and they can perform well with an efficiency of 61% which may increase to 80% over time.

Slide 27

Here is how the efficiency will be increasing. The efficiency will increase because when excess energy is stored in the boreholes, it will act as insulation for the system, and this will reduce future losses hence an increase in efficiency. Most of the stored heat will be used for space heating and the remaining will be used for domestic water heating.

My colleague Isaac will continue with the model results.

Slide 28

Thanks, Hodari. Indeed, thermal storage is so important since it balances supply and demand. As you can see our demand profile here for Wallacetown you have got your solar and your water source heat pump which seems oversized at first, but really, it is inversely correlated to the demand expected at any time. When solar supply is high then demand is low. The water source heat pump provides low grade heat. So, a lot of the possible energy it could produce will not be produced because it will cost more energy to store it into a borehole than it would to produce it in the first place.

Slide 29

So, looking at the demand of our model, you can see here is, the daily demand of Wallacetown and when you add the solar, you can see just with the solar, it does meet demand, through quite a lot of the days, but is insufficient, through a substantial portion of the year. So, adding in the somewhat dispatchable water source heat pumps, really helps to levelize that and meet the demand on most days.

When there is a peak load, we have a backup inform of an electric boiler that is rated at 500 kilowatts. And that is just to give a little extra kick to the system in case there are flow problems or it is incredibly cold and the storage is low.

You can see at the bottom left there is the energy supply per year, around a third of the solar thermal supply is recycled through the thermal storage and our capacity and our storage is full for most of the year and never goes below zero. The green is when it is taken from the storage.

Slide 30

We validated our models through a variety of methods. We created our model in Excel and validated it with nPro, which is an online model simulation tool based in Germany. We got results of less than 3 percent deviance in energy share meaning that our ratios between our technologies were accurate. The different energy demands also matched within 10%. An important note about the capital costs is that they're also taken from nPro, and so those are based on, European and German standards. But looking at other case studies, this was still within 10 percent of the expected values.

Slide 31

So going on to the capital costs we considered two scenarios. One is pre fabric improvement of the buildings in Wallacetown and this would involve the Holstein Bank. You can see here that would be a total cost of around 70 million for an initial investment. The biggest portion of that is through the decentralized heat pumps. The maintenance of the system is considered quite low in our analysis with 1 percent for technologies and 2 percent for heat pumps.

Our scenario two is a lower uncertainty option due to not requiring deep groundwork. This assumes post fabric insulation, so there's less demand, meaning that demand can be met solely with the water source heat pump.

Slide 32

Moving on to the energy usage. You can see here that there's significant reductions and equivalent electrical demand using heat pumps or district heating. Most of the electrical energy going into the system is from the decentralized heat pumps.

Slide 33

So, looking at the consumer costs, you can see that over time the more property connections that are to a district heating system, if it is sized appropriately, the levelized cost of heat, does decrease. This means that with all these features implemented, you can get savings of over 600 pounds a year for the average household in Wallacetown.

Slide 34

Going onto our environmental analysis, this is very significant. Fabric improvement does save more money just on its own but doesn't reduce emissions nearly as much. And there is the inelastic demand from direct emissions via the gas which cannot be reduced further. Whereas the emissions associated with electricity are reducing over time and could eventually meet net zero specifications.

Slide 35

So, looking at conclusions, you can see that, combining these improvements could save residents an average of 650 pounds a year in energy bills and over 90 percent in emission reductions almost instantaneously. This is all assuming a full uptake, which is a large consideration but is more for comparison between scenarios. There are some cons, however, with the high upfront cost and the maintenance costs and complexity of the system itself. Something that I would say to that is the replenishment of heat in the ground i.e., if you're due to the high heat density of the area, the ground can actually get colder over time. So having an external source like the river or the solar thermal really contributes to balancing the energy. Therefore, in conclusion, a fifth-generation district heating network (5GDHN) is feasible in Wallacetown and reduces both emissions and fuel poverty in the area.

Slide 36

Looking at further work, you can see there is support through the Scottish Heat Network Fund and now it can be used to investigate things further. It would be nice to visualize a comparison of our model against real systems. For example, looking at systems like West Whitlawburn; their demand profile was a lot higher than it was in reality. So, getting some real figures would be useful for that integration of anchor nondomestic loads that include shops and data centres. This could increase the peak power required for the system but is also likely to increase the efficiency of the system if sized properly due to increased cooling loads. With global warming, that's a factor in domestic situations as well. So, as I said earlier, finding economic analysis for Scotland rather than for European standards and the ground stability analysis of the mines, if there are any deep earthworks, then that'd be a big because the mine there is pre-1874, so it has no abandonment plan.

Slide 37

Thank you for listening.