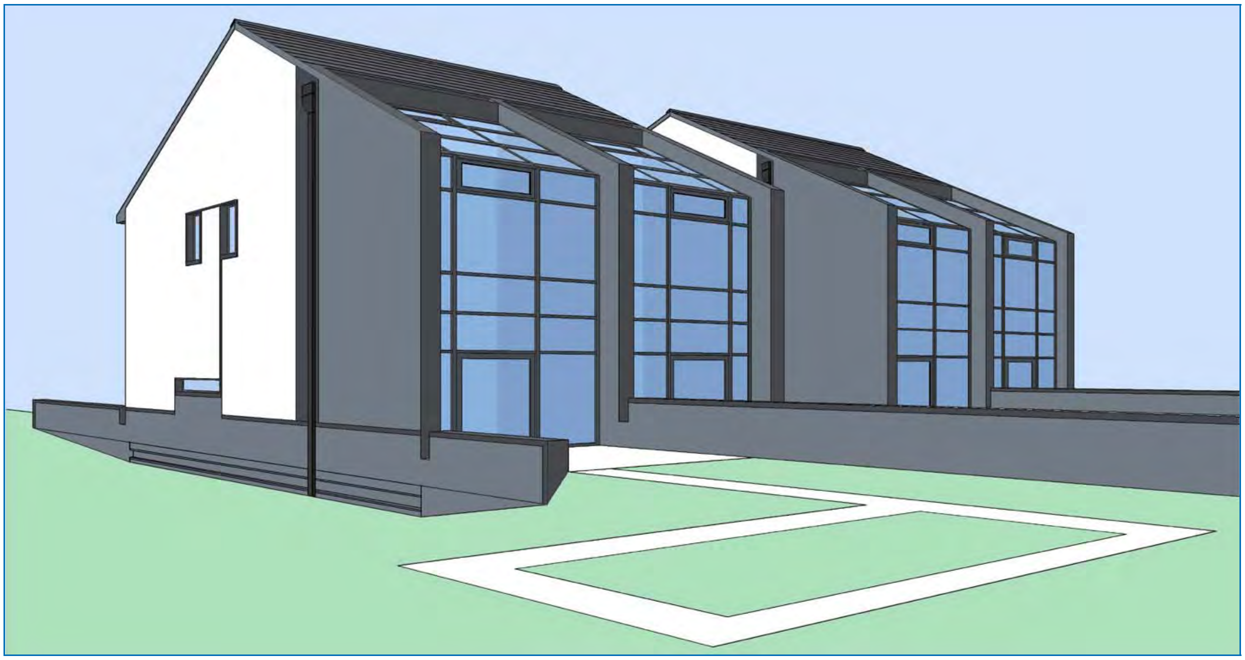
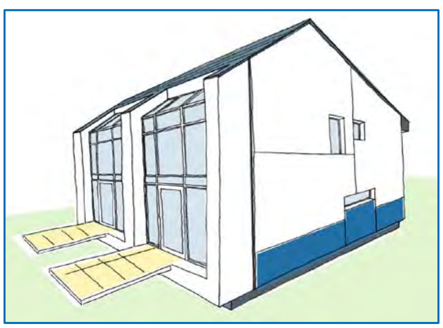
Tarryholme Sustainable Healthy House Study: Project Summary





March 2011

Contents

INTRODUCTION 3

Overview 3

Tarryholme Site Information 4

- Tarryholme Site Location and Description 4
- Site Location 4
- Site Density 4

SUSTAINABLE HOUSE STUDY 5

- Scope 5
- The Project Team 5
- Key Study Questions 6
- Priorities 6
  - ➢ Environmental (Carbon) 7
  - ➢ Social (Health) 9
  - ➢ Economic (Cost) 11

SUSTAINABLE HEALTHY HOUSE DESIGN SUMMARY 13

FINDINGS 14

Further Research 15

Recommendations 16

Appendix 1: House Design Summary 17

Appendix 2: House Comparison 18

References 19

Introduction

The purpose of this document is to provide a general summary of the key findings identified within the Tarryholme Sustainable Healthy Housing Design Study Technical Report. The summary also provides background information regarding the Tarryholme housing development site, which the Technical Report was commissioned to inform. The main Technical Report provides greater detail and it is highly recommended that it should be read in conjunction with this summary.

Overview

The vision for the Tarryholme development site to be an 'Environmental Exemplar' was established in a joint press release by Irvine Housing Association, Irvine Bay Urban Regeneration Company and the Housing Investment Division of the Scottish Government. The current economic downturn offered an opportunity for 'thinking time' to investigate the social, environmental and economic issues involved in building a sustainable house. This was initially progressed through the production of a development framework for the site, which provided general sustainability principles, particularly that of eco minimalism. This report considers sustainability principles further and provides an answer to the following questions;

1. What is a sustainable house?
2. How much will it cost to build?

The study was conducted over a 12 month period and included visits to over 30 current exemplar housing projects. The investigation revealed a number of wider industry issues including:

Main Issue:

- To meet the Government's legally binding carbon reduction targets, the Building Standards for domestic dwellings will change significantly in 2013 and 2016/17.

Main Risks:

- The changes to Building Standards will result in a potentially large increase in building costs, detrimentally affect indoor air quality and increase asthma rates in North Ayrshire; if careful design, specification and occupant advice is not employed.
- There will be significant legal implications to housing providers if indoor air quality is found to contribute to occupant ill health due to building design.
- Awareness of the impending changes and the cost implications to the delivery of housing across all sectors is low and the profile of this issue needs to be raised significantly; if cost effective solutions are to be found within the timescales set.

Main Findings:

- There is a need for cross funding sourced from Housing, Environment and Health budgets if future housing demand is to be met with truly sustainable solutions.

Tarryholme Site Information

• Tarryholme Site Location and Description

Tarryholme is a previous brownfield site that nature has taken back and is now designated as a greenfield site, which extends to 7.89 hectares gross site area (6.3 Ha net area), is located on the southern edge of Irvine, to the west of the A78 Irvine by-pass and approximately 1.2km from the town centre. It benefits from being in a good location off the main A71 access into the town.

• Site Location

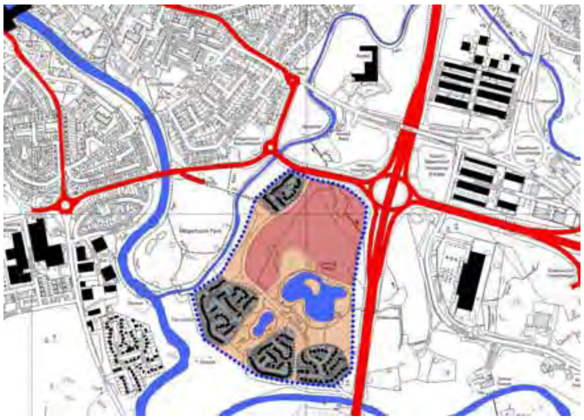


Figure 1: Location Plan

The area shaded light red in Figure 1 shows the extent of the Tarryholme site and its proximity to local roads and carriageways.

• Site Density

Figure 2: Density Exercise (Source Tarryholme Development Framework, 2008)

A density exercise was conducted as part of the Development Framework and it provided a potential site density of between 200-250 residential housing units for the site, dependant on the housing mix chosen.

Sustainable House Study

• Scope

The sustainable house study was commissioned by Irvine Bay Urban Regeneration Company and Irvine Housing Association to investigate key areas associated with the development of an environmental housing exemplar.

The scope of the study was to:

- Carry out research into existing examples of ''Exemplar Environmental Housing Projects'' within Europe and the UK
- Gather information relating to health issues associated with airtight construction
- Design an exemplar sustainable 2 bedroom 4 person house
- Produce construction costs for the design
- Produce estimated carbon emission rates
- Investigate renewable energy sources, in particular medium scale wind turbines and make recommendations.

• The Project Team

The consultants that comprised the Sustainable House Study project team are shown below:

- Client: Irvine Housing Association
- Architectural Design and Lead Consultant: Assist Architects
- Healthy House Design: Dr. Stirling Howieson (Strathclyde University)
- Sustainable Material Specification: Anna Poston (Caledonian University)
- Quantity Surveyor: Armour Construction Consultants
- Structural Engineer: WSP
- M&E Engineer: Ramboll UK

- ## Key Study Questions

It soon became apparent that there are many issues surrounding sustainable house design that overlap and in some cases become contradictory. In order to provide a greater understanding of the key issues surrounding sustainable design and the interdependencies that the project team required to take recognition of, a set of additional key questions were defined at the outset and answered through the duration of the study.

1: What are the key political factors driving the need to design and build an exemplar sustainable house?

2: What are the key elements that make up an environmental exemplar house design?

3: What are the key social factors that need to be considered?

4: What role does technology play in the creation of an environmental exemplar house design?

5: How much does an environmental exemplar cost to build?

6: What areas of environmental exemplar house design (if any) conflict with current or future legislation?

The questions stated above have been answered in detail through the technical report and the information provided through the summary is intended to give only a very brief overview of the headline findings.

- ## Priorities

Through the recommendations of the Development Framework, the use of the triple bottom line model was chosen to provide a visual basis for explaining exemplar sustainable design within a housing context. The main principles of this approach were to ensure a balance of:

- CARBON EMISSIONS REDUCTION (Environmental)
- HEALTH (Social)
- COST (Economic)

The three main principles associated to the triple bottom line were established at the outset of the project and evolved as further research was undertaken, illustrated in Figure 6 below:

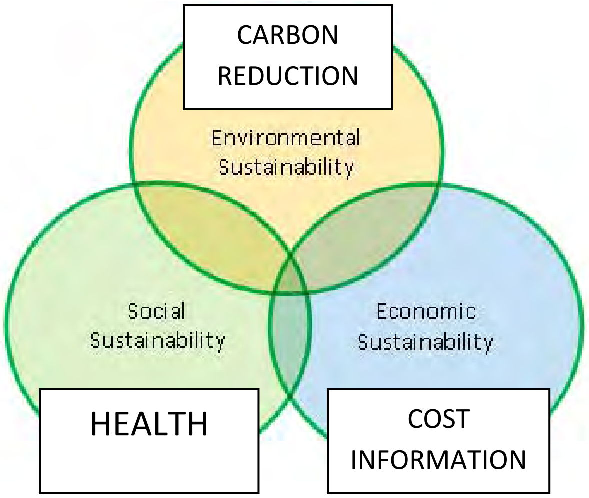


Figure 3: Triple Bottom Line Priorities

The use of the triple bottom line model provided a reminder of the effects that each element had on the other aspects of sustainable design and development. This ensured a wide range of views and impacts were considered throughout the design process. The three elements of the triple bottom line are explained in more detail through the following sections of the summary.

➢ Environmental (Carbon)

The drive to reduce carbon emissions globally is now very high on the political agendas of every country. Scotland, in particular, has identified legally binding targets to be achieved through the Climate Change (Scotland) Act 2009 (CCSA). The role that residential housing plays in assisting that reduction is well documented and the political drive to reduce carbon within the new build housing sector to 'Zero Carbon' currently stimulates large scale debate. The recommendations of the Sullivan Report (2007) and the implementation timescales for new build domestic properties are shown below:

- 30% reduction on 2007 Building Standards C02 emissions by 2010
- 60% reduction on 2007 Building Standards C02 emissions by 2013
- Zero Carbon, if practical, by 2016/17

The impending changes to Building Standards are widely anticipated to adopt the carbon reduction targets and timescales recommended by Sullivan above, with the first phase 30% reduction already in place. The legally binding targets set within the CCSA of a 42% and 80% reduction in overall C02 emissions (across all sectors), based on 1990 levels, by 2020 and 2050 respectively will result in additional future reductions in carbon usage, with further impacts and increased costs no doubt being felt within the construction industry.

The initial focus of the study was the reduction of carbon. The main carbon element focussed on was the primary heating demand, which refers to the energy used to provide space heating, water heating, lighting and ventilation within a dwelling. The following steps were undertaken through the initial development of the sustainable healthy house design:

- Design for increased levels of insulation and air tightness.
- Run the design details through a computer programme (IES thermal model) to produce theoretical energy use figures and carbon emissions.
- Revise the design to optimise energy and carbon reduction.
- Identify the most effective energy and carbon reduction options for inclusion in the final design.
- Finalise the design.

The sustainable house was initially designed to reduce energy consumption through the building fabric following the principles of 'eco minimalism' set out in the Development Framework. In order to further reduce energy consumption, the introduction of technology was required and resulted in three house designs being produced i.e.

1. Control House: Design based on meeting the new 2010 Building Standards (30% reduction on 2007 levels) for comparison purposes.
2. Sustainable Healthy House (Passive): Design based on minimal use of mechanical systems.
3. Sustainable Healthy House (Mechanical): Exactly the same design layout as the passive house with the inclusion of mechanical ventilation and other technology to further reduce carbon emissions.

A pull out giving an overview of the designs in relation to Health, Carbon and Cost elements for each house design is shown in Appendix 1.

The sustainable healthy house designs have been thermally modelled and estimates for energy in use and associated carbon emissions calculated. There are limitations in relation to what can be modelled through the computer software; therefore the figures provided are theoretical. The analysis undertaken during this process has highlighted the potential reductions that could be achieved by the different design elements working together, which cannot be modelled. It is anticipated that the carbon and energy figures could be less than those currently reported through the model, if tested in use through the construction of a pilot building.

The potential for the Tarryholme site to be a 'Zero Carbon' exemplar has increased with the introduction of Feed in Tariffs (FIT's) and the confirmation from desk top analysis that the theoretical wind speeds generated would provide sufficient capacity to generate electricity for the site. The land that has been identified as suitable for wind turbine installation is not in the ownership of the Association and discussions with partners are taking place to investigate this opportunity further as part of a larger programme. The FIT's will be reviewed by government in 2012 and any turbine would have to be installed by this time to take full advantage of this incentive programme. Through the next research phase the FIT's will be revisited to assess the impact of the reduction in FIT tariffs after 2012 and explore other appropriate and innovative technologies. This will allow a true exemplar development to be realised and demonstrate the ability to meet the Scottish Government's anticipated 2016/17 Zero Carbon Building Standards. The wind turbine option offers the greatest opportunity for carbon reduction and income generation; however, it requires a large capital outlay.

Social (Health)

The anticipated carbon emission reductions that will be enforced through Building Standards in 2013 and 2016 will see designers shift focus to the air tightness of buildings. Through the study's investigation into current examples of low energy homes, it clearly demonstrated the crucial role air tightness levels play in carbon reduction. The key question that arose through this area of the study was:

- How do increased air tightness levels impact on health?

The more air tight a building is the more ventilation is required to remove moisture (from cooking, showering and drying clothes etc.), volatile organic compounds (VOC's) and to ensure adequate incoming fresh air. A key gap in available information developed around this question, especially in relation to the low carbon housing examples visited by the design team. The commercial nature of the projects visited made it almost impossible to collate any detailed cost or performance data. The information available from ASHRAE and Dr Howieson's previous research, regarding the effects moisture and temperature have on internal air quality, provided the basis for creating a house design that balanced increased air tightness levels and the potential effects it has on relative humidity and subsequently health. Chart 1 demonstrates this principle. The sustainable house is designed to maximise the amount of time the house operates within the 40-50 optimum zone. The key element the house is designed to reduce is the presence of the house dust mite, which is one of the primary triggers of asthma and other respiratory conditions.

Chart 1: Relative Humidity Chart (Source: Adapted from ASHRAE Handbook Fundamentals 2009)

The potential for low carbon housing to increase the prevalence of respiratory illness is high given the findings of Dr Howieson's previous research. This is of particular interest within North Ayrshire which has significantly higher asthma related hospitalisations than the Scottish average, demonstrated through North Ayrshire's Community Health Profiles 2010 (Figure 6).

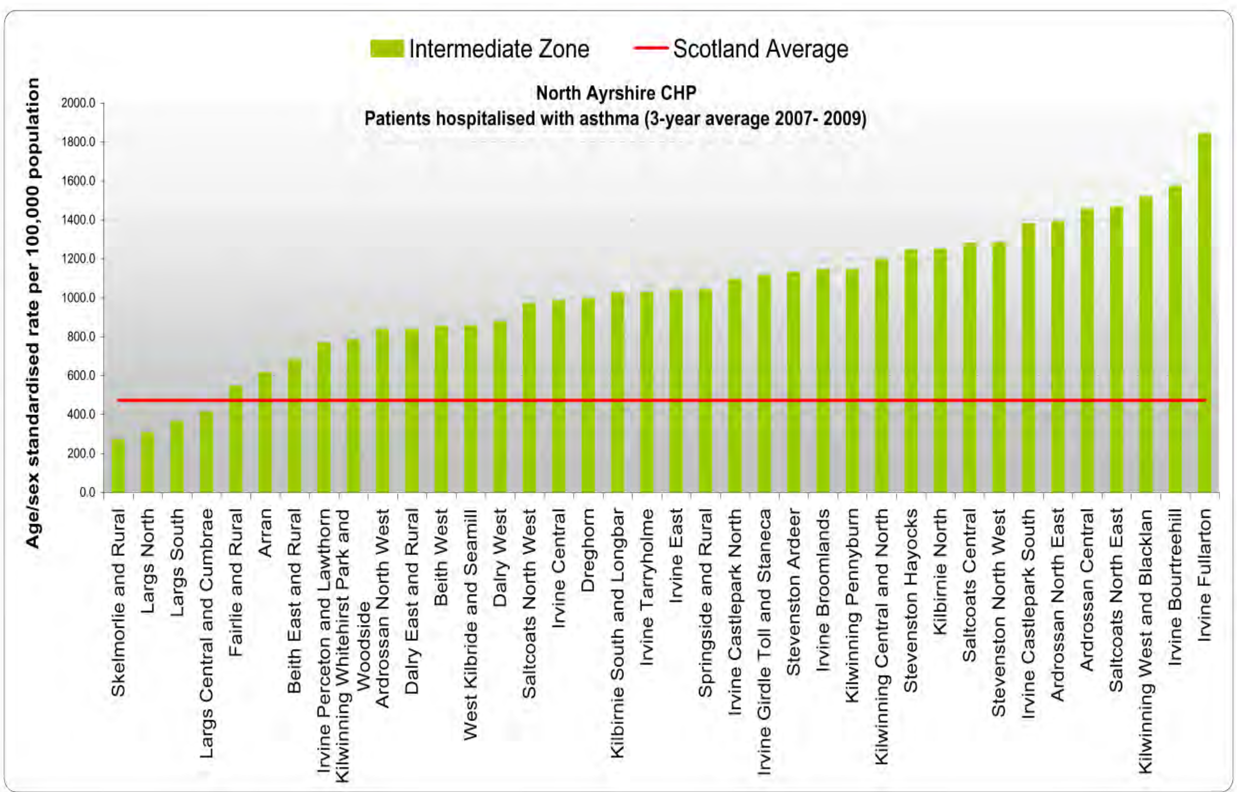


Figure 4: North Ayrshire Asthma Hospitalisation Rates (Source: Community Health Profiles 2010)

The issue of asthma within North Ayrshire potentially links with local economics to a degree; if housing is healthier then there should be a reduction in NHS costs dealing with asthma and respiratory diseases. The findings of previous research into asthma costs in Scotland have shown:

- An estimated £95 million is spent on treating asthma (Anandan et al 2009)
- A further £10.5 million is spent on emergency hospital admissions (ISD 2008/09)

It is also worth noting that the UK is ranked within the top four countries globally for the highest rates of childhood and adult asthma. Therefore, if health is not considered when designing homes to reduce carbon emissions, there is a real risk of exacerbating the asthma problem currently being experienced in North Ayrshire, Scotland and the rest of the UK. The key design principles included within the house designs to address this potential issue are:

- The use of hygroscopic materials to control humidity levels
- The specification of materials with low Volatile Organic Compounds (VOC's)
- Increased controlled ventilation levels
- Increased thermal mass to regulate internal temperature variations
- Increased space to dilute moisture and toxins.

Behavioural change is another crucial area of debate within the social element of the triple bottom line and the attitudes towards living in a low carbon house and the adjustments that have to be made will have an affect on the future design and specification of the house as it develops. The flexibility of the dwelling to meet the human comfort levels of many different types of people must be factored in and this element of liveability requires further research.

➢ Economic (Cost)

The largest issue faced in relation to the costs associated with a project of this nature is the absence of previous examples to provide any comparative costs. There are many unknowns because it is the first house design of its kind, which inevitably inflates costs due to the nature of the design and specification. The materials specified within the project are predominantly natural and non toxic, which makes them 'non standard' products within the construction industry. The 'non standard' nature of the specification and design results in a large increase in costs, e.g. the costs of the heat pump technology employed within the specification is over 8 times the price of the same pump in Sweden where it is installed in the majority of housing projects. This provides only one example of how costs can be addressed through economies of scale. It is hoped that through raising awareness of the benefits of the products specified and demonstration of their performance in use, economies of scale can be achieved in the long term. A summary of the cost information for the house designs is provided in the sustainable house design summary and Appendix 1 of this report.

An elemental breakdown was adopted for costing purposes to demonstrate the extra on cost of providing an enhanced specification for each of the key areas within the sustainable house design. The presentation of information in a ‘shopping list’ format is to assist discussions with Scottish Government and local partners to gauge perspective, in relation to what the important elements of sustainable design are and which should be included in an ‘environmental exemplar’. The impact of innovation and use of technology has impacted on cost to the amount of £143,310 additional costs in comparison with the standard 2010 base model. There are however, many elements that can be changed to reduce costs, a specific example of this are the foundations; if a normal concrete slab was used a saving of £21,700 would be achieved, however the embodied carbon of the project would go up by approx 20,000 Kg of C02. The use of a concrete floor slab is also more likely to provide local companies with employment thus achieving economic objectives. It is the subjective and complex nature of prioritising each element of sustainability that makes it demanding. The information provided within the study allows collective prioritisation to take place before any large scale housing is constructed at the Tarryholme site and costs established to ensure affordability is balanced with national and local priorities.

The current economic situation nationally and locally is also very challenging. With reducing budgets and large scale unemployment, it is very important that local economics are taken into account when undertaking any government funded capital investment project. North Ayrshire, in particular, has historically worked hard to create a thriving local economy with varying degrees of sustainment. There has been a steady decline in employment within North Ayrshire over the past decade, with North Ayrshire now ranked as 5th highest in Scotland in terms of number of people living in the 15% most deprived areas in Scotland (SIMD 2009). North Ayrshire has also increased its areas of multiple deprivation to 45, an increase of 12 zones on 2006 levels (SIMD 2009).

A key economic element highlighted through the study that could potentially be met is helping the local economy, through utilising local suppliers, materials and labour within Tarryholme and other construction projects. This, in turn, could reduce embodied carbon (reduced transport emissions etc) and, more importantly, put the capital invested by Government and local partners back into the local economy. There is further potential to help the local economy by highlighting the future strategic issues the country is facing (e.g. 2013 & 2016 Building Standards changes) to the local construction industry and help act as a catalyst to create a dynamic local sustainable construction sector, which could create growth in other sectors. There could also be potential political support and funding given the SIMD ranking of the North Ayrshire area and the Scottish Government stating ‘’*that opportunities exist across the whole Scottish economy for every business and industry to adapt to and exploit low carbon markets*’’ (Low Carbon Economic Strategy for Scotland, 2010). It is this principle that the creation of a pilot sustainable house project and the larger Tarryholme site would seek to maximise for the benefit of North Ayrshire's economic growth. The economic downturn has already affected the supply of all housing and with the additional future cost implications of meeting the impending changes to Building Standards, developers will be forced to bear the burden of these additional costs, unless innovative ways of achieving economies of scale and building better are sought now.

The Sustainable Healthy House Design Summary

The quantitative elements that can be measured and compared from the house designs are cost and carbon, the more subjective elements surrounding health and air quality are more challenging to quantify. The area of quantification of how housing design and specification affect air quality requires further investigation. Additional information on the house designs is included within Appendix 1 of this summary and Appendix 2 of the main report. As can be seen from Figure 8 below, the costs of constructing a healthy, low carbon sustainable house are notably more expensive than a standard 2010 base model house.

2B4P HOUSE	**2010 House (Baseline)**	**Sustainable Healthy House (Passive)**	**Sustainable Healthy House (Mechanical)**
Area	75.9 m²	109.6 m²	109.6 m²
Total Primary Energy Demand	11840 kWh/yr	3919 kWh/yr	1960 kWh/yr
Annual Energy Cost (Gas Equivalent)	£555.55	£183.89	£91.97
Annual Energy Cost (Electric Equivalent)	£1,356.86	£449.12	£224.64
In-Use Carbon Emissions	2725 kg/yr	986 kg/yr	493 kg/yr
Build Cost	**£86,040.00**	**£184,000.00**	**£229,350.00**

Table 1: Cost and Carbon Comparison Table

The benefits identified in Table 8 are in relation to the in use energy reduction of 9880 kWh/yr and a 2232 kg/yr C02 saving. The reduction in energy costs to the householder are not so significant as a gas fired boiler is used in the 2010 model and electricity provides the space heating in the Sustainable Healthy House model. The shift in Scottish Government policy towards a low carbon economy with renewable energy at the heart of it (Scottish Government 2010), confirms that electricity will become more widely used to heat homes in the future. This is the main reason that electricity has been chosen as the primary heat source within the sustainable house models.

Findings

The main findings from the study are as follows:

- **Social**
- Health plays a huge role in low carbon sustainable design.
- The creation of air tight buildings to reduce C02 emissions has the potential to exacerbate the asthma epidemic within the UK and in particular North Ayrshire.
- The investment of more funding in North Ayrshire's housing stock could result in significant long term savings for the National Health Service. The opposite is also true, if we do not invest more in the design and specification of our housing stock there is a real danger that we may end up increasing the costs of treating asthma to the NHS. This link must be made clear to government agencies and the construction industry nationally and locally.

- **Environmental**
- Carbon is only one element of sustainable design and health and cost are areas that must be addressed to achieve long term environmental sustainability.
- The Scottish Government's carbon targets provide tight timescales for the construction industry and those organisations that utilise it, to take action.

- **Economic**
- Cost remains the biggest challenge in developing low carbon healthy housing.
- North Ayrshire has an opportunity to exploit the Scottish Government's move towards a low carbon society.
- The creation of a healthy house design that balances all three elements of the triple bottom line of sustainability is challenging given the many conflicting elements of such a subjective term, especially in relation to balancing cost.
- Everyone must act now to investigate how we can reduce the build costs associated with the up coming changes to Building Standards and maximise the benefit to the local North Ayrshire economy.
- Scotland has an asthma problem that costs over an estimated £100 million pounds annually to treat. By investing in the creation of a healthy indoor environment there is potential to realise long term cost savings to the NHS and improve people's health in the process.

The designs created through the study offer a balanced solution in relation to health and carbon, with the cost barriers being theoretically overcome by working with the construction industry and supply chain. Cost remains the largest challenge to be addressed and investigation must begin now to identify how we can redress the balance.

Further Research

The main questions arising from the study that require further investigation are:

Social

- How do we measure the effects on health of low carbon air tight buildings and the impact of the solutions designed to mitigate them?
- Do people want, and is it practical, to live in this type of sustainable housing design?

Environmental

- Do the theoretical energy and carbon reductions match the actual performance of the building in practical use?
- What are the local priority elements in delivering an environmental exemplar housing project?

Economic

- Where is the line of affordability when building sustainable housing and how can costs be reduced?
- What capacity does North Ayrshire have locally in terms of materials, suppliers, manufacturers and trade skills to assist in delivering a project of this nature?
- What are the potential opportunities for North Ayrshire to exploit the Scottish Government's transition to a low carbon society?
- How low can we reduce costs without compromising occupant health and still achieve the 2016 Building Standards?
- Health and Housing are intrinsically linked and further investigation is required to ascertain the business case for investing in producing a healthy domestic indoor environment; by finding effective ways of measuring the potential long term cost savings and the increased health benefits to North Ayrshire's asthma sufferers.

Recommendations

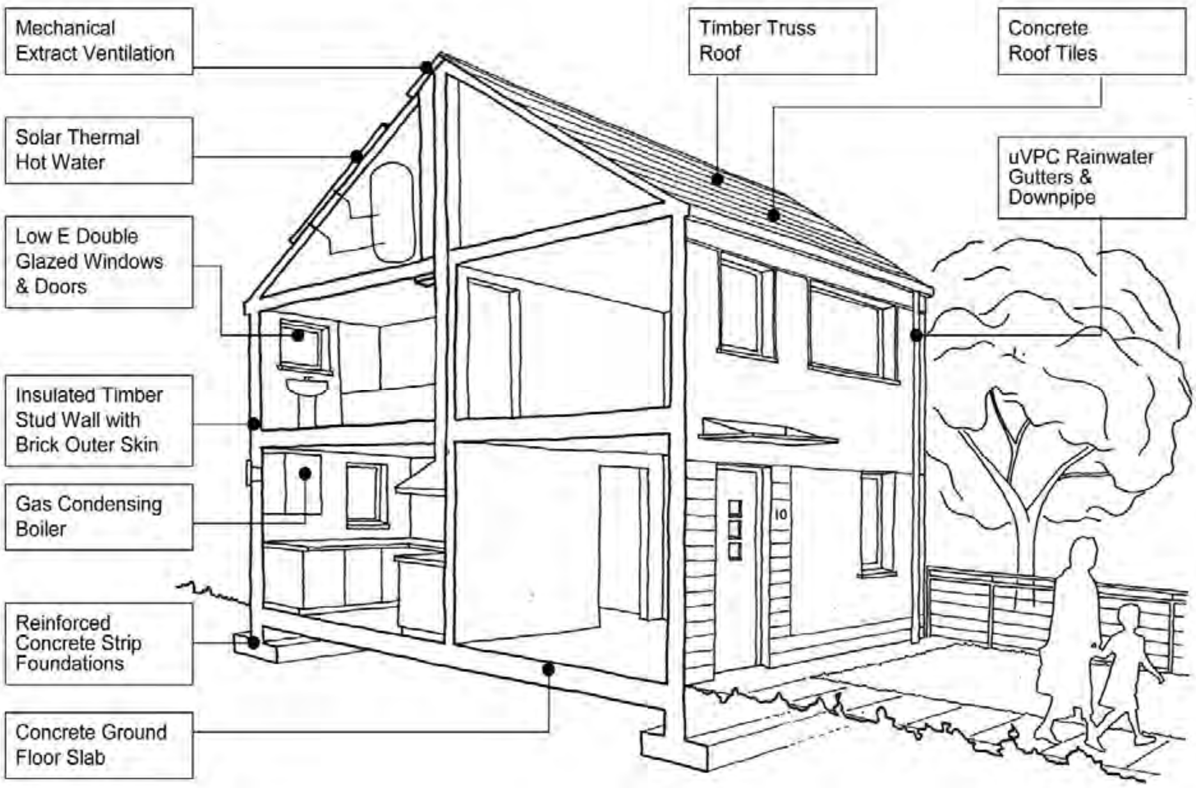
The following stages are recommended to answer the questions above and inform the creation of a North Ayrshire environmental exemplar:

- **Research Stage 2- Awareness & Value Engineering Stage:**
  - Raise awareness of the impending changes to Building Standards, in relation to health and costs, to local partners and industry.
  - Engage with Scottish Government, Local Government, Building Standards and the Health Authority to investigate the business case for reducing asthma treatment costs and highlight the health risks associated with low carbon housing.
  - Identify a suitable site to construct the pilot houses.
  - Work with all partners to maximise funding streams to ensure the construction phase of the project goes ahead and is a true exemplar.
  - Engage with local suppliers, manufacturers and contractors to assess the house designs produced through the study and work in partnership to identify any opportunities for cost reductions while balancing the key priorities of the triple bottom line.
  - Continue to work in partnership with Irvine Bay URC and North Ayrshire Council to help realise the renewable wind opportunities at Tarryholme, if practical.

- **Research Stage 3- Construction Stage:**
  - Construct a prototype of the Passive and Mechanical Sustainable house designs and test the theoretical cost, health and carbon results produced by the study.
  - Use the prototype as an opportunity to maximise local training.
  - Investigate of the economic opportunities from the transition to a low carbon society.
  - Determine the cost/benefit of the measures that have been implemented and produce an open and honest report on the costs and performance of the houses.
  - Identify key learning points for further design development and reduction in costs.

- **Research Stage 4- Post Occupancy Evaluation:**
  - Place Tenants in the prototype houses.
  - Monitor the in use performance of the prototypes in conjunction with our University partners and other stakeholders.
  - Maximise the opportunities for learning about low carbon house performance with a focus on occupant health.

Appendix 1: House Design Summary



Section 1 – 2010 Building Regulations Compliant House; 'Control' House

HEALTH

Internal moisture is prevented from entering the structure and removed via ventilation resulting in large swings in relative humidity.

Poor management of moisture can result in user discomfort and fungal growth.

Volatile Organic Compounds are present, Formaldehyde is present and large colonies of Dust House Mites are likely.

All of these factors are considered to be potential triggers of asthma attack.

EMBODIED CARBON

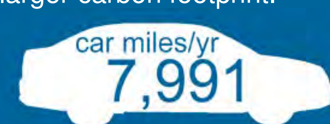
The house is constructed of common materials, readily available from wholesalers across the UK.

High energy consumption required to manufacture many of these products, combined with the fuel expended in transportation from around the world, result in a larger carbon footprint.

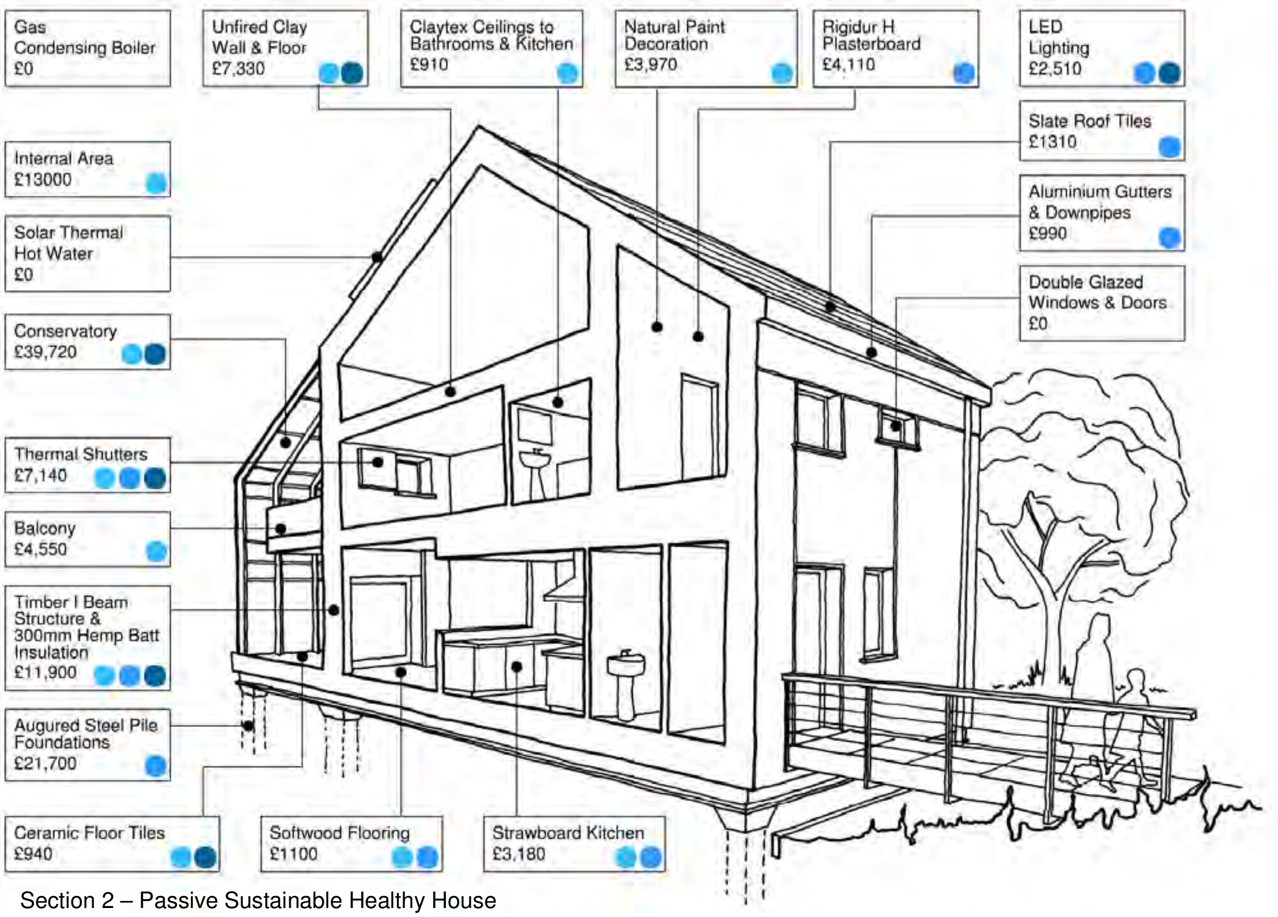
IN-USE CARBON

The timber structure of the dwelling results in a low mass, reactive building that is quick to heat and cool.

This fast response is popular with tenants but requires more energy as less heat is retained within the structure. The increase in heat demand leads to greater energy use and a larger carbon footprint.



2 Bedroom, 3 Apartment Semi-detached house – 75.9 sqm	**2010 Building Control Compliant House**
Total Primary Energy Demand	11840 kWh/yr
Annual Primary Energy Cost (Natural Gas as heating source)	£555.55
Annual Primary Energy Cost (Electricity as heating source)	£1,356.86
Construction Cost	£86,040.00



Section 2 – Passive Sustainable Healthy House
Additional capital costs for sustainable solutions over 2010 ‘Control’ House

HEALTH

Natural specification avoids the inclusion of volatile organic compounds including formaldehyde while a larger internal area allows dilution of any toxins introduced by occupants.

Internal moisture is stored in the structure and released as the dwellings atmosphere dries. This results in a stable relative humidity reducing Dust House Mite populations that can act as a trigger to asthma attacks.

EMBODIED CARBON

The house is constructed of natural materials that are low in embodied energy.

Reduced demand for these products results in limited availability, higher cost and longer lead in periods. If demand grows, we anticipate that availability will increase with cost and time reducing.

9,859 kg CO_2

car miles 28,912

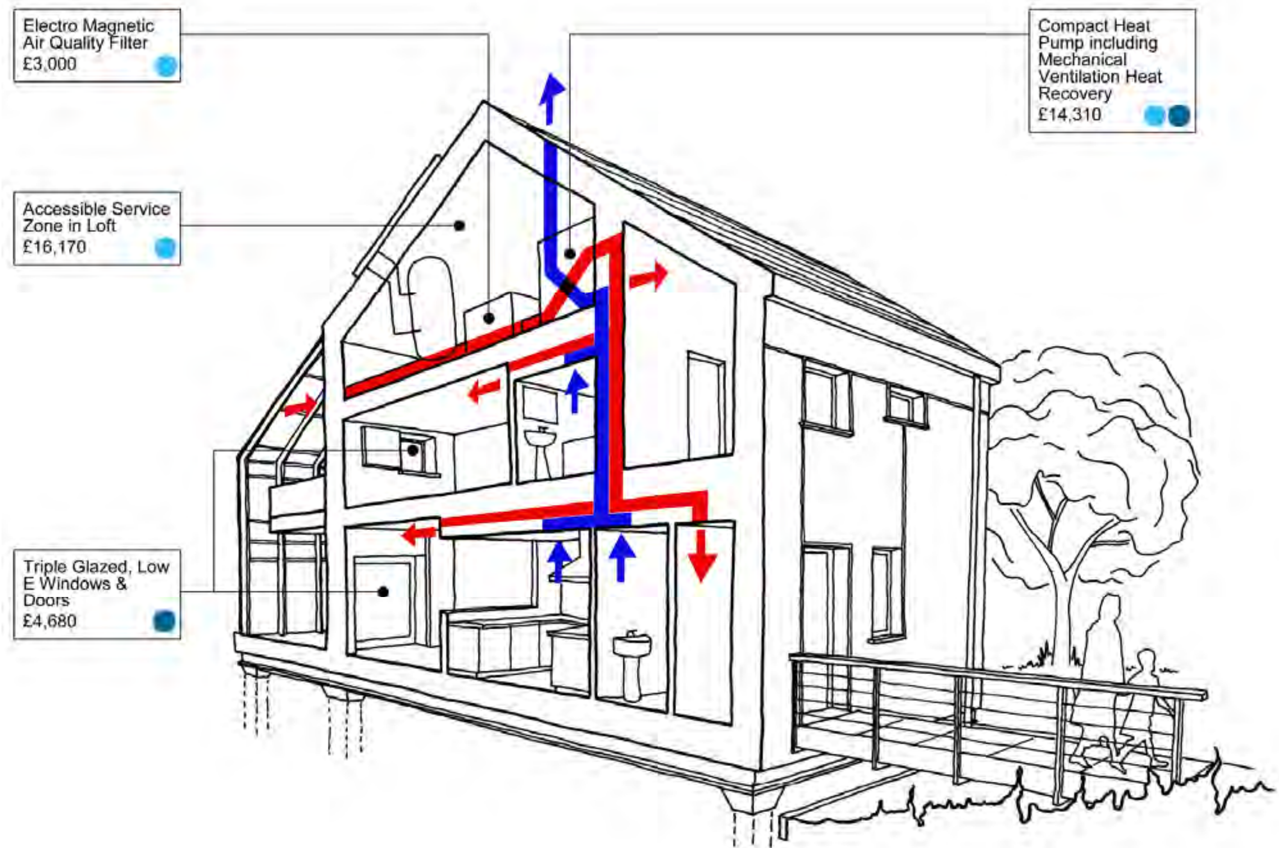
IN-USE CARBON

The dwelling is a high mass, slow reaction building that is slow to heat & cool. Natural heat gains are optimised by the inclusion of a solar conservatory while improved building fabric and planned passive ventilation protects against unwanted heat loss.

986 kg/yr CO_2

car miles/yr 2,892

2 Bedroom, 4 Apartment Semi-detached house – 109.6 sqm	**Passive Sustainable Healthy House**
Total Primary Energy Demand	3919 kWh/yr
Annual Primary Energy Cost (Natural Gas as heating source)	£183.89
Annual Primary Energy Cost (Electricity as heating source)	£449.12
Construction Cost	£184,000.00



Section 3 – Mechanical Sustainable Healthy House;
Additional capital costs for sustainable solutions over 2010 ‘Control’ House & Passive Sustainable House

HEALTH

Improved levels of air tightness coupled with MVHR and an electro-magnetic air filter prevent external air pollution, including particulate from vehicle exhaust fumes.

The resulting improvement in air quality, coupled with the delivery of consistent temperature and humidity levels provide environments that will not cause skin irritation. Together these factors will increase occupant perception of thermal comfort.

EMBODIED CARBON

The inclusion of mechanical equipment ultimately increases the carbon footprint.

10,999 kg CO_2

In addition to the increased capital and maintenance cost, the larger carbon content should be considered against the carbon saving and comfort benefits experienced by occupants .

car miles 32,261

IN-USE CARBON

Energy calculations predict that for every unit of energy consumed to run the mechanical equipment, two units will be gained

493 kg/yr CO_2

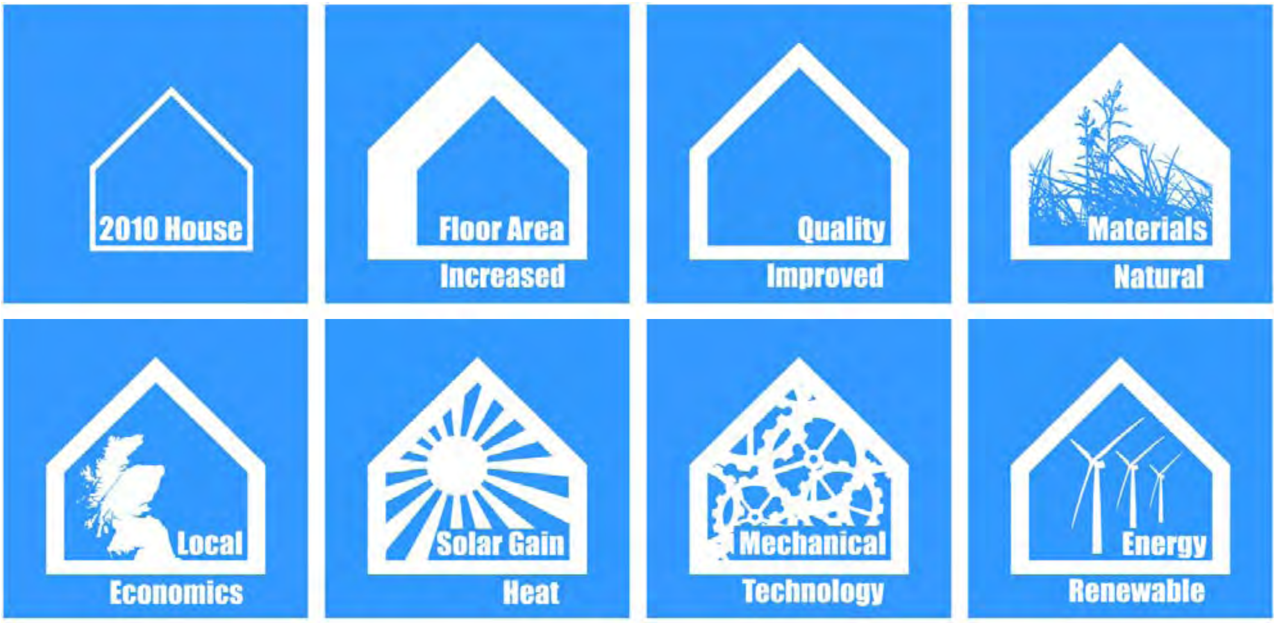
This estimate results in a further 50% reduction in energy use compared to the Passive Sustainable House.

car miles/yr 1,446

2 Bedroom, 4 Apartment **Semi-detached house – 109.6 sqm**	**Mechanical Sustainable Healthy House**
Total Primary Energy Demand	1960 kWh/yr
Annual Primary Energy Cost (Natural Gas as heating source)	£91.97
Annual Primary Energy Cost (Electricity as heating source)	£224.64
Construction Cost	£229,350.00

Appendix 2: House Comparison

HOUSE COMPARISON



2 Bedroom, 4 Person Semi-detached house	2010 Building Regulations House	Passive Sustainable Healthy House	Mechanical Sustainable Healthy House
Area	75.9 m²	109.6 m²	109.6 m²
Wall U-Value (W/m²k)	0.19	0.11	0.11
Roof U-Value (W/m²k)	0.13	0.14	0.14
Floor U-Value (W/m²k)	0.15	0.09	0.09
Openings U-Value	1.5	0.8	0.8
Air Permeability (m³/m²h at 50Pa)	7.0	>2	<0.6
Ventilation System	Natural	Passive Stack	MVHR
Heating System	Gas Condensing Boiler	Electric	Electric
Hot Water System	Solar Thermal	Electric	Solar Thermal & Heat Pump
Energy Source	National Grid	Wind Turbine	Wind Turbine

2 Bedroom, 4 Person Semi-detached house	2010 Building Regulations House	Passive Sustainable Healthy House	Mechanical Sustainable Healthy House
Total Primary Energy Demand	11840 kWh/yr	3919 kWh/yr	1960 kWh/yr
Annual Primary Energy Cost (Natural Gas as heating source)	£555.55	£183.89	£91.97
Annual Primary Energy Cost (Grid Electricity as heating source)	£1,356.86	£449.12	£224.62
In-Use Carbon Emissions	2725 kg/yr	986 kg/yr	493 kg/yr
Construction Cost	£86,040.00	£184,000.00	£229,350.00

University of Strathclyde Glasgow · GCU Glasgow Caledonian University · irvinebay · Irvine Housing Association · ASSIST

References

Anandan, C. et al., 2009. Epidemiology and disease burden from allergic disease in Scotland: analysis of national databases. Journal of the Royal Society of Medicine, 102, 431-442.

Austin Smith Lord., 2008. Tarryholme Development framework (unpublished)

ASHRAE., 2009. ASHRAE Handbook Fundamentals.

Howieson S., 2005. Housing and Asthma.

NHS National Services Scotland., 2010. Health and Wellbeing Profiles-SCOTLAND OVERVIEW REPORT. Scotland: ScotPHO.

North Ayrshire Community Planning Partnership., 2010. Regeneration Profiles Based on SIMD 2009. Scotland: North Ayrshire Council.

Scottish Government., 2010. Low Carbon Economic Strategy for Scotland. Scotland: Scottish Government.