Scottish Energy Centre
Institute for Sustainable Construction

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Scottish Energy Centre (HEI)

&

The Morrison Partnership – Chartered Architects & CDM Co-ordinators (SME)

SYNERGY OF FABRIC & ENERGY CONSERVATION IN OLDER HISTORIC PROPERTIES

CASE STUDY: VIEWPARK HOUSE IN ALYTH, BLAIRGOWRIE, PERTH & KINROSS

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CONSULTATION BRIEF

The Morrison Partnership (Architects) are involved with a private client who wishes to convert and extend a 19th century traditional built two storey mansion house in Alyth, Blairgowrie, Perth & Kinross, Scotland. The proposal is to convert the this former hospital to a home and in doing so, the SME require to propose an energy efficient heating system for both space and hot water which is not only sustainable but respects the behaviour and appearance of the existing historic building fabric. The academic consultancy will therefore identify appropriate actions in achieving minimal fabric intervention for maximum energy conservation in traditional buildings with specific reference to solid stone/ lath & plaster wall construction typical of the 19th century in Scotland. Much of the Victorian and Edwardian building stock in Scotland has many features and characteristics of both materials and construction techniques to commend itself. Implementing energy conservation measures into this fabric balance can have a deleterious effect and so the need for synergy between fabric and energy conservation is of growing concern.

The key drivers for this project include rising fuel poverty levels for owners of large domestic difficult to heat properties, the growing threat of global warming and climate change, and the specific national target of reducing carbon emissions by 42% by 2020. This last driver will prove ever more difficult to achieve since new build housing stock will not constitute as great a percentage of the housing stock in 2020 as previously assumed. This is due, in the main, to the recent downturn in house building and likely low levels of completion over the coming years. The main focus for carbon reduction in the housing sector must therefore switch to seeking affordable and practical ways of achieving energy conservation in existing buildings. Currently, existing homes account for over 25% of the UK's total carbon emissions. Part of that sector, and prevalent across Scotland as a result of the nation's heritage, are medium and large scale rural residences. These properties are often listed or carry a particular style characteristic internally or externally which make it difficult to apply many of the modern range of energy gimmicks or applied solutions in an acceptable manner.

The project aimed to address:

1. Environmental issues by seeking methods of reducing CO2 emissions and improving energy conservation and management in older difficult to heat stone built properties.
2. Social issues by improving health as a result of improved and balanced indoor air and heating quality.
3. Economic issues by considering whole-life energy costs in large domestic difficult to heat buildings in Scotland.

The proposal aimed to establish:

1. A detailed energy assessment process for the building study type that could be used in other similar projects.
2. The consultancy period is aimed at identifying future research and improvement work in this area to develop and market an energy management process for this building study type.

PROJECT OUTLINE

The building in question is an un-listed Victorian town house which is situated in an exposed site with some adjacent trees. The building is orientated North West & South West with the main entrance to the property located in the northern location. The house sits in a conservation area within the town of Alyth and therefore will have to comply with any guidelines or regulations that this may impose.

The building is partly used; there are rooms which aren't used constantly and have been assigned to storage. These storage rooms still show traces of the reminiscent hospitals previous life with tiled internal walls and some older fixed furniture.

Many of the un-used rooms are un-heated and have been left to decay with the involvement of dampness and moisture affecting the buildings fabric. This has been the primarily cause of action in the house; where by the proper intervention and re-use of rooms will benefit in the buildings thermal comfort.

In order to achieve this, the partners are committed to perform a series of recommendations and strategies to up-grade the fabric by increasing the energy efficiency of the building. There are two sets of guidelines which will be presented:

1. The intervention of the buildings fabric by upgrading walls, roof, floor and openings
2. The implementation of a Low & Zero Carbon Technology for the generation of clean energy for space and water heating.

The first area of action will be to make the building air tight and energy efficient; given the type of building, its age and its method of construction this will be achieved as best as possible. Many times the refurbishment of older properties can only achieve certain savings in energy and carbon emissions, this is because there is a priority to conserve its character and period of construction. In occasions it is difficult to minimize air infiltration in older properties but this study and consultation will look at the best ways of improving the buildings fabric and energy consumption.

It is essential to look at the building intervention in a holistic way, making sure the materials suggested for refurbishment link in properly with the older fabric materials minimising condensation problems and without changing the character of the building.

The second point of action will address the way the building can be heated by using low and zero carbon technology, i.e. the implementation of renewable energy technology. At present, the building manages to heat both water and the rooms with two condensing boilers. The building has 5 zones in which only 3 are heated and are listed below in Table 01:

Zone No.	Rooms
1	Heated - Ground floor: Living room, halls, play room, kitchens, & Lobby
2	Heated - Ground floor: Day rooms 1 & 2 and a hall way
3	Heated - First floor: All bed rooms(7), hall ways, bathrooms and toilets
4	Un heated - Ground floor: Store rooms, hall ways and bathrooms/ WC
5	Un heated - Ground floor: Boiler room, store rooms, pantry and rear entrance

Table 01

The use of renewable energy will lower the buildings carbon footprint and will also lower the cost of energy bills. This study will present a series of alternatives related to the location and building type. The use of this study will be coupled with the fabric intervention. With less energy escaping and infiltrating through it, the demand of energy will lower, thus the decrease of energy supply. The use of renewables will also lay off the dependency on finite fossil fuels.

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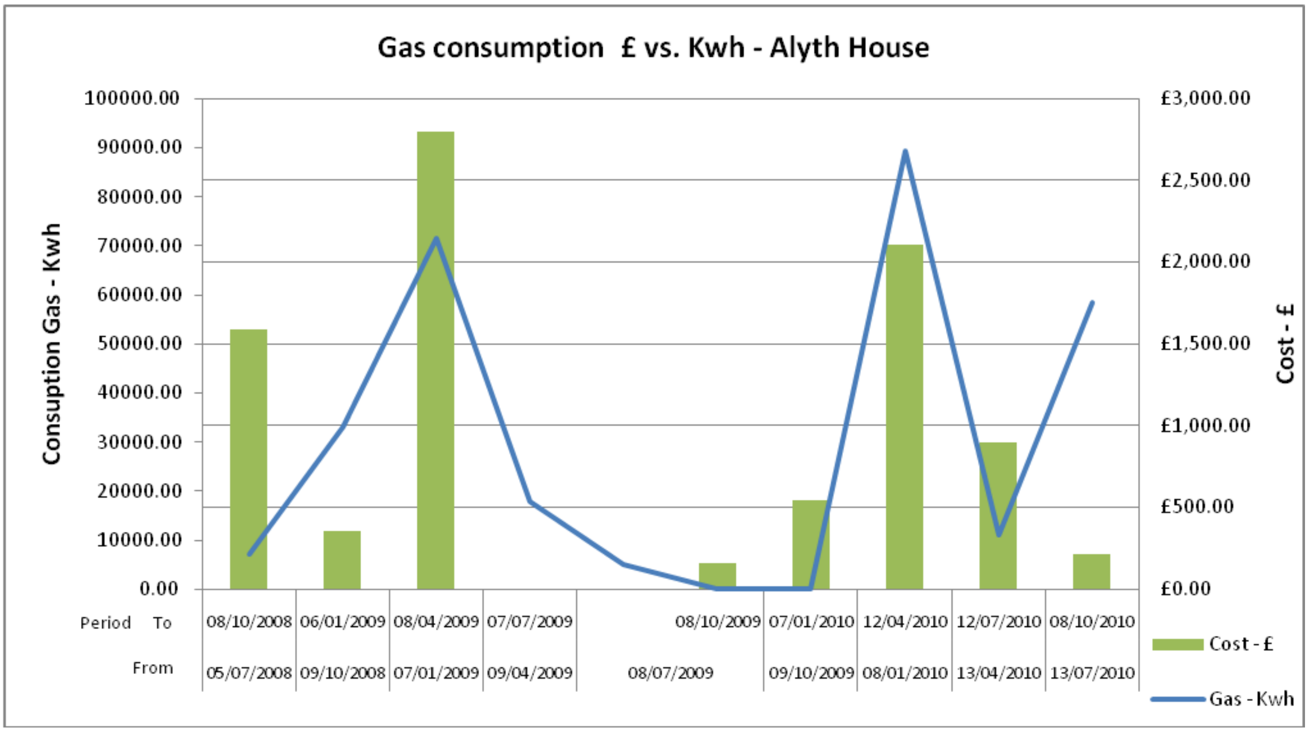
METHODOLOGY

The building was visited by both partners. An inspection of the current state of the fabric and its surroundings took place, as well as locating areas of interest noting material use in walls, roof, floor and openings which were the main areas of information that were essential for the consultancy. Just as important was the use of energy in the heated zones. By analysing the patterns of use and the efficiency of the heating sources the consultancy team can derive many conclusions and suggest alternatives.

In the visit a series of temperature and humidity loggers were located in the heated zones; one in ground floor zone 1 and the other in zone 3 in the first floor. These would give us the information that was being experienced in the house at present.

Other information, key to this work, was the energy bills and patterns of consumption both for heating and generating electricity. The current property owner is connected to the main grid and is consuming Natural Gas for space and water heating and electricity for its appliances and lighting.

The following patterns of use are derived:



Graph 01

The above graph 01 shows the gas consumption in the house over a two year period starting in the year 2008 over to the last months of 2010. A great increase occurred during 2009 winter when a great need for heat was needed.

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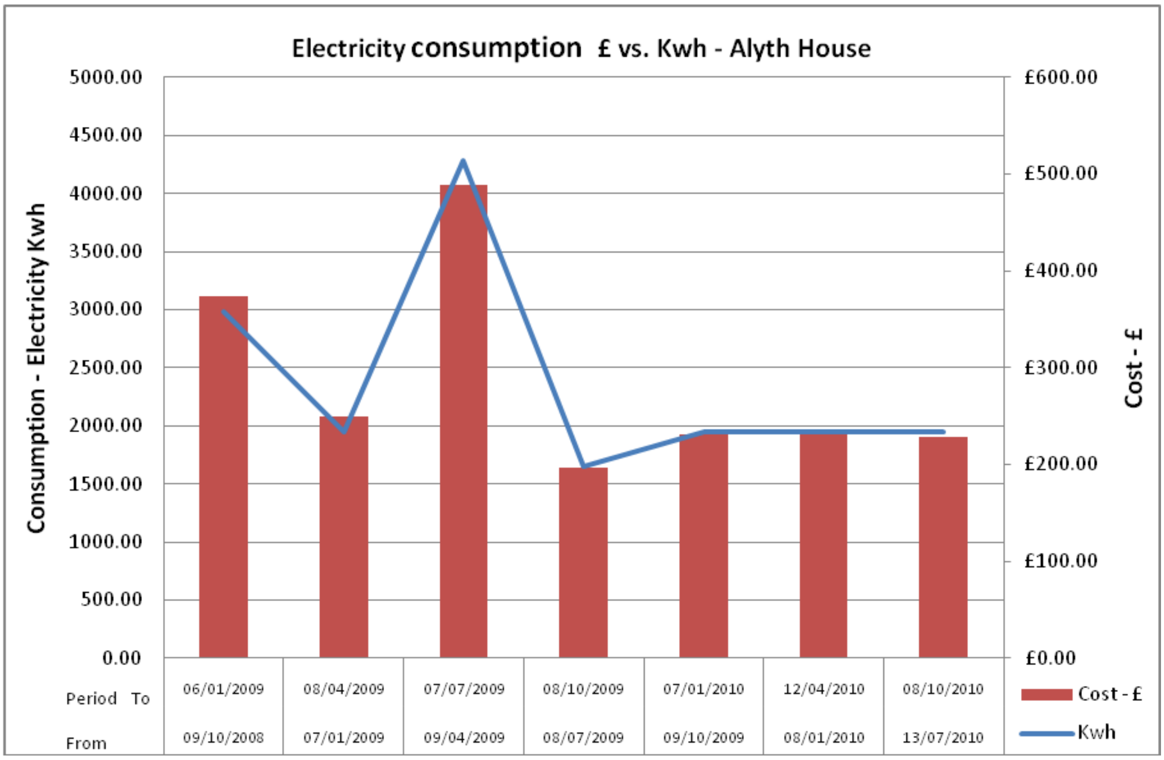

Graph 02

The above graph 02 is indicating the consumption of electricity over the same period (two years). It indicates an even use of electricity but has a big increase over the spring/summer of 2009 may indicate the use of cooling systems introduced in the building.

The period between July 2009 and July 2010 was used for the gas figures giving us a total of; **127,239** kWh/year with an annual cost of **£3,710.** In the same way we took the period between April 2009 and April 2010 for the electricity consumption giving us a total of; **9,832** kWh/year with a cost of **£1,149.** As we can observe, electricity doesn't reflect too much consumption in comparison with the gas consumption which is constantly used for space and water heating.

The academic team used this data above and what was compiled in the visit to create a computational design model of the building which mimics the current state of the building and later on use it to suggest alterations and improvements. The simulation will look at replicating the energy consumption as best as possible, related to the last year of consumption.

The software requires inputting the current state of the building fabric, listing the wall, roof, floor and openings type to simulate how the building is functioning with the current energy mix and the poor fabric state. It has been noted that all walls and floors haven't got any insulation, and that the roof has 50mm of glass wool insulation. The windows are all single glazed with timber frames and the main door is a solid oak opening.

Table 02 below shows the current fabric types that were inputted into the software for simulation.

ELEMENT TYPE	CYMAP CODE	DESCRIPTION	U-VALUE
External wall (1)	Alyth Stone Wall.ELM	A solid sand stone wall with an internal lath and plaster finish.	1.15 W/m^2K
External wall (2)	Alyth Brick Wall.ELM	An external 120mm single leaf brick wall with a rendered interior finish.	3.03 W/m^2K
External roof	Alyth Roof.ELM	External use of slate tiles ventilated air space & softwood rafters/joists. Internal ceiling insulated - 50mm of glass wool lath/ plaster finish.	0.68 W/m^2K
Buildings Floor	Alyth Floor.ELM	A suspended hardwood floor	1.01 W/m^2K

Table 02

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The above materials were applied to the building envelope of the simulated building and by assigning the current heating pattern in the building an accurate account for the thermal conditions were obtained. It can be observed that the u-values obtained in the software are relatively high and in need of improvement. In order to do this they were compared with the real energy consumption figures explained in graph 01. The indication of how much energy and the cost of this annual expenditure was obtained in the model and compared with the energy bills.

The information below (table 03) indicates the results of the buildings annual energy consumption and approximate cost in comparison with the real energy bills.

TYPE	CONSUMPTION (KWh)	COST (£)
Actual energy bills	127,239.57	3,710.65
Modelled results in original state	133,000	3,711

Table 03

The model obtained the above results in its original state by using the average temperatures in its different heated zones (zones 1,2 &3) and by also calculating the air changes per hour of the heated rooms. It was estimated that the building had an air infiltration figure of 2ac/h as a result of the house being leaky and exposed with many openings that are badly sealed, holes produced by services piping and a poor draftproofing throughout.

With the original state modelled in the software, a series of modifications were applied to the house that would show how improvements around the building fabric would lower the amount of energy consumed in the house, thus lowering the demand of boiler size and capacity and as a result of this spending less money in energy. These modifications and results would be compared with the above original state.

SUMMARY OF RESULTS

The advantage of using computational design software is that changes can be simulated to the original state of the building. This can simulate how the building would perform thermally and what the savings would be in energy and in costs.

The table in annex 01 reflects different options which will slowly build up to the optimum and preferable fabric intervention for the house.

An explanation of each package of changes is explained below of which are comparable to the original model and its similarities with the original energy consumption and energy bills.

- EXTERNAL SANDSTONE & BRICK WALLS (PACKAGE 3)

These two types of walls have been improved by adding a layer of insulated plasterboard in on the inner skin of the walls. Keeping the original lath and plaster the plasterboard is attached. The board is an integrated insulated board called Gyproc Thermaline Plus with a thickness of 48mm. It has improved the walls thermal transmittance (u-value) from 1.15 to 0.47 W/m^2k. This package of a wall improvement was applied on its own and presents an estimated annual saving of 15,000kWh and an approximate saving of £421. This product was suggested by the Architects involved in the project.

- SUSPENDED FLOOR (PACKAGE 4)

The original floor is suspended and has a big void underneath it that is partially ventilated. It currently has a u-value of 1.01 W/m^2k. With the inclusion of 200mm of mineral wool insulation suspended underneath the hardwood floorboards and in between the floor joist an improvement in u-value was obtained down to 0.16 W/m^2k. This package was also modelled on its own and it shows an estimated annual saving of 11,111kWh and an approximate of £310 in the gas bill.

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- EXTERNAL SLATE ROOF (PACKAGE 5)

This is a typical slate roof with softwood rafters and joists. Above the lath and plaster ceiling and in between the joist there is 50mm glass wool insulation which will be preserved and increased with 250mm of mineral wool insulation making sure all corners and spaces are filled and compacted as thorough as possible. This was also modelled on its own and it improved the u-value of the roof from 0.68 to 0.14 W/m^{2}k with an estimated annual saving in energy of 5,000 kWh and approximate £140 saving.

- EXTERNAL WINDOWS (PACKAGE 6)

The windows were also changed from clear single glazed units to clear double glazed standard windows. The implementation of new windows can be a costly job and there are many alternatives on the market from secondary glazing to triple or Low-e windows. The SG windows have a u-value of 5.70 W/m^{2}k while the improved DG units have a 2.8 W/m^{2}k transmittance. By applying this change on its own we can see an estimated annual saving of 8,611 kWh with an approximate saving of £238.

- DRAFTPROOFING (PACKAGE 7)

Another cost effective way of reducing air infiltration in the building is by heavily considering draftproofing throughout the house. This would include sealing all windows and giving frames mayor maintenance as well as sealing all skirting boards together with keeping a close eye on holes and gaps in the building fabric. Considerable air escapes through holes around new pipes and ducts; this should be kept to the minimum. All chimney stacks should be partially (for fire safety) sealed. Applying draftproofing in the building can be applied by reducing the air infiltration from 2ac/h to 1.5ac/h. This simply states that the building isn't leaking air as much as it used to. This presents estimated annual savings of 14,444 kWh and an approximated saving of £405.

- NORTH FACADE INSULATION AND WINDOWS (PACKAGE 8)

In this package, the only walls and windows that were upgraded were the ones facing northwards which are the ones limited for more hours from solar gains and are those that will be affected by lower temperatures. The rest of the components have been insulated and all in the same package. Floor and roof have been improved all round the house. This presents an estimated annual saving of 31,666 kWh costing approximately £884 less per year.

- INSULATION IN FABRIC KEEPING ALL WINDOWS SINGLE GLAZED (PACKAGE 9)

Window improvement has been taken out of the equation and has remained single glazed while all the fabric improvements have been compiled together. This shows how insulation will save on its own giving the client flexibility and making staged improvements depending on budget. The estimated annual savings here are of 32,777 kWh with an approximated cost saving of £909.

- INSULATION IN FABRIC WITH DOUBLE GLAZED WINDOWS (PACKAGES 10 & 11)

This combined package has been done showing two scenarios, they both have improved the fabric by adding the insulation suggested above and have also changed the old single glazed windows to improved double glazing units. The only difference is that in package 10, with 2.0 ac/h has no draftproofing, while package 11 does have, by improving its air infiltration to 1.5ac/h, this can be achieved by sealing and making sure all holes and gaps are reduced. All the above work represents a reduction in air infiltration by fitting new window components and adding insulation. Package 10 has saved an estimated 43,333 kWh with an approximate saving of £1,208. On the other hand, package 11 has an estimated saving of 58,888 kWh with an approximate annual gas bill saving of £1,640.

FEASIBILITY STUDY OF LZCT

The second stage of this analysis was to reduce carbon emissions by the integration of renewable ways of producing energy, preferably on site and possibly attached to the building envelope particularly in the roof tops of the building.

A number of alternatives have been looked at, all of which will try and reduce the dependency of the grid and be able to be self sufficient both in space/water heating and electricity.

The home consumed last year between April 2009 and April 2010 (taking into account last year's fuel prices), £1,149 or 9,832 kWh. These figures give us an indication of what the owners consumption is and in what ways we can fulfil that demand with alternative energy sources.

The main concern when opting for the use of renewable energy technology in a building is the excessive cost of the equipment and the installation. Luckily the Scottish government has put into effect two schemes that will reduce the payback periods of installing this technology and also have introduced low interest facilities for Small businesses engaging into these schemes. The two schemes are the Feed in tariff (FIT) for generating electricity and also the Renewable Heat incentive (RHI) for generating energy for space/water heating. They both are applied to technology installed and the applicant of such incentives receives £0.381 for every kWh is produced and £0.06 for every kWh you generate of space/water heating. The surplus of such energy is fed back into the grid of which will benefit other uses.

Key points of the FIT scheme:

- For Households and Communities
- Electricity generating technologies (e.g. solar electricity and wind) up to 5 MW
- Tariff levels index linked for 20 years, except PV (25 years)
- Ofgem will administer the Feed-In-Tariff scheme and suppliers will be responsible for paying their customers.
- Customers must use certified installers and products through the Microgeneration Certification Scheme (MCS).

The following are small feasibility studies for various renewable alternatives.

1. SOLAR PHOTOVOLTAIC PANELS

The introduction of PV panels would benefit a great deal to fulfil the demand of electricity of the users. The location of such panels would have to be in a shade free roof top where a south or southwest/ south east orientation would be preferable. For instance a monocrystalline type of PV panels with a suggested 4kWp can generate approximately 3,200kWh per year. Every kWp of panel accounts to an area of 10m^2, of roof space. In this case the 4kWp set of panels would require an approximate of 40m^2 of space which has to be accessible and available for repair and maintenance.

In terms of the savings, if we take the current cost of electricity through the grid is at an average £0.118 per kWh the total saving would be in the order of (3,200 x 0.118) £377 per year. This, together with the mentioned FIT incentive of £0.381 per kWh, derives 3,200 x 0.381 = £1,220 per year. In total this is estimated to generate a saving of some £1,596 per year.

This money can pay off the cost of installing the PV panels that approximately cost around £5,000 per kWp set of panels (including installation). The total expenditure would be in the order of (4 x 5,000) £20,000. With this in mind the total payback period would be approximately (20,000/1,596.80) 12.5 years.

The remaining 12.5 years after repayment would be a profit of (1,596.8 x 12.5) £19,960 that can be used to invest in maintenance or add to new equipment in the future.

2. WIND GENERATORS

According to the Department for Business, Enterprise & Regulatory Reform (BERR) and the Department of Energy and Climate Change with the aid of the NOABL (wind speed database) an estimated annual mean wind speed can be obtained. In the location of this building with a 1km square radius we would have a wind speed in the region of 5.6m/s at a height of a mast of 10 meters. This in turn can produce; if using a typical 2.5kW rated turbine, approximately 3,044kWh per year with an 11 meter mast. The approximate cost of this equipment is of £15,000 with installation.

Just like the PV panels if the current cost for grid electricity is at £0.118 per kWh this gives us an approximate saving of (0.118 x 3,044) £359 per year. With the FIT at £0.381 per kWh it gives an estimated income of (0.381 x 3,044) £1,159 per year. The total saving would be of £1,518 per year which can go towards paying the cost of the equipment.

For the payback period, we would be looking in the region of (15,000/1,518.96) just under 10 years. The government will pay the FIT for wind generating schemes for 20 years making it 10 years of profit with an approximate of (1,518.96 x 10) £15,189 after the equipment has been paid in full.

3. BIOMASS HEATING/BOILERS

Last year the house consumed 127,239kWh of gas costing the client £3,710. Carbon efficient biomass boilers using wood pellet biofuel that typically cost £0.035 per kWh and relating to the existing demand would cost in the order of (0.035 x 127,239.57) £4,453 to run.

The renewable heat incentive is offering £0.065 per kWh produced giving a total incentive of an estimated (0.065 x 127,239.57) £8,270. If we deduct the cost of the wood pellets this leaves an approximate (8,270.57-4,453.37) £3,817 towards the payback of the equipment installed.

On average a biomass device of this size can cost in the region of £13,000 to install (depending on supplier) so the payback period of the device would be approximately (13,000/ 3,817.2) 3.5 years. The tariff lifetime for biomass is of 15 years, thus leaving 11.5 years approximately of profit which accounts to approximately (11.5 x 3,817.2) £43,897.

The above calculations are considering last year's demand of energy. If the demand is reduced as a result of the improvement of the building fabric then savings would be much more substantial.

4. SOLAR THERMAL WATER HEATERS

Solar thermal water heaters can be mounted just like the solar PV panels on the roof; preferably in areas that are shade free and can have a better exposure to solar radiation. Solar thermal technology transforms direct and diffuse solar radiation into useful heat using a solar collector. For the purpose of this calculation, an evacuated tube system has been used. These use a vacuum tube collector which performs more efficiently than flat plate collectors particular in Northern Europe and other low solar gain locations.

The recommended slope for evacuated tube collectors is a 40° angle on the roof top or with a sloped roof kit. Their optimum efficiency is south, southwest, southeast.

These devices are not recommended to be used fully to operate the space heating in a building as big as the one being analysed, but they can contribute to the heating of water for washing and other needs.

Each evacuated system of 20 tubes as an indirect active system has an overall size of approximately 2.85m^2 and would receive in a location in Northern Scotland with a solar insulation of 2.26kWh/m^2/day. This would produce around 6.44kWh/day, if we consider heat losses and possible shading or obscure periods this figure should be around 4.8kWh/day. This gives us an estimated annual energy output of 1,752kWh per system. This is enough to fulfil the current hot water heating for domestic use in the building.

Each system of 20 evacuated tubes has a cost once installed in the region of £5,000. This investment would be backed for 20 years with a RHI tariff of £0.17 per kWh produced. So this Incentive would contribute approximately (1,753 x 0.17) £298.0 per year. The estimated payback period for this device would be (5,000 / 298) 17 years. This leaves 3 years approximately with a profit of (3 x 298) £894.

CONCLUSIONS

Finally, it's important to put into context the difference between improvements to a building fabric of a building and adding renewable energy systems. They will both contribute to reducing the buildings carbon footprint but will do so in different ways.

It is worth indicating that it is essential to upgrade the performance of the building fabric first, to lower the buildings demand of energy and then on a second phase introduce the use of renewable energy systems to fulfil the new buildings energy demand. This will present lower capacity of systems and smaller devices as their production of energy will be smaller and thus a lower investment in technology. Although the incentives from the government are very encouraging and show a healthy and profitable route, they are schemes that have a lifespan of between 15 and 25 years (depending on device). If the devices haven't had proper maintenance their efficiency will deteriorate and they will no longer produce optimum amounts of energy and will eventually have to be replaced. It is also unsure how long these government incentives will survive, and with the uncertainties of the economic world, let alone the country, this can become a risk of investment which will only incur into longer years of payback.

Therefore it's essential to make the building as thermally energy efficient as possible with as much upgrading as possible, understanding the limitations of age and typology of building.

This study is to look at ways of reducing the carbon footprint of the building and also see ways of obtaining energy through natural resources. By taking into consideration the above packages in different stages or as a complete retrofit of the home will present many carbon savings.

According to the Carbon Trust, for every kWh of natural gas, 0.184 kg of Carbon Dioxide is emitted so for the above savings there would be:

Package type & number	Annual savings (kWh)	Annual Carbon savings (tCO_2)
2- Original CYMAP model	Consumption: **133,055.56**	Emitting: **24.5tCO_2**
3- Insulation on walls	15,000	2.7
4- Insulation on floors	11,111	2.0
5- Insulation on roof	5,000	0.90
6- Windows from SG to DG	8,611	1.5
7- Draftproofing	14,444	2.6
8- Insulation + DG windows north	31,666	5.8
9- Insulation + SG all of house	32,777	6.0
10- Insulation + DG all of house	43,333	7.9
11- Insulation + DG + draftproofing	58,888	10.8

Table 04

Table 04 shows a summary of the estimated annual savings in energy and in carbon emissions. Package 2 is the original state which is very similar to the owners last year's energy bills and it shows an approximated emission of 24.5 tonnes of CO2. If we look at the packages that indicate a more holistic approach to upgrading the building fabric (packages 8 to 11) the savings vary approximately from 5.8 tonnes per annum to 10.8 tonnes per annum.

The integration of renewable energy is the preferred second stage to the retrofit of the building. Looking at the small feasibility figures, solar thermal water heating proves to be the least feasible technology as it depends a great deal on location, of which Scotland isn't very efficient. The investment is also very high and the only recommendation would be to use this technology as a back up to water heating for the kitchens and the bathrooms/toilets. Space heating can be achieved by other devices like the biomass boilers. If we refer back to annex 01, we can observe a plant size column which indicates the capacity of a boiler system to fulfil the energy demands. We can observe that the more intensive packages (8 to 11) have an estimated plant size of 50 kW capacity for the insulation and the DG windows to the north of the facade (package 8), while in package 11 the most holistic and preferable approach an estimated plant size capacity of 36 kW is indicated. These are approximate and they should always be higher in case of extreme circumstances.

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The integration of solar PV and Wind electricity generating devices is feasible, considering the FIT incentives are so popular and have proven to be successful. They present a reasonable payback period and most importantly a considerable number of approximate years after payback which account to profit, 12.5 for PV and 10 for wind. These profit margins can be later invested into new technology or into replacing technology for more efficient ones. This will always be the case where technology will improve through the years and will also reduce in price, becoming more mainstream and easier to purchase.

It's worth mentioning that if these renewable devices are installed and developed as a Small or Medium Enterprise (SME) the government can facilitate interest free credits for the initial investment of the technology. For more information visit the schemes organised by the Energy saving Trust.

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Annex 01 - TABLE OF RESULTS

No.	Location	Improvement type	Package	U value (w/m²K)		Heating (per annum)		Estimated Plant size	Estimated Annual Savings	
				Original	New	£	kWh	kW	kWh	Cost £
1	Original state	None	As per original energy gas bills	-	-	3,711	127,240	-	-	-
2	Original state	None - modelled to real-time internal temperature data obtained	CYMAP model - Original State - SG windows, no Insulation	-	-	3,711	133,056	64.7	-	-
3	External sandstone wall & brick walls	48mm Internal Gyproc Insulated plasterboard on lath/plaster or render finish	Insulation only on walls @ 2.0 ac/h	1.15	0.47	3,290	118,056	56.4	15,000	421
4	Suspended floor - base of ground floor	200mm of mineral fibre in the underside of the hardwood floor.	Insulation only in floors @ 2.0 ac/h	1.01	0.16	3,401	121,944	61.1	11,111	311
5	External slate roof/ timber rafters	250mm of Mineral fibre between and over the joist of ceiling.	Insulation only in roof @ 2.0 ac/h	0.68	0.14	3,571	128,056	63.3	5,000	141
6	External windows	Double glazed air filled clear glass window panes. Draftproofing in frames.	Change of SG windows to DG windows	5.7	2.8	3,473	124,444	60.4	8,611	238
7	Walls, windows, doors, roof & floor.	Sealing and installing draft excluding devices. Improving windows and openings	Draftproofing reducing infiltration to 1.5 ac/h	-	-	3,306	118,611	59.2	14,444	406
8	Improvements of fabric & openings north facade	Insulation in fabric & double glazed units	Fabric Insulation + DG windows only in North @ 2.0 ac/h	-	-	2,827	101,389	50.1	31,667	884
9	Walls, doors, roof & floor.	Insulation in fabric keeping single glazed units	All insulation in Fabric + SG windows @ 2.0 ac/h	-	-	2,802	100,278	49.1	32,778	910
10	Walls, windows, doors, roof & floor.	Insulation in fabric & double glazed units whole building	All insulation in Fabric + DG windows @ 2.0 ac/h	-	-	2,503	89,722	43.1	43,333	1,208
11	Walls, windows, doors, roof & floor.	Insulation in fabric & double glazed units whole building, major draftproofing	All insulation in Fabric + DG windows @ 1.5 ac/h	-	-	2,071	74,167	36.8	58,889	1,640