ABDEL-WAHAB, M., ALI, D. and JENKINS, D. 2013. A case study of retrofitting a non-domestic building in Scotland. Presented at *2013 Sustainable building (sb 13 Munich): implementing sustainability; barriers and chances, 24-26 April 2013, Munich, Germany*.

A case study of retrofitting a non-domestic building in Scotland.

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2013

A case study of retrofitting a non-domestic building in Scotland

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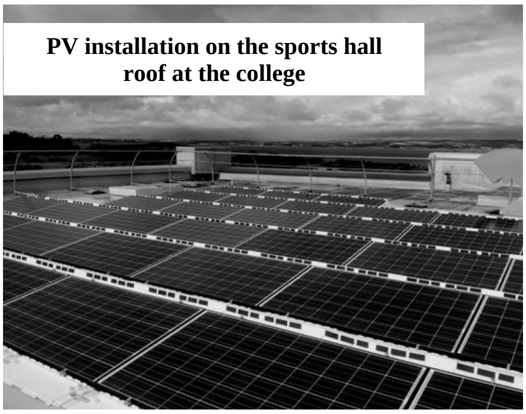
Summary

Enhancing the energy performance of buildings is a complex undertaking which involves the implementation of various measures which can include: insulation using innovative technologies in-particular for hard-to-treat buildings (e.g. historic listed buildings), installation of small scale renewable technologies, such as PV solar, solar thermal, wind-turbines…etc., and influencing end-users behaviours to reduce energy consumption.This paper presents a case study of a non-domestic building (Further Education –FE- College) in Edinburgh. The paper reports on the progress to-date for the energy refurbishment of the building which is focused on investment in renewable energy technologies. Phase one, which is now completed, involved the installation of a 50 kWp PV panels on the roof of the building at three areas: Sports Hall, Engineering section, and Southern Side. The benefits accrued from investment in renewable technologies includes: potential energy savings, research and educational, and income generation. Drawing on this project experience, the following issues should be considered in the future when retrofitting buildings: funding schemes, technology selection and integration, skills and training, and stakeholder engagement.

However, it should be noted that a key shortcoming of small-scale renewable technologies is the provision of intermittent supply which poses a risk for maintaining security of energy supply. As such, it has to be used in combination with Energy Storage Systems (ESS) such as hydrogen storage and fuel cells, which has the potential for improving power quality, supply flexibility, maintaining energy system stability and security. Phase two of the energy refurbishment of the building will explore the feasibility of the application of ESS to further enhance the energy efficiency of the building.



PV installation on the sports hall roof at the college

Finally, the rigorous evaluations of different interventions for enhancing the energy performance of buildings should be carried-out in the context of different buildings types. Such evaluations should provide indispensible case studies to establish the efficacy of these technologies in-practice. Indeed the dissemination of real world building performance information can help to inform the future decisions of retrofitting buildings and potentially informing national policy.

Keywords: Retrofitting; PV units; Energy performance; and Buildings.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1. Introduction

Minimising the impact of industrial activities on the natural environment is at the centre of the UK government policy given the Carbon Emission Reduction Target of 80% (below 1990 levels) by 2050 – as stipulated by the Climate Change Act 2008. The UK government has thus emphasised the need for minimising the impact of buildings on the environment as it is a significant contributor to greenhouse gas emissions. In its report entitled ‘Low Carbon Construction’, the UK government recommended the focus on more case studies for demonstrating how the impact of buildings on the natural environment can be minimised and in particular when it comes to the rationalisation of energy consumption and the use of greener sources of energy [1,2]. Similarly, the UK Green Construction Board emphasised the need for marshalling knowledge around the treatment of existing buildings [3].Recently, the UK Technology Strategy Board (TSB), a UK organisation which promotes technology research, development and commercialisation, has invested £17m in an initiative known as Retrofit for the Future (RfF – retrofitforthefuture.org) to support retrofitting of the UK's social housing stock.

As a part of the initiative, a database was set-up as an educational and dissemination tool, incorporating both the RfF projects as well as new and refurbished *domestic and non-domestic* low energy buildings. The aim of the database is to showcase exemplar buildings which were successfully energy refurbished. The database provides useful information on estimated energy consumption and carbon emissions, in addition to the measures implemented for achieving energy efficiency, such as insulation and PV installation. Whilst the database is intended to inform the planning and development of low energy new build and refurbishment, it contains very basic information on building services, type of construction, and estimates of energy use by fuel type. There is also no detailed information on the actual experience and process for undertaking these projects. Thus, the aim of the paper is to report on the lessons learned from retrofitting a non-domestic building in Scotland with a particular focus on the organisational issues that can impinge on investment decisions for energy refurbishment of buildings. A technical evaluation of the 50 kWp PV is beyond the scope of this paper, but it is an area for future investigation.

2. An overview of the building

The building is located at the Granton waterfront in Edinburgh and it is regarded one of the largest FE Colleges in Scotland. It employs around 700 staff and has over 16,000 students studying on a full time, part time, evening or open learning basis. The College aims to provide flexible, accessible and responsive vocational training and education that will help students develop practical skills, experience for work and/or preparation for entry into higher education. The total useful floor area of the building is 31,599 m^2, which utilises heating and natural ventilation. According to the Energy Performance Certificate (EPC), the current energy rating of the building is C+. It has to be noted that under the Energy Performance of Buildings Directive (EPBD), all EU member states must promote improvement in the energy performance of new and existing buildings and thus an EPC provides an indication of the energy efficiency of a building and ways for enhancing it.

The Building Emission Rate (BER) is stated as 30.7kgCO_2 per m^2, compared to a Target Emission Rate (TER) of 24.1kgCO_2/m^2. The building heating, cooling and ventilation systems are listed as acceptable, though there is a potential for improvement in the fabric U-values in-line with the Scottish Building Regulation guidance. The glazing, in particular, would be an obvious candidate for improvement, with single-glazing common throughout the building (with a U-value of 6W/m^{2}K being quoted in the EPC). Specifically, the predicted heating energy consumption is 67.4kWh/m^2 for the fan coil system and 74.9kWh/m^2 for the central heating systems (both estimates are "Actual", not "Notional"). Cooling energy consumption is predicted at 24.5kWh/m^2. This puts the building within "Good Practice" for heating benchmarks for a standard air-conditioned office, though slightly higher than good practice for cooling. It should also be mentioned that these are modelled energy consumption values - measured quantities will have to be explored to investigate the accuracy of these estimates.

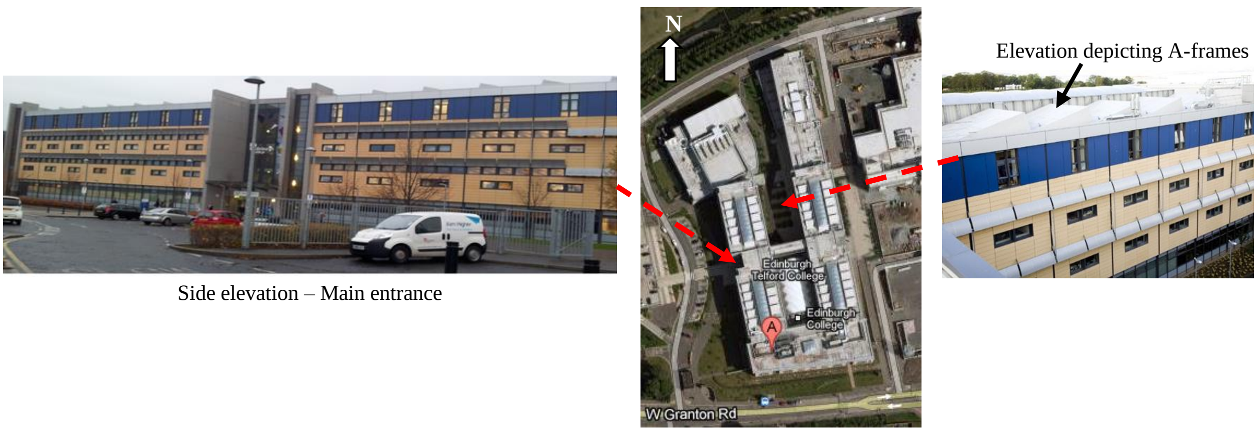

Fig 1: An overview of the building

Initial an estimated 650 solar PV panels on the roof of the FE college with a vision of being the largest PV demonstration project in Scotland. The idea was to maximise on the vast area on the roof whilst making use of the existing A-frames – See Fig 1 above. However, it was decided that Phase one of the installation will only involve the installation of 50 kWp PV units as this will not require any planning persmission from the council so it can be installed quickly to make use of the current rates of the Feed-in-Tariff scheme before reduction in the tariff was introduced in August 2012. Moreover, a survey of the roof was carried-out in order to assess the scope of work that could be achievable given the constraints of the project. Issues identified included the load created by the PV panels and the requirement of an appropriate support system. It has to be noted that the A-frames on the roof were incorporated in the initial design of the roof for the purpose of installing PV panels in the future. Whilst the A-frames provided an attractive opportunity, no work could be carried out without close consultation and consent of the roofing contractor otherwise the insurance policy would be nullified. It was found that the A-frames are unsuitable as the support structure for the PV arrays could not be mounted directly and it will require additional work. Thus, the installation of a 50 kWp PV units (on other areas of the roof – excluding the A-frames) was deemed as the most feasible starting point for retrofitting the building. The next step was to investigate possible funding routes and seek approval from the college's senior management which required putting forward a business case which is next discussed.

2.1 The business case

The business case for investment in retrofitting the building covered the following accrued benefits:

- Providing an exemplar of a building with good green credentials to the wider community which is essential for public engagement and providing good publicity.
- Reduction in energy bills for the FE College with the ability to spend energy savings on other things, such as the development of training courses or other energy-efficiency/renewable energy measures.
- The availability of PV units at the College's roof could be used for student's site visits and if further PV installations are carried-out in the future, a training facility for showcasing the latest PV technologies could be set-up at the College's rooftop.
- Providing the potential for generating income streams through CPD events and site visits.
- Carrying out research in collaboration with Universities to capture knowledge that relates to the application and performance evaluation of renewable technologies.

Initial estimates for paybacks indicated a payback period of 25 years for the initial investment. The principal maintenance item is an inverter replacement. An inverter life expectancy is 10 years. Routine or planned maintenance is not a usual requirement for PV systems and no cost for this has been provided for. It has been assumed that the College will monitor performance, insure the installation and undertake Feed-In-Tariff (FiT) administration at its own cost. Aside from planned inverter replacement any equipment failure not covered warranty represents an additional cost.

2.2 An overview of Phase one installation

The three areas of the building that are served by the 50 kWp PV units are: Engineering, Southern, and Sports hall – as shown in Figure 2 below. The installation was completed in July 2012 to make use of a Feed-In-Tariff (FiT) rate of 15.2p/kWh (over the period of March-July 2012) which was going to change to 13.5p/kWh in August 2012. Figure 3 shows the total energy generation of the PV units since its installation in August 2012. It is notable the variability of generation of the PV units which is expected given the intermittency of renewable energy. On average, only 0.3% of the total energy consumed in the building (between August and December 2012) was from the PV units. The college also started generating income from the FiT generation payments.

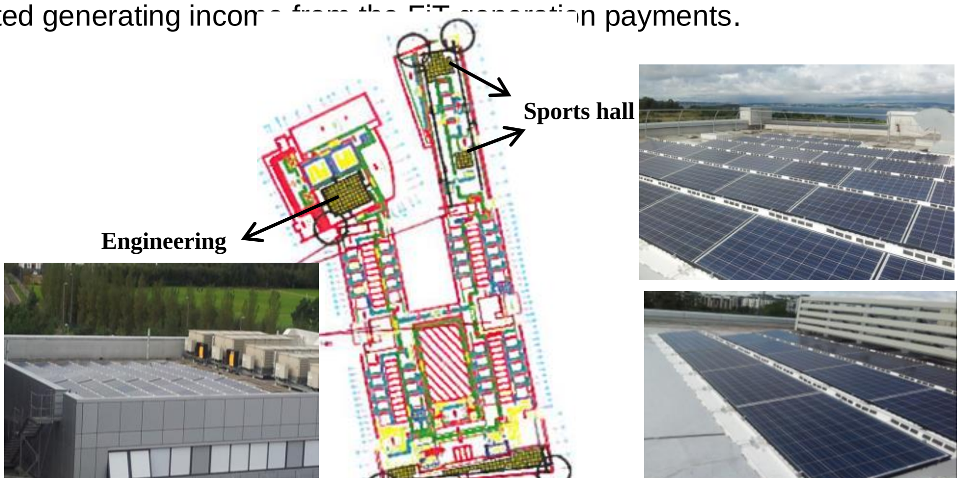

Fig 2: Roof plan of the building

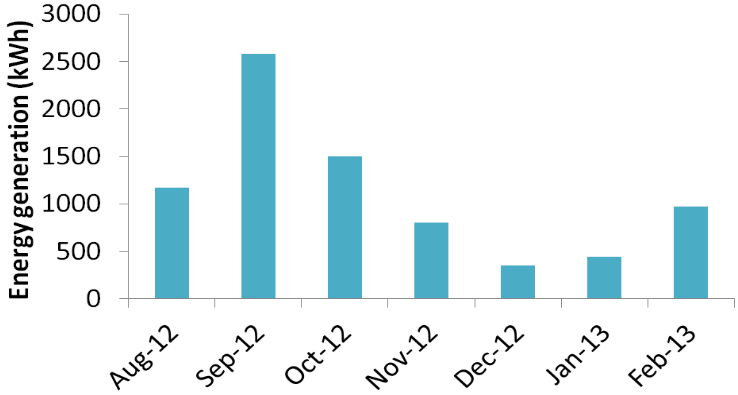

Fig 3: Total energy generation of the PV installation (monthly)

3. Plans for phase two development

The current energy rating of the FE College (C+) conforms to the requirements of the UK Energy Act 2011 which stipulates that by April 2018 all properties (both domestic and non-domestic) should at least be an 'E' rating. Nonetheless, there is a potential for further enhancing the energy rating of the building thereby reducing energy consumption and in turn reducing energy bills and potentially increasing the value of the property in the market.

Implementing further measures for enhancing the energy rating of the building requires capital investment, which could be drawn from government incentive schemes, such as Technology Strategy Board (TSB). The scope of retrofitting the FE College, at least in the short-term, is more concerned with the installation of *reliable*, *renewable*, and *efficient* energy systems as opposed to altering the building fabric, i.e. insulation, especially that the building is relatively new as it was constructed in 2009. Nonetheless, a thorough survey could be conducted which would consider measures concerned with the building fabric in the medium-long term, such as using insulation and secondary glazing for some windows (which have high U-values) as recommended in the EPC. Furthermore, there is a need for understanding end-user behavioural patterns of energy consumption, in addition to post-occupancy evaluation, which are areas that warrants further investigation.

In terms of short-term measures concerned with reliable and efficient renewable energy systems, there is a need for a scoping study to be carried out to recommend the optimum mix of technologies that could be invested in. Optimum mix could be defined in terms of cost effectiveness, reduction in energy consumption and contribution to enhancing the energy rating of the building.

Research indicates that the comparison of the energy consumption rates in buildings and production rates of electricity from renewables demonstrate how difficult it is to power modern buildings entirely from on-site renewables [6]. Moreover, the use of renewable energy or micro-generation systems brings two main challenges. The intermittent nature of renewable energy presents a challenge for maintaining security of energy supplies for end-users. In addition, the massive introduction of excess renewable energy into the electrical grid can lead to instability in the operation of electric power systems [7, 8]. Therefore, further investments in renewable energy should be in tandem with exploring the feasibility of using Energy Storage Systems (ESS). Successful energy storage systems (ESS) can allow higher renewable penetration into the grid without affecting the system stability and without having to cease the renewable energy production and pay penalties. However, storage technologies are faced with different controversies like high initial cost rates, additional transformation losses and environmental impacts largely depending on the correlation between the technologies used and the site selected [9].

Figure 4 below depicts a typical Energy Storage System (ESS) set-up. All electrical ESS have varying degrees of inefficiency as part of the energy supplied into an energy storage systems cannot later be discharged due to system efficiency losses. Typical efficiency factors range from 45% to 80% depending on technology and storage application, and is the main weakness of all existing electrical storage technologies [10]. Efficiency losses are also a significant contributing factor to the existing perception of an unfavourable business case for their use. In common with conventional power stations, the economic case for energy storage systems is also affected by many other factors such as the cost of charging electrical energy, capital costs, operation and maintenance costs and discharge/recharge) cycle life [11].

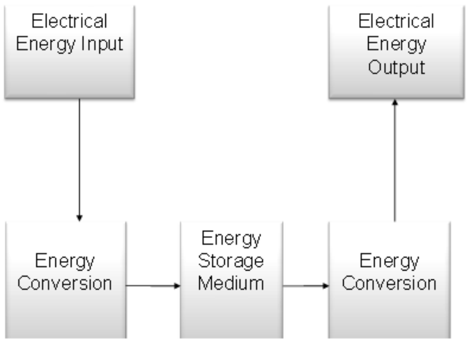

Fig 4: A schematic diagram of an Energy Storage System (ESS)

4. Issues to consider when investing in renewable technologies

4.1 Funding schemes

There are many funding schemes in the UK, as well as in Europe, which incentivises investment in energy refurbishment of buildings, such as offsetting initial capital costs. An up to-date knowledge of the current schemes is thus essential, particularly that these schemes are subject to on-going change and may even cease to exist!

The Feed-in-tariffs (FITs) scheme is available for renewably generated electricity with generation tariffs weighted depending on the type of technology and size of installation. A full breakdown of the current tariffs on offer can be found on the UK government website [12]. In the context of the case study presented in this paper, the 50 kWp PV panels were installed in July 2012, to make use of the higher rate of the Feed-in-Tariff scheme before changes were introduced in August 2012.

Moreover, the Renewable Heat Incentive (RHI) pays a consumer for the generation of renewable heat, which can include biomass boilers, ground and water source heat pumps, solar thermal installations and bio-methane/biogas production. There are also plans to expand this for air-source heat pumps. Much like feed-in-tariffs for renewable electricity production, a range of tariffs is available for different types of application ranging from 3.4p/kWh (for larger heat pumps) to 8.9p/kWh (for solar thermal collectors).

One of the recently launched UK government funding schemes is the Green Deal, which is available for both domestic and non-domestic buildings. The Green Deal is regarded as coalition government flagship programme that allows an individual to access loans at a market rate of interest to pay for the upfront cost of energy efficiency refurbishments. These loans are then paid back based on projected energy savings for that building. It remains to be seen whether the relatively high interest rates will deter organisations, who might instead choose to use their own resources or simply refrain from investing in low-carbon measures. The Green Deal, like many estimates of savings from low-carbon refurbishments, is heavily reliant on building modelling, specifically the Standard Assessment Procedure (for domestic buildings) and Simplified Building Energy Model (for non-domestic properties). The performance gap between such models and real consumption data is well documented [13], so the risk of companies investing in technologies based on such estimates is clear. Additionally, new low-carbon technologies, or new applications of existing technologies, where a market has not yet developed means that relatively few real-life exemplars exist to inspire confidence that such an investment can be cost-effective.

4.2 Technology selection and integration

Awareness of the latest technologies available in the market is important as they are ever changing and many of the technologies are imported into the UK from abroad from countries, such as Austria, Canada and Japan. In particular awareness of energy storage system, which is an emerging technology, is important when considering investment in renewables in order to address the issue of intermittency and provide a reliable backup source of energy. In addition, an in-depth knowledge of the building fabric and energy consumption patterns is essential for informing future investment decision of energy refurbishment of buildings.

Furthermore, knowledge of Distributed Generation (DG) power system is essential. DG is defined as any modular generation located at or near the load centre which can include renewable technologies and Combined Heat and Power (CHP). CHP plants or cogeneration are power plants where either electricity is the primary product and heat is used as a by-product, or where heat is the primary product and electricity is generated as a by-product. The overall energy efficiency is then increased. Many DG technologies, such as Reciprocating engines, Micro-turbines and Fuel cells can be used as CHP plants. Integration of fuel cell (CHP) and energy storage (using electrolysis) with existing systems can be used to maximise energy efficiency in a building [14] which could be explored in the development plan of phase 2. CHP technology recovers waste heat to provide heating, hot water or even air conditioning. This reduces overall energy consumption and thereby enables commercial and industrial customers to offset gas and electricity consumption [14]. Gas fired fuel cell CHP in itself enhances the efficiency of central gas heating systems by using gas more efficiently in the production of energy (electricity and heat). Integration of electrolysis-based energy storage enables fuel cell sizing and use to be optimised to generate greatest benefit for the building owner in terms of reduced energy costs and emission reductions. This can be achieved both through onsite use of overnight electricity production from the fuel cell (rather than exporting at times of lowest grid demand) and through import of cheap overnight grid electricity to generate hydrogen. Both methods can help meet peak building (and grid) power requirements and building heating needs whilst reducing gas consumption [14].

4.3 Skills and training

Skills development and training are perquisite for enhancing the energy performance of the current building stock particularly when it comes to the application of new and innovative insulation and renewable technologies. Even when it comes for training and raising awareness of end-users to ensure that their behaviour does not result in wasteful use of energy. Recent research revealed that a Scottish Housing Association invested in a communal heating system (based on a ground source heat pump) which was poorly installed and maintained due to inadequate workforce skills and training [5]. Indeed the investment in skills development of the workforce is important, in particular product-specific knowledge, to ensure that workers can successfully install and maintain such systems. It follows that a number of UK government reports and initiatives have been launched to support what is known as the ‘low carbon skills’ agenda.

For example, Skills Development Scotland (SDS), which is a non-departmental public body with a remit to support skills development and training activities in Scotland, has allocated £3m funding for SMEs training to reduce their carbon footprint. Moreover, FE colleges invests in new facilities such as the Renewable Energy Centre at Edinburgh's College, as well as the development of new courses and qualifications to support the skills development of the construction workforce in these emerging technologies. It has to be noted that whilst a FE college can provide generic training for a particular renewable technology, product-specific knowledge remains paramount when it comes to the actual installation of these technologies on-site. Many of the renewable technologies are imported into the UK, e.g. Fuel Cell Units from Japan. Whilst some renewable technologies are tested are certified by the Micro-generation Certification Scheme (MCS), yet there is still a challenge of the wider adoption of these technologies, and there is a strong need to showcasing the efficacy of such technologies in a UK building context in particular when it comes to demonstrating reduction in energy consumption of buildings and carbon emissions.

4.4 Stakeholders engagement

Involvement of different stakeholders in retrofitting buildings present a challenge notably that each is working towards different goals. Thus, the reconciliation of these goals and managing expectation is essential in order to ensure a win-win situation. The university's main interest is to advance knowledge in the area of energy refurbishment of buildings through carrying-out evaluations of different interventions, particularly novel technologies to teach students the latest cutting applications of these technologies in the context of different buildings. At the same time, such evaluations should provide indispensible case studies to support the commercialisation of novel technologies from the point of view of the industrial partner and thereby maximising business opportunities and impact. The industrial partner, which is set-up as a social enterprise, with a remit of ensuring that the benefits of renewable energy are made accessible to all sectors of society through its network of delivery partners for product installation in addition to working with clients to optimise energy savings and encourage behavioural change. According to the Energy Saving Trust UK there are 62,000 social enterprises in the UK which contribute £8.4 billion to the economy every year.

Figure 6 below is a generic depiction of the three-way collaboration between the three partners involved in this project. It has to be noted that for phase one the university role was more on a consultancy basis in particular for making the business case for the investment and setting-up the college with the industrial partner. However, for future development of phase two there is a need for vehicle for further pursuing that collaboration. There are number of schemes in the UK with an overarching aim of supporting university-industry collaboration, such as Energy and Technology Partnerships – ETPs - etp-scotland.ac.uk; and Knowledge Transfer Partnerships – KTPs - ktponline.org.uk.

A discussion of these schemes is beyond the scope of this paper but suffice to say that such schemes are great enablers for applied research in order to support addressing industrial problems and thereby maximising the value of university research by creating a win-win situation for all parties.

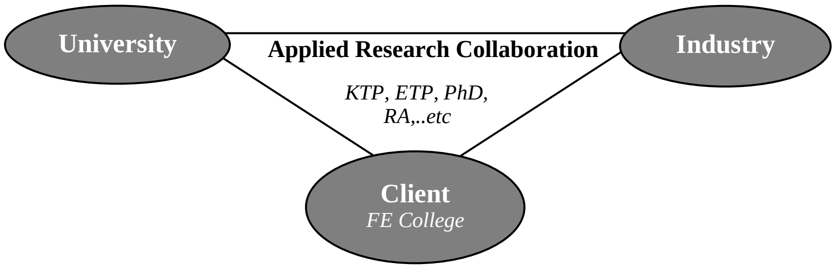

Fig 6: A generic depiction of research collaboration

5. Conclusion

The aim of this paper was to share the experience of retrofitting a non-domestic building (FE College – the project client) in Scotland. The client aspires to use the building as an exemplar of current and emerging renewable technologies whilst providing valuable on-site training facilities for students and the wider community, which was the thrust of the approved business case for investment in the PV installation. It becomes evident that it is unrealistic to rely solely on renewable energy to meet the high energy demands of non-domestic buildings.

It has to be noted that the building is fairly new and it was completed in 2009 which raises the questions around the energy credentials of the building being developed during the construction phase, particularly the energy rating of C+ on the Energy Performance Certificate. The obvious answer to this question might be the lack of funds and not applying stringent design standards, from the outset of the project to ensure optimal energy efficiency. There is also evidence that Energy Performance Certificates (EPCs) alone are not sufficient in delivering the Government's targets to 'de-carbonise' the UK's built environment as they focus on 'design intent' or theoretical energy efficiency as opposed to performance in-use [13]. The use of empirical data, as shown in Display Energy Certificates (based on energy bills), should therefore be strongly encouraged. Finally, there should be a continued dissemination of real world building performance information capable of being benchmarked, rather than marketing misinformation, to inform policy and future investment decision in the energy refurbishment of buildings [15].

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Acknowledgement

We would like to thank Colin Pentland (Facilities Manager) and John Laing (Senior Manager of Construction, Engineering and Renewables) at Edinburgh's College (Granton Campus) for their support on this project.