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# Use of Building Information Modelling in responding to Low Carbon Construction Innovations: An Irish Perspective

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*At present the Irish construction industry is facing one of its most uncertain and challenging periods and will see major cuts in all areas of the economy in 2012. Despite this, Ireland pushes forward in sustainability initiatives with the Government ruling that environmentally-friendly policies are to get priority in competing for State contracts worth up to €16 billion a year. This and further initiatives are in place, so as to reduce greenhouse gas emissions by up to 20% by the year 2020.By the end of 2018 the public sector must own or rent only buildings with high energy-saving standards and promote the conversion of existing buildings to "nearly zero" standards. Furthermore, the "retro-fitting" of Ireland's existing building stock will challenge Ireland to meet carbon targets. This paper outlines how Building Information Modelling (BIM) can be utilised on future and present public works projects in Ireland to significantly assist the Irish Government in managing a low carbon energy future. The paper will focus on the application of a sophisticated BIM model in helping to predict the performance of buildings or assess retrofit/upgrade options in managing low carbon construction. The authors' data collation methodology involved the testing and analysis of a BIM model for a public works project, used during a four day workshop in late 2011. The workshop proved a success and provided the platform for the Irish Government to see first-hand, how a collaborative BIM model used on public works projects could provide a low carbon future for both future and existing building stock.*

Keywords: Building Information Modelling, Low Carbon Construction, Public Works Projects, Sustainability,

## 1.0 Introduction

At present the Irish construction industry is facing one of its most uncertain and challenging periods and will see major cuts in all areas of the economy this year. The Irish construction industry has experienced a severe contraction in construction output since it peaked in 2007 at €38.4 billion, to a return to output volumes of around €10.5 billion by the end of 2011 (DKM, 2011). Despite this Ireland pushes forward in sustainability initiatives with the Government ruling that environmentally-friendly policies are to get priority in competing for State contracts worth up to €16 billion a year (Gormley, 2010). The Government have also announced details in 2012 of a €1.5 billion programme to provide new schools and extend existing schools across the country. These initiatives are to be complemented by the Capital Works Management Framework (CWMF) which was introduced by the Department of Finance (2007). The CWMF is a series of documents which collectively describe the operating environment, procedures and processes to be followed for the delivery of capital works projects. The aim of the CWMF is to ensure that there is an integrated methodology and a consistent approach to the planning, management and delivery of public capital works projects, with the objectives of greater cost certainty, better value for money and more efficient project delivery. Within the CWMF the Irish government published a new suite of public sector contracts. In addition to this there is a plan to bring Ireland in line with the Energy Performance of Buildings Directive (EPBD). The EPBD will ensure that Ireland meets strict EU regulations set by the European Parliament since 19th May 2010 and avoid crippling fines which could prove detrimental to an already faltering economy. This directive requires that:

- All buildings built after 31 December 2020 must have high energy-saving standards and be powered to a large extent by renewable energy.
- By the end of 2018 the public sector must own or rent only buildings with high energy-saving standards and promote the conversion of existing buildings to "nearly zero" standards.

In order to successfully compete within the public works sector and guarantee that Ireland meets its carbon target deadlines, it is recommended by the authors that the Irish Government move towards the mandatory imposition of Building Information Modelling (BIM) on public works projects by following a similar methodology to that adopted in the UK and other countries.The Irish public sector must consider a strategy similar to the recent UK Low Carbon Construction Innovation and Growth Team Report (2010), in which it is recommended that companies in the wider construction industry undertake the following three-fold tasks:

- to de-carbonise their own business;
- to provide people with buildings that enable them to lead more energy efficient lives;
- to provide the infrastructure which enables the supply of clean energy and sustainable practices in other areas of the economy.

This process requires innovation and new ways of working and the acquisition of knowledge and skills that will provide competitive advantage at home and internationally. This innovative new way of working has come through the mandatory implementation of BIM. There is a plan in the UK for a phased five-year development that projects will be required to use BIM tools and techniques from 2016. This plan was devised around a hypothesis, which defined a scenario, in which the Government client would have an estate that was smarter and better equipped to face a low carbon economy, with associated reductions in delivery and carbon emissions.

## 2.0 Methodology

In an attempt to promote BIM within the Irish AEC / FM sector, a recent pilot project was launched by the Royal Institute of Architects in Ireland (RIAI) and the Construction Information Technology Alliance (CITA).This project involved a full professional team working in conjunction with the Department of Education and Science (DOES) on a generic primary school project. The main goals of the workshop where to:

- raise awareness and promote a higher level of understanding of BIM;
- demonstrate a more effective way for teams to collaborate;
- assess / demonstrate some of the BIM software tools available;
- validate designs through digital analysis;
- test BIM technologies in responding to low carbon construction demands.

This workshop served as the primary research tool for this paper and provided data with regard to testing the implementation of BIM on public works projects, as a method for adding cost certainty to contracts and managing low carbon construction. This paper will also review the use of BIM initiatives to procure public sector buildings and manage low carbon construction internationally and relate how those experiences can be applied to Ireland.

## 3.0 Background

The authors conducted a literature review of journal papers, professional publications and research articles with regard to low carbon construction and BIM. The literature review focused on the three main areas detailed below in order to present the perceived benefits of using BIM in responding to low carbon construction innovations in Ireland:

- Construction carbon footprint and BIM.
- Global implementation and barriers of BIM.
- BIM in managing low carbon construction in Ireland.

### 3.1 Construction Carbon Footprint and BIM

Hallberg and Tarnardi (2011) identified the construction sector as the largest industrial sector in EU-15. In addition they concluded that from an environmental point of view the construction sector is in a unique position as it is accountable for 46 % of the total energy usage, 46 % of the $CO^2$ emissions and generates 40 % of all man-made waste. Okoroh et al. (2012) estimated that approximately 80% of carbon emissions caused by buildings are created during the operating phase of existing buildings. This issue is even more concerning in that Ireland's neighbours in the UK, produce 50% of their total $CO^2$ emissions from energy used in heating, lighting, and cooling buildings, with an additional 25% of $CO^2$ emissions arising from the energy used in transporting people and goods during the construction and usage of these facilities (Pearce, 2008).

These figures have illustrated that the construction industry should move towards a more productive way of doing business in order to control escalating energy costs and produce more productive methods of managing low carbon construction. This can be achieved through the use of BIM, which can ensure a thorough life cycle analyses, service life planning and more solid life-cycle optimisations of the design and use of the buildings (Hallberg and Tarnardi, 2011). BIM is beginning to change the way one builds, the way the buildings look, the way they function and the way buildings are maintained and managed (Godager, 2011). Godager further explains that resource consumption and waste production together form a construction trigger for a number of environmental problems. BIM is seen to be a very important tool to handle all these challenges. It is generally reported that the level of analysis required to predict the performance of buildings or assess retrofit/upgrade options is not feasible without sophisticated BIM models or computational analysis tools. This relatively new technology has allowed a new paradigm within the AEC sector, which has the ability to promote and encourage each stakeholder within the project to play a more prominent role. BIM has helped develop the way designers and contractors consider the entire building process from the initial design brief, all the way through the construction documentation stage, into the actual construction management stage, and finally the Facilities Management stage (Dzambazova et al., 2009).

### 3.2 Global Implementation and Barriers of Building Information Modelling

The revolution of BIM across the global construction world continues to grow and must result in Ireland adopting a similar methodology or face being left behind and unable to compete in foreign markets. The strong growth of the green building market has seen a greater encouragement in the adoption of BIM in the design and construction Industry. Green BIM is an emerging concept which can enable highly sustainable outcomes through energy simulation and prefabrication (McGraw–Hill 2010a). In order to participate in this lucrative market, Ireland must follow the example of various countries including the USA, Finland, Norway, Denmark, UK, Germany, Singapore and Korea, who are all currently in the process of developing BIM guidelines.

VTT in Finland, Rambøll in Denmark and SINTEF in Norway are the major research organizations in BIM in these countries (Wong et al, 2010).The involvement of companies in BIM initiatives within Europe, facilitated by buildingSMART, is increasing with involvement estimated to vary between 20 and 40% of the number of companies implementing BIM (Wong et al, 2009). Outside of the USA and Europe, Singapore is one of the few countries in Asia who have implemented BIM in the public sector, with Hong Kong in the process of establishing BIM guidelines to help increase productivity and meet established high standards that include tight schedules and high land costs. In a report by McGraw Hill (2010b) it was outlined that nearly 60% of total respondents are currently frequent users and 74% of Western European BIM users report a positive perceived return on their overall investment in BIM. Perhaps most encouraging to the Irish Public Sector is the move of their immediate neighbors, the UK, towards the legal implementation of BIM. Ireland needs to adopt a similar hypothesis and begin to move towards the legal imposition of BIM, in order to enhance low carbon construction and promote a carbon neutral future.

In order for Ireland to create a similar frame work to the UK there are a number of obstacles to be addressed in the form of both legal and technical categories. Some of the barriers as stated by McAdam (2010) include defining a process of implementation and ensuring all participants will be working from the same software. The same author details a number of further barriers, which include the extent to which a BIM model could stand as a legal document, the risk of the designer incurring the cost and in the case of copy right where the legal line will be drawn. One of the most effective ways to deal with these risks is to have collaborative, integrated project delivery contracts in which the risks of using BIM are shared among the project participants along with the rewards (Azhar, 2011). At present the US has two BIM specific contracts developed, the Consensus DOCs 301 and AIA E202 in which both use standard contracts for which a BIM addendum has been developed. The US Consensus DOCs 301 and AIA E202, through slightly different, offer a starting place in the development of this contract. In examining the UK Framework it is concluded that in order to work at a Level 2 that little change is required to the fundamental building blocks of copyright law, contracts or insurance. This is encouraging to an Irish perspective, as our current contracting arrangements are not considerably different to the UK despite the current suite of Government Construction Contracts Committee (GCCC) forms of contacts not been designed to encourage risk allocation or collaboration.

### 3.3 BIM in Managing Low Carbon Construction in Ireland

The need to reduce $CO^2$ emissions and energy consumption from buildings has never been more immediate. Godager (2011) outlined that there are more and more environmental requirements because of growing environmental challenges and depleting energy resources. This ultimately means that there is a need for focusing on building materials and for performance classification in the energy field. The European Union and its Member States have a large number of on-going policy initiatives directly aimed at supporting sustainability of the built environment. There are current climate and energy strategies implemented globally to try to ensure that by 2020 renewable energy will represent 20% of energy production; a reduction of greenhouse gas emissions by 20% and the reduction of $CO^2$ emissions by 80-90% by 2050 (Zeiler et al, 2012). There is a growing consensus that one must reduce one's dependence on rapidly depleting, carbon intensive fossil fuels, which, amongst other things, will involve overhauling how buildings are designed, constructed and used (Kilip, 2010). To achieve this Kilip (2010) outlined that in Ireland a combination of everything from introducing innovative policies, to enforcement of building regulations, to adapting to more advanced construction methods and technologies must be undertaken. It is critical that Ireland's return to economic growth is not matched by a corresponding growth in energy demand, where Ireland's future economic successes are not undermined by deteriorating environmental patterns and unsustainable energy usage (Lewis, 2009). The managing of low carbon construction in Ireland can be achieved through an innovative policy by the Government to implement BIM. This will provide a unique access to a combination of energy analysis tools that complement the BIM process.

Energy profiling in the built environment involves an analysis of the actual or predicted energy performance of buildings and/or an analysis of the embodied energy within the materials and methods used to construct buildings (Crosbie et al., 2009). Energy profiling involves comparisons between actual or predicted energy use and some type of benchmark or model intended to indicate regulatory requirements, average energy consumption or best practice. In a report issued in November 2010 for low carbon emission which is heavily referenced by the UK Government's Construction Client Group BIM Working Party Strategy Paper, it was found that BIM has the greatest potential to transform the habits and, eventually, the structure of the industry. With regard to house construction, Mah et al. (2010) outline how the BIM approach allows for rapid computations of $CO^2$ emissions from various house sizes, designs and materials. The use of BIM and the integration of an intelligent database permit end-users to calculate $CO^2$ emissions for different styles of houses with different types of construction methodology. The McGraw – Hill Green BIM Report (2010) details that robust tools exist within BIM to help in reducing significant carbon emissions through performing analyses on energy performance, lighting and HVAC systems.

The European AEC/FM Sector is also researching the use of BIM for sustainability designing, with a section of this research being funded by the European Commission through the EU FP7 funded project entitled 'Intelligent Use of Buildings' Energy Information (IntUBE). This project is detailed by Crosbie et al. (2009) who describe it as a scheme created to increase life-cycle energy efficiency of buildings by integrating the latest developments in the ICT-field into Intelligent Building and Neighbourhood Management Systems. The authors warn that BIMs and energy simulation tools can also hinder each other and that up to 50 % of the project team's time can be dedicated to performing energy simulation.

Other opportunities to mitigate high $CO^2$ emissions within the construction process range from scheduling changes to newer construction practices, such as pre-fabrication (Mah et al., 2010). Typical wastage rates within the industry are as high as 10-15% (McGrath and Anderson, 2000). A study conducted by the National Audit Office (NAO) showed that highly prefabricated systems can reduce construction periods by 60% and require 75% fewer operatives on site, with consequential benefits for the client, contractor and the local community. BIM is in the unique position to play a major part in the reduction of waste and, therefore, $CO^2$ emissions through the fostering of better off-site fabrication techniques. Detailing BIM software, such as Tekla Structures, can output data from the BIM model directly to machines for fabrication, saving significant time on the construction of a project, as the steel structure of a building is known to have a heavy lead time to site (Gavin, 2008). The BIM model can also allow most elements of the building, such as precast concrete elements or sheet metal and ducting systems, to be fabricated from the BIM model off-site. This all leads onto, as outlined by Mah et al. (2010), the BIM model resulting in having a positive impact on the environment due to reductions of $CO^2$ emissions and material waste disposal to landfills.

Ireland also faces significant problems in the near future through the "retro-fitting" of Ireland's existing building stock to meet carbon targets. The McGraw–Hill Green BIM Report (2010) states that Green BIM practitioners find BIM to be particularly useful when it comes to green retro–fitting. Over 25% of the survey participants views BIM as highly applicable for use in green retrofits, with a further 49% believing it to be of medium applicability. The convergence of BIM and Green Building could prove to be the catalyst for ensuring the adoption of BIM within Ireland for long-term gains for clients.

In an attempt to promote BIM within the Irish AEC / FM sector and test its application in regards to low carbon management, a recent pilot project was launched. The purpose of this workshop was to showcase BIM to the relevant Government heads and provide valuable primary data towards the implementing of BIM on Public Works Projects

## 4.0 BIM Pilot Workshop

The RIAI/CITA BIM workshop was held over four days in late 2011 with a number of subsequent presentations given to industry leaders. This workshop was used by the authors to test the research topic for this paper by conducting a number of interviews and through the collection of data from the results of the four day pilot. Semi-structured open interviews where used as the main tool of analysis.

### 4.1 Pilot Overview

The observer for the BIM project was the Department of Education (DOES) and the official observer for the event was the Office of Public Works (OPW).The workshop involved the deconstruction of an existing primary school building and rebuilding it using BIM technologies as outlined in figure 1. This involved a whole project team working in collaboration to maxamise low carbon construction and sustainability potential, through the harnessing of BIM technologies.

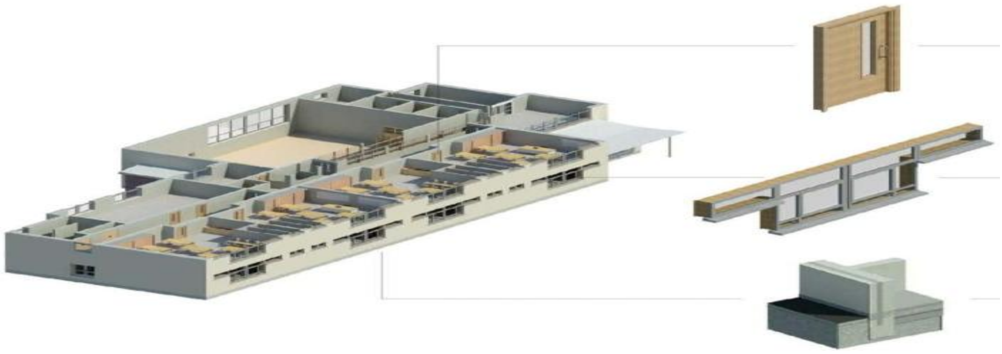

*Figure 1 Workshop Overview*

### 4.2 Pilot Team

The pilot team consisted of a number of leading design professionals from selected firms within the AEC/FM sector, integrated into the design team in order to foster the best method of collaboration, as illustrated in (figure 2). The pilot team was primarily made up of consulting engineers, services engineers, architects, and consultants as illustrated in figure 3. This team model also consisted of additional support from contractors, quantity surveyors, technical support, facilities management support for handover documentation and BIM energy specialists.

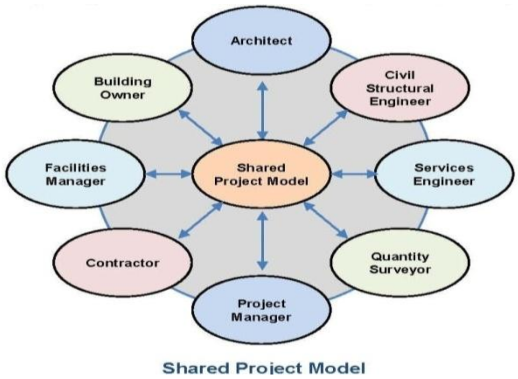


*Figure 2: Shared Project Model*

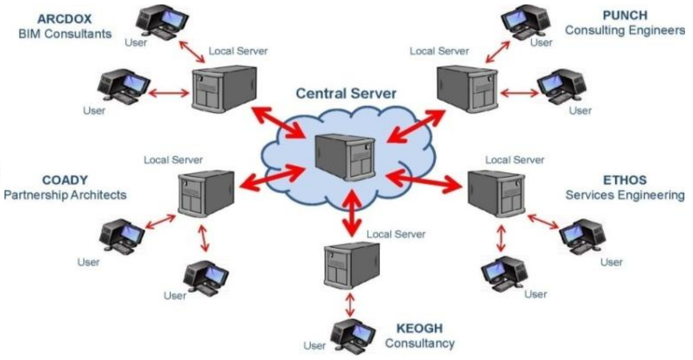


*Figure 3: Pilot Team*

### 4.3 Pilot Activities

The BIM model was developed to respond to client specific requirements using a visual communication tool to meet their expectations. The design team was provided with a digital brief with the overall goal to design a BIM model of a standard generic DOES school. This model was exploded down to its components and then given to the design team to work on specific components. The various professionals involved all worked on their own model, which was synchronised with a central server, allowing all participants of the workshop to monitor each other's work and, therefore, promoting collaboration.

### 4.4 Pilot Feedback

The workshop derived results across all sectors and disciplines and strongly advocated the application of BIM to become mandatory in future Public Works Projects. The BIM model was effectively virtually built before having to be physically built, which allowed foresight on a number of key areas and helped identify eventualities that may occur on site. The BIM process added a greater cost certainty and reduced a significant amount of the design risk associated with contractor's cost. Through the collaborative process of everyone working on the same model, the design team was able to see what the other disciplines where doing and this fostered a greater team ethic throughout the design process. This resulted in a strong group dynamic, which in turned enabled the design team to identify areas of possible clash detection, as there was no legal restrictions or copyright concerns within the pilot. This further resulted in each profession learning from each other and addressing possible collaboration problems and concerns, which may present themselves in future live projects between the concerned professions.

Energy efficiency, according to one of the workshop participants, is not normally a priority at the design stage and decisions on materials selection, amongst other things, are purely driven on cost. The BIM process permitted a different and more sustainable method of construction to be undertaken which helped designers concentrate on energy efficiency and improved carbon construction. The BIM workshop allowed the designers to create four mass models at different orientations and to perform exercises in concept energy analysis, so as to choose the most economical and sustainable building possible. The energy model was inputted with weather predictions to aid in orientation data, internal floor areas, the number of people who will use the structure, cost of electricity and fuel, average lighting power, exterior wall area, window area, etc. to enable an accurate analysis to be performed. The energy analysis armed with this data was used to calculate the energy usage for the year and so, therefore, assuming discounts rates, a life-cycle energy usage / cost could be generated. The analysis also provided the user with the predicted renewable energy potential that could be harnessed from the roof PV potential (solar electric) and the wind turbine potential for the mass model, based on its climate and geometry. These figures were subsequently used to generate the net annual $CO^2$ emissions, which is basically the $CO^2$ emissions from electricity and fuel consumption for the analysed model, minus the renewable energy potential. This in turn permitted the BIM energy specialist to provide the architect with the information to suggest the most carbon-friendly building to the client. The results from this energy analysis are illustrated in figure 4 – 7, where mass model 4 shows the least carbon emissions on a yearly basis.

The analysed energy simulations for the different mass models enabled the architect to see what design changes best impacted the carbon output of the model. These changes, if the architect felt were beneficial to the overall lifecycle of the model, could be incorporated into the design. In the workshop the form and orientation chosen for the school was not the best performance-wise. The reason for this was that the information gained from the analysis allowed the design team to understand that there were minimal energy performance gains to be achieved by opting for a form that was more energy efficient, but performed less well, as a space for the occupants for their required usage. BIM allows an excellent opportunity to perform this sort of energy analysis which can be done quickly and should be used at each stage of design. The energy analysis can also be done when deciding on room and glazing layouts along with daylight analysis. The DOES have a set natural lighting guidelines for each classroom. BIM enables designers to pick windows that will be in line with Department Education’s standards and give the best lighting design. This exercise was carried out in the BIM workshop to inform window sizes based on the required daylight factor for each classroom. The designs from the model were also imported into Studio Max which enabled the surface of the road to be created virtually. This also allowed traffic to be seen through animation and could help predict traffic flow and, therefore, manage future carbon emissions through better traffic management and design.

The use of BIM enabled the designer to have the option to choose a carbon friendly design for the primary school. The energy analysis enabled a relatively easy calculation to be performed with regard to whole-life energy usage for all four design iterations. Energy efficiency lies at the heart of improved carbon management and the designers then have this information early in the design process, which can only have a positive impact on the building’s carbon footprint. To really investigate the carbon footprint then the embodied energy of all the building materials must be carefully examined.

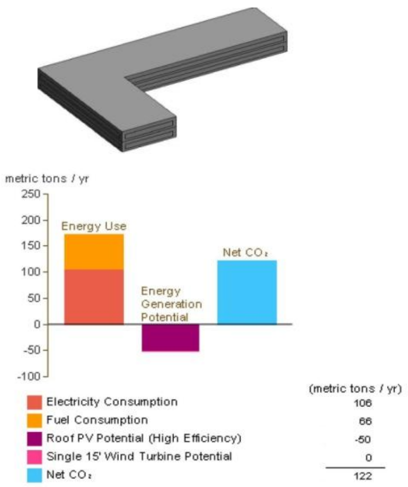


*Figure 4: Mass Model 1*

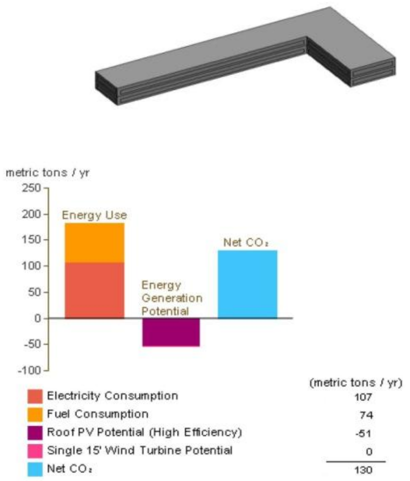


*Figure 5: Mass Model 2*

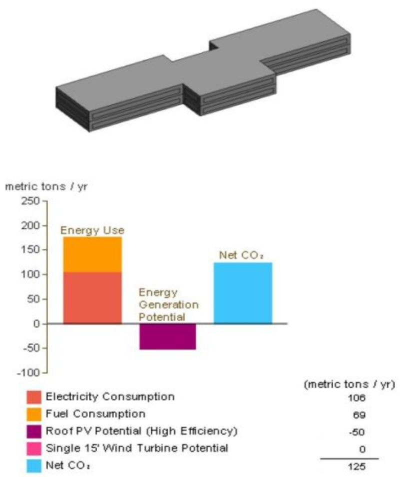


*Figure 6: Mass Model 3*

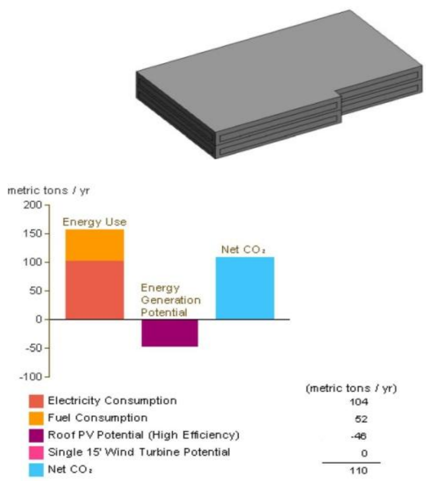


*Figure 7: Mass Model 4*

**5.0 Conclusions**

The lack of compatible systems, standards and protocols, and the differing requirements of clients and lead designers, has inhibited widespread adoption of technology on public sector projects in Ireland. These technologies have the capacity to ensure that all team members are working from the same data and that the implications of alternative design proposals can be evaluated with comparative ease. The UK government’s move to demand by 2016 that projects are modelled in 3D Technology will lead to the elimination of coordination errors and subsequent expensive changes, which was at the foundation of historical public sector project delivery problems in the past.

The CITA BIM workshop has offered the opportunity for a whole design team to break a constructed primary school down to its core elements, and re-build it using a BIM platform, which would focus on best construction practice in regards to its overall life cycle. The BIM Model allowed a data rich model, allowing testing of design solutions to provide a more responsive building design to the client brief, and better coordination of all project information. The workshop proved a success and provided the platform for the Irish Government to see, first-hand, how a collaborative BIM model used on a public works projects could provide the cost certainty and achieve $CO^2$ emissions targets they so urgently seek. This model showed how, through a relatively simple energy analysis undertaken at the beginning of the project, the designer is permitted to view the life-cycle costs of that structure. This analysis can only have a positive impact on the building’s carbon footprint and help the client and his design team choose the most beneficial carbon based construction solution. The embodied energy of all the building material must be carefully examined, which will then along with further energy analyses provide the financial and environmental tools for the client to choose their building.

There is a need for a more innovative approach in regards to better carbon construction within Ireland, so as to ensure crippling fines are not enforced and carbon targets are met. Despite the success of the workshop, Ireland is still a long way from embracing BIM on public works projects. Representatives of the OPW noted that despite the benefits that BIM would have on a number of Departments within the Government, it would still require “an act of faith” for the Irish Government to fully embrace it. There is a notable lack of incentive from the Government and reluctance to incorporate more change, due to the recent introduction of the GCCC forms of contract. This fact, coupled with the fear of legal implications, such as, who owns the BIM model and which profession will carry most liability for the model, have left the Irish AEC/FM sector in an uncertain stance towards the implementation of BIM on public works.

The next step in the process of promoting BIM includes a suite of BIM workshops in 2012. These workshops will be primarily hosted by CITA and are to be sponsored by leading professional institutes throughout Ireland, so as to promote BIM within the Irish AEC/FM industry. These workshops will address a number of key areas, such as contractual implications, development of a BIM Library, process change management, the up skilling of existing workforce and technical standards that are all required for BIM implementation. These further workshops will serve as the focus for the central role that BIM can play in ensuring the practice of design, construction and facilities management for a long-term sustainable solution for the build environment.

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