LOW CARBON HOUSING REFURBISHMENT CHALLENGES IN IRELAND, a DISCUSSION

SCHOOL OF ENGINEERING

INSTITUTE OF TECHNOLOGY, SLIGO

BERNHARD WERNER FUNKE

MSc. ENERGY MANAGEMENT

Supervisor of research: Mr. Peter Scanlon

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MAY, 2013

DECLARATION

I declare that this thesis is entirely my own work, except where otherwise stated and has not been previously submitted to any Institute of University.

Signed:

Bernhard Werner Funke

Student Number: S00095087

MAY, 2013

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ABSTRACT

There are a great many variants which need to be considered prior to undertaking a building's refurbishment, including: cost of refurbishment and the pay-back time, effects to health and the environment in respect to materials employed, annual fuel economy and cost of maintenance; aesthetics and functionality, comfort levels associated with heating, cooling, sound and air quality and then the longevity of the building fabric and improvements. (Brager, 1996)

A building in its environment forms part of a complex technological, ecological, social and esthetical system in the built environment; where sub systems which stem from these interdependencies influence the total efficiency performance. (Kaklauskas et al., 2005)

There is no single solution to studying the challenges of low carbon housing refurbishment in Ireland; the discussion to these challenges is entrenched in broader aspects which have far reaching influence; such as: energy inputs needed to produce a product, the environmental impact associated with product choice, the informed management of material choices, the balance between economic development and the environment such as poverty and other social economic aspects, the question of land and resource management including the legalistic rights to these decisions, the optimisation and use of smart technologies both in the wider distribution sense as well as in local deployment of renewable energy integration; it became apparent that a holistic approach was needed to establish a solid discussion on this topic and therefore included but is not exclusive to the opening chapters on Embodied Carbon in Construction and Sustainability.

This research therefore explores the rationale to refurbishment prior to the challenges and exposes the necessary underlying influences, barriers and enablers, such as life cycle assessment, the impact of building materials, tools to calculate and manage informed choices, sustainable development models including the question of biomass in a modern society, low carbon opportunities and the natural impetus of community involvement in a sustainable and harmonised network, and then the outlook and arguments for refurbishment as part of Ireland's response to meeting the Kyoto Agreement and the 2020 GHG emission levels through decision making models and other tools which currently present.

1. INTRODUCTION

1.1 Background

Ireland is committed to limiting its greenhouse gas (GHG) emissions to 113% of 1990 levels over the period 2008-12 and to 84% of 2005 levels by 2020 under the Kyoto Agreement and the EU's 2020 target by 2020 respectively. National policies have targeted many industry sectors but have failed to directly tackle GHG emissions associated with construction activity.(Acquaye and Duffy, 2010)

The Climate Change Response Bill 2010 was published 23 December 2010 for consultation; where like the Oireachtas bill, the Government bill does not address how the targets are to be achieved, this is a serious omission.(TheIrishEconomy, 2010) In July the ESRI published a report stating that the Republic may meet its Kyoto Protocol commitment for 2008-2012 but that its longer term targets for 2020 and beyond 'remain stringent,' due to the recession.(InsideIreland.ie, 2010)

From the above; it is clear that the Government require informed measures and procedures detailing how targets are to be achieved for 2020 and beyond, specifically in relation to construction activity. Limited success in retention reveals the need for engagement with key stakeholders and product manufacturers, whilst European policy should focus on a carbon credit system coupled with information to motivate consumers. (Boardman, 2004) Future progress will require careful consideration in the way policy is formulated (Lowe and

Oreszczyn, 2008) coupled with planning exemptions for certain renewable technologies. (department of the Environment, 2007)

To be successful, refurbishments require a detailed assessment incorporating extensive information gathering, including utility bills, a structural survey and usage analysis culminating in a comprehensive materials schedule married to correct use, cost and installation. (Jaggs and Palmer, 2000a)

Evidence suggests that retention to refurbish has an important role in improving a communities health (Blackman et al., 2001) whilst community involvement coupled with low carbon programmes (SEAI, 2008), VAT incentives and information to education programmes facilitate up-take and create local momentum. (Davies and Osmani, 2011a)

The Heritage Council, Dublin City makes a strong case for retention to refurbishment (TheHeritageCouncil, 2004) citing architectural, cultural, historic and aesthetic merit from an economic, environmental and cultural perspective. Innovative technology, methods and materials have made it possible to retain valuable protected enlisted buildings (Bastianini et al., 2005) thereby making a positive contribution to the appearance, character and quality of local streetscapes and the sustainable development of a given city.

1.2 Research focus

It is generally acknowledged in Ireland and throughout the world that climate change is the single greatest challenge faced by humankind. In order to reflect that priority the Government is committed to taking decisive action to reduce our emissions of carbon dioxide.(department of the Environment, 2007)

Carbon emission targets are important, and whilst national policies have targeted industry, energy efficient building can be key, where according to Durkan, approximately 40% of national CO2 emissions can be attributed to Energy in Buildings (Durkan, 2009).

According to Power, at least 87% of all homes constructed today, will still be standing and in use by 2050 (Power, 2008), retrofitting of existing buildings to an energy efficient standard, is therefore paramount as part of a suit of measures in reducing Ireland's overall GHG emissions. If only 20% of new dwellings constructed in Ireland complied with the Passivhaus Standard, the potential savings per year (21 ktCO2 / 66 GWh) are significant. (SEAI, 2007)

Construction has been accused of causing environmental problems ranging from excessive consumption of global resources both in terms of construction and building operation to the pollution of the surrounding environment.(Ding, 2008)

Design and assessment systems that may promote uptake of more sustainable urban design and development are reliant on a comparison between building and neighbourhood scales.(Frame and Vale, 2006)

1.3 Overall research aim and research objectives

The overall aim of this research is to examine the barriers and enablers to retrofitting and refurbishment vs. rebuilding in the current Irish market context. To define the benefits and draw-backs in context of the urban and rural location

It is anticipated that the research outcome will contribute towards Ireland achieving a marked reduction in GHG emissions in respect to the 2020 targets through the retrofitting of existing buildings. In trying to define the benefits and draw-backs, the research encompasses the broader aspects such as embodied carbon, life cycle assessment, impact of material selection, low carbon opportunities in Ireland and fuel poverty, sustainable networking and then Refurbishment, recognising arguments for Regeneration and Greenfield site development. The contribution to the existing field of knowledge is expected to give credence to Refurbishment in the context of the current socio-economic dispensation in Ireland.

The importance of adopting new approaches to the supply and use of energy is a key theme of Strategy. In particular, a Strategy expressly recognises that taking action to reduce emissions also means:(department of the Environment, 2007)

- Making Ireland's energy use more sustainable
- Creating new levels of energy efficiency in our buildings
- Harnessing the business sector's capacity for innovation
- Diversifying agriculture towards producing energy crops and expanding afforestation
- Improving waste management systems even further and using waste as an energy source.
- Funding research and public awareness programmes.
    - To understand how diversification can feed into societies trends, education and information platforms.

- Developing local employment initiatives; Labour market integration and social inclusion; Initiatives encouraging shared use of human resources and facilities for research, development, education, culture, communication and health.
- The role of the government is more related to education and income distribution (via tax, social actions, etc) and encouraging energy conservation through education and behavioural change.
- Collaboration between local authority, local community, local politicians, planners, developers, business, residents, educational institutes as well as energy suppliers and service providers are required in order to attain a structured, intelligent and integrated energy management technique within the community. (SEAI, 2010)

1.4 Specific objectives of the research

The question to demolish, retain and refurbish or Greenfield development remains widely debated, and thus offers up numerous barriers, drivers and enablers which remain contentious; this is due to specific areas of information which remain unclear, such as the exact embodied energy values, energy and environmental impacts associated with demolition and then costs associated with refurbishment. (Power, 2008)

Specifically, the objectives of this research are:

1. To better understand what is meant by the term: 'Embodied Carbon in Construction'
2. To evaluate the impact of building material in construction in terms of Carbon Management.
3. To ensure that the literature review presents an overview of the relevant research.
4. To endeavour to contribute to existing knowledge through this research in highlighting the similarities and differences between a range of viewpoints
5. To review underlying theories within a theoretical framework and accentuate the predominant facts
6. To avoid deficiencies and gaps in what the research presents.
7. To address the topical questions raised in the Chapter 2: Literature Review
8. To evaluate the term 'sustainability' in terms of the built environment, energy and harmonisation.
9. To obtain an in-depth understanding of refurbishment and the challenges in the Irish context.
10. To explore and obtain an appreciation for the 'term' sustainability in terms of zero carbon and diversification of agriculture to energy in whole town strategies.

1.5 Outline of the research structure

The research work is structured in nine chapters and follows a simple direct approach, namely a non experimental fixed strategy appropriate for discussion, based on desktop research coupled with a questionnaire survey as outlined below:

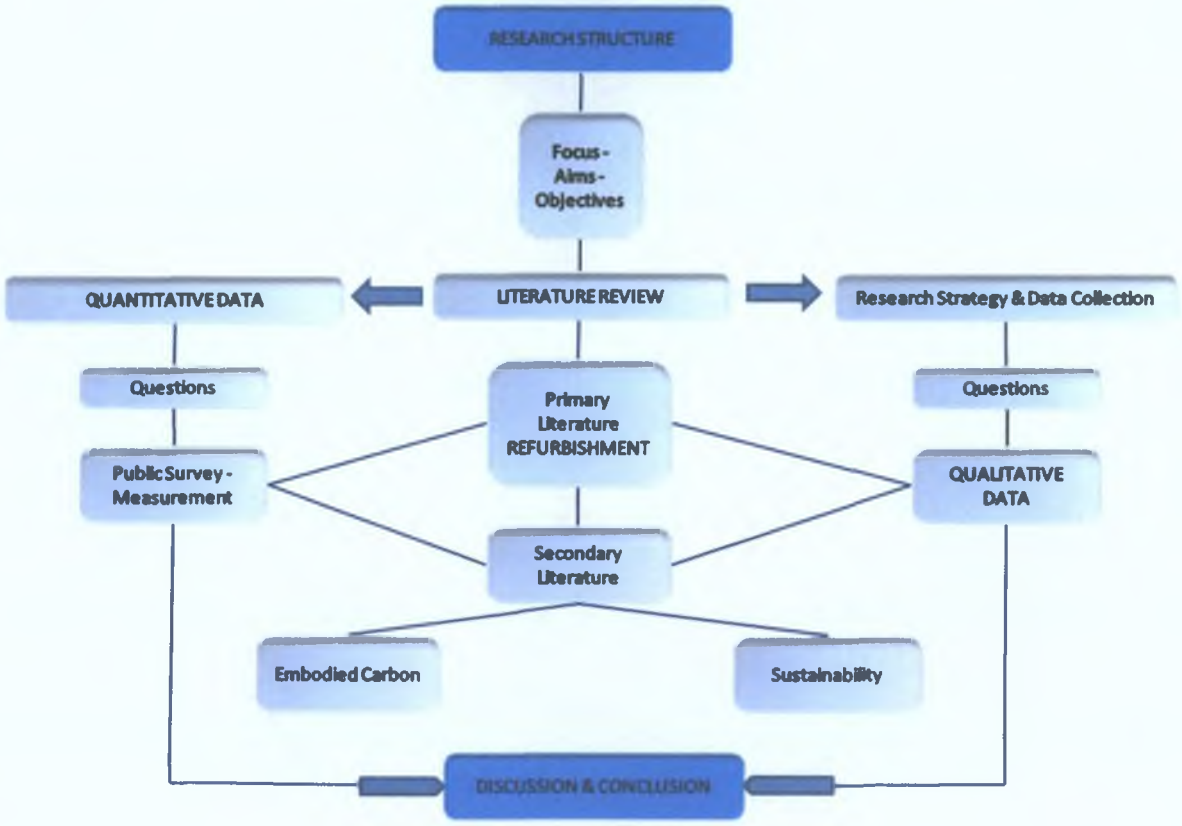


Figure 1: Schematic of Research Structure

1.5.1 Chapter 1: Introduction

This chapter provides the reader with the background to the research and the overall aim and specific objectives of the research.

1.5.2 Chapter 2: Literature Review

The research focused on trying to address a series of questions which initiated from the research topic, namely:

1. To understand what is meant by the term 'Low Carbon'
2. To understand and better appreciate what the 'Challenges' associated with 'Refurbishment' might be.
3. To understand Irelands position in relation to 'Low Carbon Refurbishment' and the wider effects in terms of energy and efficiency in buildings.
4. To understand Irelands energy use and the use of energy in terms of domestic rural and urban housing and commercial outflows.
5. To understand how diversification can feed into societies trends, education and information platforms.

During the literature review and research; it became increasingly apparent that in order to refine the research, a series of chapters would be necessary to address broader issues and suitably interpret results to greater understanding. The following lead-in topics required research to present an overview and place the respective research questions into perspective, namely:

- chapter 3: embodied carbon in construction
- Chapter 4: Sustainability

1.5.3 Chapter 3: Embodied Carbon in Construction

This chapter explores a fundamental aspect to this research which includes the various life cycle techniques in assessing the environmental impact associated with the stages of a products life in compiling an inventory of energy, work and material inputs and environmental releases. Deficiencies in the LCA process are highlighted by way of critique prior to focusing on the impact of a building material in construction, where the service life of a product is significant in terms of the products environmental profile. Carbon calculator tools are briefly explored in order to gain an understanding as to how carbon might be managed and legislated. Observations have been impressed, where methods for selecting materials and allowing stakeholders to make informed decisions which impact embodied carbon and life cycle assessment on buildings from planning through to delivery can be made to bear.

1.5.4 Chapter 4: Sustainability

This chapter endeavours to explore the term 'sustainability' from a holistic perspective and starts with a report titled 'Our Common Future, a global agenda for change' which became known as the Brundtland Report. The report proposes long term environmental strategies for achieving sustainable development, recognising that it is impossible to disconnect economic development from environmental issues.

The research takes a broad view and covers a wide array of topics; including population growth, migration, sustainable development models, sustainable energy and renewable energy in buildings.

This chapter also reviews global energy sources in terms of the most obtainable source of energy for households, building and material manufacture; including alternative sources in

biomass and developing countries where the greatest population increase is set to consign in future years. This chapter makes a case to prove that GHG's are playing a dominant role in global temperature increase and that human activities are the primary factor in global climate change.

The research on sustainability supported a synergy with regards to the primary topic of whether to retrofit, demolish and develop brown-field sites or whether to simply continue constructing new dwellings. This led to an amalgamation of pertinent sub topics which included low carbon opportunities for Ireland and the hypothesis of a global sustainable network, and then even further sub-topics which included fuel poverty, a sustainable community, land rights and efficiency and sustainability.

1.5.5 Chapter 5: Refurbishment

This chapter sets the locale with a preface to the primary topic, and then provides evidence and argument in each category, albeit with increased emphasis on Refurbishment, consistent with the research title 'Low Carbon Housing Refurbishment Challenges in Ireland, a discussion.'

1.5.6 Chapter 6: Public Survey

This chapter strives to establish the level of awareness, understanding and link the overall aims of consumers and construction professionals in relation to the following topics:

- The National Refit Scheme in Ireland
- The consumer's appetite for investing in the Refit scheme
- The consumer's perceived benefits of retrofitting to passive house standard or to the zero carbon standards.

- Climate change and construction.
- New buildings and the effect on the environment
- Energy neutral housing in Ireland
- Embodied carbon in construction
- Sustainability and net energy export
- Challenges associated with increasing the energy performance of the existing housing stock in Ireland
- Challenges associated in 'retooling' to meet the requirements of increased energy performance in retrofitting and carbon conscious construction

1.5.7 Chapter 7: Overall Discussion and Conclusion

This chapter incorporates secondary subject matter pertinent to the key topic and accentuates the synergies to the research title and contributes to the synopsis and recommendations, as follows:

- Zero carbon and zero carbon strategy
- Anaerobic digestion as a sustainable alternative energy source for decentralised supply
- The issue of waste

The conclusion to supposition, summarises the salient arguments, synthesises and integrates the body of research to evaluation and critique. Key issues are clarified and summarised so as to feed into the recommendations.

The synopsis summarises the most poignant barriers and enables to regeneration and Brownfield development, Greenfield development and then Refurbishment to coincide with the main research topic.

The recommendation portion of the conclusion chapter proposes recommendations which stem from the findings through evaluation and deduction of the research presented.

1.5.8 Chapter 8: Bibliography

This chapter contains alphabetical listing of the sources referred to in this study.

Most of the research focuses on academically authoritative texts like academic books, journals, research reports and government publications. To ensure that the research is founded on a broad, balanced and impartial base; it was necessary to include news papers, magazines and internet publications in the research.

The Harvard System of Referencing (author-date system) is used

1.5.9 Appendices

The appendices contain diagrammatic annexure which is referred to in the main body of the text.

2. CHAPTER 2: LITERATURE REVIEW

The research topic presented the following questions:

- The Climate Change Response Bill 2010 was published 23 December 2010 for consultation; where like the Oireachtas bill (1.1), the Government bill does not address how the targets are to be achieved, this is a serious omission.(TheIrishEconomy, 2010) How will climate change targets be addressed and legislated in Ireland, specifically in terms of housing?
- Limited success in retention reveals the need for engagement with key stakeholders and product manufacturers (1.1), whilst European policy should focus on a carbon credit system coupled with information to motivate consumers. (Boardman, 2004) How can retention and refurbishment be brought to mainstream consumers and product manufacturers?
- To be successful, refurbishments require a detailed assessment incorporating extensive information gathering (1.1), including utility bills, a structural survey and usage analysis culminating in a comprehensive materials schedule married to correct use, cost and installation. (Jaggs and Palmer, 2000a) How is detailed assessment possible with inexhaustible factors ubiquitous?

The literature review impelled a number of additional and indubitable questions which in turn, prompted the research to detach into two main sub themes, namely: chapter 3: embodied carbon in construction *and* Chapter 4: Sustainability. These sub themes were found to have a corresponding relationship to the research topic and as a result were included to synthesize and integrate the main Chapter 5: refurbishment

2.1 Theme: Embodied Carbon in Construction

2.1.1 Embodied energy:

Embodied Energy is defined as the sum of energy inputs that are used in the work to manufacture and produce a product, from the point of extraction and refining of the materials, the manufacture of the product, bringing it to market including the disposal and recycling of the material. (Curran, 2006)

Embodied energy is a concept for which scientists have not yet agreed absolute universal values because there are so many variables to take into account, (Chen, 2010) this theme is dealt with in greater detail in chapter 3: embodied carbon in construction

2.1.2 Life Cycle Assessment:

Life cycle assessment is a technique to assess environmental impact associated with all the stages of a products life from raw material extraction through materials processing and refining, manufacture, distribution, use, maintenance and repair and disposal or recycling, thereby facilitating in compiling an inventory of relevant energy, work and material inputs and environmental releases whilst evaluating the potential impacts associated with these identified inputs and interpreting the results to help make informed decisions. (Wolf, 2012)

It is clear from LCA, however, that the service life of a product is of particular significance in terms of that products environmental profile. (Atlee, 2011)

2.1.3 Carbon Management:

The management function, whilst simple in form, has been proposed as an effective and functional tool to facilitate designers, specifiers, architects, engineers, property managers and property owners, it consists of five main components, as follows: (CarbonTrust, 2011)

1. Design / Project Management carbon (PMc)
2. Material Embodied carbon (Ec)
3. Construction carbon (Cc)
4. Operating / Running / In-use carbon (Rc)
5. Deconstruction carbon (Dc)

2.1.4 Measuring Carbon:

Professor Geoff Hammond and Craig Jones from the department of Mechanical Engineering (University of Bath) have published a database of the embodied energy of a large number of building materials, where this database has been used to release an Inventory of Carbon & Energy (ICE) with over 400 values of embodied carbon broken down into approximately 170 different building materials. (ICE, 2011)

A high level review of some calculator products became necessary during the research in order to obtain an overview of how the impact of construction materials affects the environment and how the calculation tools suggest ways in which to consider carbon and carbon savings during the planning, design and construction phase.

2.1.5 Observations:

The overall objective outlined in the ((EuropeanCommission-JointResearchCentre, 2011) is to facilitate the availability and access to consistent and quality-assured life cycle data for robust Life Cycle Assessment studies and reliable decision support in public policy and business. (Bare, 2000)

2.2 Theme: Sustainability

A report was presented to the UN General Assembly in 1987 and subsequently became known as the Brundtland Report. The report proposed a long term environmental strategy for achieving sustainable development via mutually supportive objectives, namely: Economic, Social and Environmental (see Figure 11: Elements of Sustainable Development. (IPCC, 2000))

2.2.1 Sustainable Development:

The IPCC advocates coordinated action through social and democratic consensus but with efficient institutional mechanisms involving small and large firms, the state, non-governmental organisations and multilateral organisations; where the elements of sustainable development convolute around a complex matrix involving infrastructure, income distribution, education, jobs, modernization, natural resources and government. (IPCC, 2000)

2.2.2 Global energy and climate change:

There is no single unambiguous accounting method for calculating primary energy from non-combustible energy sources such as non-combustible renewable energy (RE) and nuclear energy. (PIK, 2012) Coal and Oil are responsible for 47% of all electricity generation; whilst RE sources produce less than 18% of all electricity generated. (PIK, 2012)

2.2.2.1 Biomass

Biomass resources need to be produced and managed in sustainable ways as their impacts can be felt from micro to macro scales by increasing carbon stocks in the biosphere, reducing carbon emissions from unsustainable forest use and by replacing fossil fuel based systems in the generation of heat, power and modern fuels. (PIK, 2012)

2.2.2.2 Renewable energy

Historically, economic development has been strongly correlated with increasing energy use and growth of GHG emissions, renewable energy (RE) can help decouple that correlation, contributing to sustainable development (SD). In addition, RE offers the opportunity to improve access to modern energy services for the poorest members of society, which is crucial in addressing concerns about relationships between human society and nature. (PIK, 2012) The building sector in 2008 accounted for about 92 EJ, or 32% of total global final energy consumption (Figure 19). (PIK, 2012)

2.2.2.3 Smart grid

In essence, a smart grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it; the generators, the consumers and those that do both, in order to ensure an economically efficient and sustainable power system with low losses and high levels of quality and security of supply and safety. (SEAI, 2011b)

2.2.2.4 Fuel Poverty

Clinch and Healy (2001) provided a comprehensive definition of fuel poverty:

> ***"The inability to heat ones home to an adequate (safe and comfortable) temperature owing to low income and poor (energy inefficient) housing"***

2.2.3 Sustainable Energy Community

A Sustainable Energy Community (SEC) is a community in which everyone works together to develop a sustainable energy system; where a SEC can provide a link between sustainable energy, social cohesion and economic development. (SEAI, 2010)

2.2.4 Sustainable Networking

2.2.4.1 INTERREG

Interreg is an initiative that aims to simulate cooperation between regions with-in the European Union and involves collaboration among authorities of two or more Member States. (EURDF, 2012b)

Promotion of urban, rural and costal development; Strengthening the spirit of enterprise; Developing local employment initiatives; Labour market integration and social inclusion; Initiatives encouraging shared use of human resources and facilities for research, development, education, culture, communication and health; Environmental protection, improving energy efficiency and renewable energy sources; Increasing cooperation in legal, administrative and institutional potential and promoting effective sustainable transport systems together with regional development strategies. (Interreg, 2010)

2.2.4.2 Harmonisation

Priorities are linked to the National Spatial Strategy (Central Government, 2002) which defines a commitment to working with the market in pursuit of greater eco-efficiency, the coordination and better enforcement of producer responsibility, to better implement and enforce EU Strategic Environmental Assessment Directive, the promotion of greater participation and ownership of SD at local and regional levels via Agenda 21, create mechanisms for stakeholder involvement and support of policy development through research.

2.2.4.3 Sustainable Accounting

It is difficult to understand the breadth, complexity and enormous challenges which require significant commitment of resources to achieve and implement a sustainable accounting framework successfully. (Lamberton, 2005)

2.2.4.4 Land rights and sustainable development

The concept of sustainable development arose after the 1974 United Nations adoption of a Declaration for the establishment of a New International Economic Order, an excerpt from the 1976 U.N. conference on Human Settlements (Habitat I) stated the following:

> ***"Land…cannot be treated as an ordinary asset, controlled by individuals and subject to the pressures and inefficiencies of the market…"***

2.2.5 Observations

Woodward, poses the argument that an efficient economy is not necessarily a sustainable economy, and that when considering policy alternatives to address global warming, economic principals may not necessarily realize the required results. (Woodward, 1995)

The National Spatial Strategy (NSS) sets out the vision and strategic framework for achieving sustainable and balanced regional development in Ireland, "developing the full potential of each area to contribute to the optimal performance of the State as a whole – economically, socially and environmentally," (Central Government, 2007a)

2.3 Topic: Refurbishment

> ***"…the Sustainable Development Commission (SDC, 2006. Stock Take) argues the urgent need to upgrade the existing housing stock on the grounds that 70% of all homes that will exist in 2050, even with an ambitious new building programme, already exist." (Power, 2008)***

Power argues that in order to achieve the required cut in energy use in housing, refurbishment demonstrates a more sustainable approach with less environmental and social consequences, and that this target could be achieved more quickly and more easily through refurbishment

than with demolition and rebuilding. (Power, 2008) Around 80% of the population live in urban areas, new buildings add approximately 1% a year to the existing stock, the other 99% of buildings are already built and produce most all of the associated carbon emissions, whilst at least 87% of all homes constructed today, will still be standing and in use by 2050. (Power, 2008)

Ireland's total primary energy requirement (TPER) in 2010 was 14.57m Tonnes of Oil Equivalent (TOE), and increase of 5.7% since 2000.(CSIR, 2010) The Total Primary Energy (TPE) use is increasing due to the increasing number of households and larger dwelling size; with a direct relationship between GHG emissions and space heating, this area is contributing to climate change (4.1.2) and global warming.(Galvin, 2010)

> ***"The main barriers to progress are located in policy, process and availability of humane resources, rather than in technology as narrowly defined." (Lowe and Oreszczyn, 2008)***

The key objective of developing Ireland's Sustainable Development Model is to equate environmental pressure to relevant economic developments; policy instruments can then be formulated to target future pressure points where environmental problems are likely. (Lyons, 2006)

2.3.1 Greenfield Development

> ***"There is a need to apply pressure on land owners to achieve sustainable development showing that the benefits gained by such actions far outweigh the costs, while benefiting the rest of society in the process." (Bullard, 2002)***

New Buildings incorporating modern construction methods may offer substantial rewards.

"When compared with traditional methods of construction the modern methods of construction (MMC) house resulted in a 34% reduction in embodied carbon." (Monahan and Powell, 2011)

2.3.2 Brownfield Development

"The human pressure on land as a resource requires agricultural regeneration of land and buildings used in the past and not to build on land, especially the green field sites. In an ideal situation only brown-field sites should be used for development." (Bullard, 2002)

Brownfield urban design should include the key aims as prescribed (Central Government, 2007b) by the Quality Housing Guide for Sustainable Communities through the creation of a high quality built environment, by reducing as far as possible, the necessity to travel, particularly by private car for the purpose of employment, education and recreation, and to avail of local services and amenities necessary for living.

2.3.3 Refurbishment

Limited success in retention reveals the need for engagement with key stakeholders and product manufacturers, whilst European policy should focus on a carbon credit system coupled with information to motivate consumers. (Boardman, 2004) Future progress will require careful consideration in the way policy is formulated (Lowe and Oreszczyn, 2008) coupled with planning exemptions for certain renewable technologies. (department of the Environment, 2007) Evidence suggests that retention of buildings (commercial, public and residential) to refurbish has an important role in improving a communities health (Blackman et al., 2001) whilst community involvement coupled with low carbon programmes (SEAI, 2008), VAT incentives and information to education programmes facilitate up-take and create local momentum. (Davies and Osmani, 2011a)

3. CHAPTER 3: EMBODIED CARBON IN CONSTRUCTION

Energy inputs need to be carefully considered when a decision is made to produce a product and then whether the product selection is most suitable for the end use and after-life use.

3.1 Introduction

Embodied energy is defined as the sum of energy inputs that are used in the work to manufacture and produce a product, from the point of extraction and refining of the materials, the manufacture of the product, bringing it to market including the disposal and recycling of the material. Energy inputs include the fuels, power, materials, energy required to manufacture capital equipment, heating and lighting of the factory, human resources and transport (Wolf, 2012). Embodied carbon is an accounting methodology which aims to find the sum of the total energy for an entire product lifecycle which includes raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and decomposition or recycling. (Curran, 2006)

In the absence of a comprehensive and complete global embodied energy database, embodied energy calculations may omit important data such as transport distance from quarry to mill, the efficiencies of the extraction and transport systems, the efficiencies of the manufacturing system and plant, types of fuel employed during the different process stages, human services such as marketing and advertising including the energy employed in constructing and maintaining, transport and infrastructure services used in the process. Embodied energy is a concept for which scientists have not yet agreed absolute universal values because there are so many variables to take into account, however the Australian Government provides a global average of $0.098tCO_2 = 1GJ$, in other words, $1MJ = 0.098kgCO_2$ or $1kgCO_2 = 10.204MJ$. (Chen, 2010)

3.2 Life cycle assessment

Low carbon LCA associated with building and refurbishment is fundamental in managing carbon and the decision making process as environmental impacts relating to the use of these materials dominate the life cycle profile.

A life cycle assessment is a technique to assess environmental impact associated with all the stages of a products life from raw material extraction through materials processing and refining, manufacture, distribution, use, maintenance and repair and disposal or recycling, thereby facilitating in compiling an inventory of relevant energy, work and material inputs and environmental releases whilst evaluating the potential impacts associated with these identified inputs and interpreting the results to help make informed decisions. (Wolf, 2012) In general, most LCA studies are designed to support one or more of the following goals:

1. Documenting environmental performance for communication and marketing purposes
2. Developing policy and regulations
3. Assessing potential liability
4. Evaluating environmental performance to document improvement for environmental management systems
5. Green labelling
6. Purchasing and procurement decisions

The procedures for life cycle assessment are part of the International Organisation for Standardisation 14000 environmental management standards in ISO 14040:2006 which describes four general steps to be performed in any LCA, namely: (ISO, 2011)

1. Goal and scope definition, including functional units that define a measure of equivalent service when comparing competing products.

2. Inventory analysis, in which all the energy, water and materials flowing into and out of every process in the product life cycle, including pollutants are quantified and categorised.
3. Impact analysis or life-cycle impact assessment (LCIA), in which the inventory of inputs and outputs is related to actual or assumed impacts, based on a series of environmental indicators or impact categories, such as global warming potential, human toxicity, ozone depletion, ecosystem toxicity, acidification, diminished human health and resource depletion.
4. Interpretation and conclusions.

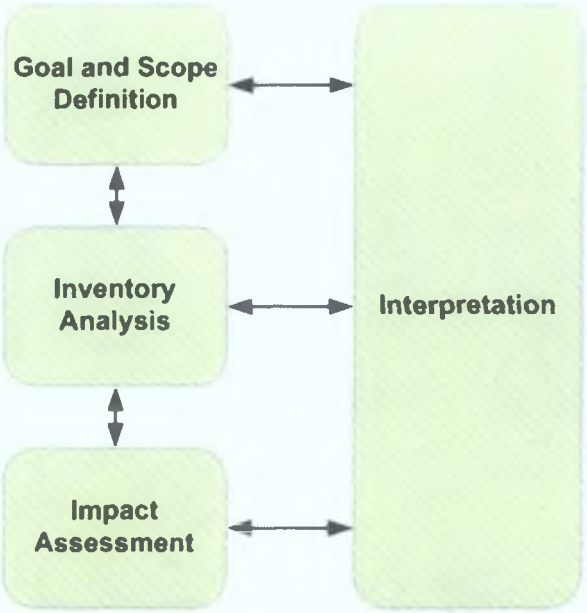


Figure 2: Phases of LCA. Arrows indicate that insights gained from one phase can and will influence how other phases are completed. (ISO, 2011)

Impacts such as global warming and ozone depletion are estimated based on international established methods that convert emissions of a wide range of gases to a cumulative impact measurable on a single scale (EPA, 2012). In the case of global warming, emissions of methane, chlorofluorocarbon's (CFCs) and other gases are compared to carbon dioxide CO2 based on their contribution towards global warming, the cumulative emissions of these gases are then characterised on a scale of CO2 equivalency. It is important to note that the characterisation factors depend on the gases different potencies and life spans in the

atmosphere, so an impact assessment must clearly state the time-horizon assumed in calculations. (Atlee, 2011)

To quantify energy and resource flows at each step in the LCA of a product and understand the impact of those flows, practitioners are in effect trying to describe an infinitely complex world with a set of categories and numbers (Curran, 2006). To make this task manageable, LCA practitioners make simplified assumptions at every step of the way and exploit computer data bases, bringing into question the results of any LCA study conducted on 'say' a building material and the accuracy and validity of the process. Simple questions as to how long a particular product will serve its intended purpose and what maintenance it may require during this period need to adopt certain premise, such as all product is of the same quality, all product is delivered in good order, standardisation of workmanship and waste, the boundaries on which the LCA is based and then that technicians will all adopt the same approach and techniques in orchestrating the required maintenance. It is clear from LCA, however, that the service life of a product is very significant in terms of that products environmental profile (Atlee, 2011).

With generic products, practitioners often rely on industry average data, which may come from a sampling of manufacturers, from trade organisations, or from pre-existing databases (Wolf, 2012). Data from any of these sources will vary in accuracy depending on how it was collected and compiled and how current it is. Data relating to commodities such as electricity, fossil fuels and raw materials is often based on industry average or proprietary data which exacerbates problems when trying to compare alternatives for a specific application, where the user of the LCA can see the results but not the details of what information was used to generate those results. It is difficult to ensure the accuracy of proprietary data sets as only the developers or selected reviewers have access to the 'actual' data. (Ecomii, 2011)

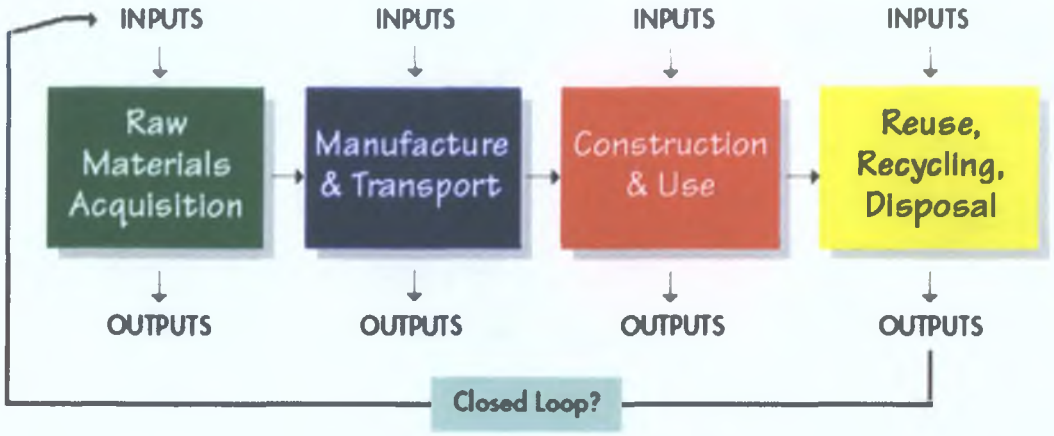


Figure 3: Materials Life Cycle, LCA practitioners characterise and quantify inputs and outputs of a products life to assess the overall environmental performance. (Atlee, 2011)

Life cycle inventory analysis involves creating an inventory of flows from and to nature for a product system accounting for its mass and energy used which includes inputs of water, energy, raw materials and releases to air, land and water. Inventory flows can number in the hundreds depending on the system boundaries which are briefly discussed below:

3.2.1 Cradle to grave

Cradle to grave involves the full inventory and cycle assessment from raw material extraction, manufacture production to end use and then disposal and is therefore deemed to be the most stringent and comprehensive of the boundaries. As an example, paper produced from a tree could be used as an energy saving product by way of insulation in a home over an approximate life span of 40 years, saving an approximate 2000 times the energy used in its production. The insulation fibres are then replaced and disposed of or used as a fuel; all the inputs and outputs are considered for all phases of the life cycle. (Braungart et al., 2007)

3.2.2 Cradle to gate

Cradle to gate involves the full inventory and cycle assessment of all energy in primary form from raw material extraction, manufacture production to the factory gate. Transport from the factory to various distributors and consumers including the use and disposal or recycling of the product are therefore not considered. The boundary after cradle to gate is cradle to site,

which includes all energy consumed until the product has reached the point of use, say on a building site.

3.2.3 Cradle to cradle

The cradle to cradle approach to design was developed by William McDonough, a notable architect in sustainable buildings, and chemist Michael Braungart in 2002, who in their assessment also evaluated toxicity as well as potential reuse of materials. Cradle to cradle is often referred to as open loop production where the end of life disposal step for the product is a recycling process, thereby employing sustainable production and disposal practices, such where new identical products are created from recycling the worn or disused product after its use. For example, glass bottles from collected glass bottles, carpets from worn carpets collected by employing sustainable production methods, asphalt pavement from discarded asphalt pavement. As Braungart and McDonough explain (Braungart et al., 2007), in recycling, unhealthy materials are processed back into useful materials, this process often requires a great deal of energy and often, the recycled materials end up being 'downgraded' into a lesser form. McDonough argues that a C2C material starts out as a healthy material, designed to be reused and recirculated back into the same thing it was originally intended for, for example, a chair made from healthy plastics originating from corn, not oil, can be recirculated to make the same chair again and again. In assessing the life cycle of the open loop production, a credit is often granted by way of 'avoided burden' which alludes to the impact of virgin material resource which is avoided by the use of the recycled material, although McDonough argues that recycling is simply reinforcing the use of unintelligent, unhealthy materials, whilst C2C is designed based on the systems found in nature, where there is no such thing as waste, C2C calls for eliminating the concept of waste entirely. Products can now get C2C certification, demonstrating environmental responsibility, where C2C products

have relatively no negative impact on the environment and can be returned safely to the earth in a perpetual nutrient cycle. C2C is further discussed in section 3.2.6 critique.

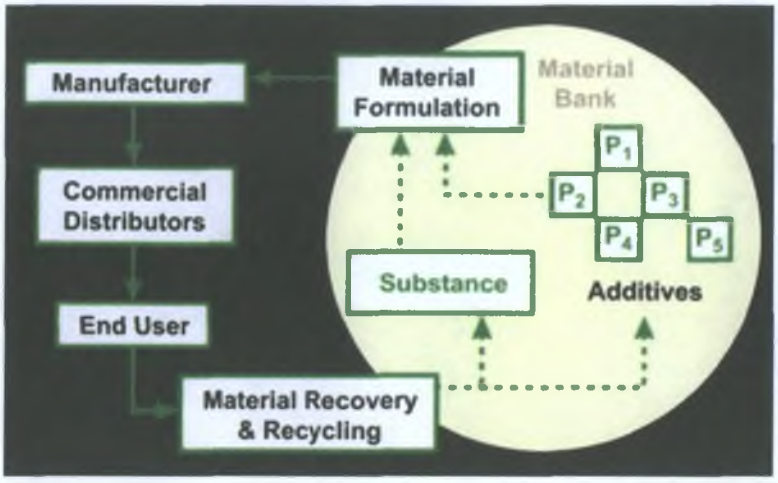


Figure 4: Material flows in the context of an Intelligent Materials Pooling community. (Braungart et al., 2007)

Eco-effectiveness and cradle-to-cradle design presents an alternative design and production concept to the strategies of zero emission and eco-efficiency.

3.2.4 Gate to gate

Gate to gate is a partial LCA which focuses on a narrow boundary of one process with in the entire production chain, for example, the extraction of raw material to arrival at the process mill. LCA practitioners are able to accurately assess and quantify the embodied energy of a singular activity task with-in an entire process, where gate to gate modules may later be linked in their appropriate production chain to form a complete evaluation.

3.2.5 Well to wheel

The well to wheel analysis is commonly used to assess total energy consumption, or energy conversion efficiency and emissions impact of marine vessels, aircrafts and motor vehicle emissions, including their carbon footprint. (Wikipedia, 2011)

3.2.6 Critique

Life cycle analysis is only as valid as its data, it is therefore crucial that data used for the completion of a LCA is accurate and current. Often when products are compared, equivalent

data is not available for both products and product processes in question. Data validity is a concern for LCA due to the rapid pace of research and development, new materials and manufacturing methods and then the shift in geographical manufacturing locations due to market conditions, where data capture takes time and is often not in tandem with dynamic market trends. (Wolf, 2012)

There are two basic types of LCA data, unit process data and environmental input and output data (EIO), where EIO data is based on national economic input output data and unit process data is derived from direct surveys of companies and plants producing the product, this is carried out at unit process level and restricted by the system boundaries as defined. (Curran, 2006)

Economic input output LCA (EIOLCA) involves the use of aggregate sector level data, where averages may or may not be representative of the specific relevance to a particular product and therefore may not suitable for evaluating environmental impacts or how much environmental impact can be attributed to each sector of the economy and how much each sector purchases from other sectors, EIOLCA is however useful where such analysis can account for long chains. (UNEP, 2011)

Ecologically based LCA (Eco-LCA) considers a much broader range of ecological impacts and was developed by Ohio State University Centre for resilience, where services are categorised in four main groups: supporting, regulating, provisioning and cultural services. Eco-LCA is designed to provide a guide to management of human activities by understanding the direct and indirect impacts on ecological resources and surrounding ecosystems. (Curran, 2006)

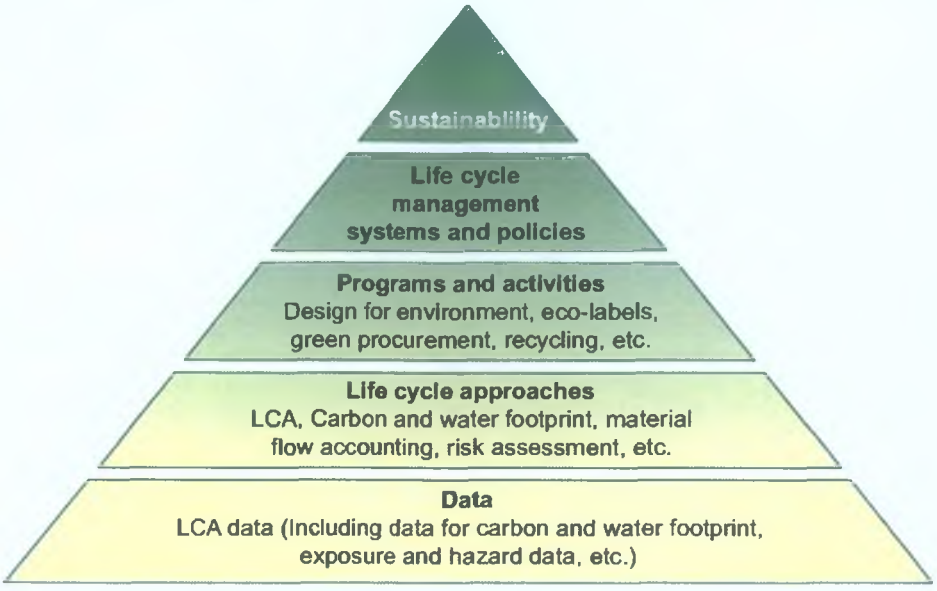


Figure 5: Life cycle management framework for the environmental sustainability of products. (UNEP, 2011)

Life cycle energy analysis (LCEA) establishes and accounts for the total life cycle energy inputs to produce a product, not only direct energy inputs during manufacture, but all energy inputs, including materials and services. The main criticisms of LCA are that simple energy analysis does not take into account the renewable energy flows, the toxicity of waste products and attempts to eliminate the monetary costs of analysis by replacing the currency by which economic decisions are made with an energy currency (UNEP, 2011). Incorporating Dynamic LCA may help to mitigate this criticism by using sensitivity analysis of renewable energy technologies and their share of the electrical grid system. (UNEP, 2011)

Life cycle assessment is a valuable tool for analysing physical quantities which may be measured with different units; however, not every factor can be reduced to a number and inserted into a model, where social implications are generally lacking from in life cycle analysis, indeed, the closer we analyse LCA, the more complicated it becomes where one is trying to describe the infinite complex real world with a series of categories and numbers. (Maguire, 2008)

The availability, quality, consistency and accuracy of data including the validity of data insofar as direct relevance (unrepresentative sampling), industry averages and time period (outdated results) from capture to release can contribute to inaccuracy.

Boundary critique in critical systems thinking, according to Ulrich, states that the validity of professional propositions always depend on boundary judgements considered, therefore if different boundary judgements exist, different statistical information and different product use can sway LCA validity due to varying parameters. There are guides to reduce conflicts in results but practitioners are still able to decide on what is important, how the product is typically manufactured and how it is typically used. (Maguire, 2008)

Agro-ecosystem analysis is a multidisciplinary life cycle tool which considers aspects from ecology, sociology, economics and politics with equal weight when analysing an agricultural environment and products manufactured agricultural materials such as ethanol and bio diesel, however, standards and definitions often cause conflict in the validity of the results. (Wahnschaffe, 1998)

3.3 Impact of building material and construction

LCA for building materials tend to have a relatively long service life or use phase, as a result, any environmental impacts relating to the use of these materials, such as energy use, tend to dominate the overall life-cycle profile of the product; however, specifically in commercial use, although the material service life may be durable, they might be replaced relatively quickly for aesthetic or economic reasons, there is a high level of uncertainty on the result of the 'as-built or as planned' LCA. It is worthy to note, the service life of a product is significant in terms of the products environmental profile, that is, LCA advocates that a greener building should have a long life or be constructed from reusable materials. (Atlee, 2011)

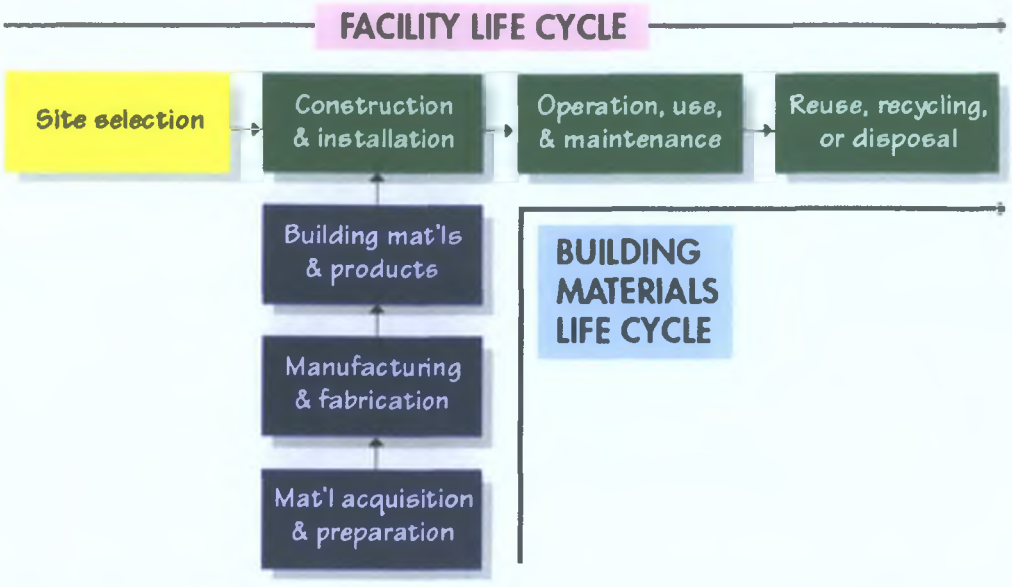


Figure 6: Facility and Material Life Cycle, during the construction stage, the life cycles of the materials and the facilities merge. (Atlee, 2011)

3.3.1 Embodied carbon ladder

The Embodied Carbon Ladder (ECL) endeavours to track carbon from extraction through to manufacture, construction, operating in-use and then to deconstruction, thereby feeding into the carbon management process required when making materials and construction decisions. There are primarily two forms of embodied energy in construction, namely: (Angelini M., 2008)

1. Initial embodied energy: Non-renewable energy consumed both directly and indirectly
   (A) Direct energy: The energy used to transport all materials and products to the construction site, the construction of the building including personnel travel, temporary site accommodation and infrastructure as well as waste removal from the site.
   (B) Indirect energy: The energy used to extract raw materials, transport of all process requirements including chemicals, processing of raw materials, manufacture, distribute including all transport and waste which arrises at each stage.
2. Recurring embodied energy: Non-renewable energy consumed during the life-span of the installed product with-in a building, such as the repair, maintenance, restoration,

refurbishment and replacement of materials and components which have been installed.

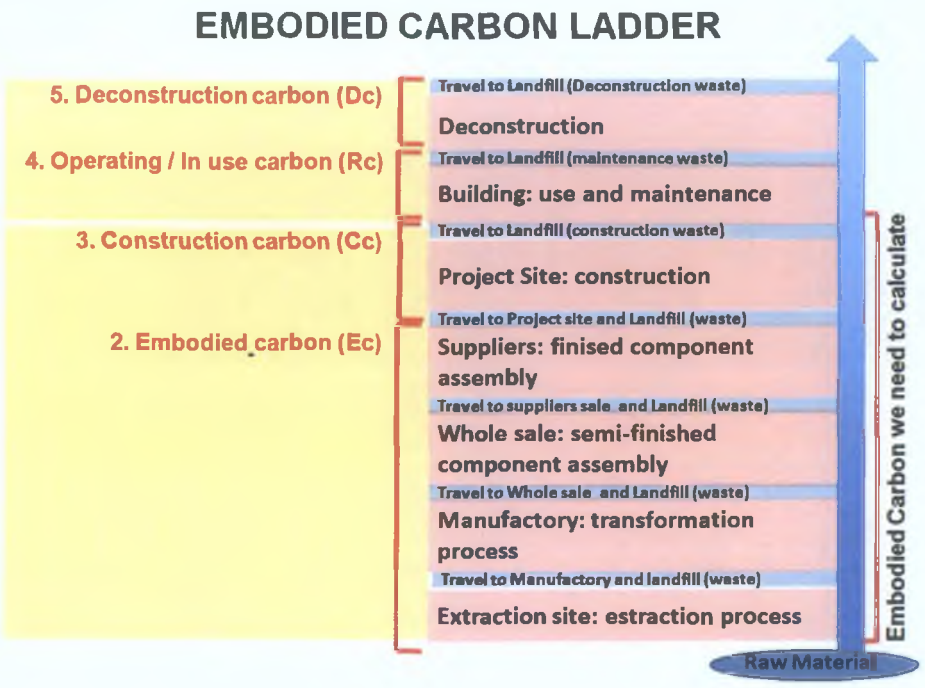


Figure 7: Embodied Energy Ladder. (Angelini M., 2008)

3.3.2 Carbon management

In order to meet the Climate Change Response Bill targets on GHG emissions by 2020 and beyond, a carbon management system is necessary in order to collect, quantify and manage carbon use within the construction industry. The Carbon Trust in conjunction with Davis Langdon has identified risk and management functions associated with low carbon buildings, based on real data from 28 case studies via the Department of Energy and Climate Change's Low Carbon Buildings Programme in the UK 2006. The management function, whilst simple in form, has been proposed as an effective and functional tool to facilitate designers, specifiers, architects, engineers, property managers and property owners, it consists of five main components, as follows: (CarbonTrust, 2011)

6. Design / Project Management carbon (PMc)

   PMc as a function is included in all five components of the management constituent, and encompasses all carbon count from project concept to project inception and

completion. Carbon created includes all personnel involved in the project, from designers, administrative staff, contractors, suppliers and the client.

7. Material Embodied carbon (Ec)

   Ec encompasses carbon within the materials used including the geological process and material sourcing, extraction, refining, processing, manufacture and transportation, that is 3.2.2 Cradle to gate.

8. Construction carbon (Cc)

   Cc encompasses carbon through the construction process including site development and soil displacement, direct and indirect energy employed (3.3) in machinery and equipment, site labour, personnel transport, all energy used on site including material delivery (3.2.2) the boundary after cradle to gate, namely cradle to site, which includes all energy consumed until the product has reached the point of use, say on a building site.

9. Operating / Running / In-use carbon (Rc)

   Rc is the amount of carbon equivalent energy consumed over the complete lifespan of the building including maintaining each material product, cleaning, renovation, refurbishment and redecoration.

10. Deconstruction carbon (Dc)

    DC is the amount of carbon equivalent energy consumed at the end of the building lifespan, where each material product is removed to their various constituents.

The management function as devised by the (CarbonTrust, 2011) in conjunction with Davis Langdon has in effect formulated a gate to gate partial LCA (3.2.4) with the focus on separate narrow boundaries within the construction sectors various phases, effectively breaking the process of low carbon building into consecutive stages and linking them together in an appropriate chain to form a complete evaluation, thereby alleviating the issue of

misinterpreting (3.2.6) boundary judgements. The analysis is however subject to the usual critique associated with the availability, quality, consistency and accuracy of data including the validity of data, where the use of aggregate sector level data is not suitable for evaluating environmental aspects (3.2.6) or environmental impacts, but is useful where such analysis can account for long chains.

Risk management in low carbon buildings as defined by the Carbon Trust (UK) in conjunction with Davis Langdon is a process of identifying and actively managing risk for projects with the aim of making the project more likely to succeed. The risk management process commences from inception through to planning approval, cost planning analysis, technology and material choices associated with performance, environmental assessment, bespoke solutions, passive and renewable energy systems, where emphasis is placed on the following deliverables, namely:

1. Improve delivery certainty
2. Deliberate focus on the big issues
3. Place the organisation in control with a measurable process
4. Enable better informed decisions
5. Provide tangible and meaningful links between contingency and risk
6. Improve communication and understanding.

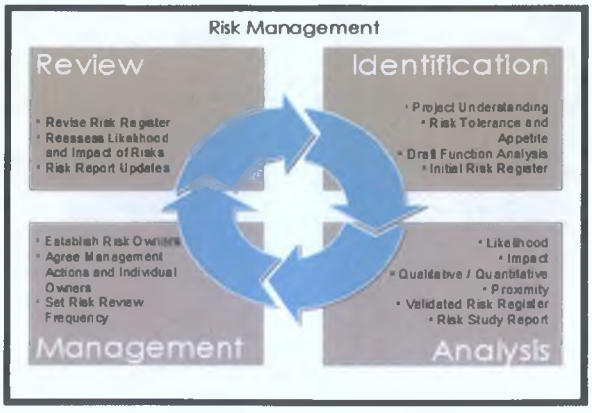


Figure 8: Risk Management in low carbon buildings. (CarbonTrust, 2011)

The top five perceived risks and risks response strategies are outlined in (Table 1) where each project should be individually assessed in order to determine specific risks.

Table 1: Top five perceived risks for low carbon buildings. (CarbonTrust, 2011)

Key risks for low carbon buildings

The top 5 perceived risks and risk response strategies are:

Risk description	Risk response strategy
Planning permission delays or permission not granted for wind turbines	Early discussions with Planners and on-going discussions with Case Officers
Over optimistic costs used at feasibility stage	Upfront involvement of experienced contractor
Incorrect technology chosen at feasibility stage	Rigorous feasibility study including use of performance benchmarks
Planning permission delays or permission not granted for photovoltaic panels	Early discussions with Planners and on-going discussions with Case Officers
Environment Agency extraction licence for open loop ground source and renewal may not be granted	Seek permission from Environment Agency as part of early feasibility study

3.3.3 Measuring the embodied carbon

If carbon is not measured, it can not be managed, during the research conducted, it became evident that there are a myriad of different carbon equivalent calculators used throughout the world, such calculators have been developed by private organisations, large industrial concerns, large energy corporations, and government sponsored organisations, universities, research institutes and various government bodies (Udo de Haes, 1999). Most calculator tools have been developed to realise specific LCA objectives, as example, the (EuropeanCommission-JointResearchCentre, 2011) has developed a Handbook titled 'Recommendations for Life Cycle Impact Assessment' which considers impact categories such as ozone depletion, eutrophication, acidification, human toxicity, respiratory inorganics, ionising radiation, ecotoxicity, photochemical ozone formulation, land use and resource depletion. The EC-JRC makes use of and evaluates five different models in each of the LCI assessment categories, namely: IPCC model, EPS2000, ReCiPe, Ecoindicator 99 and the LIME model, thereby evaluating each models strengths and weaknesses and enabling a more accurate assessment within the respective categories. Whilst LCA is an immensely intricate

undertaking with complex model adaptations, most LCA's are structured around the basic life cycle stages.

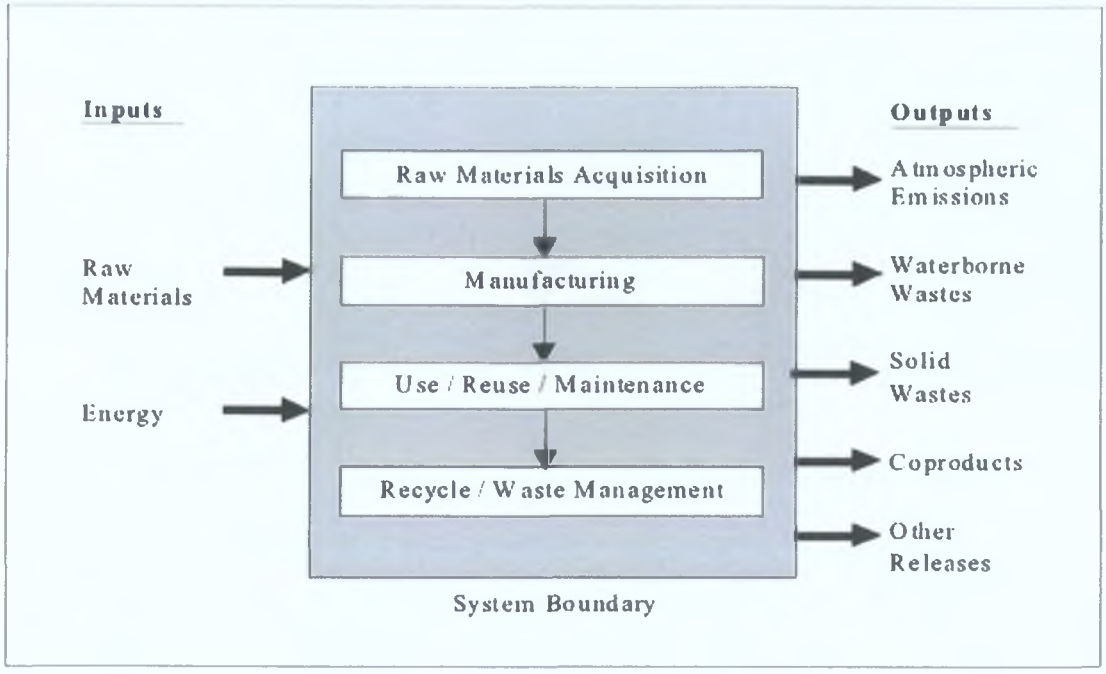


Figure 9: Life Cycle Stages. (EuropeanCommission-JointResearchCentre, 2011)

It has become common practice to specify the embodied energy as cradle to gate, professor Geoff Hammond and Craig Jones from the department of Mechanical Engineering (University of Bath) have published a database of the embodied energy of a large number of building materials, where this database has been used to release an Inventory of Carbon & Energy (ICE) with over 400 values of embodied carbon broken down into approximately 170 different building materials. (ICE, 2011)

During the research conducted, it became prevalent that Carbon Inventories are as prolific as there are Carbon Calculators (Struijs, 2009), where the respective values used in the adopted calculator are usually extracted from an inventory which is deemed to be local to the proposed building project on which the LCA is being carried out. The calculator in effect, makes use of the values extracted from a locally devised carbon inventory (3.2.2 Cradle to gate) and ideally translates these values into a constructed product including deconstruction (3.2.1 Cradle to

grave) thereby affording designers to obtain a full assessment of the proposed design whilst prompting questions, specification changes and inclusions to the respective clients operation and maintenance manual.

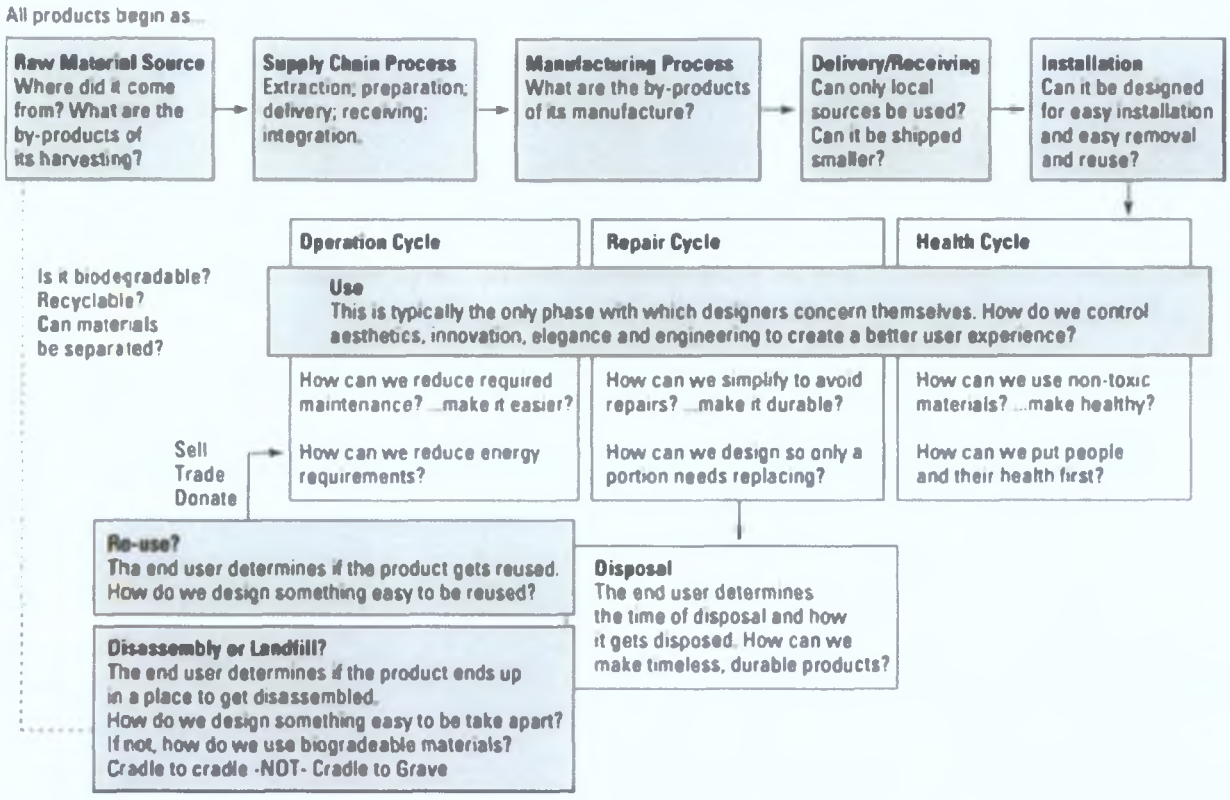


Figure 10: The Life Cycle of any Product. Integrate Carbon Inventory and Calculator. (ECI, 2011)

3.3.4 Carbon Inventory

Carbon Inventories are the benchmark of carbon calculating and carbon management. In this research paper, the author has studied the Carbon and Energy Inventory as published by the (ICE, 2011), where each of the 170 building materials listed are sub-categorised for a more accurate assessment on use and origin. For example, the material Aluminium is sub-categorised into general, cast products, extruded and rolled, where values are expressed as Embodied Energy MJ/kg or Embodied Carbon $KgCO_2/Kg$ under the following headings, namely: Typical of the UK market, Primary Materials and Recycled Materials.

Table 2: Sample Embodied Energy & Carbon Inventory, ICE Version 1.5 Beta-IEC. (ICE, 2011)

EMBODIED ENERGY & CARBON SUMMARY								
Materials	Embodied Energy & Carbon Data							Comments
	Embodied Energy MJ/Kg				Embodied Carbon - KgCO2/Kg			
	Typical (of the UK market)	Primary Materials	Recycled Materials	of which Feedstock energy	Typical (of the UK market)	Primary Materials	Recycled Materials	
Aggregate								
General	0.15	-	-	-	0.008	-	-	
Aluminium								
General	154.30	217	27	-	8.53	11.9	1.69	Assumes UK ratio of 25.6% extrusions 55.7% Rolled & 18.7% castings
Cast Products	167.50	238.9	22.55	-	9.21	13.08	1.36	
Extruded	153.50	213.5	31.74	-	8.49	11.7	1.98	
Rolled	150.20	211.5	25.85	-	8.35	11.64	1.67	
Asphalt								
General	2.8	-	-	1.91	0.045	-	-	
Road & Pavement	2.41	-	-	0.82	0.14	-	-	
Road Example	2,672 MJ/Sqm	-	-	908 MJ/Sqm	134 KgCO2/Sqm	-	-	
Bitumen								
General	44.7	-	-	37.7	1	-	-	Feedstock taken as typical energy content of Bitumen, uncertain carbon dioxide emissions

3.3.5 Carbon Calculator Tools

The Environmental Agency in conjunction with Jacobs has formulated an on-line carbon calculator to measure the impact of construction materials; the calculator is in Excel format and allows the calculation of embodied carbon and CO_2 emissions associated with material transportation and construction activities. (EnvironmentAgency, 2011) The tools also suggests ways in which to consider carbon savings during the planning and design process and can be used to estimate the carbon footprint of a project which has already achieved completion.

The Edinburgh Centre for Carbon Management (ECCM) has developed a user friendly Building Materials Carbon Calculator, the tool is the first of its kind and helps decision makers select the best materials to minimise the carbon footprint of a building and creates awareness of the environmental impacts of material selection at concept stage. (CAMCO, 2011)

The Waste and Resources Action Programme (WRAP, 2011) have devised an Excel based CO_2 emissions estimator for aggregates used in construction, where this tool also facilitates decisions relating to construction techniques and aggregate supply alternatives. This tool has been developed by TRL Limited, Costain and Taylor Woodrow Technology under contract to WRAP, where the tool is designed to assess the CO_2 output resulting from four types of construction involving aggregates, namely: bound bitumen, concrete, hydraulically bound and

unbound concrete. This tool is especially valuable for large scale civil engineering works and compares options whilst also prompts alternative mixtures with varying percentages of recycled and secondary aggregates (RSA).

There are many carbon calculator tools available; however, careful consideration needs to be granted when selecting the appropriate calculator in reference to the project specifics and then the primary focus on the type of analysis required; where deficiencies, appropriateness and short-falls have been highlighted in a case study undertaken on three public buildings in the West Midlands, UK. (angelini, 2008)

3.3.6 Quantifying Carbon in Construction

For the purposes of this research paper, a rudimentary framework for information sourcing, delegation and control for every stage of the carbon ladder are proposed. As this is not the primary focus of the research topic and only illustrates to highlight the relationship synergies in Low Carbon Refurbishment, it is not deemed appropriate to particularise in greater detail than is tabulated in Table 3: Embodied Carbon Information and Sources. (angelini, 2008)

Following from the research and content 3.3.2 Carbon management; quantifying the embodied carbon in construction is an arduous and rigorous task which requires astute management and risk assessment from inception through to completion, operation and deconstruction. A fundamental principal to successful management is to ensure systems and procedures are implemented from top down and that specific information and sources are clearly identified (3.3.1 Embodied carbon ladder) and appropriated from the inauguration of any project.

Table 3: Embodied Carbon Information and Sources. (angelini, 2008)

Carbon Ladder	Embodied Carbon	Information requested (Mass and Miles)	Sources
Project Site	Waste Travel Project site to Landfill	Waste mass and miles	Suppliers + Software (Google map)
	Project Site: construction	Personal Travels Plant Emissions	Environmental Agency tool or Project - Site manager managers
Supplier	Travel supplier to Project site	Material mass and miles	Suppliers + Software (Google map)
	Waste Travel Suppliers to Landfill	Waste mass and miles	Waste transport note by suppliers (not considered in the project)
	Suppliers: component assembly	Carbon produced	Suppliers information or ICE *(Inventory of Carbon&Energy University of BATH)
Whole Sale	Travel whole sale to suppliers	Material mass and miles	Suppliers + Software (Google map)
	Waste Travel Whole Sale to Landfill	Waste mass and miles	
	Whole sale: component assembly	Carbon produced	
Manifacture	Waste Travel to Whole sale	Waste mass and miles	
	Travel Manufacture to Landfill	Material mass and miles	Suppliers information or ICE *(Inventory of Carbon&Energy University of BATH)
	Manufacture: transf. process	Carbon produced	
Raw Material	Waste travel Extraction site to Manufacture	Waste mass and miles	
	Travel Extraction site to landfill	Material mass and miles	
	Extraction site: extraction	Carbon produced	

1. Waste Mass: A waste management policy and plan needs to be enacted, where waste is strictly segregated prior to removal from site. Weigh-bills dockets will identify the type / category of waste, waste mass, haul distance and number of loads.
2. Material Mass: The materials mass is typically extracted from the Bills of Quantities. The European Council of Construction Economists (CEEC, 2011) are currently working to incorporate the function of converting all taken quantities into weight by kilogram to facilitate the quantification of carbon, this is done by utilizing each materials density index. The Society of Chartered Surveyors in Ireland has a delegate board member in the CEEC, where Mr. Michael O'Connor will be instrumental in the implementation of these new requirements, whilst the Royal Institute of Chartered Surveyors in the UK is also following suite. European Standards Authority CEN and the CEEC have prepared a new standard EN 15221 for Facilities management which contains new standards for measuring buildings which is closely based on the European Code of Measure, where EN standards are obligatory in all EU countries. Order requisitions, supplier tracking and sub contractor orders will be logged so as to assess the region and distances of materials and associated services.

3. Transformation Process: A suitable carbon inventory register needs to be selected, currently such register was not located in Ireland, for this purpose, the ICE carbon and energy inventory (ICE, 2011) is selected, where adjustments will need to be made to the various coefficients to take account of the additional transport, handling and distribution in Ireland.
4. Personal Travel and Plant Emissions: This is extrapolated from the resource histogramme during project planning phase; whilst a rigorous company and personnel sign in and out register should be enacted on site, similar to the Health and Safety Authorities requirements for personnel on site. It has been suggested that in pre-commencement Cost Planning, the Environmental Agency (EnvironmentAgency, 2011) tool may be used to give a general assessment of carbon impact based on the total size of the project.

3.3.7 Observations

The overall objective outlined in the ((EuropeanCommission-JointResearchCentre, 2011) is to facilitate the availability and access to consistent and quality-assured life cycle data for robust Life Cycle Assessment studies and reliable decision support in public policy and business. (Bare, 2000) For this reason, compliance rules and entry-level requirements are categorised in three basic groups in the International Reference Life Cycle Data System (ILCD) Data Network, namely:

1. ILCD-compliant – High quality data
2. ILCD-compliant – Basic quality data
3. ILCD-compliant – Data estimate

The ILCD identifies the documents and sources for the implementation of the quality, method, nomenclature, review and documentation compliance rules, where these requirements build on the ILCD handbook with further specified requirements to support the electronic data network.

This research has identified severe deficiencies in LCA associated with construction and low carbon methodologies (Bare, 2002), from the system of principals and terms, classification and naming through to ISO quality criteria which encompasses but is not limited to documentation extent, ILCD format, nomenclature compliance, data quality, technological and time-related representative-ness, quantitative criteria for accuracy and completeness, methodological consistency, data process compliance, registered independent external review through all processes, accounting procedures, computer integrated modelling and IT integration between computer calculators and inventory data bases.Low carbon LCA associated with building and refurbishment is currently found to be a fragmented and haphazard undertaking with an ad-hock approach and little or no consistency in terms of the ISO quality standards and procedures as stipulated by the (EuropeanCommission-JointResearchCentre, 2011).Life Cycle Thinking (LCT) is a scientific approach behind modern environmental policies and business decision support related to Sustainable Consumption and Production (SCP), where such thinking is gaining momentum amongst practitioners in the construction field and whilst not yet robust and entirely coherent, valuable data is being built up which should facilitate momentum to a universal approach and integrated development. In recent case studies, (angelini, 2008) it was found that certain KPI's are being established, and although rudimentary in nature, remain valuable for early benchmarking, for example: Construction Projects ranging from €5m to €15m depicted 133.1 tCO_2/mln € and 133.8 tCO_2/mln € respectively; similarly, 0.454 tCO_2/t material and 0.395 tCO_2/t material; whilst the same study showed a larger discrepancy in tCO_2 over the Gross Floor Area (GFA) which indicated the different building uses, namely 0.454 tCO_2/m2 and 0.257 tCO_2/m2 respectively.

4. CHAPTER 4: SUSTAINABILITY

4.1 Introduction

"Development is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987)

From space, we can see and study the Earth as an organism whose health depends on the health of all its parts. The World Commission on Environment and Development (WCED) responded to an urgent call by the General Assembly of the United Nations to commission a report titled 'Our Common Future, a global agenda for change' in 1983, the report was presented to the UN General Assembly in 1987 and has subsequently become known as the Brundtland Report. The report proposes long term environmental strategies for achieving sustainable development, recommends strategies for greater cooperation between countries including social and economic development which may lead to the achievement of mutually supportive objectives that takes account of the interrelationship between people, resources, environment and development with emphasis on protecting and enhancing the shared environment.

There is a growing realization in governments and multinational institutions that it is impossible to disconnect economic development from environmental issues, many forms of development displace and erode environmental resources upon which they are founded, where environmental degradation can in turn undermine economic development. Environmental issues can therefore not be viewed without a broader perspective which encompasses factors such as poverty, international inequality and the various social and economic aspects occurring in the micro fabric of sustainable strategy. (Brundtland, 1987)

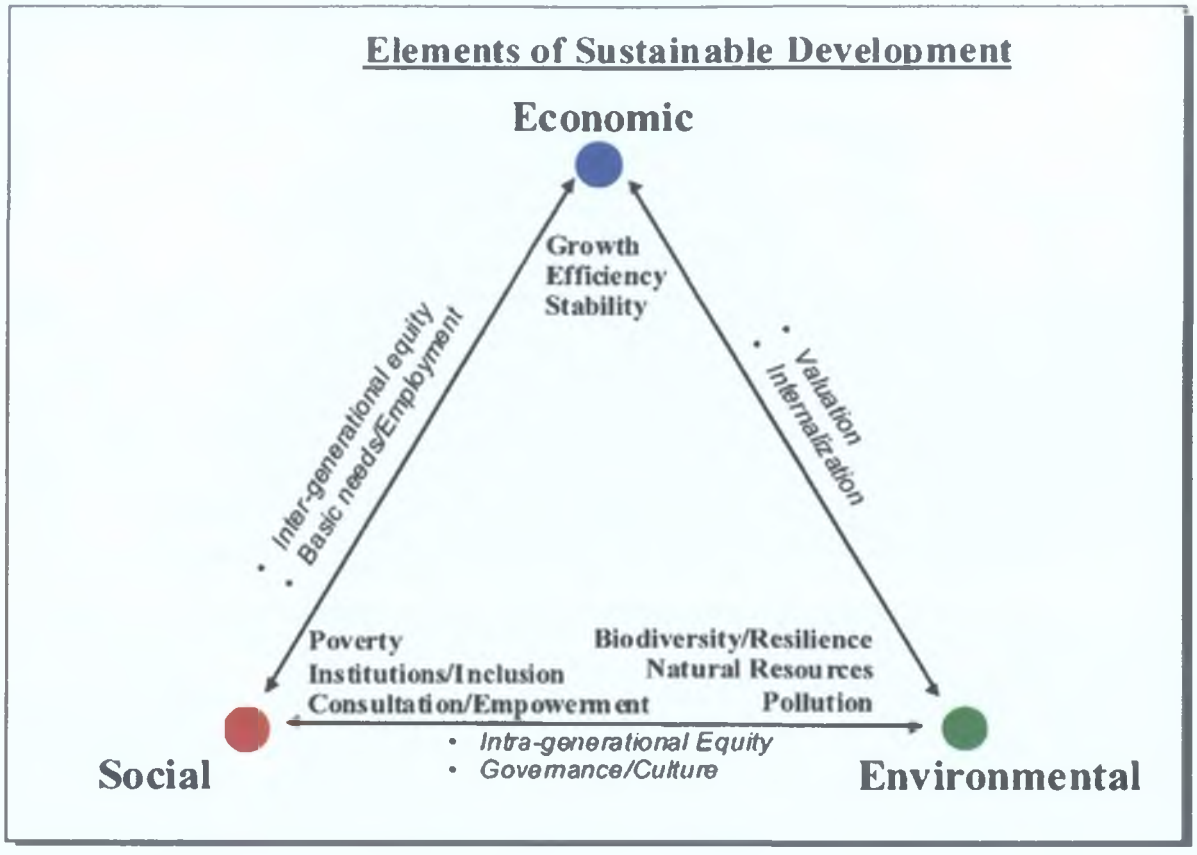


Figure 11: Elements of Sustainable Development. (IPCC, 2000)

According to UN projection; the human population could stabilise at 10.5Bn in the year 2050, it is important to note that population growth over time-span peaked in the year 1999 at 1Bn growth over a 10 year period, growth has subsequently slowed to 1Bn over 12 years and 1Bn over a 14 year period between 1999 to 2011 and projected between 2011 to 2025 respectively. The remarkable increase in population of an estimated 6Bn people from 1830 to 2011 is closely linked to development (modern medicine, hygiene standards, agricultural advancements, global colonialization, global fertility rates, etc), where 90% of the increase will occur in the poorest countries. (UNFPA, 1999)

Activities in developing countries that produce GHG are generally related to fulfilling basic needs such as energy for cooking, keeping tolerably warm, engaging in agricultural practices, energy for lighting and occasionally for travel by public transport. In contrast; developed countries where populations are more affluent, GHG production generally stems from

operating personal vehicles, central heating and cooling, intense manufacturing and energy embodied in a wide variety of manufactured goods and the use of such goods (IPCC, 2000). The IPCC argues that wealth has a direct bearing on the vulnerability to the impact of climate change and that by virtue of being richer, some countries will be able to adapt more effectively to climate change, where poorer countries may be less prepared to adopt mitigation and adaptation strategies, this was highlighted at the 2002 World Summit on Sustainable Development (WSSD or Earth Summit) held in Johannesburg, South Africa; key objectives were frustrated by developing countries, where poverty held implications of urgency over national priorities and time scales used in policy planning. In 2012; the United Nations will convene in Brazil, Rio de Janeiro as a 20 year follow up to the historic 1992 United Nations Conference on Environment and Development (UNCED) that was held in the same city. The conference has two themes agreed upon by the member states; the first being: Green economy within the context of sustainable development and poverty eradication; and the second being: Institutional framework for sustainable development.(UNCSD, 2012) Since climate change constitutes situations where activities of one country affect others, such conventions on climate change must arrive at some compromise between the two extremes as encountered between developing countries and developed countries, given that 90% of population (4.1) growth (estimated at 4Bn) over the next forty years will occur in developing countries.

4.1.1 Sustainable development

The IPCC advocates coordinated action through social and democratic consensus but with efficient institutional mechanisms involving small and large firms, the state, non-governmental organisations and multilateral organisations, identifying the following interrelated functions, namely:

1. Expansion of modernisation
2. Education of the whole population and diffusion of science and technology

3. Increase of formal employment and creation of jobs
4. Equitable income distribution to benefit the poor people
5. Natural resources exploitation and development of agriculture
6. Infrastructure and energy supply for industrial development
7. Private dynamics of modern sectors of the economy
8. Role of government and audited actions monitored.

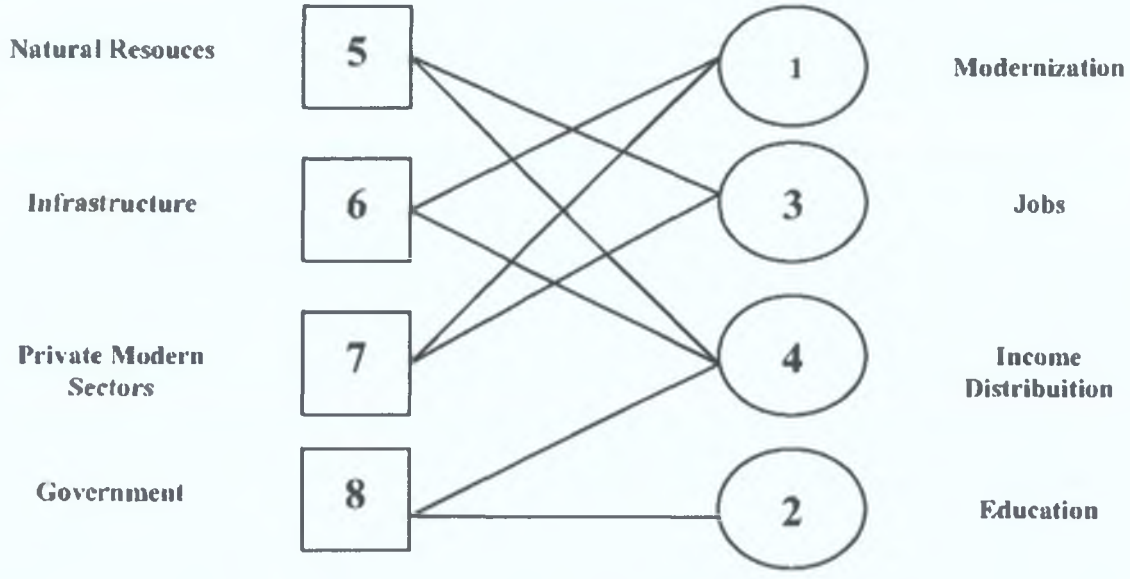


Figure 12: Mechanism in a Simple System approach. (IPCC, 2000)

A more complex arrangement stems from Figure 12: Mechanism in a Simple System approach. (IPCC, 2000); this is structured to suit local environmental and community conditions. In a Complex System approach; the main relationships between variables and functions are structured around the dynamics of local resources and infrastructure, this model will therefore vary according to a region with-in a particular country, for example: see Figure 13: Mechanism in Complex System approach. (IPCC, 2000)

(a) Natural resource exploration and agriculture are more related to job creation and income distribution.

(b) Infrastructure is more related modernisation and income distribution (through household electricity supply, water, cross subsides)

(c) Economic private sector is more related to modernisation and job creation

(d) The role of the government is more related to education and income distribution (via tax, social actions, etc)

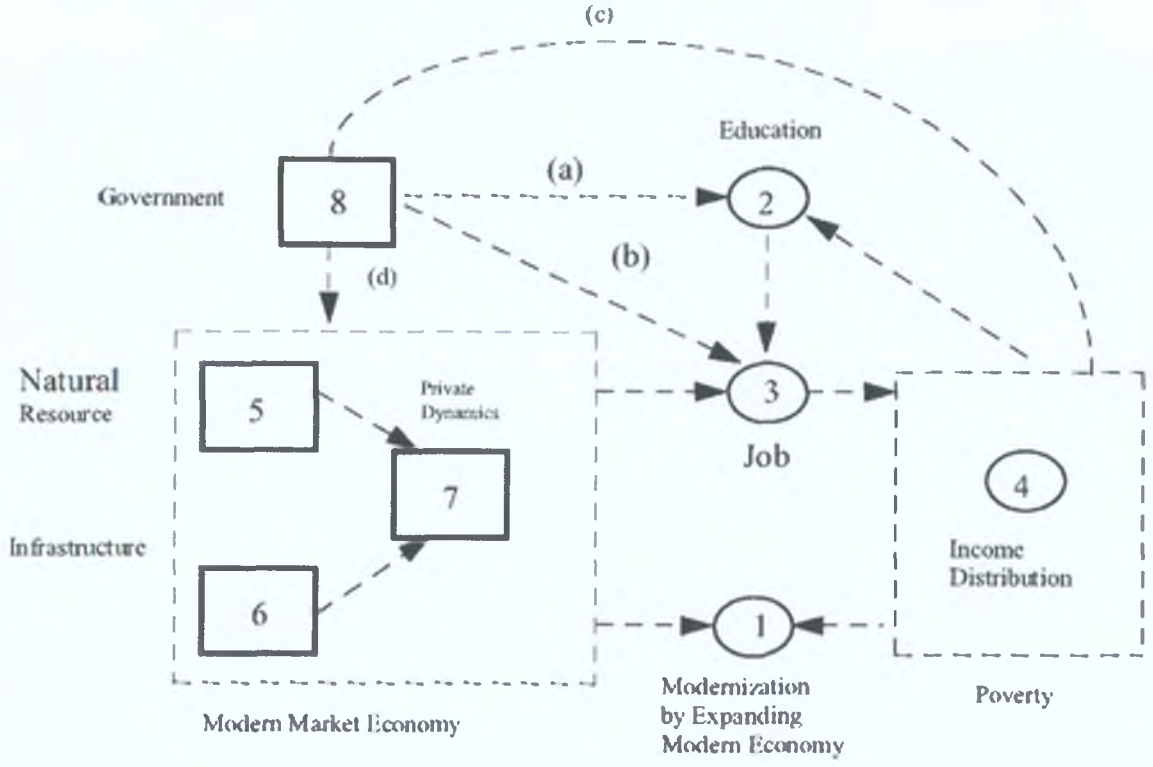


Figure 13: Mechanism in Complex System approach. (IPCC, 2000)

In the Complex System approach; there are four possibly ways for the government to start the process of taking people out of poverty (a, b, c & d), that is by way of education (2), job creation (3) and income distribution (4), which all have the aim of including the whole population in the modern economy.

Expansion of the modern economy to include the whole society will involve scientific and technological knowledge, training and vocational skills. Appropriate technology for low cost housing with local materials, local job creation and local design will facilitate in reducing poverty and facilitate income distribution. Isolated communities will require government intervention to facilitate labour intensive technologies to make local products, certain products to be protected against imports and energy schemes to be subsidised, preferably in renewable

technologies such as hydro, district heat, solar, ground source and air to air heat pumps, wind and anaerobic digestion from agriculture and community waste.

4.1.2 Global energy and climate change

There is no single unambiguous accounting method for calculating primary energy from non-combustible energy sources such as non-combustible renewable energy (RE) and nuclear energy. (PIK, 2012) The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) adopts the direct equivalent for accounting primary energy supply; in this method, fossil fuels and bio-energy are accounted for based on their heating value, while non-combustible energy sources such as nuclear energy and non-combustible RE, are accounted for based on the secondary energy they produce.

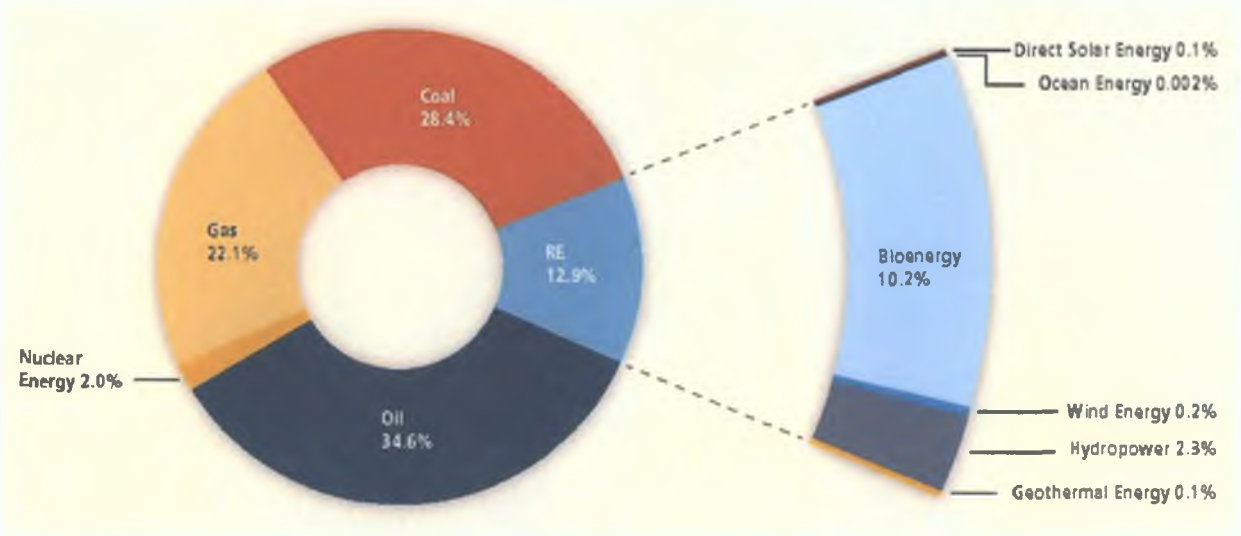


Figure 14: Shares of Energy sources in total global primary energy supply in 2008 (492 EJ). (PIK, 2012)

The total global primary energy supply in 2008 by direct equivalent 492 Exajoule (EJ = 10^{18} Joules)

During the initial discovery period of global climate change, extensive research was put into determining what role, if any, the sun has in global warming or climate change. According to a NASA Goddard Institute for Space Studies (GISS); the solar increases do not have the ability

to cause large global temperature increases, greenhouse gases are indeed playing the dominant role; that is; human activities are the primary factor in global climate change. (NASA, 2012)

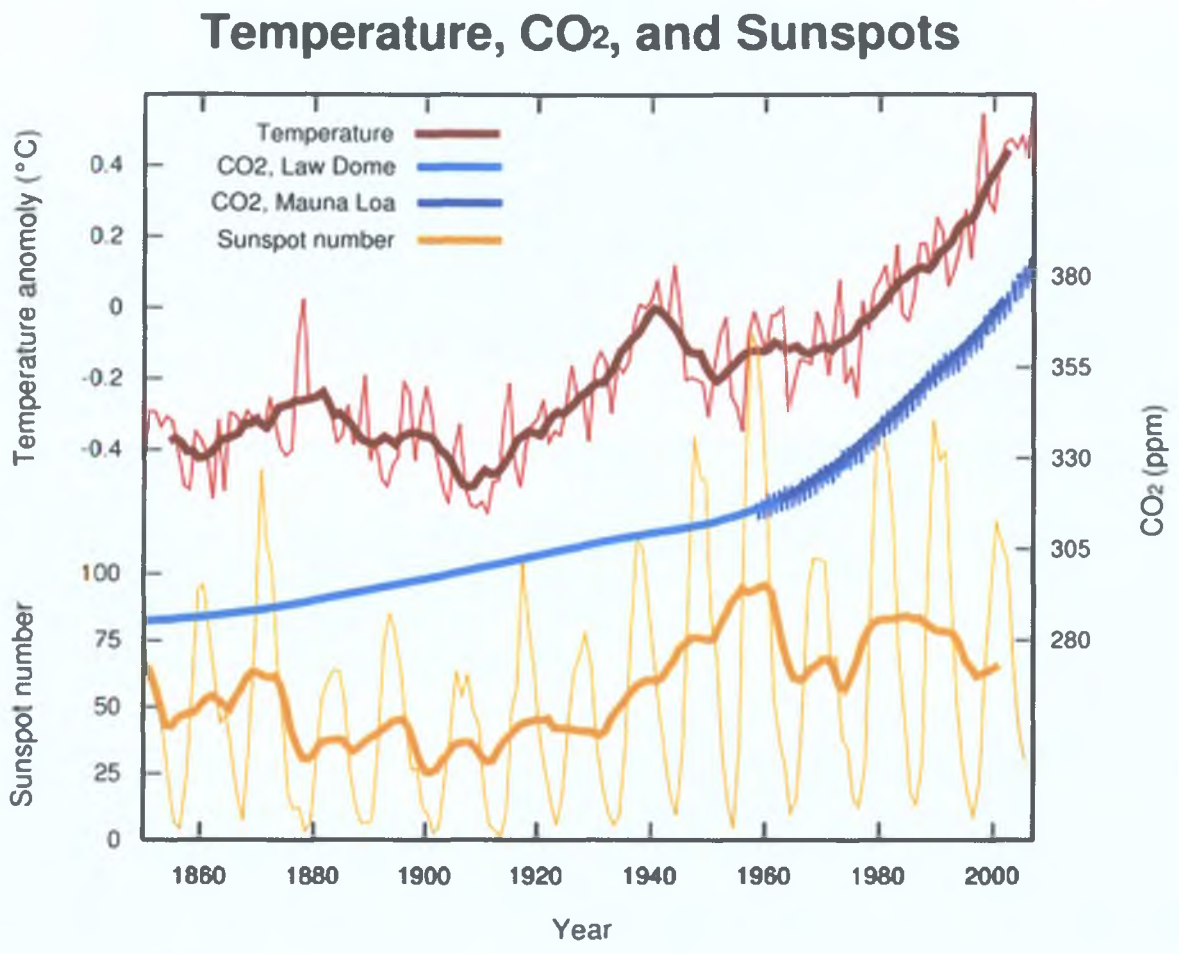


Figure 15: Temperature, CO2 and Sunspots. (NASA, 2012)

Pre Industrial Revolution concentrations of CO2 were approximately 275 parts per million (ppm). According to readings taken at Mauna Loa on January 2012, concentrations are now at 393 ppm (NOAA, 2012) taken at an altitude of 3400 m in the northern subtropics and therefore may not be the same as the globally averaged CO2 concentrations at the surface. Although CO2 concentrations occur naturally through the carbon cycle and volcano eruptions, global concentrations are now 35% higher than they were before the Industrial revolution and are now linked to burning fossil fuels. (EPA, 2012) Detailed scientific analysis has shown that the earth has warmed by 0,76°C on average during the last 100 years, since 1995, we have observed 11 of the warmest years on record. The Intergovernmental Panel on Climate Change

(IPCC) fourth assessment report on climate change 2007, summary for policymakers notes the following significant influences due to global warming, namely: rise in sea level (15-95 cm by 2040), altered rainfall and temperature patterns, change in agriculture / ecosystems and human habitation patterns, decline in global food production, gulf stream shut down; secondary effects could lead to migration, poverty, famine and regional conflict.

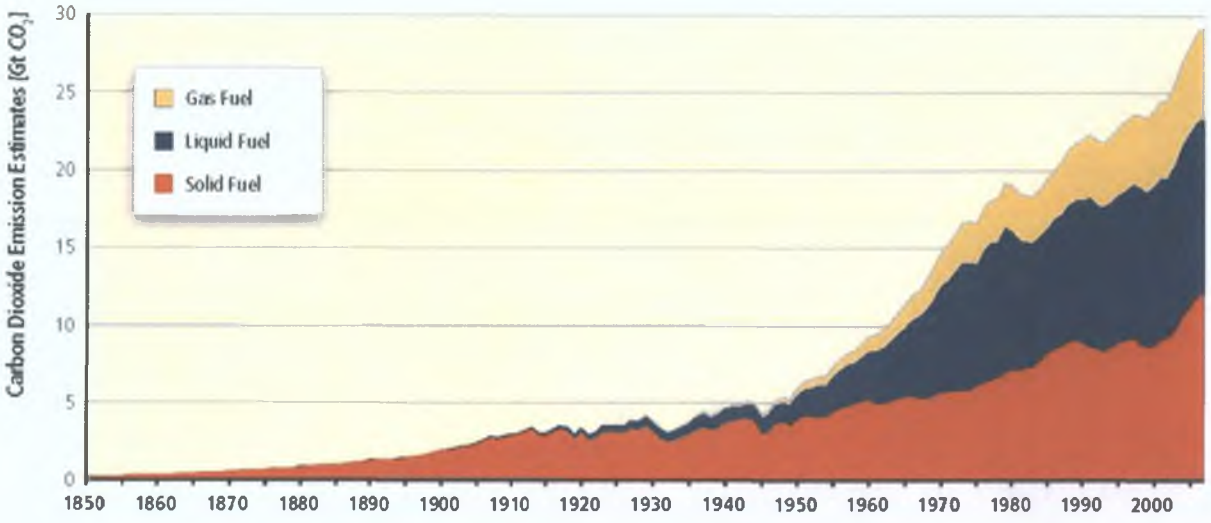


Figure 16: Global CO2 emissions from fossil fuel burning, 1850 to 2007. (PIK, 2012)

As there is now a direct correlation between GHG emissions, the burning of fossil fuels due to human activity and global warming which may have far reaching and devastating effects on all human kind, it would be noteworthy to assess how our most obtainable source of energy is generated for households, building and manufacture, namely electrical generation.

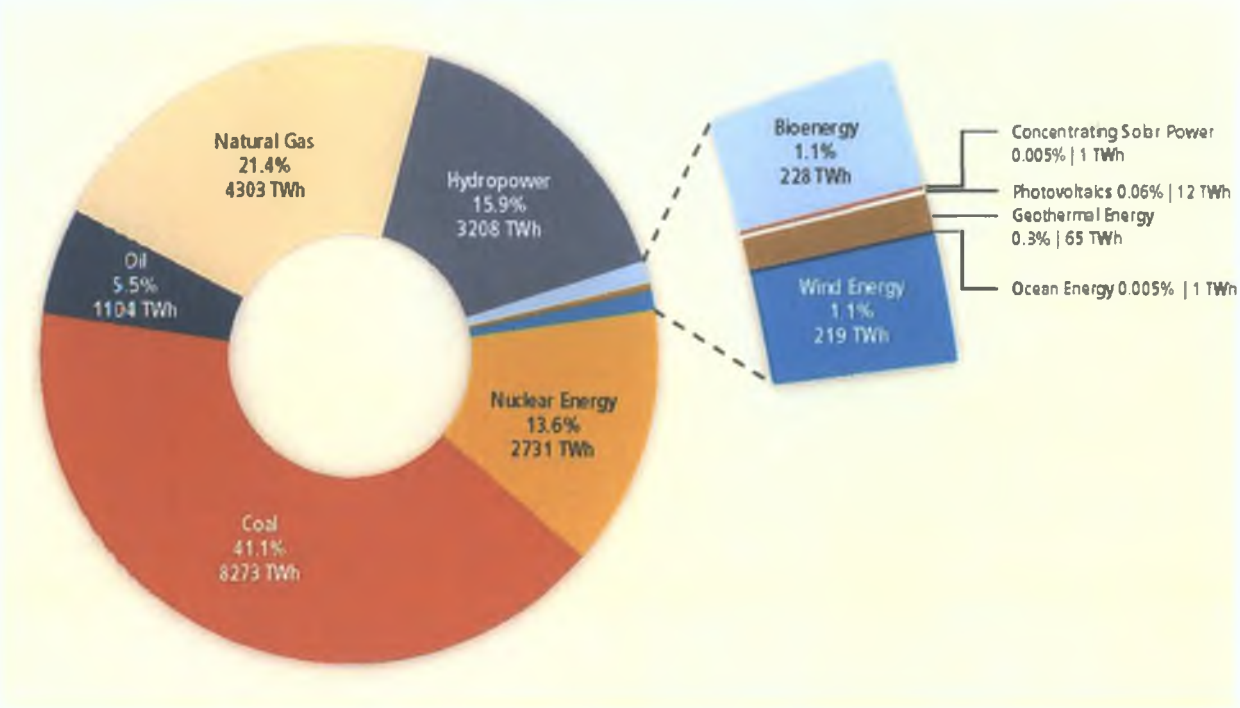


Figure 17: Share of primary energy sources in World Electricity Generation, 2008. (PIK, 2012)

Coal and Oil are responsible for 47% of all electricity generation; whilst RE sources produce less than 18% of all electricity generated.

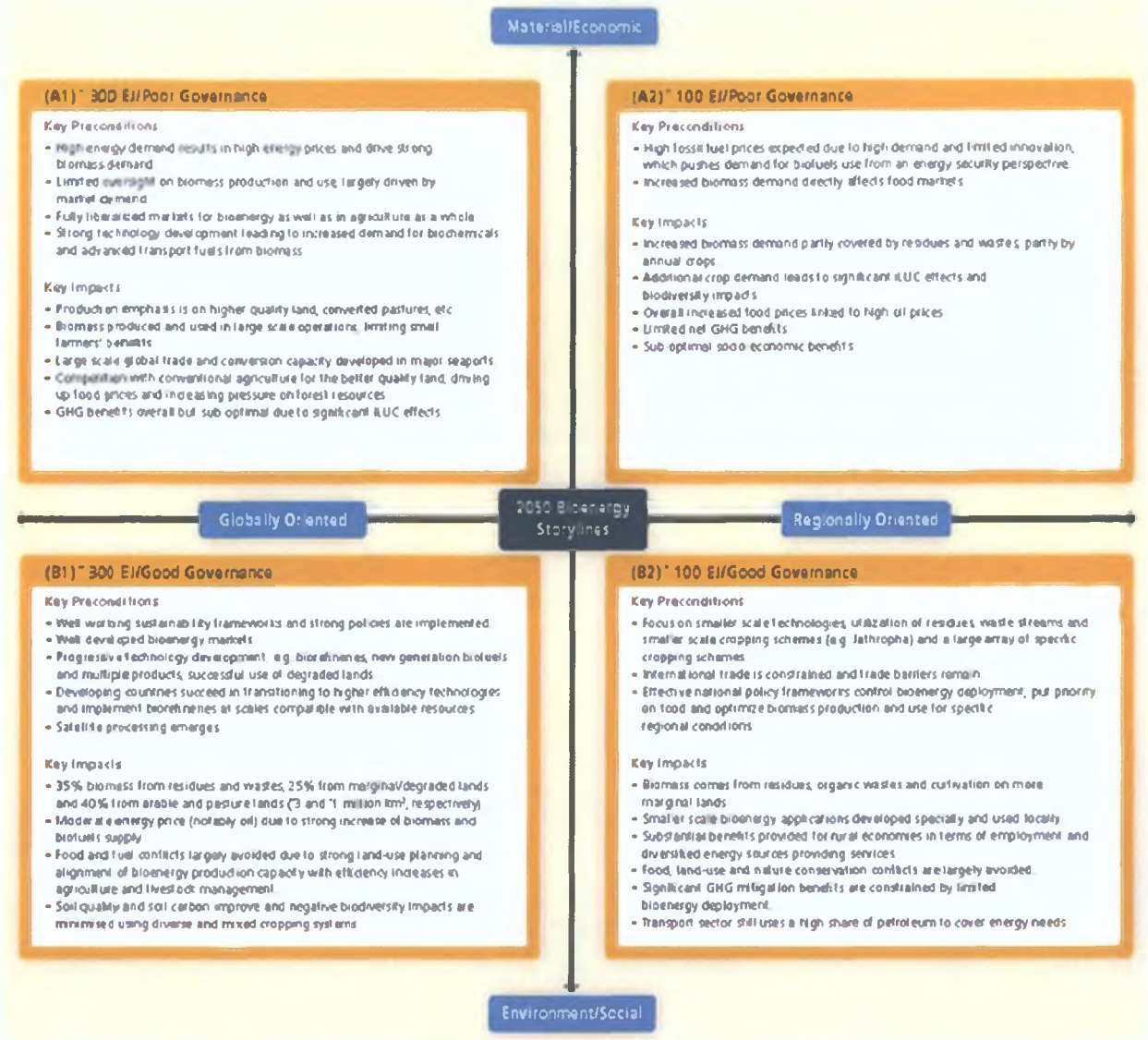
4.1.3 Biomass and developing countries

It is estimated that 90% of the world population growth will stem from the poorest countries and communities (4.1), it follow that biomass is a key ingredient to a Sustainable solution. Countries differ in their priorities, approaches, technology choices and support schemes for bio-energy development due to the many aspects which affect bio-energy deployment such as agriculture and land use; forestry and industrial development; energy policy and security; rural development and environmental policies. Furthermore, technology development; availability and cost of resources; priorities and access to bio-energy differ widely from country to country and then also between various regions with-in the country. Bio-energy deployment is therefore not straightforward, where the myriad of different options result in different GHG savings, savings depend on how land use is managed. Assuming sustainability and policy frameworks

to secure good governance of land use and major improvements in agricultural management, the resultant resources could be substantial, such as: (PIK, 2012)

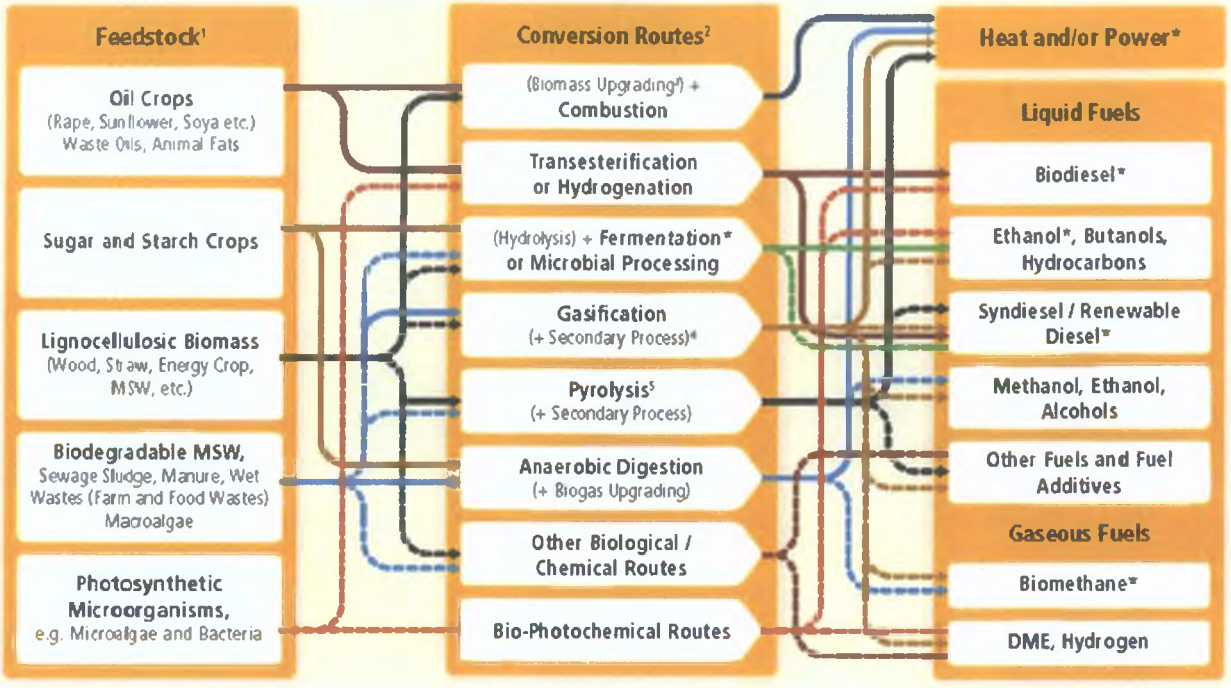
- Biodiversity induced limitations to set limits on extraction in agriculture and forestry thus ensuring the maintenance of healthy ecosystems and avoid soil degradation.
- Multi-functional land use systems with bio-energy production integrated into agriculture and forestry could contribute to biodiversity conservation and help restore and maintain soil productivity and health ecosystems.
- Cultivation of suitable crops and woody species can lead to higher technical potential with the production of bio-energy on land less suited for cultivation of conventional food crops.
- There is also potential to make use of suitable energy crops that are drought tolerant which will then help facilitate downstream water availability needs and convert land into bio-mass production in water scarce regions.

Table 4: Poor and Good governance in Global and Regional scenarios. (PIK, 2012)



Bio-energy has complex and dynamic interactions among society, energy and the environment including climate change impacts and various spatial and temporal scales on all resource uses for food, fodder, fibre and energy. Biomass resources need to be produced and managed in sustainable ways as their impacts can be felt from micro to macro scales by increasing carbon stocks in the biosphere, reducing carbon emissions from unsustainable forest use and by replacing fossil fuel based systems in the generation of heat, power and modern fuels. It is therefore imperative that a coordinated approach between food and fuel is adopted in conjunction with detailed assessments on land use in context of the micro region. Good governance will also include sustainable frameworks that generate effective policies that lead to sustainable ecosystems whilst providing opportunities for regional economic development.

Table 5: Schematic view of bio-energy from feedstock, conversion route and deliverables. (PIK, 2012)



The schematic view of the variety of bio-energy routes stemming from feedstock through conversion routes to heat, power, combined heat and power (CHP) and liquid or gaseous fuels clearly depict the diversity and benefits which are possible through good governance and policy strategy. Parts of each feedstock, such as crop residues, could also be used in other routes, where each route also provides for co-products such where anaerobic digestion process releases methane and CO_2, removal of the CO_2 often called the upgrade gas produces bio-methane.

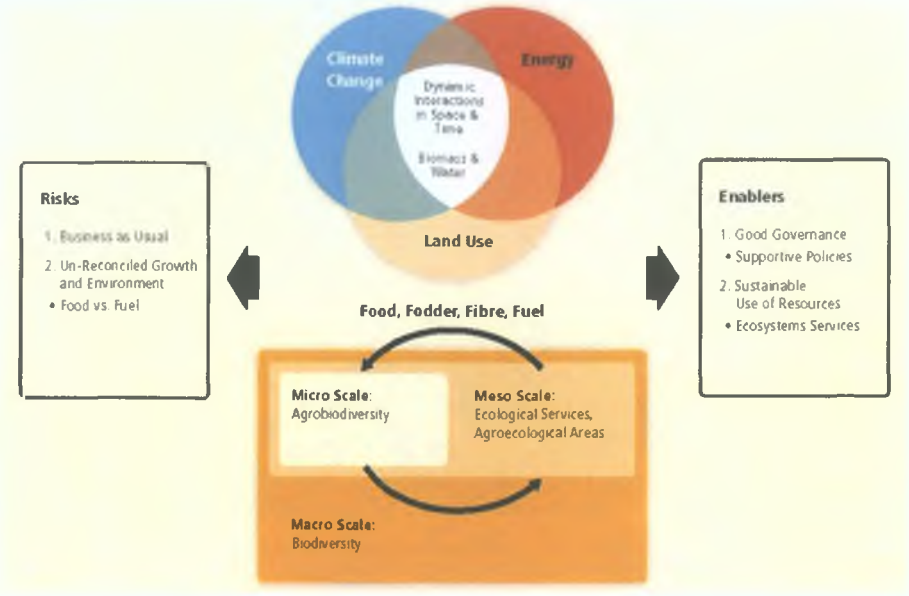


Figure 18: Risks and Enablers in Climate Change, Energy and Land Use balance. (PIK, 2012)

4.1.4 Sustainability and renewable energy

Historically, economic development has been strongly correlated with increasing energy use and growth of GHG emissions, renewable energy (RE) can help decouple that correlation, contributing to sustainable development (SD). In addition, RE offers the opportunity to improve access to modern energy services for the poorest members of society, which is crucial in addressing concerns about relationships between human society and nature. Traditionally, SD has been framed in three pillar model, namely: Economy, Ecology and Society with the three pillars being interdependent and mutually reinforcing. The relationship between RE and SD can be viewed as a hierarchy of goals and constraints that involve both global, regional and local consideration. Sustainable development has to be evaluated in a country specific context, where RE offers the opportunity to contribute to a number of important SD goals, namely: (PIK, 2012)

- Social and economic development
- Energy access
- Energy security
- Climate change mitigation and the reduction of environmental and health impacts

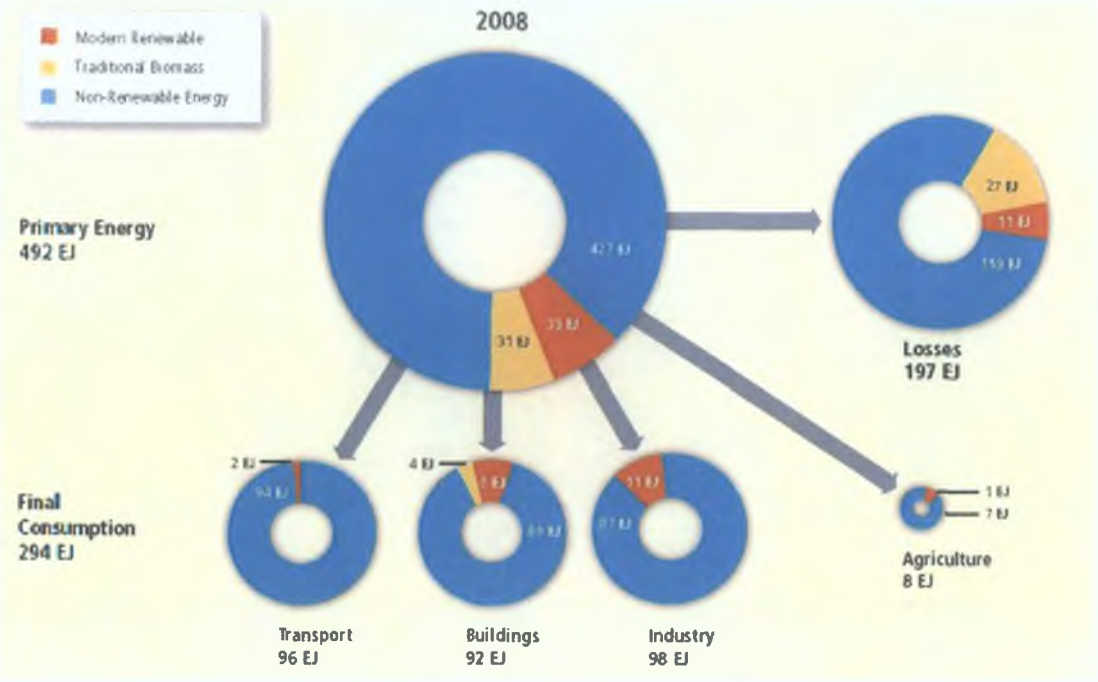


Figure 19: Renewable Energy shares of primary and final energy in Transport, Industry, Buildings and Agriculture. (PIK, 2012)

It is anticipated that increased urbanisation will continue and that 50% of the 6,4 billion world population living in cities and towns today, will rise by 60% in 2030 to 8,2 billion people. (UNEP, 2011)

In the long term, the potential for fossil fuel scarcity and decreasing quality of fossil reserves represents an important reason for a transition to a sustainable world wide RE system. Given the interdependence of economic growth and energy consumption, access to a stable energy supply is a major political concern and a technical and economic challenge facing both developed and developing economies.

By way of example; Germany devoted significant resources to RE technology development and market development and has subsequently seen rapid growth of electricity generation from RE. Germany's share of electricity from RE rose 3,1% in 1991 to 7,8% in 2002 and more than doubled again by the end of 2009 to 16,9%. (PIK, 2012)

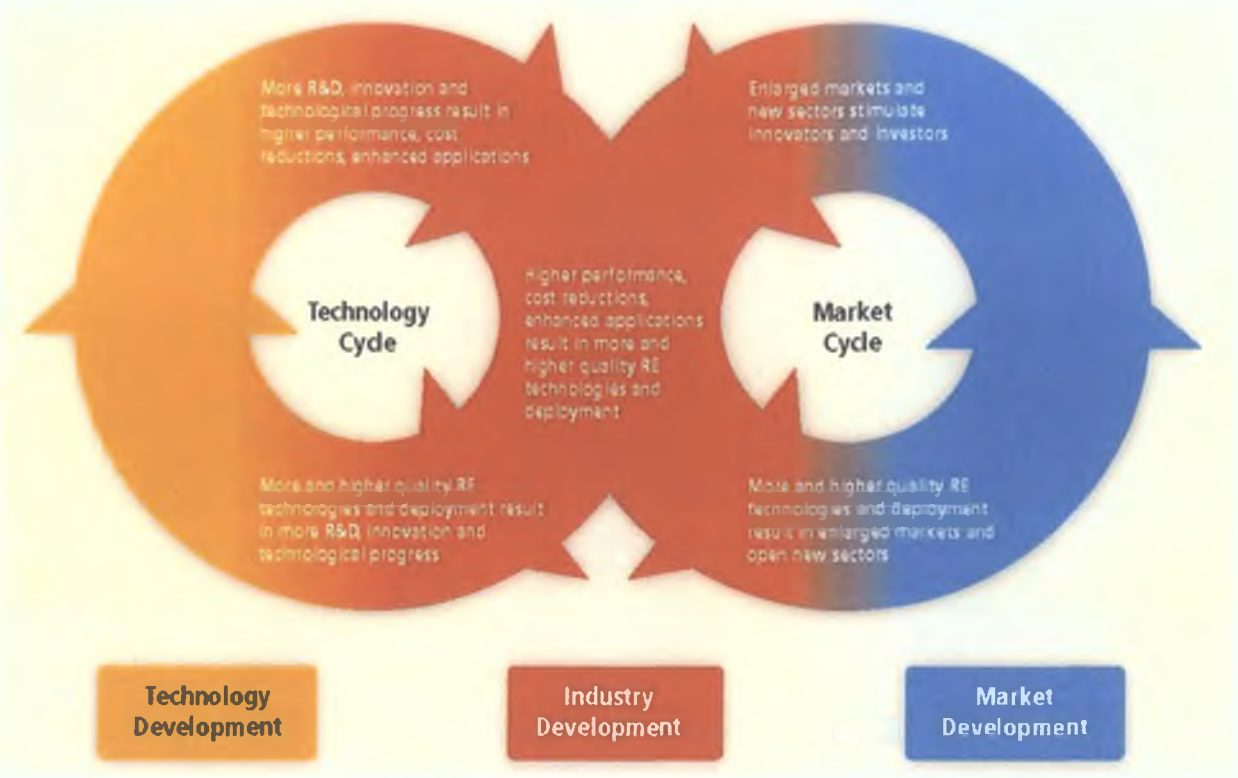


Figure 20: The mutually reinforcing cycles of technology development and market deployment drive down technology costs.

Research and Development (R&D) investments are most effective when complimented by other policy instruments, particularly policies that simultaneously enhance demand for new RE technologies, where early deployment policies in a technology's development accelerate learning both via R&D and through utilization as a result of manufacture and cost reduction. Therefore; together, R&D and deployment policies create a positive feedback cycle and induce private sector investment whilst stimulating and enlarging markets thereby driving costs down and allowing RE to become feasible and popular. (Tommerup, 2006)

A well-implemented Feed in Tariff (FIT) as adopted in Germany helped guarantee high investment security due to a combination of long-term fixed price payments, network connection and guaranteed grid access on all renewable generation. Well designed FITs have encouraged both technological and geographic diversity and have been found to be more

suitable for promoting projects of varying sizes. The success of FIT policies depends on the details, namely:

- Utility purchase obligation
- Priority access and dispatch
- Tariffs based on cost of generation and differentiated by technology type and size of project
- Tariffs guaranteed for a long enough time period to ensure an adequate rate of return
- Integration of costs into the rate base and shared equally across country or region
- Clear unambiguous connection standards and procedures to allocate cost for transmission and distribution
- Streamlined administrative and application processes
- Attention to exempted groups such as low-income and vulnerable customers versus major users on competitiveness grounds.

4.1.5 Renewable energy in buildings

To ensure a positive up-take and continued momentum in the retrofitting of existing buildings, the Energy Positive concept (see Fig: Figure 21) is fundamental. In many developed countries, heating and cooling and to a lesser extent lighting, have the highest potential to reduce energy demand in buildings and thereby offer an opportunity for cost effective integration of RE into new building developments as well as building refurbishments to continue towards achieving zero-energy buildings or even energy positive buildings where RE technologies meet the energy demand of the inhabitants and generate more energy than the building consumes. RE deployment in a building can be combined with energy efficiency measures and encouraging energy conservation through education and behavioural change of the occupants.

The building sector in 2008 accounted for about 92 EJ, or 32% of total global final energy consumption (Figure 19), where the residential sector consumed over half the total building energy demand followed by the commercial and public service buildings. GHG emissions from the building sector, including through electricity use, were about 8,6 Gt CO_2 in 2004, with scope for significant reduction potential mainly from energy efficiency. (PIK, 2012)

The composition of age class of the building stock of a country influences its future energy demand, especially for heating and cooling. Many buildings in developed countries have average life spans of 120 years and above, hence energy efficiency measures and the integration and deployment of RE technologies will need to result mainly from retrofitting of existing buildings. Developing countries have stock turnover rates of 25 to 35 years on average with relatively high new building construction growth, offering good opportunities to integrate RE technologies through new designs. (PIK, 2012)

Investment of both RE and energy efficiency in building can reduce costs and CO_2 emissions, however the comparative savings per unit of investment for either option will vary with building type and location.

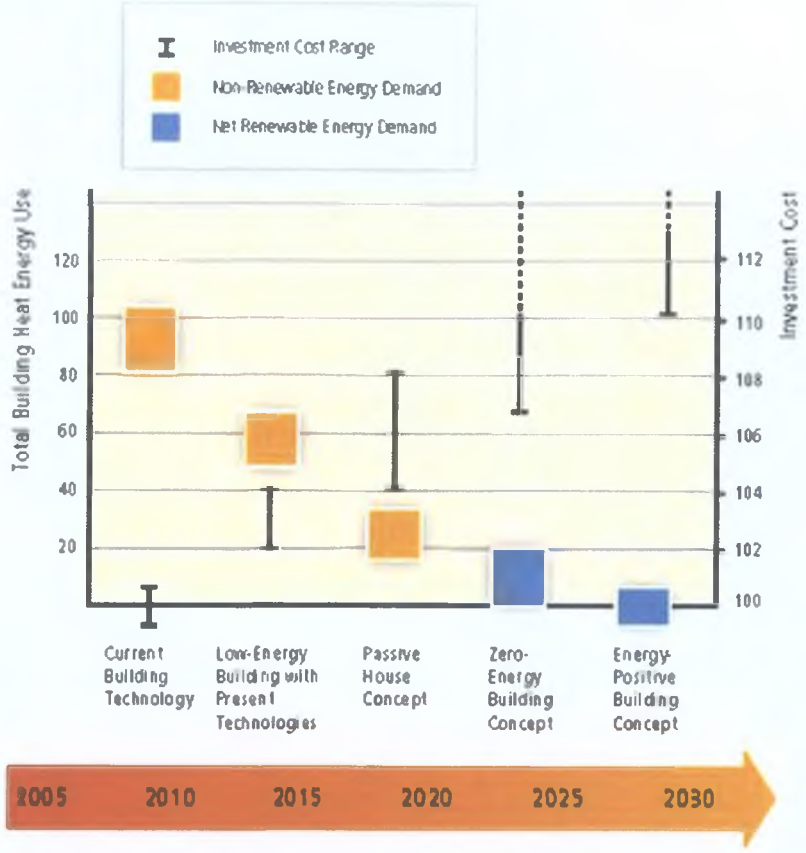


Figure 21: Estimated Investment Cost Range from current building technology to Energy Positive Building Concept. (PIK, 2012)

The relative performance of current building technologies to meet energy demands, compared with future designs of energy-efficient building with integrated RE systems related to estimated investment costs is depicted in Figure 21, where this has been based on a full scale demonstration project in Finland 2009. (PIK, 2012)

In high density urban areas, the energy demand per hectare of built land area usually greatly exceeds the local flows of RE, which are typically below 10 kW/ha annual average. In contrast, buildings located in rural and low density urban areas could more easily become autonomous for their net energy needs, excluding transport. (PIK, 2012) In the current economic landscape, where there is a low new building stock turn-over, policy attention has shifted towards retrofitting existing building stock in Europe.

4.2 Low carbon opportunity Ireland

4.2.1 Introduction

Ireland's economy has contracted by 10% since 2007, returning in 2010 to 2005 levels. Energy demand reduced by 9% to 2003 levels and energy-related CO_2 emissions have fallen by 12% to 2000 levels. Ireland's import dependency was 86% in 2010, down from a peak of 90% in 2006. Oil consumption reduced by 4.8% in 2010 and represented 50% of Ireland's overall energy supply, but 61% of final energy demand. Natural gas consumption increased by 9.2% in 2010 and increased its share to 32% of overall energy supply. Coal consumption decreased by 24% since 2007. (SEAI, 2011a)

Energy use in buildings increased by 7% in 2010 and accounted for 42% of final demand. Increased energy use in buildings was driven by exceptionally cold weather at the start and end of the year. Residential energy use increased by 5.9% in 2010; however, when climate corrected due to the spike in exceptionally cold weather, showed a decrease of 2.9%. Energy consumption per household was 5.2% lower in 2010 than in 2009, once climate corrected. (SEAI, 2011a)

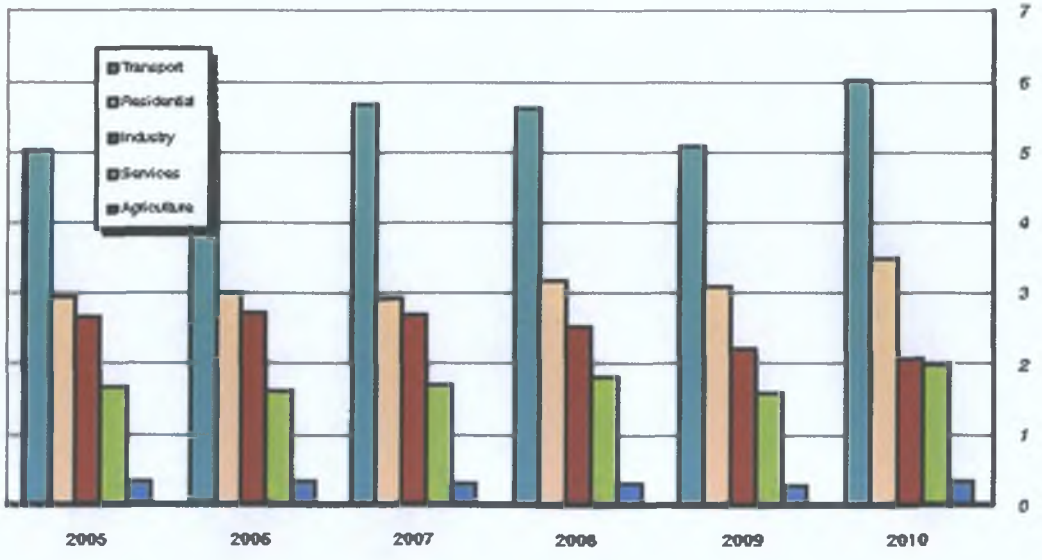


Figure 22: Final Energy Consumption by Sector, Ireland 2010. (CSIR, 2010)

The UK is Ireland's closest neighbour; where it is reported that the most important energy end-use in the building sector is space heating, which is responsible for 25% of carbon emissions and accounts for over 60% of delivered energy and over 40% of energy costs in the residential sector. A study in the 1980's revealed that over two-thirds of energy savings achievable in buildings could come from space heating, where in spite of improved building regulations and financial incentives aimed at encouraging the up-take of energy efficient measures, there is no clear downward trend in the national energy statistics in space heating over the last 30 years. (Z. Liao., 2004)

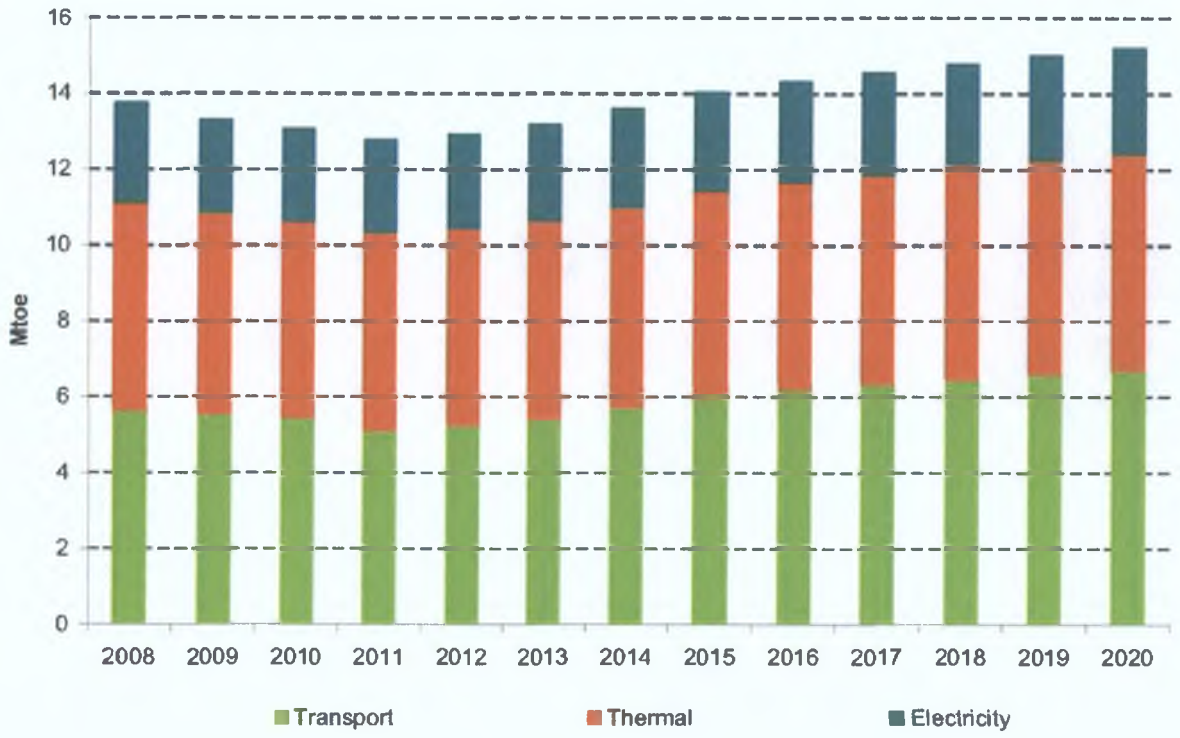


Figure 23: Energy Consumption by Mode of Application, Ireland. (SEAI, 2009b)

The thermal requirements projected by the SEAI 2009 Report titled 'Energy forecasts for Ireland to 2020', depicts an increase in energy consumption associated with heating, which correlates to the study and findings in the UK.

4.2.2 Smart grid

The Sustainable Energy Authority Ireland (SEAI) smart grid roadmap in conjunction with the European Smart Grid Taskforce (Commission, 2011) have defined expected services, functionalities and benefits of smart grids which has been based on detailed analysis and to some extent assumptions in a localised context, namely:

- Decarbonisation of electricity in the Irish system will result in annual savings of over 13 million tonnes of CO2 by 2050, 8 million tonnes of this will be delivered directly from the implementation of the smart grid, whilst the remaining 5 million tonnes will result from the displacement of fossil fuels due to the electrification of transport and thermal loads.
- Greater integration of indigenous renewable energy sources via the smart grid will realise a reduction in energy imports in excess of 4.3 Mtoe (tonne of oil equivalent)
- By 2025 Ireland will have 1.4 GW (Giga Watt) of interconnection, the SEAI analysis indicates that a further 1.6 GW of interconnection will be required by 2040.
- More than 10 000 Irish jobs will be created by the implementation of smart grid infrastructure and its associated technologies. (SEAI, 2011b)

In essence, a smart grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it; the generators, the consumers and those that do both, in order to ensure an economically efficient and sustainable power system with low losses and high levels of quality and security of supply and safety. A smart grid employs innovative products and services together with intelligent monitoring, control, communication and self healing technologies.

Table 6: EU Commission Smart Grid Benefits and potential KPI's. (Commission, 2011)

Benefit	Potential key performance indicators[6]
(1) Increased sustainability	Quantified reduction of carbon emissions Environmental impact of electricity grid infrastructure Quantified reduction of accidents and risk associated to generation technologies (during mining, production, installations, etc.)
(2) Adequate capacity of transmission and distribution grids for "collecting" and bringing electricity to the consumers	Hosting capacity for distributed energy resources in distribution grids Allowable maximum injection of power without congestion risks in transmission networks Energy not withdrawn from renewable sources due to congestion and/or security risks An optimized use of capital and assets
(3) Adequate grid connection and access for all kind of grid users	Benefit (3) could be partly assessed by: - first connection charges for generators, consumers and those that do both - grid tariffs for generators, consumers and those that do both - methods adopted to calculate charges and tariffs - time to connect a new user - optimization of new equipment design resulting in best cost/benefit - faster speed of successful innovation against clear standards
(4) Satisfactory levels of security and quality of supply	Ratio of reliably available generation capacity and peak demand Share of electrical energy produced by renewable sources Measured satisfaction of grid users with the "grid" services they receive Power system stability Duration and frequency of interruptions per customer Voltage quality performance of electricity grids (e.g. voltage dips, voltage and frequency deviations)
(5) Enhanced efficiency and better service in electricity supply and grid operation	Level of losses in transmission and in distribution networks (absolute or percentage)[7] Storage induces losses too, but also active flow control increases losses Ratio between minimum and maximum electricity demand within a defined time period (e.g. one day, one week)[8] Percentage utilisation (i.e. average loading) of electricity grid elements Demand side participation in electricity markets and in energy efficiency measures Availability of network components (related to planned and unplanned maintenance) and its impact on network performances Actual availability of network capacity with respect to its standard value (e.g. net transfer capacity in transmission grids, DER hosting capacity in distribution grids)
(6) Effective support of trans-national electricity markets by load-flow control to alleviate loop-flows and increased interconnection capacities	Ratio between interconnection capacity of one country/region and its electricity demand Exploitation of interconnection capacities (ratio between mono-directional energy transfers and net transfer capacity), particularly related to maximisation of capacities according to the Regulation of electricity cross-border exchanges and the congestion management guidelines Congestion rents across interconnections
(7) Coordinated grid development through common European, regional and local grid planning to optimize transmission grid infrastructure	Benefit (7) could be partly assessed by: - impact of congestion on outcomes and prices of national/regional markets - societal benefit/cost ratio of a proposed infrastructure investment - overall welfare increase, i.e. running always the cheapest generators to supply the actual demand) → this is also an indicator for the benefit (6) above - Time for licensing/authorisation of a new electricity transmission infrastructure. - Time for construction (i.e. after authorisation) of a new electricity transmission infrastructure.
(8) Enhanced consumer awareness and participation in the market by new players	- Demand side participation in electricity markets and in energy efficiency measures - Percentage of consumers on (opt-in) time-of-use / critical peak / real time dynamic pricing - Measured modifications of electricity consumption patterns after new (opt-in) pricing schemes
(9) Enable consumers to make informed decisions related to their energy to meet the EU Energy Efficiency targets	- Base to peak load ratio Relation between power demand and market price for electricity - Consumers can comprehend their actual energy consumption and receive, understand and act on free information they need / ask for - Consumers are able to access their historic energy consumption information for free in a format that enables them to make like for like comparisons with deals available on the market. - Ability to participate in relevant energy market to purchase and/or sell electricity - Coherent link is established between the energy prices and consumer behaviour
(10) Create a market mechanism for new energy services such as energy efficiency or energy consulting for customers	- 'Simple' and/or automated changes to consumers' energy consumption in reply to demand/response signals, are enabled - Data ownership is clearly defined and data processes in place to allow for service providers to be active with customer consent - Physical grid related data are available in an accessible form - Transparency of physical connection authorisation, requirements and charges - Effective consumer complaint handling and redress. This includes clear lines of responsibility should things go wrong
(11) Consumer bills are either reduced or upward pressure on them is mitigated	- Transparent, robust processes to assess whether the benefits of implementation exceed the costs in each area where roll-out is considered are in place, and a commitment to act on the findings is ensured by all involved parties - Regulatory mechanisms exist, that ensure that these benefits are appropriately reflected in consumer bills and do not simply result in windfall profits for the industry - New smart tariffs (energy prices) deliver tangible benefits to consumers or society in a progressive way - Market design is compatible with the way the consumers use the grid

4.2.3 Fuel Poverty

Although the term fuel poverty is widely used in Ireland and the UK, it is not common in other European member states. Poverty, and in particular income poverty is a significant factor in a persons ability to meet fuel and other energy costs. Some definitions in use describe fuel poverty pertaining to a household needs to spend more than 10% of income on energy in order to maintain an acceptable level of heat throughout the home. Most descriptions of fuel poverty, if not all, fail to reference other essentials, such as hot water provision, cooking, household appliances or lighting. Later, Boardman (1991), in her widely regarded doctoral thesis on fuel poverty included the crucial energy-efficiency component into the definition: (SEAI, 2003)

> ***"The inability to afford adequate heat because of energy inefficiency in the home"***

Later Clinch and Healy (2001) provided a comprehensive definition of fuel poverty:

> ***"The inability to heat ones home to an adequate (safe and comfortable) temperature owing to low income and poor (energy inefficient) housing"***

Although fuel poverty in Ireland steadily dropped between the years 1994 to 2003, from the year 2004 there has been a steady incline in fuel poverty; where in 2005 the share of households experiencing an inability to meet adequate heating requirements was 15.9%, whilst in 2008 the percentage had risen to 19.4% (households No. 301,368). (Department of Communications, 2009)

4.2.3.1 Housing Conditions

Extensive research work was commissioned by Energy Action Ltd in 1999, the key findings of the report were:

- Fuel poverty in Ireland is amongst the highest in Europe
- Irish housing standards are amongst the lowest in Northern Europe from the point of thermal efficiency.

- The least well off tend to live in the worst of these houses and the share of income they devote to heating is three times higher than the expenditure share of the average household.
- Excess morbidity and mortality in Ireland due to poor housing standards is amongst the highest in Europe

The report found that there would be considerable long-term economic, environmental, health and social benefit if the thermal efficiency of the Irish housing stock was increased to the requisite level. (Watson, 2003)

4.2.3.2 Income

The level of income of the resident also impacts upon their ability to make capital investment improvements to their homes. When purchasing warmth, the price depends upon housing condition and the technical characteristics, such as the central heating system and the building fabric, as well as the type of fuel purchased. (Watson, 2003)

4.2.3.3 Thermal efficiency

Retro-fitting the Irish housing stock to improve thermal standards will have substantial social and cost-benefit to society. When home income levels remain static, current research shows that:

- Placing warmth in a thermally inefficient home is a bad investment
- A long term solution to fuel poverty revolves around removing thermal inefficiencies
- Whilst behavioural changes are required, research suggests that investment capital is key to improving thermal / energy efficiency in houses.

4.2.3.4 Dwelling Age

In a study conducted by the Urban Institute Ireland at the University City Dublin (UCD) 2001; older dwellings were found more likely to be occupied by those experiencing fuel poverty than those in newer dwellings, where the highest numbers experiencing fuel poverty were found to be occupying homes build in the 1940's to 1970's. Data relating to dwelling age can be grouped into four distinct categories on the basis of energy efficiency characteristics; that is: pre-1940 dwellings which were mainly solid wall construction, 1940's to 1970's where cavity wall construction was implemented, 1980's where improved U-values for both walls and attics were introduced in various building regulations, and then in the 1990's where more stringent building regulations were introduced in 1997 and then amended again in 2003.

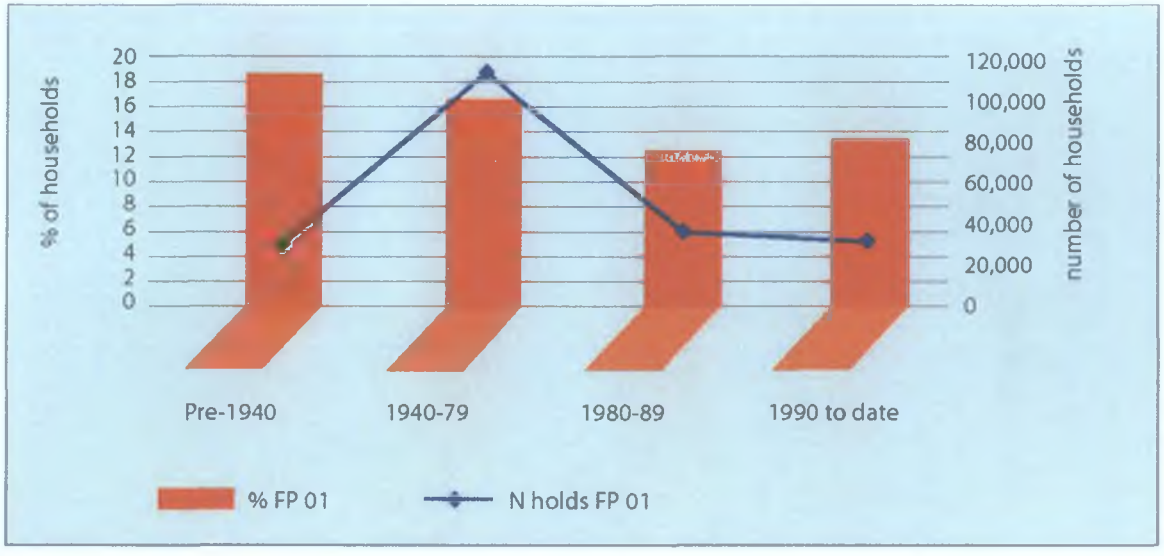


Figure 24: Fuel Poverty by Dwelling Age in Ireland. Source Healy and Clinch 2002. (SEAI, 2003)

There are many factors which attribute to the measure of fuel poverty in Ireland; some of which have been mentioned here such as Housing Conditions, Income, Thermal efficiency and Dwelling Age; where fuel poverty and the alleviation of fuel poverty has a direct correlation to GHG emissions, Sustainable Development, Government Policies and the National Climate Change Strategy as well as Economic and Social implications. The long term solution starts at removing thermal inefficiencies in retrofitting projects as well as building regulation for new projects.

4.2.4 Sustainable Energy Community

A Sustainable Energy Community (SEC) is a community in which everyone works together to develop a sustainable energy system; where a SEC can provide a link between sustainable energy, social cohesion and economic development. The key aims in a SEC are to be energy efficient, to make use of renewable energy and to develop decentralise energy supplies; where collaboration between local authority, local community, local politicians, planners, developers, business, residents, educational institutes as well as energy suppliers and service providers are required in order to attain a structured, intelligent and integrated energy management technique within the community. (SEAI, 2010)

Dundalk is serving as a model of good practice in leading the way on integration of sustainable energy techniques and technology, facilitating business and community collaboration and bringing about behaviour change. Key features of a SEC can be summarised as follows, namely:

- It enjoys strong community / stakeholder commitment
- It is located in a defined geographical area called a Sustainable Energy Zone (SEZ)
- It includes the entire spectrum of sectors, activities and stakeholders with-in society
- It must have a defined management structure and process with clear and visible benefits.
- The baseline energy use in the community must be fully understood, including in terms of future expansion and growth.
- Targets that are more ambitious than national targets must be agreed and it should be an exemplar for other communities to follow and replicate
- Energy efficient projects should be balanced with the development of sustainable energy supply.

A SEC offers a wide range of benefits to all stakeholders whilst allowing national policy to be delivered at local level. Carbon Dioxide emissions are reduced when low carbon and renewable energy sources are used which in turn lowers the environmental impact of the community and also facilitates Demand Side Management by greater self sufficiency whilst increasing energy security. New working partnerships are formed between the community, SME's, providers, consumers and householders with reduced energy consumption and therefore reduced cost and reliance on volatile fossil fuels. There is an increase in local economic activity, job creation as well as the development and deployment of technology; thereby reducing the cost of implementation, this coupled with sound governance on Renewable Feed In Tariff's (RFIT, 4.1.4) could have the same effect and consequence as RE in Germany.

4.2.4.1 Sustainable Energy Zones

A Sustainable Energy Zone (SEZ) is a focal point for a SEC with critical mass, where the phased implementation of prioritised projects ultimately builds momentum in a specific geographic zone.

Figure 25: The radiating influence of a SEZ. (SEAI, 2010)

The benefits of a SEZ are many and varied but are concentrated on the anchor activities in a defined geographical area known as a zone; this allows stakeholders to effectively plan for what / how and when defined goals are to be achieved, where this integrated and coordinated approach makes it possible to deliver much more than could be done at an individual level. This approach creates momentum and stakeholders interest in common objectives which can then be expanded into the broader community and region, the momentum thus created by the SEZ and the deliverables realised, influences and radiates out into the wider community.

The particular benefits of a SEZ can be itemised as follows, namely:

- Acts as an incubator for SE techniques and technologies
- Allows projects, proposals and partners to be integrated in a structured way
- Provides a focal point for the community to develop and refine sustainable development and a sustainable energy system around anchor activities and needs.

4.3 Sustainable Networking

For low carbon refurbishment to be successful and have a marked effect on reducing Ireland's GHG emissions, partnership and networking is paramount to ensuring coordination between local governance and legislation from grass roots up.

4.3.1 INTERREG

Interreg is an initiative that aims to simulate cooperation between regions with-in the European Union and involves collaboration among authorities of two or more Member States. It was established in 1989 and is financed under the European Regional Development Fund (ERDF); where co-funding ranging from 50% down to 0% is provided by Member States, regional authorities or the project leaders themselves. Once a programme has been approved by the European Commission, the implementation of the programme is coordinated by

Steering Committees, which consist of representatives of the authorities responsible for Cohesion Policy, where the final beneficiaries of Interreg funds are usually public authorities, interest associations and non-profit organisations. The current programme is Iterreg IV which covers the period 2007 to 2013 and is made up of three strands, namely: Interreg A (cross-border cooperation), Interreg B (trans-national cooperation) and Iterreg C (inter-regional cooperation) (EURDF, 2012b)

SusSET (Sustaining Small Expanding Towns) is a partnership between 12 towns from Scotland, Sweden, Poland and Greece and is an EU Interreg IIIC (inter-regional) funded project (SusSET, 2008) which is based on the three pillars of sustainability (4.1.1; Figure 11: Elements of Sustainable Development. (IPCC, 2000), namely: Economy, Environment and Social. Priorities across all three strands are but not confined to the following: Promotion of urban, rural and costal development; Strengthening the spirit of enterprise; Developing local employment initiatives; Labour market integration and social inclusion; Initiatives encouraging shared use of human resources and facilities for research, development, education, culture, communication and health; Environmental protection, improving energy efficiency and renewable energy sources; Increasing cooperation in legal, administrative and institutional potential and promoting effective sustainable transport systems together with regional development strategies.

Figure 26: Toolkit for Best Practice – Sustainable Small Town Strategy. (SusSET, 2008)

There are currently 43 Interreg approved and funded projects in Ireland under the operational programme: Border, Midland and Western (BMW), Southern and Eastern as well as cross-border, Atlantic Area, Ireland-Wales, North West Europe, Northern Ireland, Ireland and West Scotland, United Kingdom-Ireland and the Northern Periphery. Projects range from developing sustainable regions through responsible SMEs (Small to Medium Enterprises) (Ballincollig), cooperation to foster renewable energy efficiency (Donegal County Council), green infrastructure network (Fingal County Council, Swords), eco-accommodation in rural regions (Shannon development) to enhancing next generation access growth in Europe (ERNACT EEIG, Letterkenny). (EURDF, 2012a) Making use of the Toolkit for Sustainable Small Town Strategy (Figure 26); Table 7 and Table 8 offer some expanded commentary in the context of the National Report on Regional Sustainable Development, Ireland 2007 after taking stock of the recommendations levied by the Sustainable Development Commission, 2006.

Table 7: susSET Toolkit for sustainable small town strategy; Interreg, Irish context. (SustainableDevelopmentCommission, 2006) (SusSET, 2008) (EURDF, 2012a) (Mullally, 2007)

Category	Recommendations	Comments
Social	**PARTNERSHIPS / LOCAL GOVERNANCE & LEGISLATION**	
A	Vertical Partnerships' - joining together different levels of government from international down to local;	Voluntary community standards based on local market instruments and behavioural & information instruments
B	'Horizontal Partnerships' - which can connect different government departments at the same level, or local governments from a number of different towns; or	Future direction of regulation & timescale for inducing higher standards
C	Public-Private- Community Partnerships' - where various members and organisations from government, business and community join forces.	Single National Standards for both existing homes, towns and new homes and structures
D	People want to participate in meaningful ways and will resist consultations which see them (the public) as passive recipients of information.	Local Level
E	It is about getting people involved in the formation of a development proposal, policy plan, performance review, etc and by doing so, gives ownership.	Local / Public (Government) & Public Level
F	The involvement must be a two-way process	Technical Fixes will require active community participation
G	An inclusive community is one where each resident has the same access to services and opportunities as everyone else.	Sustainable Whole Town Strategy
H	Identity is a key component of a town strategy in that it differentiates the town from its competitors and provides the framework within which civic pride can develop.	Tourism (adds economic growth & employment / sustains better transport links / attracts inward investment) Existing Protected Structures of Local Character & Distinctiveness / Monuments & Physical features such as lakes, canal & river.
I	*Community facilities* can include any shared facility that has been provided for the benefit of the entire community. Usually they include places like schools, colleges, libraries, churches, hospitals, halls, banks and postal services. They can also include recreational areas like open spaces, playing fields, swimming pools or skate parks and places for entertainment.	Primary schools and secondary schools, library, churches, old age frail care homes, a community hall and a post office. Open spaces and recreational areas should be in close proximity to the village / town
J	A whole town approach increases a small town's ability to become more sustainable, since it can explore, discuss and resolve issues in the context of the town as a total entity.	A WTS approach can increase community activism in a small town, provide a clear sense of direction for all groups, and make the strategic goals such as 'sustainable development' and 'quality of life' more meaningful.
Environment	**ENVIRONMENT QUALITY**	
A	Natural heritage includes landscapes, coastal areas, rivers, geological (rock) formations, wildlife habitats or general flora and fauna.	Although the landscape is predominantly flat there are natural undulations and hills. Establish nature reserves and protected areas.
B	Small towns can serve as a place for outdoor physical activities, and have a positive impact on the mental health of local residents	Trail walking, historic sight seeing (ancient Fairy Fort), fishing, trail biking, adventure parks, hunting & boating.
C	Transport and its related infrastructure are responsible for the movement of people and goods.	Provide safe and attractive walking and cycle routes between amenities. Provide regular low carbon transport options between major commuter (train & bus) links. General awareness and encourage car pooling, electric hybrids including on-line grocery purchase and community delivery.
Economy	**JOBS & EMPLOYMENT**	
A	Decreased levels of physical activity leading to obesity; Loss of people using town centre shops and services to out-of-town shopping centres leading to reduced economic investment; or, decreased levels of social encounters resulting in the loss of community spirit.	Economic sustainability is best secured by the creation of local or regional self-reliant community economies. Local currencies, community corporations, regional food economies and other locally orientated efforts.
B	Establish working groups that will widen the involvement of others, skill up volunteers, empower them for decision-making and with management of resources, encourage organisational development and high quality management practices.	Self-sufficiency through energy generation, water harvesting, sewage treatment, traditional building materials locally sourced. Locally sourced employment from local resources / quarries to manufacture products such as eco concrete such as papercrete and employment in water harvesting bunds, sewage treatment bunds and permeable paving.
C	Marketing and promotion is the process by which a town or settlement communicates with and sells its development opportunities to investors. In order to generate economic growth, it is necessary to attract investment into the local economy.	Decentralised renewable energy systems, establishment of wood lands & bio crops and possibly reed and thatch, retention of community infrastructure, reduction of transport and greater reuse of materials and waste.

Table 8: susSET Toolkit for sustainable small town strategy; Interreg, Irish context. (SustainableDevelopmentCommission, 2006) (SusSET, 2008) (EURDF, 2012a) (Mullally, 2007)

Category	Recommendations	Comments
Energy	**WHOLE TOWN STRATEGY**	
A	Identify local rivers with all year flow, possibly sufficient to power a small hydro scheme or water to air source heat exchanger may be successfully deployed, where the power required for pumps and motors (distribution) could be sustained by the hydro flow rate. (District Scheme)	RIVERS
B	Identify large pig farms and sizeable chicken farms, including surrounding farm lands which support dairy and meat cattle farming. An Anaerobic Digester (AD) could easily be established to produce methane gas to power a gas turbine for electricity and heat. The heat could be used in the farrowing, weaner & fattening houses where boilers can be relatively easily substituted with heat pipes from the generator where biogas is produced (used as a fuel source). It should be noted that areas of intensive agriculture, already have a large electrical infrastructure, where the electricity produced via the CHPU (Combined Heating & Power Unit) can be fully dispatched into the existing electrical grid. The AD system may also take account of energy from sewage and wet household waste.	FARMING & WASTE
C	Energy crops, SRC Willow, Timber and miscanthus (Grant Scheme) could all be produced on marginal land minimising transport (less than 8 miles circumference)	AGRICULTURE
Food	**SELF SUFFICIENCY**	
A	National Canals which may be in close proximity to the village / town could be established as a viable fishery and fish breeding ground, also contributing to job creation and tourism and local cuisine.	GEOGRAPHICAL ATTRIBUTES
B	Grow your own and grow allotments could be established in the fertile lands of the parish; minimising transport, creating pride & employment whilst empowering the community to a sustained healthy environment with the establishment of local markets. Indigenous herbs and berries should be harvested (Elder Berry Wine)	LOCAL INDUSTRY / JAM / BOTTLED PRODUCE / MARKETS
C	Other local produce could include poultry, meat, fruit, milk & dairy, vegetables (organic) and fish. Such home grown industry could attract outside investment for establishment of local slaughter and process houses. Community driven (church and school) programmes can stimulate and invigorate the parish whilst providing sustainable longativity to such ventures by the possible inclusion of home economics / cooking & growing into the educational curriculum.	INVESTMENT / EDUCATION /
Waste	**MINIMISE**	
A	The establishment of a localised recycle centre with total segregation (Glass, paper, plastics, metals, wood, textiles & green wastes). Wet wastes, biodegradable waste, timber and natural waste to compost and the Anaerobic Digester Plant. Plastic bottles & containers for wash and reuse at markets, plant and seedling containers, etc. Tin cans and metal to be crushed, stored and sent for De Facto recycle. News papers and cardboard to compost and / or recycle centre or reused for school and art projects and re-packaging.	REUSE / RECYCLE
B	Slurry and sewage to the AD Plant; once innate, then as compost and fertilizer.	LOCAL SUSTAINABILITY
C	Recycle, reuse, repair old appliances and consumer goods to feed back into community via charity shops, second hand good's shops, swap shops and markets stalls. Target retailers to comply with a packaging / wrapping return scheme and reduce negative environmental impacts of materials and waste to landfill.	RETAILING
Houses	**BUILDINGS / STRUCTURES / DWELLINGS**	
A	All existing dwellings / buildings and structures to be brought to Passive House Standard; whilst new structures to achieve Zero Carbon and incorporate micro generation features, such as : Wind Power / Photovoltaic Cells / Solar Collectors / Air to Air Heat exchangers / Ground to Air Heat Pumps, Micro CHP, etc	ENERGY CONTRIBUTION
B	Design & Specification Stage consideration in respect of materials employed from recycled / local materials, embodied energy and CO2, dismantling for reuse, Life Cycle Costing and purpose of use insofar as adaptation of locally sourced materials such as straw bales, timber and reed for thatch, local quarries and existing business such as papercrete concrete, etc must be considered.	LIFE CYCLE CONSIDERATIONS
C	Greater awareness and behaviour to peak energy tariffs, employment of smart metering with import / export capability, Building Energy Management Systems, Energy Performance Certificate and Demand Side Management awareness, smart electrical grid and energy efficient appliances where replacement to new is required.	BEHAVIOUR & AWARENESS
Water	**OBSERVED AS A COMMODITY**	
A	Rainwater harvesting from roofs, gutters and permeable paving systems to be stored and reused for gardening, washing, toilet flush and industry / agriculture.	WATER EFFICIENCY COMMITMENT
B	Brown water to AD or naturally filtered via reed beds and fed back to ground source waters.	WATER AWARENESS
C	Natural filtering systems to be employed such as permeable paving with proprietary filter membranes, green roofs and green walls which may also facilitate nutrient rich water and fresh air cooling	EFFICIENT DELIVERY
D	Water Metering, water charges and carbon taxes / credit system to be employed, water efficient fittings (low flow taps / showers), water efficient appliances (dishwashers, washing machines), leak detection and retrofit variable toilet flush	CONSUMER AWARENESS
General	**ALL ASPECTS**	
A	Focus on overcoming barriers by identification, engagement, encourage, enable and exemplify.	COMMUNICATION
B	Develop a Small Town Sustainable Code from grassroots up as to "what works"	BEHAVIOUR
C	Lobby Government for Tax / VAT incentives on key sustainable measures employed	INCENTIVES

4.3.2 Harmonisation

Comhar was established in 1999 to promote consensus on sustainable development after the OECD Environment Performance Review highlighted Ireland's remarkable economic performance on the one hand, yet in spite of the structured transformation, there was a weak decoupling of economic growth and environmental pressures to best international practices (OECD 2000: 19-26). Decoupling of economic activity and environmental degradation requires greater economic efficiency and is considered a key aspect to over arching sustainable development. (Mullally, 2007) Comhar's membership includes both State and non-governmental (NGO) representation in an endeavour to foster a National Sustainable Development Partnership, where the twenty-five members of Comhar are drawn from five nominating panels, made up from seventy-one relevant organisations with a national remit, from State sector, economic sectors, environmental NGOs, social and community NGOs and the professional academic sector.

National initiatives are linked to regional sustainable development priorities which are based on the principals established for sustainable development and the communities support framework. Priorities are liked to the National Spatial Strategy (Central Government, 2002) which defines a commitment to working with the market in pursuit of greater eco-efficiency, the coordination and better enforcement of producer responsibility, to better implement and enforce EU Strategic Environmental Assessment Directive, the promotion of greater participation and ownership of SD at local and regional levels via Agenda 21, create mechanisms for stakeholder involvement and support of policy development through research.

4.3.2.1 Sustainable Accounting

Research linking accounting to the emerging concept of sustainability surfaced in the early 1990s, and has received continuing attention in academic and professional literature. It is difficult to understand the breadth, complexity and enormous challenges which require significant commitment of resources to achieve and implement a sustainable accounting framework successfully; where Gray (1993) identifies three different methods, namely: (Lamberton, 2005)

1. Sustainable cost and full-cost accounting: is the hypothetical cost of restoring the earth to the state is was prior to impact, i.e. the amount of money required at the end of an accounting period in order to place the biosphere back to its position at the start of the accounting period. This method recognises the need to maintain the stock of 'natural' capital for future generations.
2. Natural capital inventory accounting: involves the recording of stocks of 'natural' capital over time, with changes in stock levels used as an indicator of the declining quality of the natural environment. Various types of 'natural' capital stocks are distinguished, namely: Critical (ozone layer, tropical hardwood, biodiversity) / Non-renewable (oil, petroleum and mineral products) / Substitutable (waste disposal, energy usage) / Renewable (plantation timber, fisheries)
3. Input-output analysis: accounts for the physical flow of materials, energy inputs, product and waste outputs in physical units. It aims to measure all material inputs and outputs of finished goods, emissions, recycled materials and waste for disposal.

The World Summit on Sustainable Development (WSSD) held in Johannesburg August 2002, provided a rigorous framework for the application of Triple Bottom Line (TBL) accounting and the Global Reporting Initiative (GRI), where the guidelines draw on the accepted three-

dimensional definition of sustainability using a series of performance indicators to measure each of the economic, environmental and social (employee, consumer, human rights, corruption and bribery) dimensions; however many of the social performance indicators are difficult to measure in quantitative units, more-over, absent is any guidance as to how these competing elements are prioritised, whilst it is doubtful whether continued economic growth is compatible with ecological sustainability.

Environmental accounting research has focused considerable attention on the valuation of environmental assets, liabilities and costs; this has led to estimation techniques for facilitating the valuation process and is therefore potentially destructive. (Lamberton, 2005)

In 1999, the Central Statistical Office (Ireland) published a report on Pilot Environmental Accounts (PEA) within a national accounting framework to show how the economic development in a variety of different sectors impacts on the environment and the economy; although the PEA did not make inclusion of the social aspect, national environmental accounting is being considered for policy integration in the Irish context. (Mullally, 2007)

The ESRI Environmental Accounts are the most extensive accounts for Ireland, and the only one's that adhere to the international standards which were agreed in 2003. There are four parts to the environmental accounts, namely:

1. Emissions and waste
2. Resource use
3. Expenditures on environmental protection
4. Economic value

The data comes primarily from the Central Statistics Office (CSO), the Environmental Protection Agency (EPA) and the Sustainable Energy Authority Ireland (SEAI). Data on the

economic value of the environment is scattered and inconsistent, whilst the amount of Data on emissions and resource use is impressive at first glance, the ERSI Environmental Accounts are heavily biased towards the climate and energy with reasonable coverage on waste and acidification. (Lyons, 2006) The use of land, water and materials is largely omitted; whilst the social aspect and large groups of chemicals including many potential harmful ones are ignored, this reflects the paucity of data.

4.3.2.2 Land rights and sustainable development

The Roman concept of 'allodium' (absolute ownership) is still in use in many countries, but the status of land ownership in the future must be to establish both the legal status and the state's control over an individual's rights. To enforce owners to use their land so that sustainability can be achieved must be a consideration for future development, where planning applications for development must investigate the sustainability nature of any proposal, and be monitored to ensure their actions after approval are implemented. (Bullard, 2002)

The concept of sustainable development arose after the 1974 United Nations adoption of a Declaration for the establishment of a New International Economic Order, an excerpt from the 1976 U.N. conference on Human Settlements (Habitat I) stated the following:

> ***"Land...cannot be treated as an ordinary asset, controlled by individuals and subject to the pressures and inefficiencies of the market..."***

Sustainable development was brought to America when President Clinton initiated the Presidents Council on Sustainable Development, where the decision making committee began with Agenda 21 which was unveiled at the 1992 Conference on Environment and

Development. Agenda 21 addresses virtually every aspect of life and is primarily divided in four sections, namely: (Clarke, 2009)

- Section I : Social and Economic Dimensions
- Section II : Conservation and Management of Resources for Development
- Section III : Strengthening the Role of Major Groups
- Section IV : Means of Implementation

In each of its forty chapters, Agenda 21 presents many policy recommendations that member states are expected to adopt; for example, chapter 5 Demographics and Sustainability; chapter 7 Human Settlements and the foundation for sustainable communities; chapter 10 Planning and Management of Land; chapter 18 Management of Water; chapter 30 The role of Business and Industry and then chapter 38 International Mechanisms and Institutions. Agenda 21 calls for the creation of:

> ***"...National strategies, plans, policies, and processes which are crucial in achieving a sustainable world."***

Agenda 21 cites that private land use decisions are often driven by strong economic incentives that result in several ecological or aesthetic consequences, and that the key to overcoming this is through public policies. (Clarke, 2009)

In Britain the signing of the Magna Carta by King John at Runnymede in 1215 together with the Bill of Rights in 1688, did not achieve for Britain the powerless and nominal monarchy that had been intended (Cahill 2001). The 63 Articles of the Magna Carta have become the source of many of today's concepts of human rights and incorporated into the European Convention on Human Rights as statute law in October 2000. (Bullard, 2002)

The object of sustainability is to leave the land in a better state than that which the owner found it in at the time of acquisition of their respective right; hence the ideal would be for all citizens to cooperate with the government to achieve sustainability on the land which they own or rent, however, there should be a healthy balance between human rights and government legislation and controls, that is peoples precious land rights should not be diminished in the process of change to achieve sustainability. (Bullard, 2002)

The Foundation for the Economics of Sustainability (FEASTA) made a submission on Sustainable Development to the Oireachtas Sub-Committee on Sustainable Development 27 October 1999; where FEASTA suspects that if Irish sustainability is monitored in terms of the thirteen factors which contribute to the quality of life rather than the monetary aspect, the Committee will find that the country is moving away from sustainability rather than towards it. This has lead to the re-emergence of the land question in Ireland 10 October 2003; where FEASTA cites the downside of privatised land ownership has lead to housing becoming more expensive, rent levels in the private rent sector have escalated, local authorities have been priced out of the land ownership market, cities and towns have sprawled as more and more land was zoned and single house site sales have started to impact on the environment and effect community servicing costs and farmland prices. The knock-on effects of high land costs have affected infrastructure development programmes, business competitiveness and Ireland's attractiveness as a tourist destination including social cohesion and democracy.

4.3.2.3 Sustainability in a Networked World

(Petzel, 2009) argues that the World Wide Web has huge collaborative potential which can be strategically harnessed towards sustainability. Petzel explores the research led by Peter Gloor of MIT titled 'Collaborative Innovation Networks' (COINs) in the practical application of how sustainable networking could be part of a global movement towards a sustainable society,

where millions of practitioners could successfully collaborate around a shared vision, much like Linux and Wikipedia. It is important to ascertain a means by which to evaluate strategic sustainability implications of an organisational structure and its actions; where the extensive body of research by Karl-Henrik Robert et al, titled 'the Framework for Strategic Sustainable Development' FSSD state that in a sustainable society, nature is not subject to systematically increasing:

- Concentrations of substances from the earths crust
- Concentrations of substances produced by society
- Degradation by physical means
- And that, in society, people are not subject to conditions that systematically undermine their ability to meet their own needs. (Holmberg and Robert, 2000)

Further; FSSD explores how COINs may or may not be strategic towards sustainability, where the five step framework outlined in FSSD need to be understood and appreciated for the proposed collaboration to work, namely:

1. Looking at society within the biosphere and identifying characteristics and principals integral to the functioning of the system, such as: diversity, interdependence, and self organisation.
2. Defining what success means within the system
3. Identifying guidelines to ensure any actions taken towards sustainability are strategic towards success.
4. Evaluate all actions against strategic guidelines, so as to ensure they will move towards success within the system.
5. Considering tools to help support and implement these actions.

Petzel concludes by stating that although FSSD can provide the necessary shared language and COINs holds the potential to accelerate societies movement towards sustainability; the most probable barrier remains the lack of understanding of the difficulties and problems associated with web-based collaboration, whilst FSSD supports vision led working, COINs requires strong well-communicated visions in order to succeed. (Petzel, 2009)

4.3.3 Efficiency and Sustainability

Woodward, 1995, poses the argument that an efficient economy is not necessarily a sustainable economy, and that when considering policy alternatives to address global warming, economic principals may not necessarily realize the required results. (Woodward, 1995) Further; Woodward argues that carbon taxes are the justification for the use of the tax policy which again is based on the theory of economic efficiency, where taxation uses the market mechanism to allocate adjustments to the GHG emissions problem and does not sufficiently address the implications associated with sustainability. The efficiency criterion does not help distinguish between sustainable and unsustainable time paths; where already, evidence indicates that our production and consumption activities have committed future generations to a warmer climate than present, and with much diminished economic opportunities for future generations; hence, policies arising from benefit-cost criterion will be incomplete if society's objective is a sustainable economy.

Following Woodward's argument, it would seem that the UK, Ireland's closest neighbour has arrived at the pronouncement of the choice ultimately facing most western economies, to stick with high carbon or make the necessary transition to low carbon, right for climate change, energy security and new market job creation, where 40% of all electricity should be obtained

via low carbon sources by 2020. (Central Government, 2009) The UK now recognises that the consensus of scientists spanning over 130 countries agree that human activities are causing global warming, ocean acidity is rising and having a detrimental impact on many ocean animals that build shells of calcium carbonate, whilst the warmest year in the UK on record was recorded in 2006. Academics in the UK are warning of irreversible changes even if the world could stabilise levels of greenhouse gas levels tomorrow, warming levels of at least 1,4°C by 2100 are almost certain due to the time lag between emissions and temperature rise.

Figure 27: Limiting temperature rises to 2 °C. (Central Government, 2009)

In the National Development Plan 2007 – 2013; Ireland has identified several weaknesses in current policy, namely:

- Continuing imbalance in regional development
- Major environmental challenges which must inform investment and land use decisions
- Housing affordability problems, especially in urban areas
- Signs of declining competitiveness, with some costs rising at levels higher than global competitors
- Under development in Science, Technology and Innovation

The National Spatial Strategy (NSS) sets out the vision and strategic framework for achieving sustainable and balanced regional development in Ireland, "developing the full potential of each area to contribute to the optimal performance of the State as a whole – economically, socially and environmentally," (Central Government, 2007a) where these policies will be explored to a greater degree in the ensuing chapters.

5. CHAPTER 5: REFURBISHMENT

5.1 Introduction

It is generally acknowledged in Ireland and throughout the world that climate change is the single greatest challenge faced by humankind. In order to reflect that priority the Government is committed to taking decisive action to reduce our emissions of carbon dioxide.(department of the Environment, 2007)

> ***"Despite efficiency improvements, total energy use has been rising in the residential sector by around 1% per annum and in non-residential buildings by 0.4% per annum since 1970, with any reductions in carbon achieved only through fuel switching." (Hinnells, 2008)***

Ireland's total primary energy requirement (TPER) in 2010 was 14.57m Tonnes of Oil Equivalent (TOE), and increase of 5.7% since 2000.(CSIR, 2010)

Evidence published by the Environmental Change Institute at Oxford University indicates family size is declining from 3 persons per dwelling in 1960 to a projected 2.1 persons in 2050 (Boardman, 2004) whilst at the same time population is increasing (4.1) and the total number of homes are increasing. According to Roberts; homes are not getting proportionately smaller in line with the family size decline, hence the result is more space per person. (Roberts, 2008) Boardman has calculated that per capita, the energy consumption is roughly 60% higher for a single-person household than for a two-person household, with more people sharing appliances and a lower floor area per person associated with heating needs. (Boardman, 2004)

According to Hinnells; there has been a significant increase in the proportion of detached homes, with an increase from 1970 levels at 10% to 22% in 2005 and an estimated 25% in

2050 culminating in more external wall space which results higher heat loss. This trend coincides with an increase in wealth, comfort levels, demands for hot water, consumption of electricity in lights and appliances. (Hinnells, 2008) Power states that 70% of newly formed households are single people living alone, which has increased the energy consumption per person of energy space. (Power, 2008) According to Pitts; the increase electricity based energy demand from buildings, has increased by more than 150% since the 1970s, with the largest increase coming from the spread of consumer electronics (Pitts, 2008b). Total energy usage within the UK housing sector has risen by 23% and energy consumed by lighting and appliances has more than doubled in the last 35 years (Davies and Osmani, 2011b). Regression analyses on large households as published in the Irish National Survey of Housing Quality 2001 – 2002 and CSO Household Budget Survey 2004 – 2005, revealed that those homes that have more energy saving features are also likely to have a high potential energy use by way of appliance ownership. (Lyons, 2006) It is estimated that electrical lighting constitutes 30% of total domestic electricity consumption and 19% of global electricity use, (Mahlia, 2004) Xing suggests that lighting energy use can be reduced by 75-90% through combing day-lighting (smart window, glazing and shading technology), energy efficient lighting and the use of controls. (Xing et al., 2011)

Space heating accounts for approximately 50% of the household energy use in the UK, and in the EU27, this figure averages closer to 70%. The Total Primary Energy (TPE) use is increasing due to the increasing number of households and larger dwelling size; with a direct relationship between GHG emissions and space heating, this area is contributing to climate change (4.1.2) and global warming.(Galvin, 2010) Xing states that space heating accounts for the largest building energy use (about 40% of final energy consumption and about 85% of domestic energy consumption); where external wall insulation and improving air tightness greatly reduces energy bills. (Xing et al., 2011)

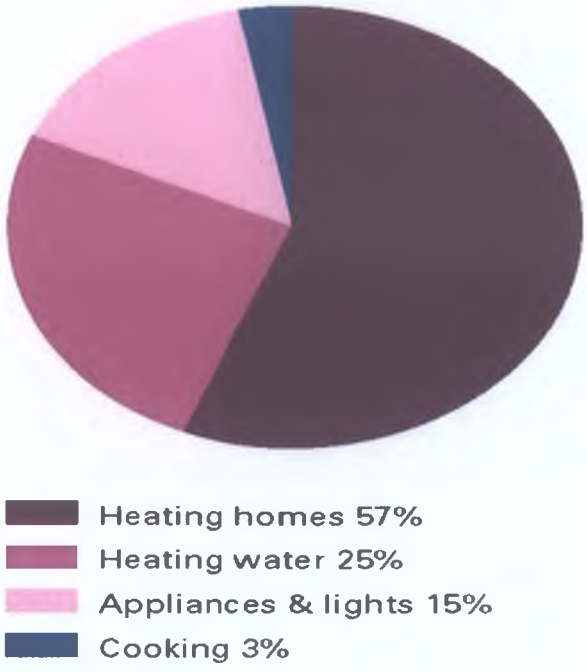


Figure 28: Energy Trends, UK. (Central Government, 2009)

Rapid and deep reductions in CO_2 emissions can only be realised through energy and environmental policy; however, such policies must also ensure that the resilience of the energy supply system is retained and that key renewable generation is enhanced. (Lowe and Oreszczyn, 2008) Significant changes in the way policy is formulated and implemented is key to ensuring energy efficiency in dwellings is achieved if the global mean temperature (4.1.2) rise, is to be held to 2K. (Lowe and Oreszczyn, 2008) The UK government has developed a policy framework to encourage the deployment of district heat networks, where it was noticed the importance in developing business logic as sparsely distributed housing stocks posed challenges, mainly due to high connection costs. (Xing et al., 2011) Seasonal thermal storage can play a significant role in balance heat demand and RE supply, such as underground thermal energy storage (UTES) and phase change materials (PCMs) can prove lantern heat in shorter term. Underground cold water reservoir and boreholes for passive cooling in hot arid regions, whilst thought to simple material choices such as microencapsulated impregnated wall board which will offset air-conditioning plant.(Xing et al., 2011)

"The main barriers to progress are located in policy, process and availability of humane resources, rather than in technology as narrowly defined." (Lowe and Oreszczyn, 2008)

There are two main European Directives influencing the environmental, cultural and financial drivers on Low Carbon House Refurbishments (LCHR) in the UK; namely, the EU Renewable Directives which sets binding targets on energy from renewable resources and the Energy Performance Buildings Directive (EPBD) which is focused on the improvement of energy efficiency and the development of a national calculation methodology for monitoring energy use (Davies and Osmani, 2011b).

The key objective of developing Ireland's Sustainable Development Model is to equate environmental pressure to relevant economic developments; policy instruments can then be formulated to target future pressure points where environmental problems are likely. (Lyons, 2006)

In the National Spatial Strategy 2002 – 2020; the government encourages residential development in small towns and villages, thereby supporting the economic provision of existing infrastructure. (Central Government, 2002) Whilst this policy might encourage Greenfield development; the government advocates Refurbishment in certain instances to protect the urban identity, to protect buildings, structures and other physical elements of cultural heritage and also to minimise disruption to communities, and Brownfield regeneration in others to prevent urban sprawl, reduce the loss of agricultural and other land to urban uses as well as to create a green setting for cities and towns which will provide people with opportunities and access to outdoor recreation and create tourist and business interest.

"The challenge of urban sustainable development is to solve both the problems experienced with cities and the problems caused by cities, recognising that cities themselves provide many potential solutions" European Commission Expert Group on the Urban Environment. (Central Government, 2007a)

According to Power, the overall cost of insulation measures in buildings is negative; the energy savings resulting from insulation measures have demonstrable payback times within the lifetime of the products and without economic subsidy.

Agenda 21 initiatives by local authorities can bring together many critical urban policies, which influence sustainable development of urban developments.

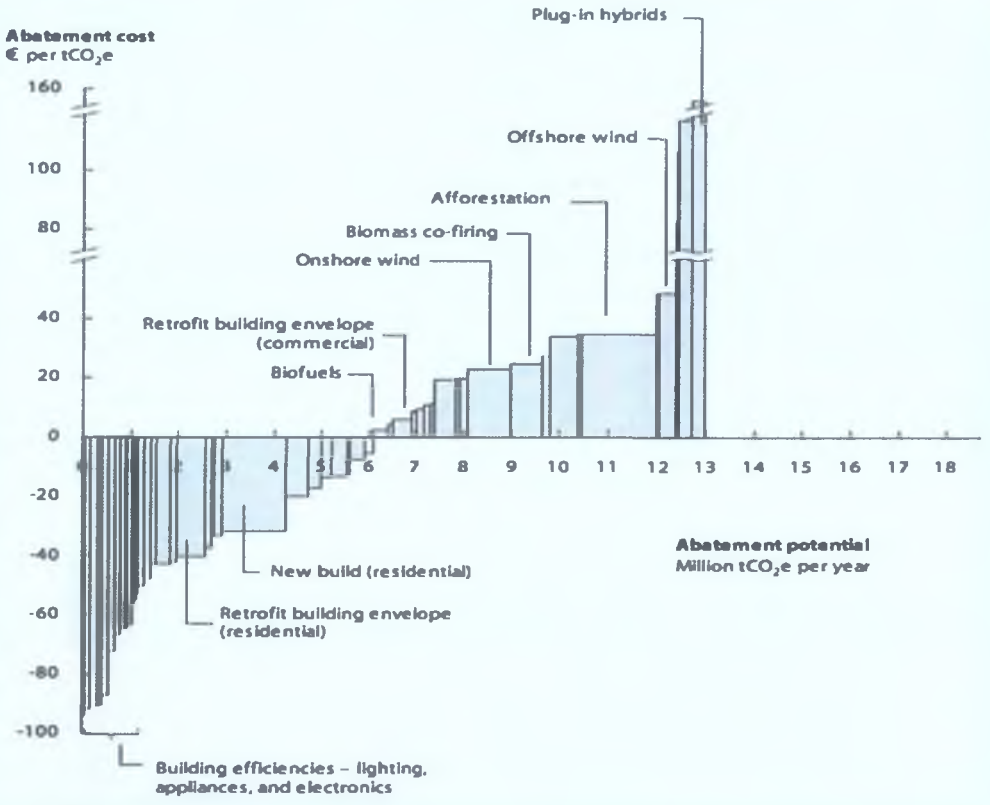


Figure 29: Ireland 2020 abatement cost curve (Motherway., 2009)

Figure 29: Ireland 2020 abatement cost curve (Motherway., 2009) shows that approximately 1 million tCO2e can be saved per year with a negative cost of €80 per tCO2e by implementing simple building efficiencies in lighting, appliances and electronics. Almost 2 million tCO2e

can be saved with a negative cost of approximately €40 per tCO_2e in retrofitting residential building envelopes, such as double glazing, external wall insulation and roof attic insulation measures; whilst new residential build will have similar savings and costs by the implementation of energy efficient 2008 Building Regulations. Power substantiates this in stating that 60% reduction in energy use can be achieved in tenement flats with insulation to roofs, external walls, double glazed windows, gas central heating and draft sealing doors; however, it may be technically possible, using current available technology, to achieve CO_2 emission reductions in excess of 80% by the middle of this century. (Power, 2008)

Figure 29 assumes a crude oil price of $60 per bbl (the standard barrel of crude oil is 42 US gallons or 158.987 L, and is still used as the unit for measurement, pricing, tax and regulatory codes); according to the SEAI and Motherway, emissions reductions of around 12.4 million tCO_2e can be achieved in the year 2020, of which approximately one-third relates to installations in the power-generation and industrial sectors that are covered by the EU ETS (European Union Emission Trading Scheme, as of June 2012, the EU ETS covers more than 11,000 factories, power stations and other installations with a net heat excess of 20 MW in all 27 of the EU Member States plus Iceland, Norway and Liechtenstein). The scheme provides economic incentives for abatement at a marginal cost up to the international market price allowances, where to date, EU Allowances have been trading at substantially less than €80/ tCO_2, the remaining reduction potential of approximately 8 million tCO_2e, lie outside the EU ETS. The net reduction is substantially less than Ireland's binding 20% national reduction target against 2005 levels. Further, Motherwell argues in the Technical Appendix that an additional 4 million tCO_2 can be achieved via behavioural measures (Motherway., 2009); whilst DEFRA claims that behavioural change is as much needed as regulation and enforcement, whilst enforcement can only progress so far. Dobson (2007) recommended fiscal incentives, whilst it has also been argued that Corporate Social Responsibility (CSR) has the

potential to be a commanding driver with reduced operational costs coupled with the potential for higher rents and sales for energy efficiency. (Davies and Osmani, 2011b)

The new Renewable Energy Directive covering electricity, heat and transport sets out a target of 16% renewable energy for Ireland by 2020 and 20% of the EU's total energy consumption from renewable energy by 2020. In Ireland, a recent study estimated that meeting the current target of 40% renewable electricity by 2020 will create more than 10,000 jobs from activity associated with Ireland's domestic renewable target; according to Motherway, these jobs are in the areas where Ireland has the right skills. The export opportunities associated with the skills, services and technologies could be far greater. (Motherway., 2009)

SEAI Strategic Plan 2010 – 2015 proposes specific Irish policy goals which have proven to be over-optimistic in the current economic climate, such as the acceleration of renewable electricity from 15 per cent demand in 2010 to 40 per cent by 2020; the fast tracking of ocean energy deployment to a leadership position of 500 MW by 2020; the support of micro generation development and deployment, and to enhance fuel diversity in generation. (SEAI, 2011a) More realistic policy proposals revolve around a growing suit of new energy positive buildings complimented by strong energy retrofitting of all existing buildings through robust new standards and regulations to support retrofitting with an emphasis on quality and a leadership position demonstrated by the public sector and policies such as the National Energy Retrofit programme to transform Ireland's existing building stock and the Energy Demand Reduction Target which emphasises the role of utilities and service companies.

5.1.1 Outlook

According to the NEEAP submitted in 2007, Ireland has targeted the residential sector as the source of the largest share of its energy savings at 56% in total. (Dineen, 2010) The SEAI published over 90,000 Building Energy Rating's (BER) in 2010, bringing the total homes rated to over 170,000. The suit of consumer print, information and web-based materials was complimented with a smart phone application in 2010 based on the booklet 'Householders', be your own energy manager, plots a simple roadmap to facilitate consumers manage and reduce their energy bills by up to 20%. The SEAI's educational Schools Programme aims to help form good long term behaviours and attitudes to energy efficiency, where books, DVDs and posters were distributed to over 600 schools. The programme delivered 710 energy climate change workshops nationwide, reaching 20,000 students and the annual school competition, 'One Good Idea' attracted 156 entries from around 800 students. (SEAI, 2010)

Hazardous waste, for which projections are shown in Ireland's Sustainable Development Model (ISus) version 0.4 (actual data to 2007) Figure 30, is dominated by the construction and demolition sector, which produces contaminated soil. It has been assumed that the industrial waste (chemicals) arising are proportional to sectoral output, so projections show a strong association with the economic cycle. (Lyons, 2006)

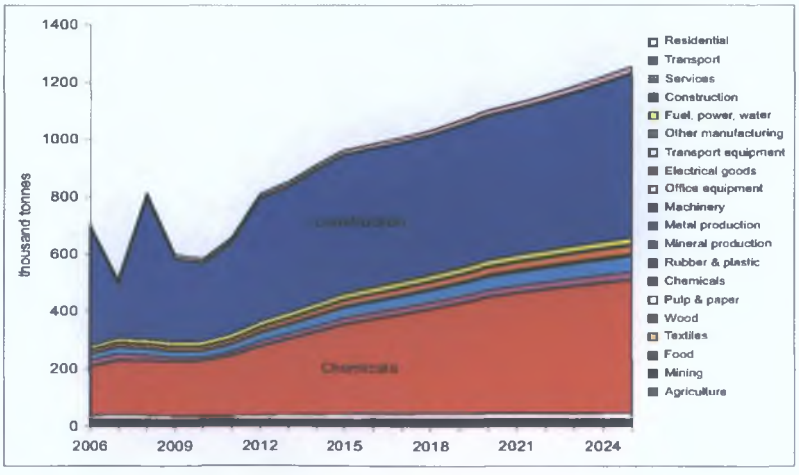


Figure 30: Hazardous waste by source as projected by ISis, version 0.4 (Lyons, 2006)

Demolition and buildings are the largest source of landfill by volume, approximately 30% of the total volume. (Power, 2008) Power makes a strong economic case against demolition, stating that the average cost to demolish a home is £17,000 to £35,000, this excludes costs associated with delays, new infrastructure and new housing.

The number of births in Ireland was 75,100 in the twelve months to April 2011, while deaths stood at 27,400 resulting in a natural increase of 47,700. Whilst the natural increase in population continues to be strong, the overall emigration is estimated to have reached 76,400 in the year to April 2011, this is an increase of 16.9% on the year 2010 (65,300), this resulted in a negative population growth over this period, bringing the population estimate to 4.48 million in April 2011 (CSO, 2011) and has been a contributory factor in house completion decrease as per Table 14.

5.1.2 Greenfield Development

> ***"The design of the built environment is recognised as having an impact on people's well-being and behaviour and, thereby, on people's health. Good design in new housing and in upgrading and rehabilitation is important for the creation of sustainable living conditions."*** **(Davies and Osmani, 2011b)**

According to Pitts; the provision of space for alternative energy supply, capture and storage, such as Biomass, solar photovoltaic, wind turbines and small scale micro combined heat and power (CHP) is more easily provided in new construction as opposed to contemporary designs which make no allowance for these extra requirements. Further, new construction techniques and materials more readily effect reduction in demand by obvious building design features such as orientation, insulation, glazing, shading, ventilation, pre-cooling in summer,

positioning of rooms, the use of exposed thermal mass and the use of low power or passive systems. Low-energy cooling such as night-time ventilation or natural cooling can be exploited via the use and deployment of integrated and smart sophisticated control systems, connecting alternative energy sources, grid supply and energy storage such as fuel conversion devices and equipment. (Pitts, 2008b)

Hamza advocates new construction where quality assurance checks and energy regulations are observed; evidence of improved quality of construction to deliver air tightness, air pressure testing, separate energy metering and proof that the as-built construction has an accepted building emission rate that does not exceed the BER simulated in the design stage. (Hamza, 2008)

5.1.3 Regeneration and Brownfield sites

> ***"The human pressure on land as a resource requires agricultural regeneration of land and buildings used in the past and not to build on land, especially the green field sites. In an ideal situation only brown-field sites should be used for development." (Bullard, 2002)***

The Department of the Environment has taken the initiative to promote higher residential densities in redeveloping Brownfield sites and also endorses infill inner city social housing capitalising on the proximity of existing services, amenities and to town centres. (Central Government, 1997)

In March 1997, the Minister for the Environment and the Minister for Housing and Urban Renewal Ireland, announced a major redevelopment of the Ballymun Brownfield housing

estate, in an integrated strategic plan for economic and social development. (Central Government, 1997) The tower and spine blocks of flats were demolished progressively over eight years and replaced with a self-sustaining urban centre for 20,000 people who will continue to live in and around the area. The Brownfield development included consultation with, and the involvement of the local community in its implementation.

5.1.4 Retention to Refurbishment

Human activities in existing buildings consume approximately 40% of the world's total primary energy (TPE) consumption; in the UK this figure is around 30%. (Galvin, 2010)

Existing buildings represent the greatest opportunity for efficiency improvements and sustainable development, according to Xing; where the European Union (EU) is shifting away from heavy industry and towards the services sector; and since 2000, close to 80% of the total working population in the UK are employed in the services sector, resulting in increased floor area, increased space heating, lighting and cooling. Buildings have become the largest sector in terms of energy consumption and account for some 45% of carbon emissions, where Xing states that an estimated 80% of buildings that will be occupied in 2050, have already been built. (Xing et al., 2011)

In a lifecycle costing method used for high-rise housing in the UK, the results indicated that there was a difference of between 25% to 60% in the heating loads of the first and top floor apartments, whilst ventilation control measures were found to be the most effective in reducing heating loads for floors between. Wall insulation measures were shown to be the least effective in view of the relatively high percentage of glazing; however, Gorgolewski

found that several envelope insulation measures installed together saved more than the sum of their individual savings. (Gorgolewski et al., 1996)

According to Galvin; renovating a 1950s German apartment block to the pre-2004 minimum standard can cost less than 3 cents per kilowatt hour (kWh) of Primary Energy (PE) saved over the lifetime of the renovation. This compares to the much higher cost of generating energy from renewables such as wind power at 8 cents, photovoltaics at 28 cents and the spot price of electric generation costs of 7 cents and heating oil costs of 6 cents per kWh. Refitting homes, if sensibly planned, can be one of the most economical methods to save energy and reduce GHG emissions. (Galvin, 2010)

Ireland's recently published National Energy Efficiency Action Plan (NEEAP) for 2009-20 includes for quantitative estimates to avoid CO2 emissions through refitting of existing buildings and enforcement of new building regulations.

5.2 Greenfield Development

In Ireland, 5.6 houses and apartments were completed per 1,000 of population in 1990; however, by the year 2007 the ratio had increased to 18 per 1,000 with a population peak in 2005 when 20.9 houses and apartments were completed per 1,000. (CSO, 2008)

In general, there should be a presumption against urban-generated one-off rural housing, unless permission is for certain categories of person whose occupation requires them to be rurally based, thereby catering for genuine needs. In any event; principals for such Greenfield development should apply, namely: (Scott and Murray, 2009)

- Development along national primary and secondary roads should not be allowed for traffic safety reasons;

- The need to preserve landscapes and views of special importance should be recognised;
- Appropriate design, building materials and good use of site;
- The rehabilitation of derelict houses should be encouraged;
- The site must be suitable for sewage disposal and drainage, alleviating any concerns for groundwater contamination

The House of Tomorrow Programme has its origins in the Government's Green Paper on Sustainable Energy 1999, which identified deficiencies in the energy performance of Irish housing; where in 1993 only 66% of households had attic insulation, only 59% had lagged hot water tanks and only 32% had double glazing. (Central Government, 1997) The Sustainable Energy Authority Ireland (SEAI, House of Tomorrow: energy technology specifications, 9.2) confirmed a total of 90 projects over a five year period (2001 – 2006) which would receive approximately €22 million in funding and include 4,000 homes. (SEAI, 2004)

In the SEAI abatement potential (SEAI, 2009a) on emissions in Ireland 2030; the top three levers for building emission abatement are:

- New build efficiency package residential (2.8 $MtCO_2e$)
- Retrofit building envelope package 1 – residential (1.1 $MtCO_2e$)
- Retrofit building envelope, package 2 – residential (0.8 $MtCO_2e$)

New residential completions based on SEAI data are 40,000 in 2014 stabilizing with the average new build to be 130 m2 at 150kWh/m2 and a building life of 60 years (commercial growth based on GDP growth adjusted for ESRI credit crunch projections). New build efficiency package should achieve an energy consumption comparable to passive housing of 40 kWh/m2 by reduced energy demand through improved building design, orientation,

insulation, air-tightness, improved materials and construction of walls, roof, floor and windows whilst also ensuring usage of high efficiency HVAC and water heating systems.

> ***"There is a need to apply pressure on land owners to achieve sustainable development showing that the benefits gained by such actions far outweigh the costs, while benefiting the rest of society in the process." (Bullard, 2002)***

The life expectancy of the population is increasing, the occupancy of housing is therefore lengthening, these factors question the design and construction of housing for the future as well as energy requirements.

5.2.1 Evidence and argument

Given the frenzied development trends employed in Ireland over recent years, Greenfield development has gained a negative nuance. Pratt argues that with poignant planning and research into corporate demands and trends, business and industry can be integrated within the dwelling landscape whilst having the potential to consider a 50 year time horizon to future trends and technologies.(Pratt, 2008) Therefore; good urban planning coupled with Part L:2008 regulations which apply for all new homes, limit the heat loss and, or maximise the heat gains through the fabric of the building; require 40 % improvement in energy efficiency, (Durkan, 2009) must provide a proportion of their heating or power from onsite renewable energy sources, a minimum of 10kWh/m2/annum by utilizing solar thermal panels, heat pumps or either biomass boilers, or alternatively a minimum of 4kWh/m2/annum from solar photovoltaic or wind turbines, in addition to an air permeability pressure test of 10m3/hr.m2 can more easily be realised through new developments, construction techniques, materials and modern design. (TheHeritageCouncil, 2004)

New Buildings incorporating modern construction methods may offer substantial rewards.

"When compared with traditional methods of construction the modern methods of construction (MMC) house resulted in a 34% reduction in embodied carbon." (Monahan and Powell, 2011)

When undertaking Greenfield development; it worthy to note that the materials choice and specification may be carefully selected to coincide with planning, life cycle of building occupants and potential future use as well as embodied energy. An effective means of reducing fossil fuel and net CO2 emissions to the atmosphere would be to incorporate wood by-products into energy systems and design, according to (Gustavsson and Sathre, 2006) The opportunity for careful planning and evaluation also exists as

"Case study results showed that a low-carbon product design can be simple and easy to apply in the evaluation of alternative design solutions; thus, making low-carbon product design possible during the embodiment design stage." (Song and Lee, 2010)

From an energy consumption and carbon emissions stance; timber as a material was found to be the preferred option with steel being least desirable.(Dias and Pooliyadda, 2004) Greenfield development, according to Szalay can greatly influence our choice and selection of materials in new-builds where we are able to take into account the energy needed for manufacturing materials against the rationality of operational energy saving measures. (Szalay, 2007) This research is further supported by Zabalza, where

"The building industry uses great quantities of raw materials. Choosing materials with high content in embodied energy entails an initial high level of energy consumption in the building production stage but also determines future energy consumption in order to fulfil heating, ventilation and air conditioning demands." (Zabalza Bribián et al., 2011)

"Challenging targets are now in place for new housing to move towards low or zero energy and carbon standards." (Wright, 2008)

With improved design from inception, higher Building Energy Ratings (BER), lower embodied emissions and greater running efficiency; Demand Side Management, emissions as well as ESB grid reinforcement may be alleviated, whilst reducing fuel poverty. (SEAI, 2008). Greenfield development can greatly facilitate

"life cycle zero energy buildings (LC-ZEB), as a factor to aid in building design with a life cycle perspective." (Hernandez and Kenny, 2010).

Ramesh argues that there is a fine line between designing for low energy buildings vs. self-sufficient building, where excessive use of passive and active systems in a building may be counterproductive and lead to higher operating energy and a loss in efficiency in the life cycle context. (Ramesh et al., 2010)

In Greenfield development; new services and infrastructure could mitigate against leaking pipes and employ smart metering and smart technology from the onset, thereby allowing greater flexibility, higher efficiencies and better control. The buildings can incorporate space for alternative fuels and for energy storage systems anticipated in Part L 2010 requirements. (Pitts, 2008a)

It is thus important to make the distinction that although Greenfield development; if correctly employed, can have a sustainable effect on resources, embodied energy, running and life cycle costs as well as demand, emissions, design for deconstruction and recycling; given that cities already have infrastructure, transport routes and amenities in place, there is a strong argument to drive retention and refurbishment in the short term,

"the densities with which urbanised regions are occupied can have a significant impact on energy use and emissions, via the patterns of personal mobility that are enabled and encouraged." (Gordon, 2008)

Power further substantiates this argument by motivating retention and upgrading of existing stock, thereby saving materials and land, enhancing the momentum for regeneration by maintaining existing communities and alleviating the need for further infrastructure and area blighting.(Power, 2008)

5.3 Regeneration and Brownfield Development

Successful Brownfield development requires a partnering approach involving cross-sectoral consultation and participation between local authorities and organisations, business and community interest's representative of the local area. Following the enactment of legislation by the Oireachtas, the Dublin Docklands Authority was established on 1 May 1997, this lead to social and economic regeneration of the Docklands Area and was later recognised as being highly successful in directing investment towards urban regeneration thereby confirming the value in terms of sustainability of renewing inner urban areas. (Central Government, 1997)

Although all parts of the country experiences population growth; the majority of the national population growth in absolute terms is takes place in the Leinster area, approximately 62%, with the greater Dublin Area growth being the fastest and most prolific (Central Government, 2002), regeneration then, is part of the natural solution to cater for this growth in a sustainable manner.

Table 9: Spatial Strategy, evaluation framework. (Central Government, 2002)

Housing Location in Urban Areas	Evaluation Considerations
The Asset Test	Are there existing community resources, such as schools etc, with spare capacity?
The Carrying Capacity Test	Is the environmental setting capable of absorbing development in terms of drainage etc?
The Transport Test	Is there potential for reinforcing usage of public transport, walking and cycling?
The Economic Development Test	Is there potential to ensure integration between the location of housing and employment?
The Character Test	Will the proposal reinforce a sense of place and character?
The Community Test	Will the proposal reinforce the integrity and vitality of the local community and services that can be provided?
The Integration Test	Will the proposal aid an integrated approach to catering for the housing needs of all sections of society?

Broad evaluation frameworks as suggested in Table 9 propose a test as to the most appropriate action for housing in urban areas, which may lead to possible urban consolidation priorities (Table 15) identifying opportunities for re-use and extension within the existing urban environment.

5.3.1 Planning

Brownfield urban design should include the key aims as prescribed (Central Government, 2007b) by the Quality Housing Guide for Sustainable Communities through the creation of a high quality built environment, by reducing as far as possible, the necessity to travel, particularly by private car for the purpose of employment, education and recreation, and to avail of local services and amenities necessary for living. Additional features of sustainable neighbourhoods should include:

- Compact, energy efficient incorporating high quality materials;
- Accessible via public transport networks and also meeting the needs of the pedestrian and cyclist;
- The provision of a good range of amenities and services within easy and safe walking distance

- Access the characteristics of the neighbourhood that can be built upon to strengthen local identity and reinforce local communities;
- Make full use of the site's natural features that can help to create a more sustainable development; and
- Integrate the development with the surrounding built environment, using the correct materials, forms and landscape elements by respecting existing street lines and existing urban structures.

Power argues that demolition plans are mostly drawn up on an area than on a single property basis, removing already renovated and well maintained properties alongside inadequate or derelict ones.

In addition, the Sustainable Development Policy Framework for the National Spatial Strategy (Central Government, 2002) captures further concepts which are important to urban development, namely:

- Has economic, social and environmental dimensions which together can contribute to a better quality of life;
- Will only be sustainable if a balance is achieved between these three dimensions;
- Should allow future generations to enjoy a quality of life at least as high as our own; and,
- Should respect our responsibilities to the wider international community.

5.3.2 Evidence and argument

Brownfield sites are typically referred to as: abandoned, idled or underused industrial and commercial facilities, a phrase coined in the USA in the mid 1980s. (Thornton et al., 2007)

Most environmentalists advocate a careful balanced approach in considering arguments for demolition; where a selective 'scalpel' approach is preferred to whole-area large scale demolition such as the statutory demolition of unsanitary slums during the 1960s (Roberts, 2008) in the UK. The political, social and wider environmental impacts, coupled with the embodied carbon of new construction, policy tools, impact to the elderly and the built heritage need to be carefully analysed. (Power, 2008)

It is widely agreed that select sites or specific areas do require demolition and regeneration; such where whole town centres comprising of mixed development including schools, shops, energy efficient housing and green spaces may evoke a better living standard (De Sousa, 2003) and attract business to key localities where infrastructure and transport are already well established, thereby contributing to the scales of density, such as Athlone Town Centre and the Ballymun regeneration project. (Doick et al., 2009). Derelict and underused inner city locations may attract anti social behaviour whilst enjoying prime real estate zones, in addition, there may be perceived contamination (such as the Quays in Dublin and the UK) which would in any event require a clean-up process and intervention to bring them back to beneficial use and rejuvenate the wider demographic, (Thornton et al., 2007)

There is strong evidence to suggest that Construction & Demolition Waste (C&DW) can be viably recycled and in some instances for the manufacture of high grade products. (Soutsos et al., 2011) ***"can be used for this new higher value market."*** However this again requires additional energy input and more often than not, specialist equipment, knowledge, transport and double handling. Although Duran makes a case for using recycled C&DW in landfill, once the cost of using primary aggregates exceeds the cost of using recycled aggregates (Duran et al., 2006), evidence would suggest that this is not a viable environmental solution let alone energy efficient. (Power, 2008)

Brownfield sites are often more complex and require greater capital investment to develop; where specialist surveys are conducted to establish possible contaminants and materials prevalent, social barriers to relocation and then Health and Safety aspects associated with noise, increased heavy traffic and particulate dispersal, where air borne and settled particulates display the greatest risk, long after demolition activity has ceased. (Farfel et al., 2005) Specialist consultants and companies are primarily procured to assess, demolish, remove and dispose of these elements. For these reasons, public intervention, funding, incentives and social inclusion are necessary to ensure sustainable regeneration. (Thornton et al., 2007)

Local Irish studies have shown that constructing new buildings on Brownfield sites typically culminates in far greater costs (up to 50%) than the re-use and refurbishment of existing buildings; notwithstanding the greater value for the environment, cost savings over the future life of the building and greater heritage value to the local area.(O'Dulaing, 2006) These studies have been further substantiated by Power, who argues that upgrading existing stock to high standards can be achieved cheaper than demolition over a far shorter period without the addition of embodied carbon associated with new materials, additional transport, increased landfill, loss of built resources, local economic empowerment and employment, retention of community structure and infrastructure as well as systematic neighbourhood renewal; whilst Power also highlights that each new dwelling, however efficiently built, adds significantly to CO2 emissions in embodied energy, (Power, 2008) new homes use approximately eight times more resources than an equivalent refurbishment. (Yates, 2006) Furthermore, research shows that embodied energy constitutes 35% of the total CO_2 emitted over an estimated 50 year period on new properties, whereas the embodied energy for renovation is approximately 7% of the total energy over the lifetime. (Power, 2008)

5.4 Refurbishment

Jones and Leach (2000) and DEFRA (2005) identify that there is no single solution to achieving a sustainable existence; a holistic approach is needed to reach the established CO_2 reduction targets. (Davies and Osmani, 2011b)

5.4.1 Heritage

There is now a much greater awareness in the value of conserving our Architectural Heritage and the built environment in the refurbishment of older buildings and ensuring the retention of detail and character which revitalises cities and towns, supporting the aesthetic value and promoting a distinctive identity. (Central Government, 1997) The report Sustainable Communities – a Guide for Ireland, 1997 suggests extensive new legislative proposals, working with the Minister for Arts, Culture and Gaeltacht on a joint package of administrative and financial measures to facilitate an effective framework for protecting the built heritage. According to Davies, there are a significant number of dwellings within the UK existing housing stock which have great historic value, and are therefore protected by multiple public interest groups and heritage conservation orders which have inadvertently prevented the adoption of LCHR principals and strategies. Davies suggests that architectural conservation bodies can facilitate the current impasse (Davies and Osmani, 2011b) and points out that conversion and extension projects of Listed and Victorian dwellings have increased during the current economic climate, whilst demolition and new building activities have decreased. In accordance with the Housing Corporation (2008) and DEFRA; superior cavity wall insulation, low energy light fittings and loft / floor insulation are commonly specified to increase energy efficiency and reduce CO_2 emissions in a 'fabric first' approach. (Davies and Osmani, 2011b)

Among many buildings that have been retrofitted to enable high Renewable Energy penetration levels for meeting the heating, cooling and electricity demands, the 'Renewable Energy House' in Brussels is a good example. Opened in 2006, it now houses the headquarters of the European Renewable Energy Council and fifteen RE Industry associations. The aims of refurbishing the 120 year old 2,800 m2 building were to reduce the annual energy consumption for heating, ventilation and air conditioning by 50% compared to a similar size reference building. Key elements of the heating system are two biomass wood pellet boilers of 85 kW and 15 kW; solar thermal collectors (half being evacuated tubes and half flat plates); and four 115 m deep geothermal borehole loops in the courtyard, these connected to a 24 kW ground source heat pump (GSHP) also used in summer for cooling. Most cooling, however, is derived from a 35 kW solar absorption cooler driven by low temperature solar heat at 85 degrees Celsius and a little electrical power for the controls and pumps providing cooling at 7 to 12 degrees Celsius. (PIK, 2012) Whilst grid electricity is readily available in urban areas, it is relatively expensive and therefore limited to providing basic needs; there is therefore scope for increased penetration of independent, small scale RE systems as backup support or for self generation as is the case Table 13: Integrated RE heating and cooling systems installed in a 120 year old building. (PIK, 2012)

5.4.2 Local Authority Housing

The Remedial Works Scheme was introduced in 1985 to assist local authorities to improve substandard housing and upgrade the physical environment in certain older and pre- 1940 local authority housing estates, dwellings and inner city flat complexes. (Central Government, 1997) Between 1985 to 1996, some 6,500 units were improved with further funds approved from 1997 to 2008.

The refurbishment of 100 Dublin City flats at Queen Street, Ballybough and Bridgefoot Street (May 2003 – Dec 2004) demonstrates how simple solutions can provide a high standard of energy efficiency in the refurbishment of social housing units. Refurbishment was considered in the context of several priorities, namely: Reduction of greenhouse gases, Combating fuel poverty and the Preservation of housing stock. (SEAI, 2010) Key energy features included high efficient natural gas boilers to replace solid fuel open fires, south facing balconies enclosed to incorporate living space reducing heat loss from overhanging floors and ceilings and new high performance windows are double glazed, argon filled, low-e, timber frame reducing the U-value from 5.0 W/m2K to 1.5 W/m2K. Fabric elements include retrofitted wall insulation and mineral fibre quilt insulation between joists, whilst user-friendly smart cards allow residents to pre-pay for their gas consumption creating energy awareness.

5.4.3 Multivariant analysis

It is necessary to carry out an exhaustive investigation of all solutions in order to design and realise an efficient building refurbishment. (Kaklauskas et al., 2005) There are a great many variants which need to be considered prior to undertaking a building's refurbishment, including: cost of refurbishment and the pay-back time, effects to health and the environment in respect to materials employed, annual fuel economy and cost of maintenance, aesthetics and functionality, comfort levels associated with heating, cooling, sound and air quality and then the longevity of the building fabric and improvements. (Brager, 1996)

Multivariant design and multiple criteria analysis allows for a broad spectrum of data to be processed and evaluated; often solutions of an alternative character allow for a more rational and realistic assessment of economic, ecological, legislative, climatic, social and political conditions, thereby catering to individual and collective needs in reducing refurbishment cost

and facilitating market penetration of innovative and effective retrofit solutions. (Kaklauskas et al., 2005)

5.4.3.1 EPIQR

An evaluation tool referred to as the Energy Performance Indoor Environmental Quality Retrofit (EPIQR) features a computer based multimedia programme which is aimed for use in existing apartment buildings of three or more stories, (Jaggs and Palmer, 2000b) and should be used at the concept decision stage through the whole process of refurbishment. EPIQR is designed to:

- Improve indoor environmental quality
- Optimise energy consumption
- Incorporate renewable energy technologies
- Improve cost effectiveness of refurbishment
- Facilitate the decision and implementation process

The EPIQR tool is based on an existing method developed in Switzerland (MERIP) and allows for a building to be broken down into 50 elements, such as façade, heating, roofing and permits for six different types of construction and four stages of possible deterioration, whilst it also allows for comparisons to be made to facilitate analysis and decision making. By way of example; the comparison analysis of energy use is considered under seven headings, namely:

- Space heating (calculated by means of the CEN European Standard)
- Domestic hot water
- Boiler replacement
- Space cooling
- Artificial lighting of shared spaces

- Insulation of heating distribution pipes
- The use of thermostatic radiator valves

Retrofit actions within the scope of EPIQR have been compiled as a result of discussions with local authorities, housing associations and other large scale apartment building owners who have been involved with retrofitting actions and on site testing. According to Jaggs, the EPIQR methodology addresses the need for building owners, operators, surveyors, architects and engineers to carry out cost effective refurbishment and encourages refurbishment and retrofit projects which improve the structural condition, improve living conditions and reduce energy costs and CO2 emissions. (Jaggs and Palmer, 2000b)

Genre states that in order to make a decision to proceed with any refurbishment project, there is a need for a reliable report describing the current state of the building, where the EPIQR methodology and software applied to the specific refurbishment works and cost assessment of building refurbishment needs; specifically with respect to energy conservation and indoor environmental improvement is essential. (Caccavelli and Genre, 2000) EPIQR is a decision tool combining financial, technical, energy and comfort analysis and enables rapid low cost acquisition of all data and comprehensive analysis taking over 800 parameters into account. Natural ventilation is considered a powerful means to improve indoor air qualities with night ventilators, thermal mass and shading devices; with the proper control system, natural ventilation has great potential to avoid overheating problems in buildings, (Pilkington, 23 March 2011) however, mechanical ventilation with heat recovery (MVHR) is considered more efficient that natural ventilation and can ensure better air quality.

5.4.3.2 Decision making models and Methods

A building in its environment forms part of a complex technical, technological, ecological, social and esthetical system in the built environment; where sub systems which stem from these interdependencies, influence the total efficiency performance. (Kaklauskas et al., 2005)

According to Kaklauskas et al, one of the fundamental aspects in decision making is an assessment of the extent of physical degradation and the extent of the necessary work and cost required to renovate a building. The process for determining the system of criteria are expressed in numerical values and weighted based on the various experts methods. The 'decision tree' which uses all the criteria calculated for the whole project, decomposes the refurbishment problem into sub-problems that are in turn, decomposed into a further level of sub-problems and so on, until the problem is represented as a decision tree of criteria. In order to create possible combinations, the efficiency of separate elements; for example, windows, walls, thermal units and the roof of a given building renovation need to analysed through five stages, namely:

1. The weighted normalised decision-making matrix
2. The sums of weighted normalised indexes are described by maximum indexes reflecting comfort and aesthetics whilst the minimum indexes representing the cost of the building refurbishment.
3. The significance of comparative alternatives is then determined on the basis of describing positive and negative project characteristics
4. Determination of building refurbishment priorities
5. Determination of the significance, utility degree and priority of all building renovation elements; further on, one repeats the first five stages until the significance, utility and degree priority of all the renovation elements of a building are estimated.

Numbers of feasible alternatives can be as large as 100,000 as each alternative may be described from various perspectives; the problem therefore arises as how to perform design and multiple criteria analysis based on the enormous amount of information. Kaklauskas et al has therefore developed codes of building refurbishment alternative solutions and a further eight stages in order to derive the most advantageous solution alternatives from the data presented; according to priority based on stakeholder and local needs. For example, the noise level inside and outside a building is not of equal importance to inhabitants, the weighting is therefore made compatible in two directions; that is, horizontally among criteria and vertically among solutions. This method ensures that opposing priorities are equally weighted; such as the Landlords priority around the cost of refurbishment and then the Tenants priority which is more concerned with the annual utility cost and aesthetics.

According to Kaklauskas et al; multivariant and criteria analysis allows for the evaluation of economic, technical and qualitative architectural, aesthetic and comfort aspects in respect of the needs and opportunities of clients, designers, contractors, users and local participants. In addition, this methodology allows one to determine the strongest and weakest points of each building refurbishment project and its constituent parts, whilst calculations determine the degree to which one decision is better than another and the reasons for this. (Kaklauskas et al., 2005)

5.4.4 Retrofitting to Passive House Standard

Power argues "that upgrading this stock to high environmental standards can actually be achieved more cheaply than demolishing, and with as significant carbon reduction." Power also considers "major social, economic and environmental benefits of refurbishment compared with demolition, including: a reduction in the transport costs, reduced landfill disposal, greater reuse of materials, reuse of infill sites and existing infrastructure, reduced new building on

flood plains, local economic development, retention of community infrastructure, neighbourhood renewal and management." (Power, 2008)

One of the cheapest ways to reduce CO2 emissions is thermal renovation of existing homes. (Galvin, 2010) An ERSU Project Report conducted in Scotland with similar house typologies levies a strong argument to the feasibility of retrofitting for thermal improvement to existing dwellings. (see: Table 16: Proposed Retrofitting to Passive House Standard in Rural Ireland (1 of 2) (SEAI, 2007) (SEAI, 2009c) (GreenSpec, 2010)) Refurbishment to PassivHaus standard has two key requirements for energy demand, namely: space heating energy demand lower than 15kWh/m2yr, and a total primary energy demand lower than 120kWh/m2yr. (Xing et al., 2011)

Experience on Continental Europe suggests that retrofit costs to the full Passivhaus Standard typically equate to approximately 60% of what it would cost for to build the same dwelling completely from new. It must be stressed that such works are most economically viable when dealing with an old dwelling which, irrespective of energy performance, needs to be completely upgraded.(SEAI, 2009c)

5.4.5 Implementation

Whilst a number of studies such as SSN (2006) report that the knowledge and desire for sustainable lifestyle is increasing, Davies argues that if household awareness is to be effective, there is a need for homeowners to be positively engaged and show a sustained commitment to the low carbon agenda. (Davies and Osmani, 2011b)

The 2020 Transition Plan in the UK is structured to ensure that emissions from heating homes will fall by 29% from 2008 levels whilst ensuring that the most vulnerable are protected from fuel poverty. In September 2008, the Prime Minister announced an ambitious £1bn Home Energy Saving Programme to help families permanently cut energy bills and reduce demand for energy, such as Figure 69: The Whole House Approach, UK. (Central Government, 2009) where this approach considers a households energy needs and carbon dioxide impacts as a whole, thereby establishing a tailored but comprehensive package of measures to address them. This coordinated method also includes for renewable energy measures where appropriate to the property. A key benefit to this approach is that it ensures that the needs of the property are assessed as a whole and that the measures happen in the right order with minimum disruption.

To help people meet the costs of transformation, the UK government has launched a pilot scheme, by way of example, Figure 70: Possible Pay as you Save Model, UK. (Central Government, 2009) provides a finance model and enables householders to move away from upfront payment. The Government will work with the Energy Savings Trust, energy companies, Local Authorities, the Distribution Network Operators (DNOs) and others to facilitate household uptake and initiate the generation of micro power and heat generation in low carbon ways. In addition; the UK Government has invested more that £22 bn since 2001 through the Decent Homes programme, raising the condition of social housing in terms of warmth and comfort. By 2010, about 95% of all social housing stock in England is expected to meet the Decent Homes standard.

5.4.6 Refurbishment Drivers

5.4.6.1 Employment

The Retrofit programme encompasses all SEAI's domestic grant schemes; the Home Energy Saving Scheme (HES) for installation of energy efficient measures; the Greener Homes Scheme (GHS), supporting the installation of renewable energy heating technologies; and the Warmer Homes Scheme (WHS) which upgrades homes experiencing fuel poverty.

In the 2010 Annual Report; the SEAI stated that the Retrofit programme will deliver on major government priority and improve the way we use energy by creating savings for homes and business alike and providing jobs and investment towards a sustainable and competitive economy. (SEAI, 2010)

In 2010, SEAI received its highest allocation of funding from the Department of Communications, Energy and Natural Resources (DCENR), exceeding €115 million which equates to an increase of over 40% on 2009 and almost 80% on the 2008 grant levels.

Table 10: Breakdown of SEAI grant aid 2010

The HES registered contractors grew to over 2,500; whilst more than 5,500 employees were nominated to carry out HES work. The WHS supported 600 jobs and achieved annual energy

savings of €4 million whilst the GHS registered installers increased to 1,500 contractors. In addition to this; employment was also realised in surveys undertaken, administrative and certification functions as well as research trials with energy suppliers to test large-scale retrofit models to Irish homes. The SEAI worked with financial institutions on developing new financial mechanisms for funding retrofits in Irish homes.

5.4.6.2 Erstwhile Drivers

In a study conducted in the UK; the results revealed that contribution towards a sustainable community and the production of less waste and pollution were considered as significant LCHR drivers, whilst refurbishment to increase land conservation also featured high on the agenda from respondents (Davies and Osmani, 2011b). Respondents also suggested 'different scales of VAT rates for different types of housing refurbishment' to assuage the perception of government favouritism towards demolition and new build rather than LCHR, such as zero VAT rating for refurbishments to listed buildings.

According to Power, new homes use four to eight times more resources than an equivalent refurbishment (Power, 2008), this is because most of the building mass and structural elements in existing property are already there and only rarely need replacing. (Gustafsson, 1995) Refurbishment of older homes can perform over a 60 year period as well as new homes built to current standards.

5.4.7 Barriers

5.4.7.1 Skills

In a study conducted in the UK; the questionnaire results indicated that a lack of skilled site personnel is a challenge; however, it was noted that this is being actively addressed through development and training schemes. (Davies and Osmani, 2011b) (Xing et al., 2011) states that a dramatic increase in skills and awareness amongst the construction professions remains a

challenge to refurbishment. According to Power, the overwhelming majority of builders are small firms with invaluable experience in repair, upgrading and small scale development. (Power, 2008)

5.4.7.2 Erstwhile Barriers

In a study conducted in the UK; the respondents defined the 'lack of a uniform approach for applying sustainable strategies' as a hindrance for successful LCHR design and implementation, where it was suggested that there should be a 'Code for Sustainable Housing Refurbishment' (CSHR) addressing the lack of clarity surrounding Building Regulations for refurbishment, whilst it was also noted that Part L of the Building Regulations is not stringent enough in terms of compliance obligation in regard to refurbishment, and that non-retrospective principal behind the Building Regulations is a serious LCHR obstruction (Davies and Osmani, 2011b). Further, the respondents noted financial and business challenges, design and technical aspects, legislative, environmental and cultural impediments which transformed into LCHR barriers. Long payback periods of a number of micro-generation technologies, such as photovoltaic and solar were also raised by respondents as an exigent to LCHR and subsequently a primary reason for architects not frequently specifying these renewable technologies. (Davies and Osmani, 2011b)

5.4.8 Technical

The (SEAI, 2009c) basic retrofit building package, level 1 is designed to improve an average dwelling to 175 kWh/m2 or to level C2 on the BER scale by improved building air-tightness in sealing baseboards and other areas of air leakage, weather stripping to doors and windows as well as insulation to the attic and wall cavities. The Level 2 retrofit package is designed to incrementally improve a dwelling to 150 kWh / m2 or to level C1 on the BER scale by improvements or replacement of windows, external insulation or internal dry lining.

Retrofitting improvements to Heating, Ventilation and Air Conditioning (HVAC) include replacing boilers with AFUE (annual fuel utilization efficiency) rating above 95%, replacement of the electric furnace with a high efficiency electric heat pump or solar water heater, reducing the energy consumption of systems through improved maintenance, replacement of incandescent and CFLs with LEDs, replacement of inefficient T12s / T8s with new T5s, the inclusion of dimmable ballasts, photo-sensor controls and the use of high efficiency home appliances and consumer electronics.

5.4.9 Evidence and argument

Limited success in retention reveals the need for engagement with key stakeholders and product manufacturers, whilst European policy should focus on a carbon credit system coupled with information to motivate consumers. (Boardman, 2004) Future progress will require careful consideration in the way policy is formulated (Lowe and Oreszczyn, 2008) coupled with planning exemptions for certain renewable technologies. (department of the Environment, 2007)

To be successful, refurbishments require a detailed assessment incorporating extensive information gathering, including utility bills, a structural survey and usage analysis culminating in a comprehensive materials schedule married to correct use, cost and installation. (Jaggs and Palmer, 2000a) This thought process is mimicked by (Hens, 2010) where technologies employed must justify the end means, similarly in a high rise apartment solution, wall insulation measures were shown to be least effective whilst ventilation control measures were found to be most effective. (Gorgolewski et al., 1996)

Thermal renovations, principally insulation to external walls, window treatments and air permeability measures are economical and most popular (Goldman, 1985); where Germany is

cited as a world leader in such measures and has employed a strict building code coupled with an innovative renovation infrastructure and generous subsidies, however Galvin argues that

> ***"It is found that the lowest standard is an order of magnitude more cost-effective than the highest, in terms of both energy saved per euro invested, and return on investment over the lifetime of the renovations, regardless of fuel prices", (Galvin, 2010)***

which calls into question why German subsidies are only offered for projects which specify beyond the minimum standard and not in relation to the most advantageous solution to a specific site, locality or project. Power advocates renovating to a higher standard than the ECI proposes; where a new home will outperform a renovated home after 9 years, but will take 28 years to outperform a higher efficiency renovated home in terms of basic improvements to walls and floors.

Evidence suggests that retention to refurbish has an important role in improving a communities health (Blackman et al., 2001) whilst community involvement coupled with low carbon programmes (SEAI, 2008), VAT incentives and information to education programmes facilitate up-take and create local momentum. (Davies and Osmani, 2011a)

The Heritage Council, Dublin City makes a strong case for retention to refurbishment (TheHeritageCouncil, 2004) citing architectural, cultural, historic and aesthetic merit from an economic, environmental and cultural perspective. Innovative technology, methods and materials have made it possible to retain valuable protected enlisted buildings (Bastianini et al., 2005) thereby making a positive contribution to the appearance, character and quality of local streetscapes and the sustainable development of the city.

Credible research clearly demonstrates the benefits for retention and refurbishment; some of which include economic benefits, maximum use of existing infrastructure and resources, localised employment, reduction in transport and landfill. (Power, 2008)

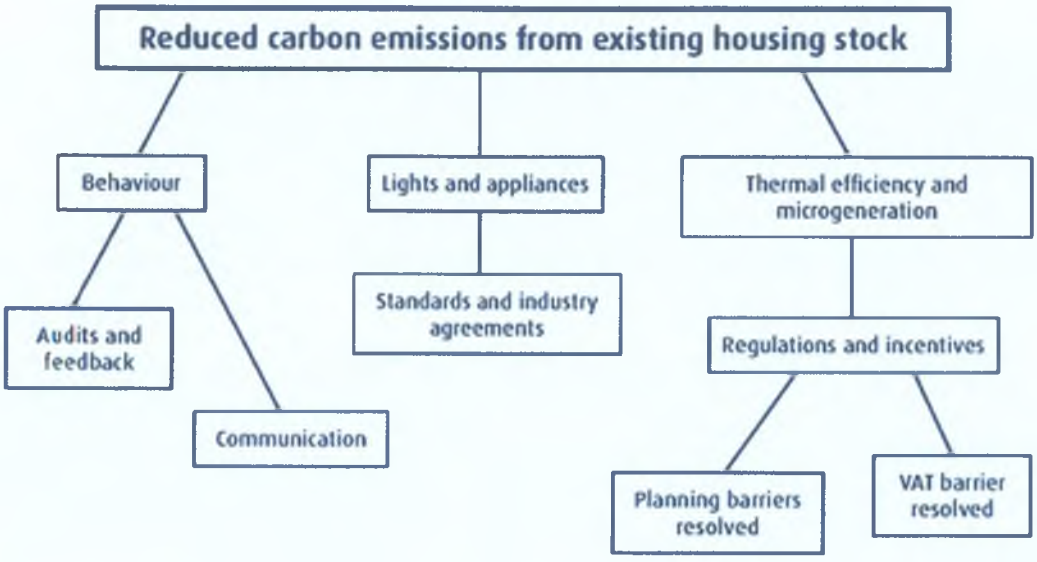


Figure 31: Whole Town Strategy: Housing. (SustainableDevelopmentCommission, 2006)

Evidence to date would suggest that it is feasible to raise the energy performance of existing homes to at least as high standards as current new build, (Power, 2008) cutting the energy in use by an estimated 60%. (Roberts, 2008)

6. CHAPTER 6: SURVEY

6.1 Preface

The objective of the survey: to obtain an understanding and appreciation of the exposure, knowledge and opinion of professionals engaged in the broader construction industry. To evaluate the respondents riposte in terms of the subject matter raised, namely:

- To better understand what is meant by the term 'Embodied Carbon'
- To evaluate the impact of building materials in construction, in terms of Carbon Management.
- To ensure that the literature review presents an overview of the relevant research
- To evaluate the term 'sustainability' in terms of the built environment, energy and harmonisation.
- To obtain an in-depth understanding of refurbishment and the challenges in the Irish context.

6.1.1 Survey approach

The survey was launched on 20 January 2013 and closed on the 23 February 2013, affecting a five week (34 open day) period. A total of 180 construction and construction related professionals were approached via Email (see Figure 71: Sample Survey Enquiry Email) where 20 emails were returned as undelivered. From the 160 delivered enquiries; a total of 50 respondents returned questionnaires (31%), of which 35 were fully complete questionnaires (21.8%) and 15 were partially complete questionnaires (9.2%).

All questionnaire responses were confidential; the respondents name(s) and details are not known to the author, the author was therefore required to levy the same number of email enquires on a follow up request.

6.1.2 Survey composition

The survey consisted of 37 questions over four areas, namely: (see Figure 72: Survey Questionnaire)

- General - question No's 1 to 5
- Embodied carbon - question No's 6 to 14
- Sustainability - question No's 15 to 27
- Refurbishment - question No's 28 to 37

The 37 questions posed encompassed 111 individual check boxes over nine pages, these required mark-off to be considered as a fully complete submission. The mean response time to the questionnaire over the 50 respondents was 25 minutes and 51 seconds.

6.1.3 Survey observation

The survey questionnaire format and statistical software used was Survey Methods (https://www.surveymethods.com/Index.aspx?out=1). According to Frederick C Van Bennekom (an authority on operational reporting systems); the response rate of a survey is dependant on the length of the survey, whether an incentive is offered, the type of survey, the target market, whether the survey enquiry is personalised and the timing of the follow-up reminder. According to Van Bennekom; an acceptable median survey response rate to a medium length survey with one follow-up and no incentive is between 15 to 30% depending on the target market.

6.1.4 Section: general – respondents

6.1.4.1 Respondents Age Category

Over the 50 responses received, a total of 82% respondents occurred between the 35 to 65 year age group, whilst 18% were under 35 years of age. Similarly; over the 35 complete responses received, the age percentages were 82.86% (29 No) and 17.14% (6 No) respectively.

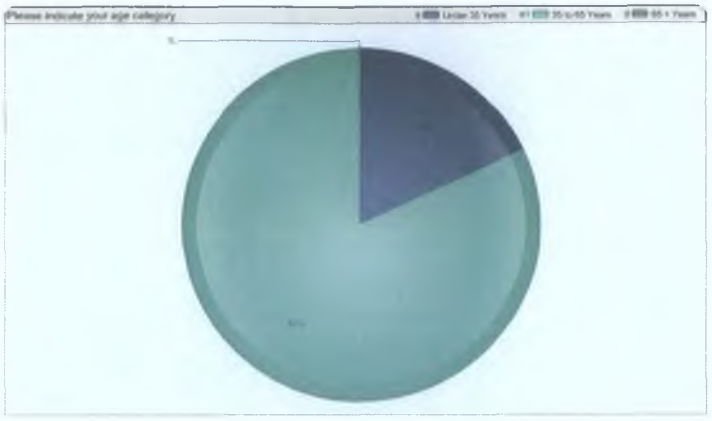


Figure 32: Respondents Age Category (Q.1)

6.1.4.2 Respondents Occupation

Over the 50 responses received, the greatest percentage at 18% was from Quantity Surveyors (contractors side & RQPS), 10% of respondents were from Architectural, Building Services and Contracts Management backgrounds respectively. A total of 24% of respondents occurred in occupations not specifically listed (other), these occupations all related to the target assemblage of the questionnaire, albeit for Dispute Analysis (1 No) and Safety Manager (3No) (see Figure 73: Survey occupation comments Q.2)

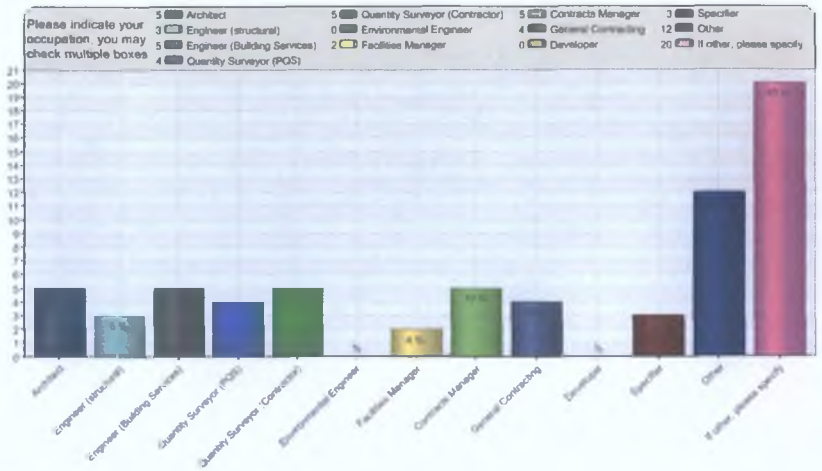


Figure 33: Respondents occupation category (Q.2)

From the 35 complete respondents; 14% of respondents were from Architectural, Quantity Surveying and Contracts Management backgrounds, whilst 9% were from Building Services. A total of 22% of respondents occurred in occupations not specifically listed.

6.1.4.3 Respondents duration in occupation

Over the 50 responses received, a total of 29% respondents have held their respective occupation for 10 years, 39% from 10 to 20 years and 32% for longer than 20 years. Similarly; over the 35 complete responses received, the occupation duration percentages were 29% (10 No), 42% (14 No) and 29% (10 No) respectively.

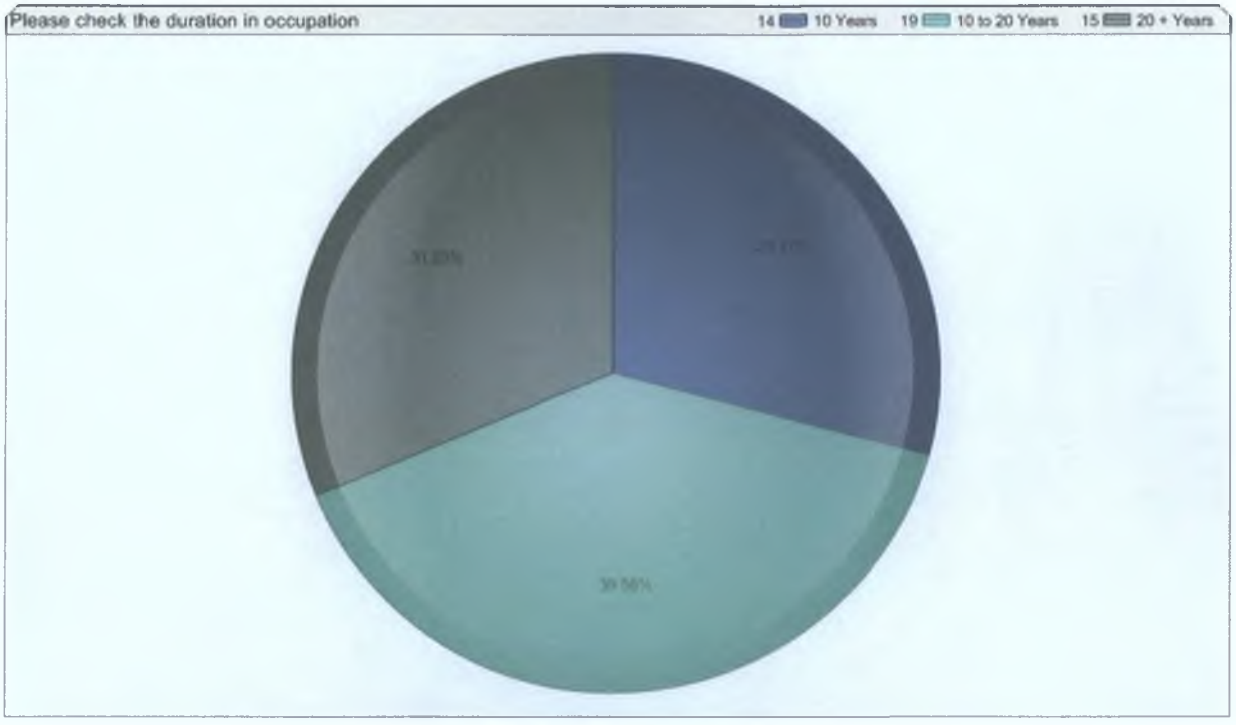


Figure 34: Respondents duration in occupation (Q.3)

6.1.4.4 Respondents resident country

Over the 50 responses received, a total of 84% respondents reside in the Republic of Ireland, 2% from Northern Ireland, 10% from the UK, 2% from Mainland Europe and 2% from Other (Unknown). Similarly; over the 35 complete responses received, the resident country percentages were 80% (ROI), 3% (NI), 12% (UK), 3% (MLE) and 2% (Other) respectively.

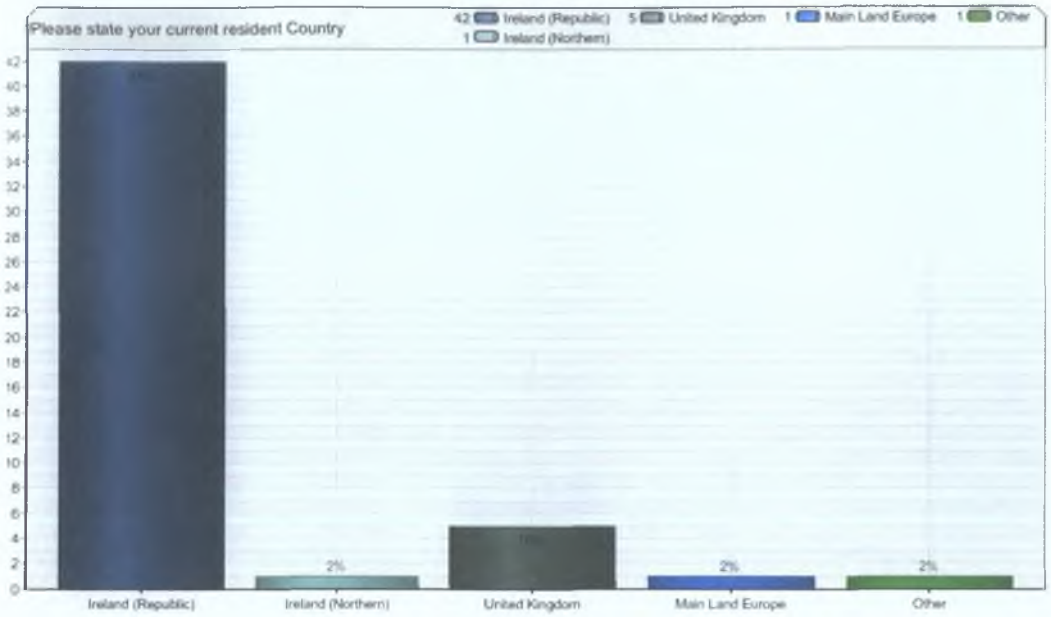


Figure 35: Respondents resident country (Q.4)

6.1.4.5 Respondents resident cities

The majority portion (42%) of respondents reside in Dublin, 8% Limerick, 6% Sligo, Galway and London respectively.

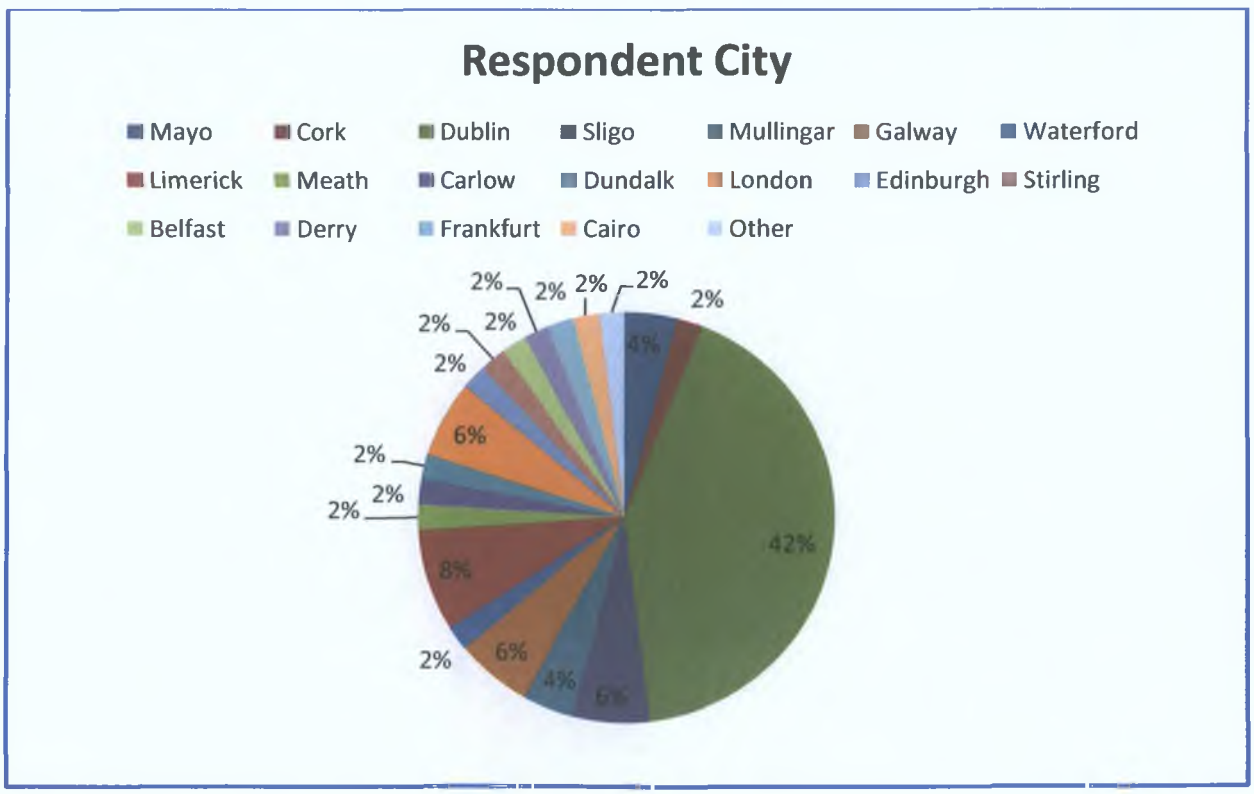


Figure 36: Respondents resident cities (Q.5)

6.2 Survey Results and Commentary

6.2.1 Section 1 of 3: Embodied Carbon

6.2.1.1 Question 6

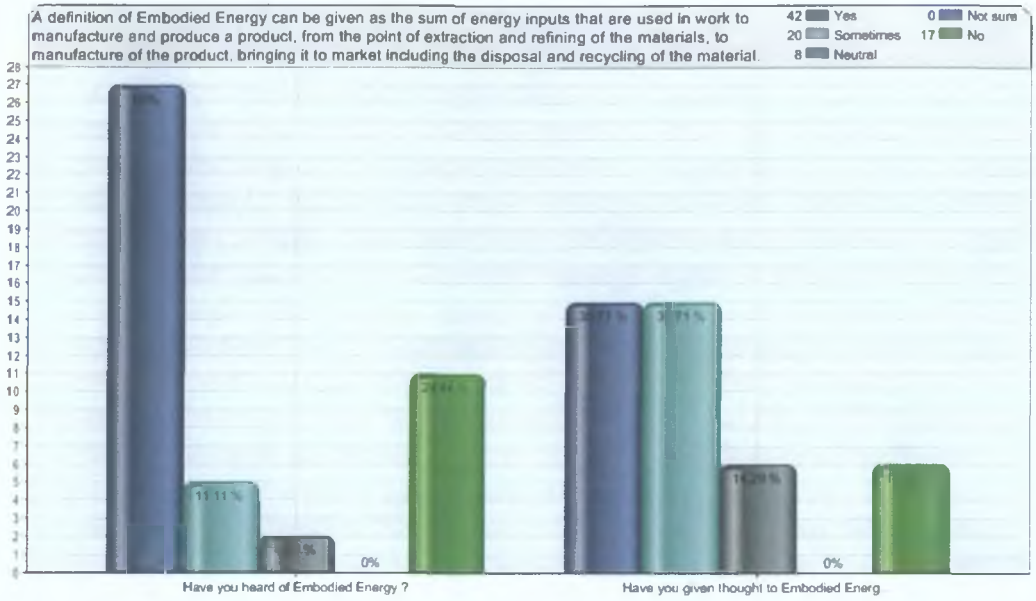


Figure 37: Survey Question 6 Response

Sixty percent of respondents confirmed that they had heard of embodied energy; whilst only 35% confirmed that they had given thought to embodied energy. Interestingly 24% of respondents stated that they had never heard of embodied energy and 14% had never given thought to embodied energy.

6.2.1.2 Question 7

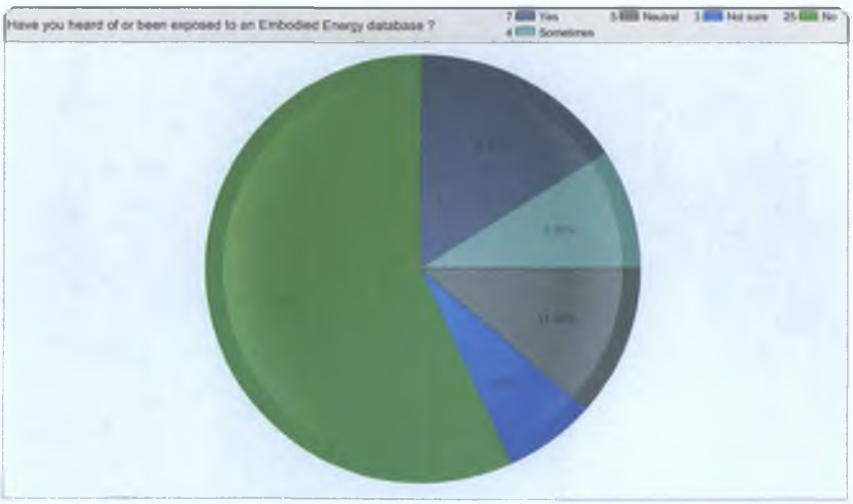


Figure 38: Survey Question 7 Response

The majority portion of respondents (56%) stated that they had never heard of or been exposed to an embodied energy database, whilst only 16% confirmed that they had exposure.

6.2.1.3 Question 8

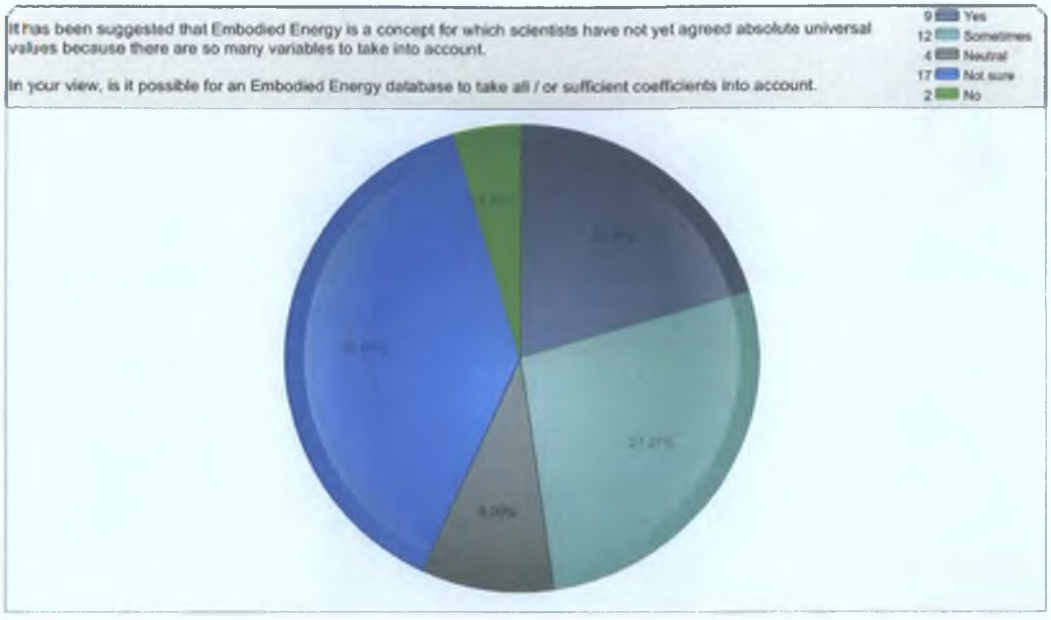


Figure 39: Survey Question 8 Response

Thirty nine percent of respondents stated that they are 'not sure' whether it is possible that an embodied database can take all / or sufficient coefficients into account, whilst 20% stated that in their view, this is possible.

6.2.1.4 Question 9

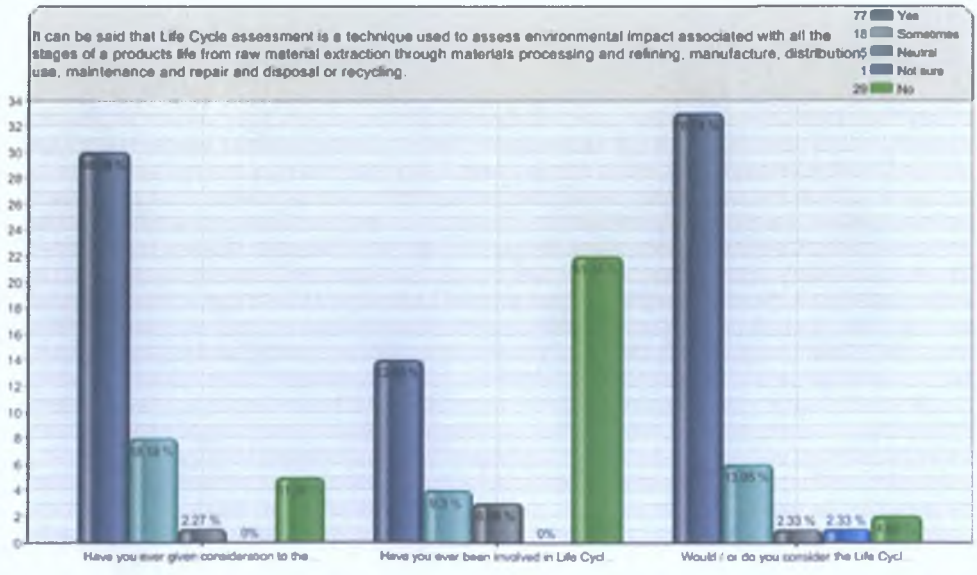


Figure 40: Survey Question 9 Response

It is interesting to note that 30% of respondents stated that they have given consideration to the LC of a product and 33% confirmed that they considered LCA to be worthwhile. In contrast, only 14% of respondents have been involved in LCA and 22% stated that they had not been involved in LCA.

6.2.1.5 Question 10

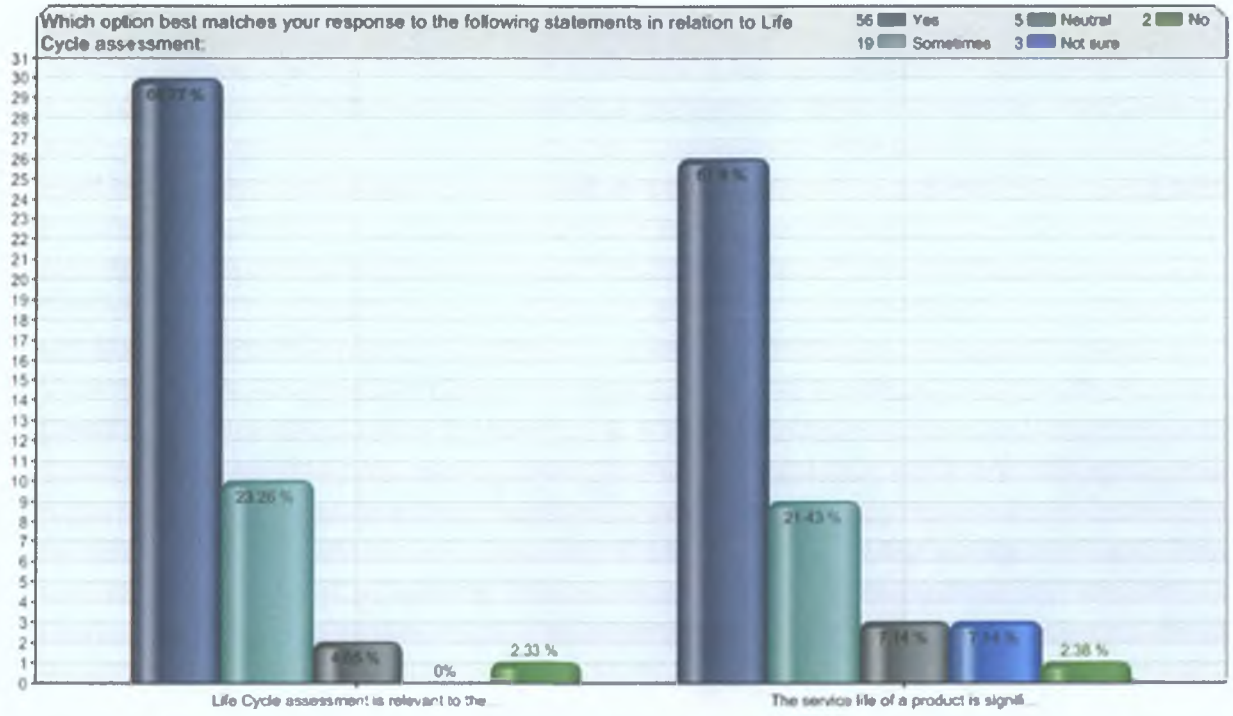


Figure 41: Survey Question 10 Response

It is interesting to note that whilst only 14% of respondents have been involved in LCA (see Figure 40: Survey Question 9 Response) and the majority portion of respondents (56%) stated that they had never heard of or been exposed to an embodied energy database (see Figure 38: Survey Question 7 Response); asked whether LCA is relevant to the choice of materials specified, 70% of respondents confirmed 'yes' to this question (23% sometimes) and asked whether the service life of a product is significant in terms of that products environmental profile, again a high proportion (62%) stated yes to this question and 22% stated sometimes. It would seem that whilst respondents questioned have had no formal exposure to an embodied

energy database, there is a high proportion who would consider the process of an embodied database worthwhile in making product and material choice specifications.

6.2.1.6 Question 11

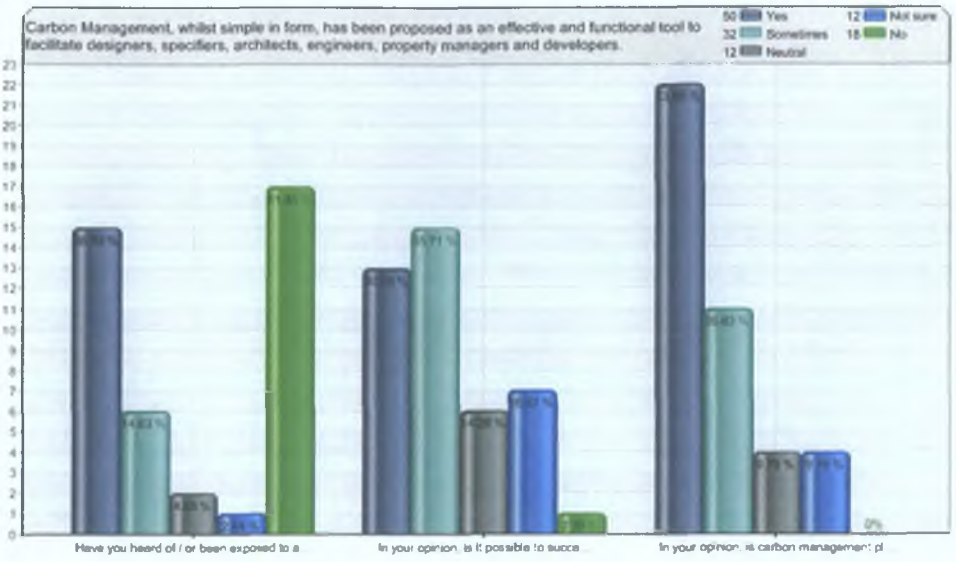


Figure 42: Survey Question 11 Response

Thirty seven percent of respondents stated that they had heard of / or been exposed to a carbon management system, whilst 42% answered 'no' to this question. Thirty one percent stated that it was possible to successfully manage carbon (35% sometimes) whilst 54% stated that in their opinion, carbon management is plausible (27% sometimes).

6.2.1.7 Question 12

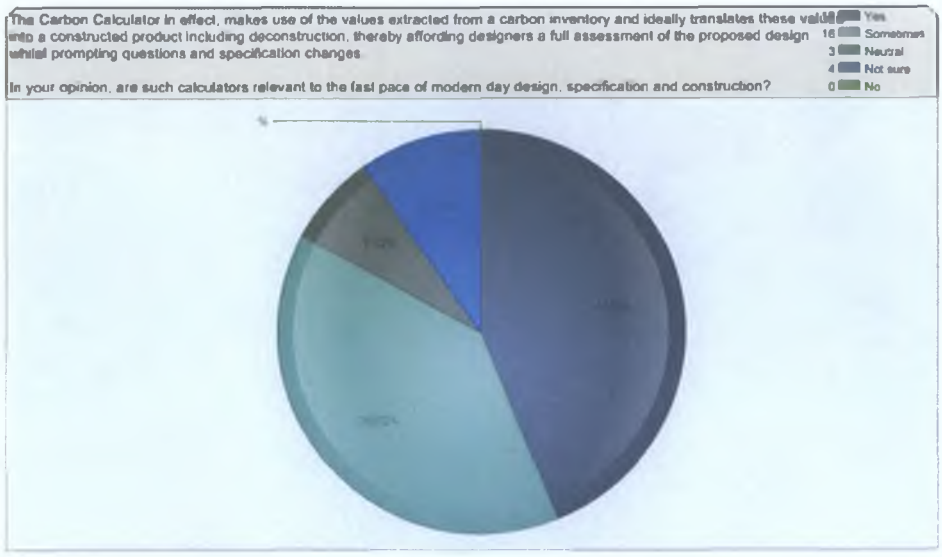


Figure 43: Survey Question 12 Response

Asked whether carbon calculators are relevant to the fast pace of modern day design, specification and construction; respondents were almost evenly split between answering yes and sometimes at 44% and 39% respectfully, whilst no respondents checked the 'no' answer. From the proportion of results attributed to the answers: not sure, neutral and sometimes (56%) collectively, it may be deduced that the majority of respondents are not well informed on the question of carbon calculators.

6.2.1.8 Question 13

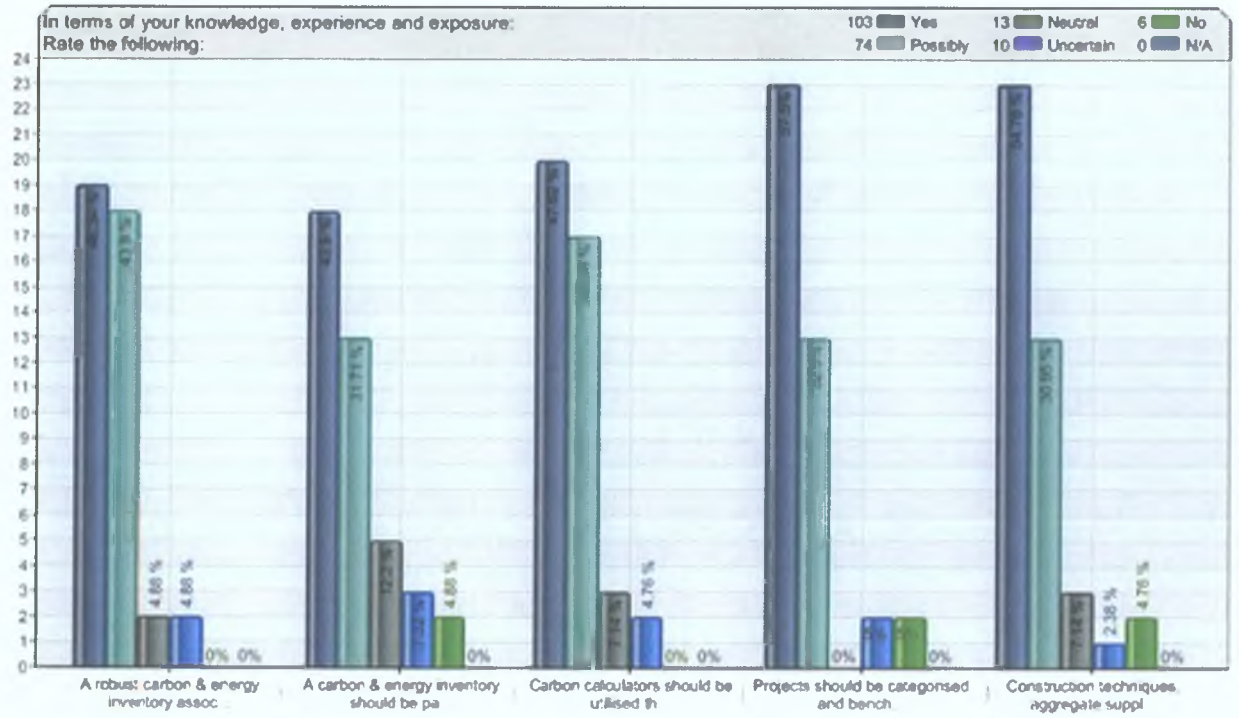


Figure 44: Survey Question 13 Response

In terms of knowledge, experience and exposure; respondents were required to rate against the following statements, namely: (Yes (Y) / Possibly, Neutral & Uncertain (PNU))

- A robust carbon & energy inventory associated to building materials is imperative for policy makers, designers, specifiers, engineers and the like. (Y-46% / PNU-54%)
- A carbon & energy inventory should be paired to zoned local conditions – in order to accurately reflect carbon in a particular jurisdiction. (Y-44% / PNU-56%)

- Carbon calculators should be utilised throughout the construction process, from inception to test / commission and client hand-over files (Y-48% / PNU-52%)
- Projects should be categorised and benchmarked at planning stage to a maximum limit / amount of calculated embodied carbon tCO2/m2 (Y-58% / PNU-42%)
- Construction techniques, aggregate supply and alternatives should be mandated in tender / procurement schedules (Y-55% / PNU-45%)

Whilst the response received was predominantly positive; again, it may also be said that a great a proportion of respondents were unsure, with a large spread of results across: possibly, neutral and uncertain.

6.2.1.9 Question 14

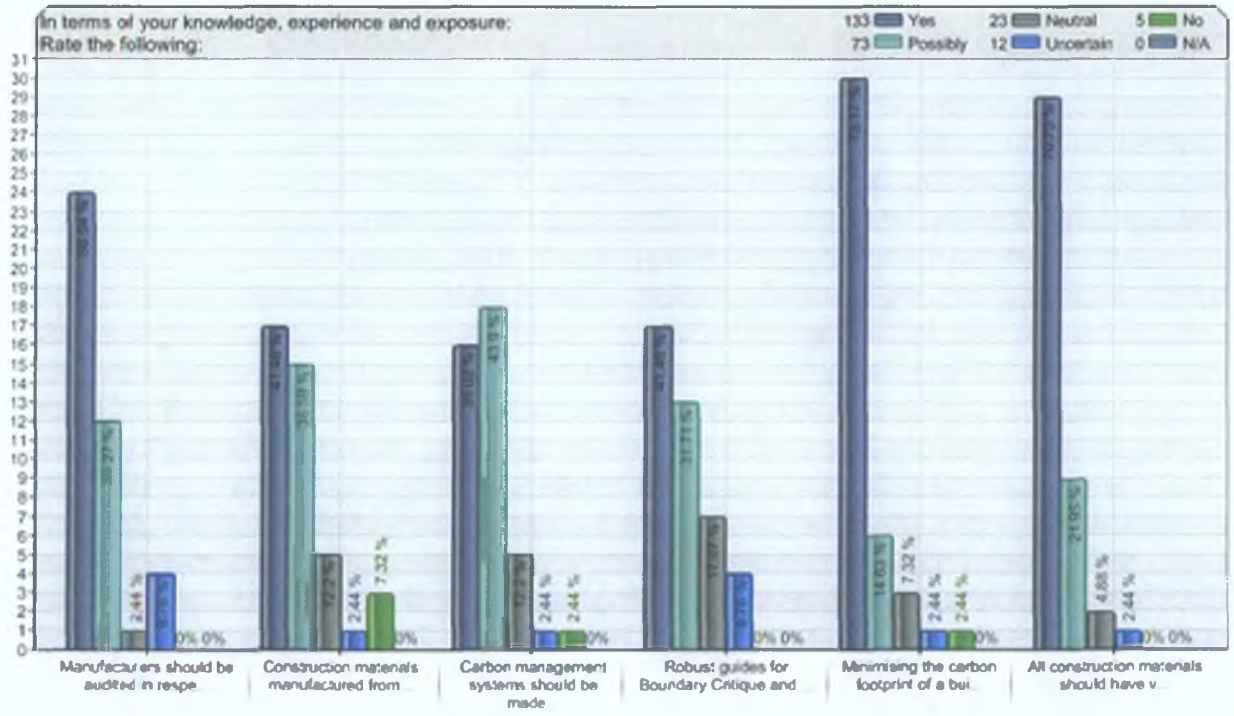


Figure 45: Survey Question 14 Response

In terms of knowledge, experience and exposure; respondents were required to rate against the following statements, namely: (Yes (Y) / Possibly, Neutral & Uncertain (PNU))

- Manufacturers should be audited in respect of a products embodied carbon and a certification process should be mandatory. (Y-59% / PNU-41%)

- Construction materials manufactured from healthy plastics originating from 'say' corn (not oil), organic compounds or recycled material should be VAT exempt (Y-42% / PNU-58%)
- Carbon management systems should be made mandatory in company Quality Assurance and Pre Qualification tender registers. (Y-39% / PNU-61%)
- Robust guides for Boundary Critique and Boundary Judgement in Embodied Carbon inventories is critical to ensure statistical information relating to construction material is accurate and consistent. (Y-42% / PNU-58%)
- Minimising the carbon footprint of a building creates awareness of the environmental impacts of material selection, product development and the manufacture process. (Y-73% / PNU-27%)
- All construction materials should have visible labelling – confirming source and carbon footprint at source of dispatch. (Y-71% / PNU-29%)

Whilst the response received was predominantly positive; again, it may also be said that a great a proportion of respondents were unsure, with a large spread of results across: possibly, neutral and uncertain. It is interesting to note the high percentage marked against awareness and also material labelling, 73% and 71% respectively.

6.2.2 Section 2 of 3 Sustainability

6.2.2.1 Question 15

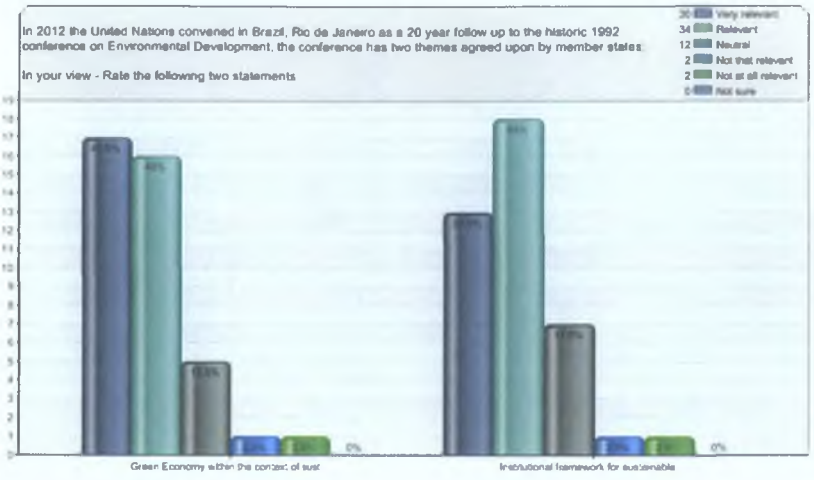


Figure 46: Survey Question 15 Response

The respondents were required to rate the following themes in milieu, namely: "Green Economy within the context of sustainable development and poverty eradication", 42% of respondents stated that this is 'very relevant', whilst 40% stated 'relevant' and 13% were neutral. Similarly; to the second theme, "Institutional framework for sustainable development", 33% stated 'very relevant', 45% stated 'relevant' and 17% remained neutral.Respondents rate sustainable development, poverty eradication and the green economy as high on the agenda.

6.2.2.2 Question 16

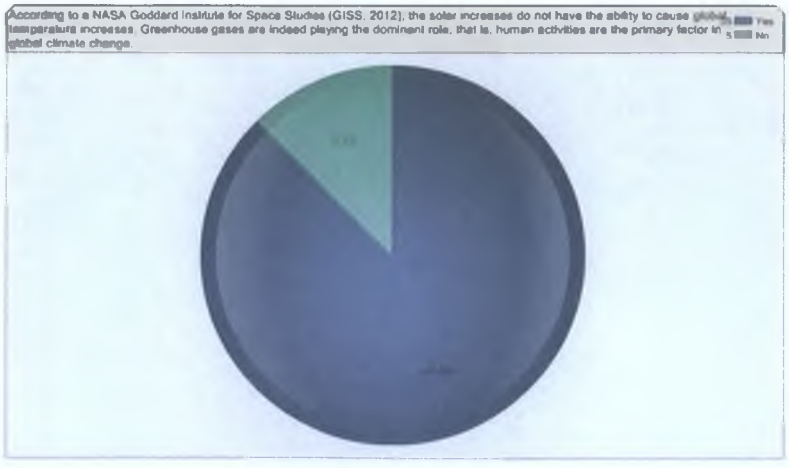


Figure 47: Survey Question 16 Response

In context of the GISS 2012 quote; 88% of respondents agreed that human activity is the primary factor in global climate change. Further comments levied by respondents stated that whilst human activity is the dominant factor, it is one of the primary factors which humans have complete control of.

6.2.2.3 Question 17

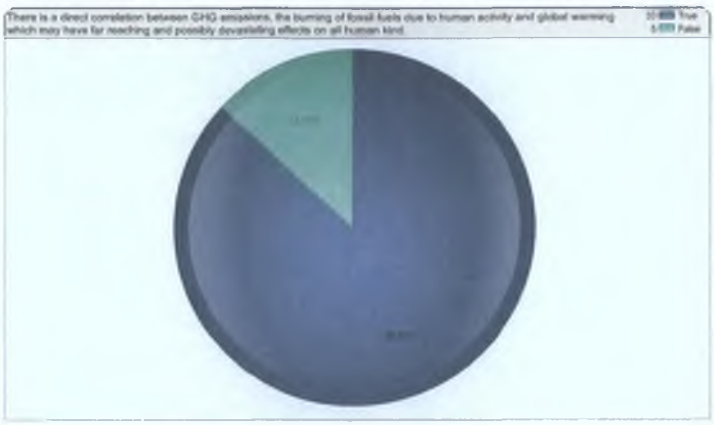


Figure 48: Survey Question 17 Response

An overwhelming majority of respondents (87%) stated 'true' to the statement in Question 17; whilst some of the comments received, stated that GHG emission reductions are necessary, but elimination remains impossible. One responded noted that whilst environmental effects appear to be slow, the affects are far reaching.

6.2.2.4 Question 18

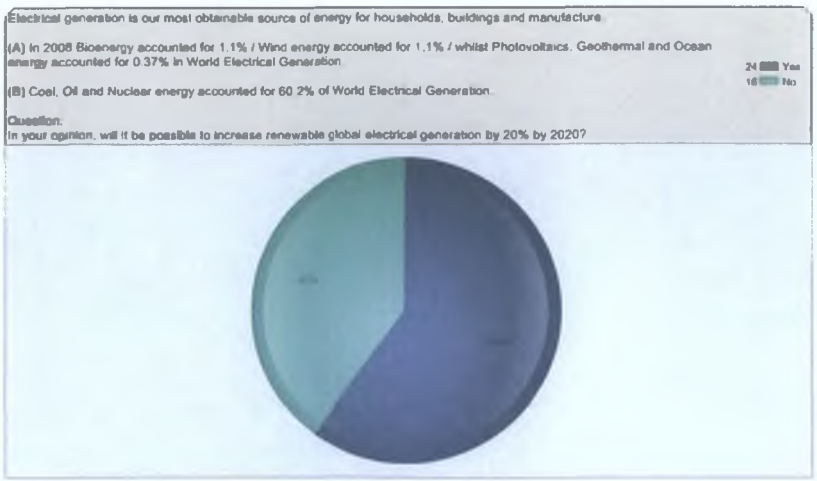


Figure 49: Survey Question 18 Response

Notwithstanding the statistics presented; respondents (60%) stated that in their opinion it will be possible to increase renewable global electrical generation to 20% by 2020. The respondents who stated it would not be possible (40%) also levied comments to the effect of: lack of political will power, planning, electrical grid adaptations and discontinue the subsidising of oil, gas and coal producers.

6.2.2.5 Question 19

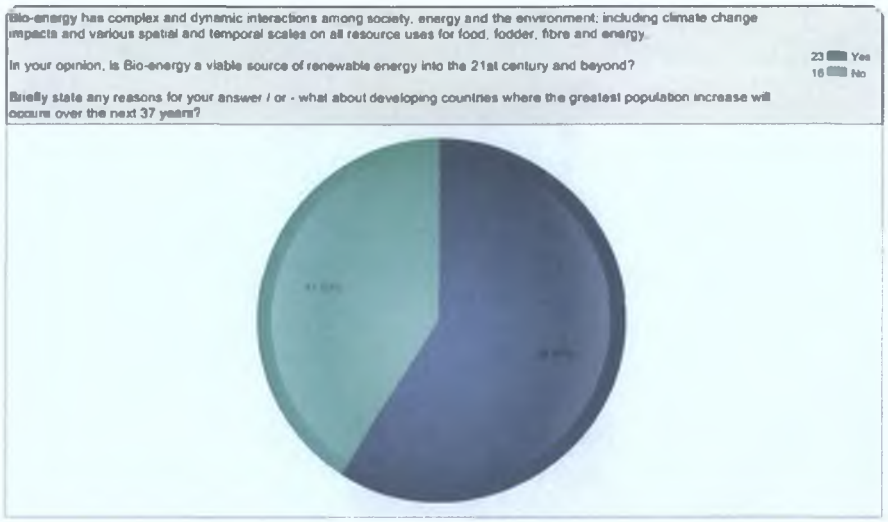


Figure 50: Survey Question 19 Response

Respondents (59%) stated that in their opinion, Bio-energy is a viable source of renewable energy into the 21st century and beyond. There were 15 comments received from 39 respondents, comments varied, from: 'a balance between food and the production of bio-fuels' to 'land for food growth and not energy crops'.

6.2.2.6 Question 20

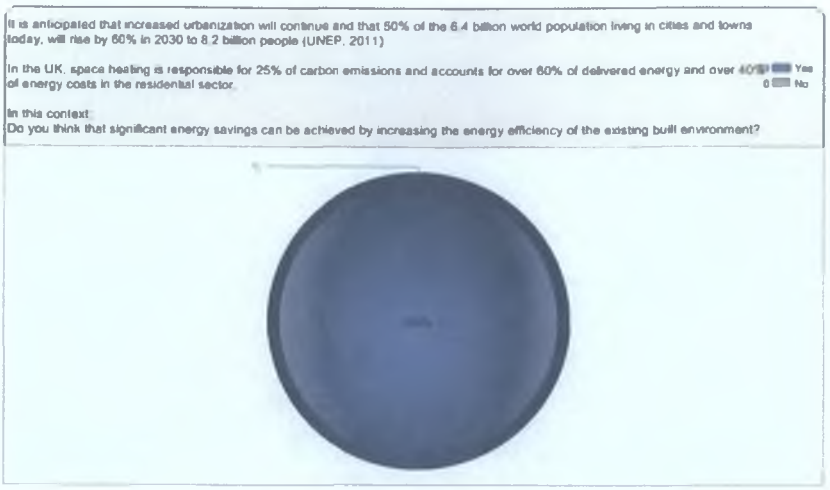


Figure 51: Survey Question 20 Response

A 100% of respondents stated that in their opinion, significant energy savings can be achieved by increasing the energy efficiency of the built environment. There were seven comments received from 39 respondents; comments ranged from: 'there has to be greater than 70% up take', 'this should be motivated by incentives' and 'the domestic stock is not retrofit friendly'. (Figure 78: Survey additional comments Q.20)

6.2.2.7 Question 21

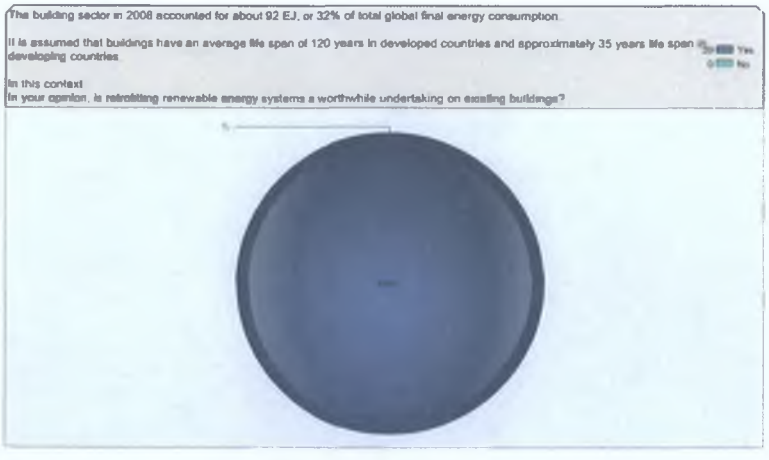


Figure 52: Survey Question 21 Response

Again, 100% respondents stated that retrofitting renewable energy systems is a worthwhile undertaking, there were a total of twelve comments levied, see Figure 79: Survey additional comments Q.21.

6.2.2.8 Question 22

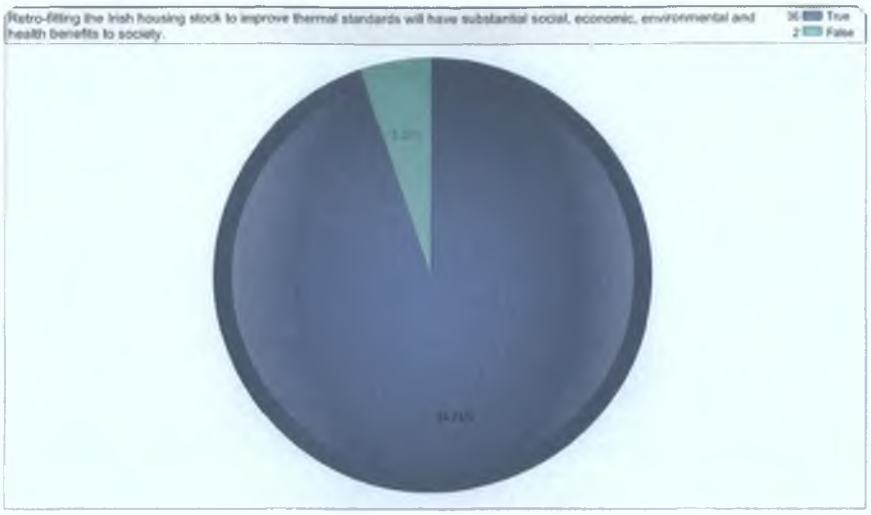


Figure 53: Survey Question 22 Response

Approximately 95% of respondents agreed to the statement: 'retro-fitting the Irish housing stock to improve thermal standards will have substantial social, economic, environmental and health benefits to society'.

6.2.2.9 Question 23

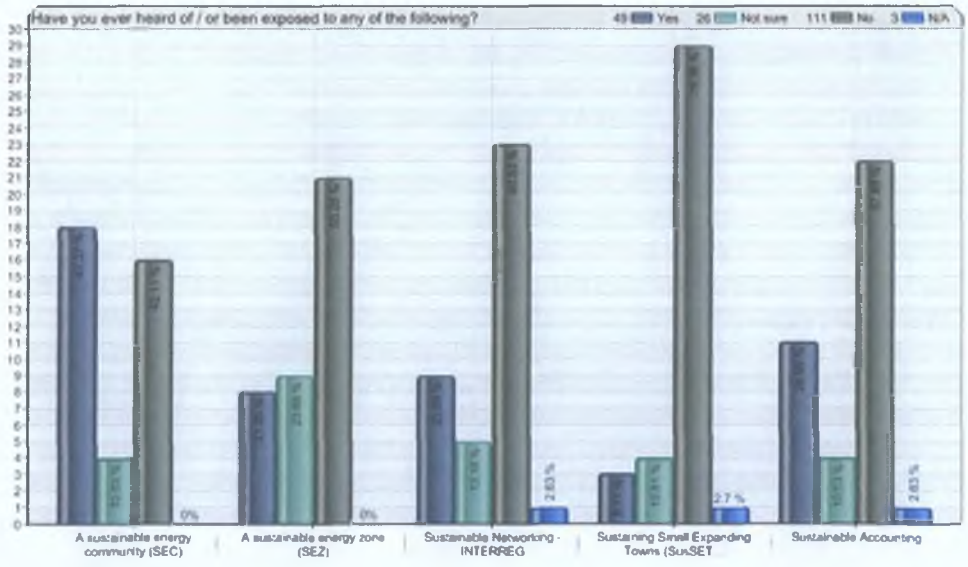


Figure 54: Survey Question 23 Response

Respondents were asked whether they had been exposed to any of the following, namely:

- Sustainable Energy Community (SEC): 47% yes / 11% not sure / 42% no
- Sustainable Energy Zone (SEZ): 21% yes / 24% not sure / 55% no
- Sustainable Networking INTERREG: 24% yes / 13% not sure / 60% no / 3% n/a

- Sustainable Small Towns (SusSET): 8% yes / 11% not sure / 78% no / 3% n/a
- Sustainable Accounting: 29% yes / 11% not sure / 57% no / 3% n/a

The response recorded is interesting insofar as 84% of respondents reside in the ROI; yet 42% stated that they had not been exposed to or heard of SEC (4.2.4) which is by nature designed to promote social cohesion and economic development. Dundalk (Figure 25) was expected to have a radiating influence, yet 55% of respondents confirmed that they had no knowledge of SEZ. As all respondents targeted are construction professionals or affiliated to construction and environmental services, it is surprising that 60% have not heard of or been exposed to Sustainable Networking (Interreg) which is an EU collaborative among authorities of member states which currently has approved and supports No. 43 projects in Ireland. Similarly; 78% and 57% of respondents have not head of or been exposed to the Sustainable Small Town networking or sustainable accounting respectively, this may indicate that these initiatives and drivers are not finding their passage to grass root level and the wider stakeholder base.

6.2.2.10 Question 24

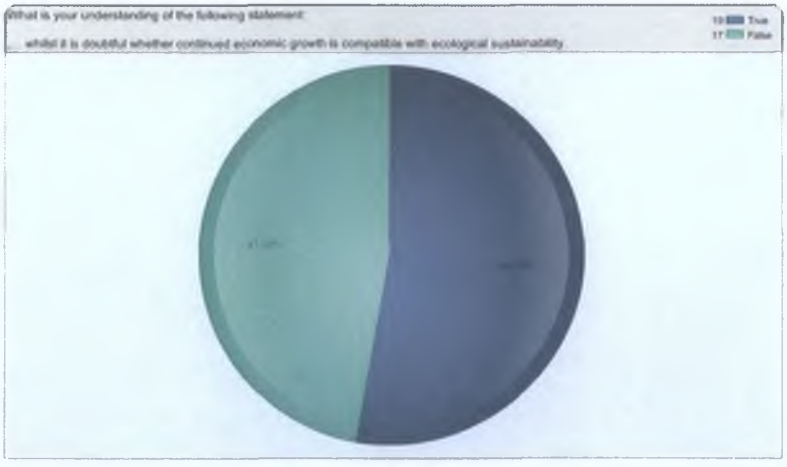


Figure 55: Survey Question 24 Response

Asked whether 'continued economic growth is compatible with ecological sustainability'; 53% of respondents stated True, whilst 47% of respondents stated False to their understanding of this statement.

6.2.2.11 Question 25

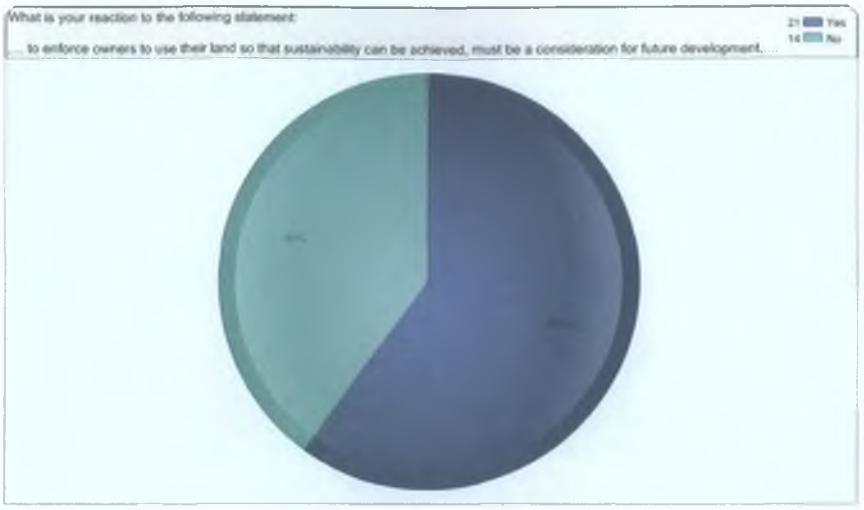


Figure 56: Survey Question 25 Response

Asked to state their reaction to the following statement: '…to enforce owners to use their land so that sustainability can be achieved, must be a consideration for future development…'; most respondents (60%) stated yes to this but with the caveat that sustainable land use should be motivated with incentives and education as opposed to enforcement.

6.2.2.12 Question 26

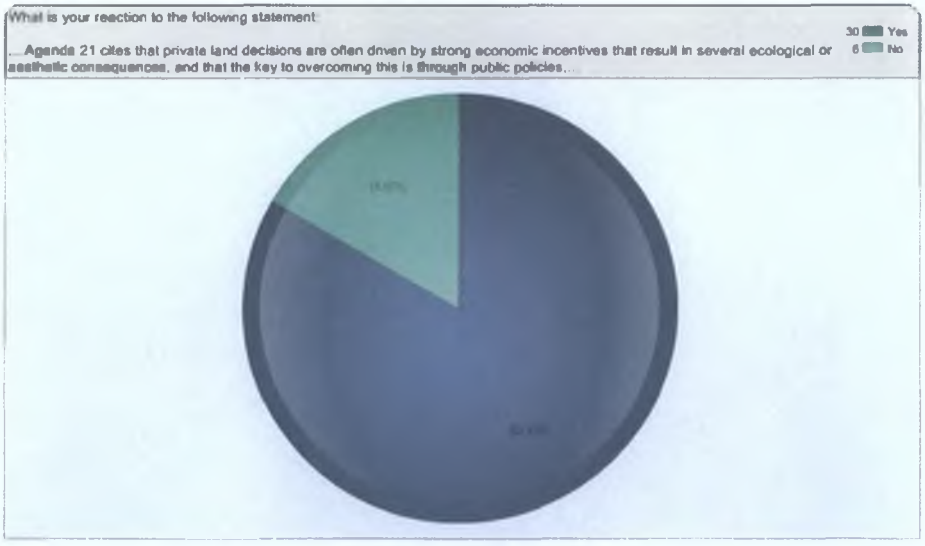


Figure 57: Survey Question 26 Response

Respondents were requested to react to a statement taken from Agenda 21 which contends that public policy is key to overcoming ecological and aesthetic consequences which are a product of economic and market incentives, 83% of respondents agreed with this but also confirmed that policies are not enough on their own and that public consultation is required.

6.2.2.13 Question 27

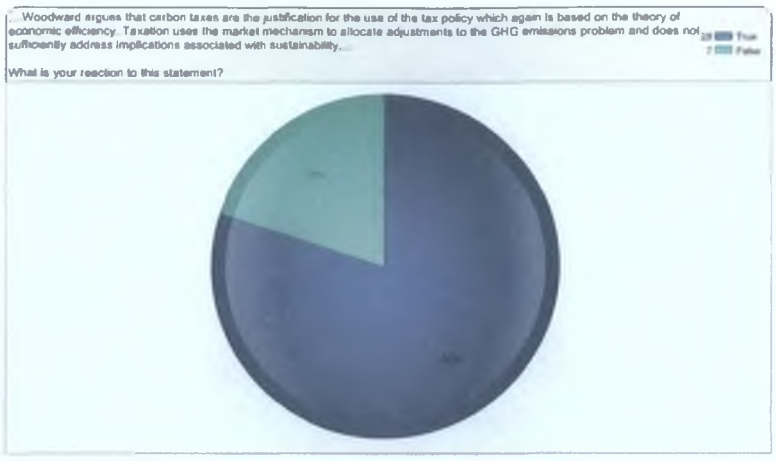


Figure 58: Survey Question 27 Response

Asked whether they agree with Woodward, who argues that carbon taxes are the justification for the use of a tax policy which again is based on the theory of economic efficiency (market mechanism); respondents (80%) agreed.

6.2.3 Section 3 of 3: Refurbishment

6.2.3.1 Question 28

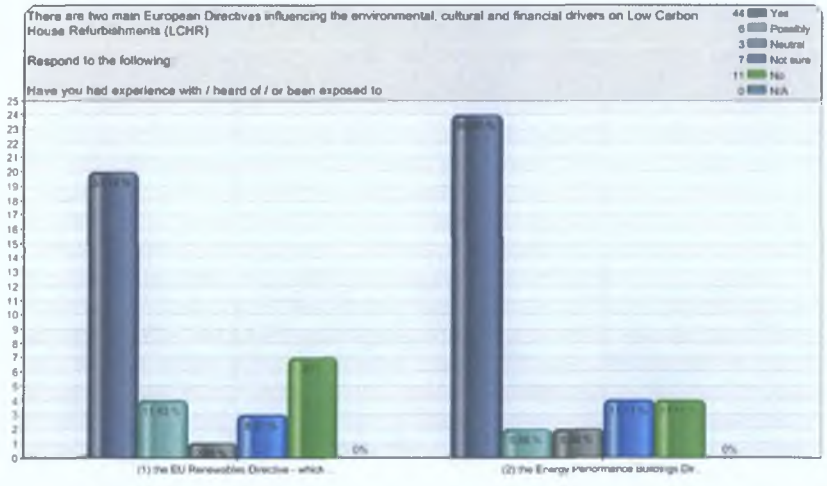


Figure 59: Survey Question 28 Response

Respondents were asked whether they had experience with / heard of / or been exposed to the two main EU Directives influencing the environment, cultural and financial drivers on Low Carbon Refurbishments (LCHR). To the first directive; 57% respondents stated yes, 11% said possibly, 3% remained neutral, 9% said not sure and 20% said no; to the second directive, 66% yes, 6% possibly, 6% neutral, 11% not sure and 11% stated no as the response. The

response is interesting insofar as a high proportion of respondents confirmed that they had head of or been exposed to these two main directives.

6.2.3.2 Question 29

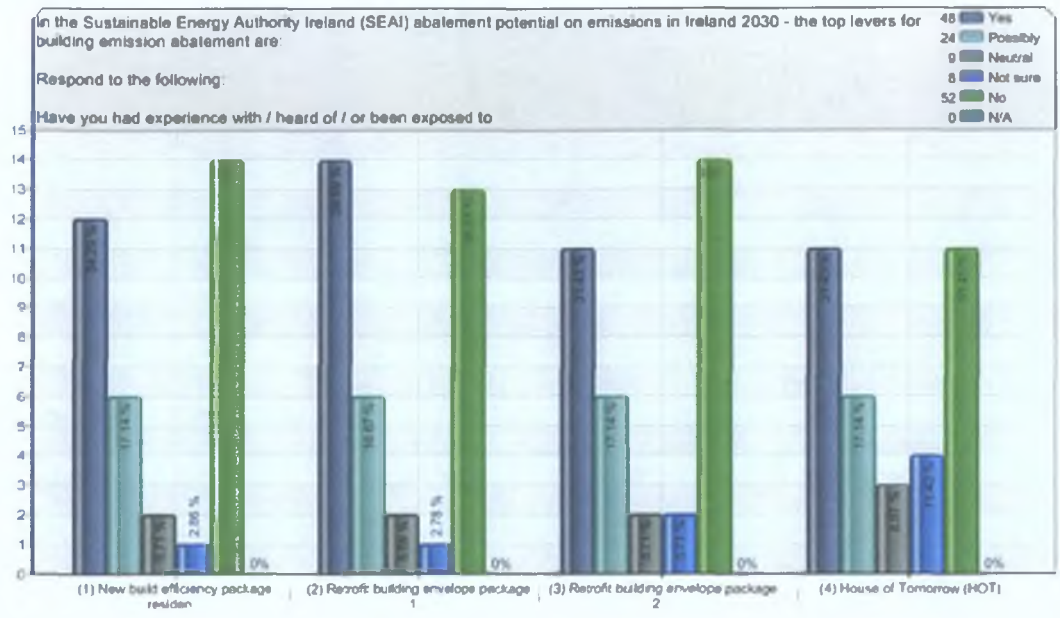


Figure 60: Survey Question 29 Response

Asked whether they have had experience with / heard of / or been exposed to any of the following SEAI abatement levers, respondents answered as follows:

- New build efficiency package: Yes (Y) 34%, Possibly (P) 17%, Neutral (N) 5%, Not Sure (NS) 4%, No (N) 40%.
- Retrofit building envelope package 1: Y 39%, P 17%, N 5%, NS 3%, N 36%
- Retrofit building envelope package 2: Y 31%, P 17%, N 6%, NS 6%, N 40%
- House of Tomorrow (HOT): Y 31%, P 17%, N 9%, NS 11%, N 32%

6.2.3.3 Question 30

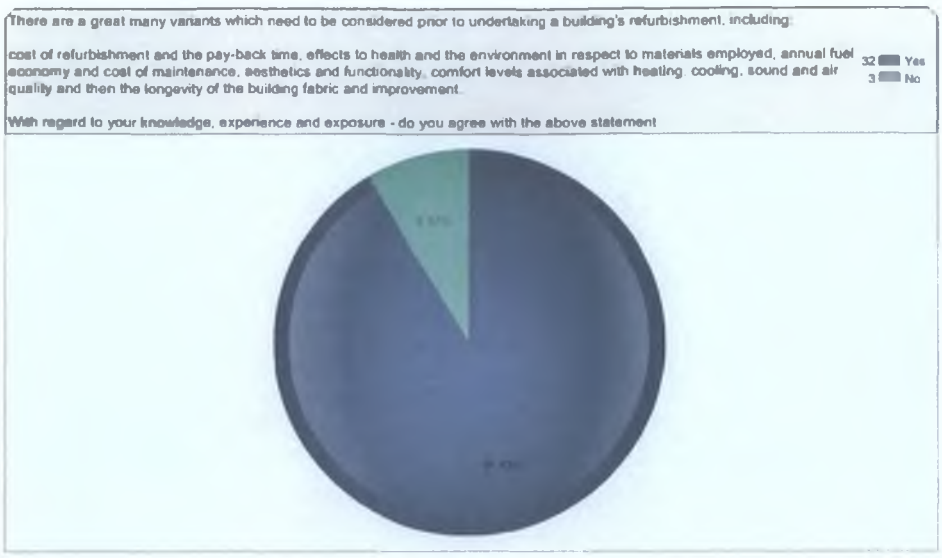


Figure 61: Survey Question 30 Response

Asked whether they agreed that there are a great many variants which need to be considered prior to undertaking a building's refurbishment; 91% of respondents agreed but also stated that payback as a means of establishing viability is wrong, whilst others stated that basic products such as insulation are still not being installed correctly. One respondent stated that reduction in energy costs and higher comfort levels seemed to be most important to consumers.

6.2.3.4 Question 31

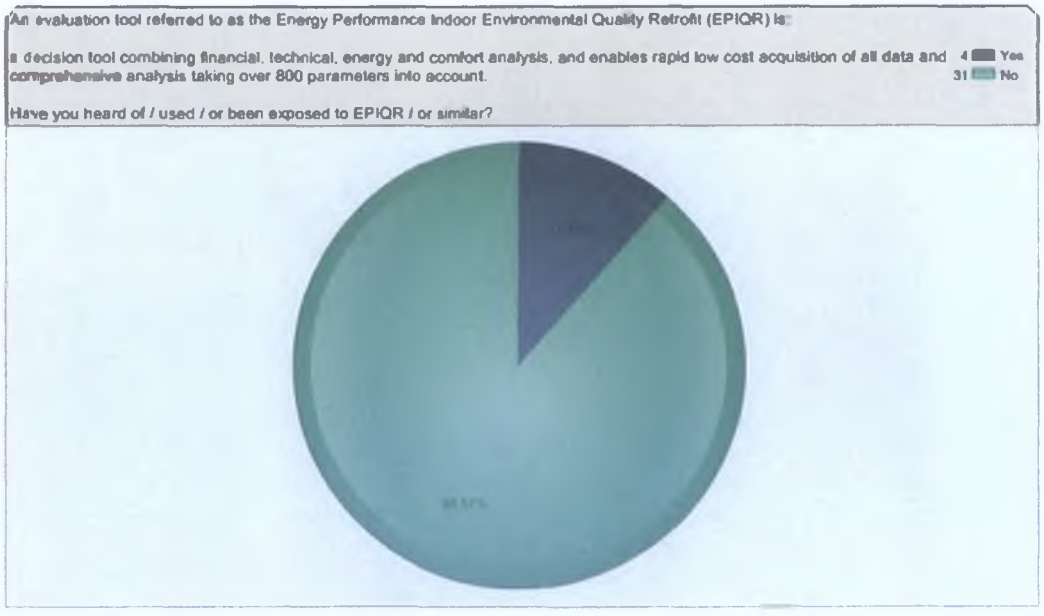


Figure 62: Survey Question 31 Response

Asked whether respondents had heard of Energy Performance Indoor Environmental Quality Retrofit (EPIQR) as an evaluation tool; 89% stated that they had not.

6.2.3.5 Question 32

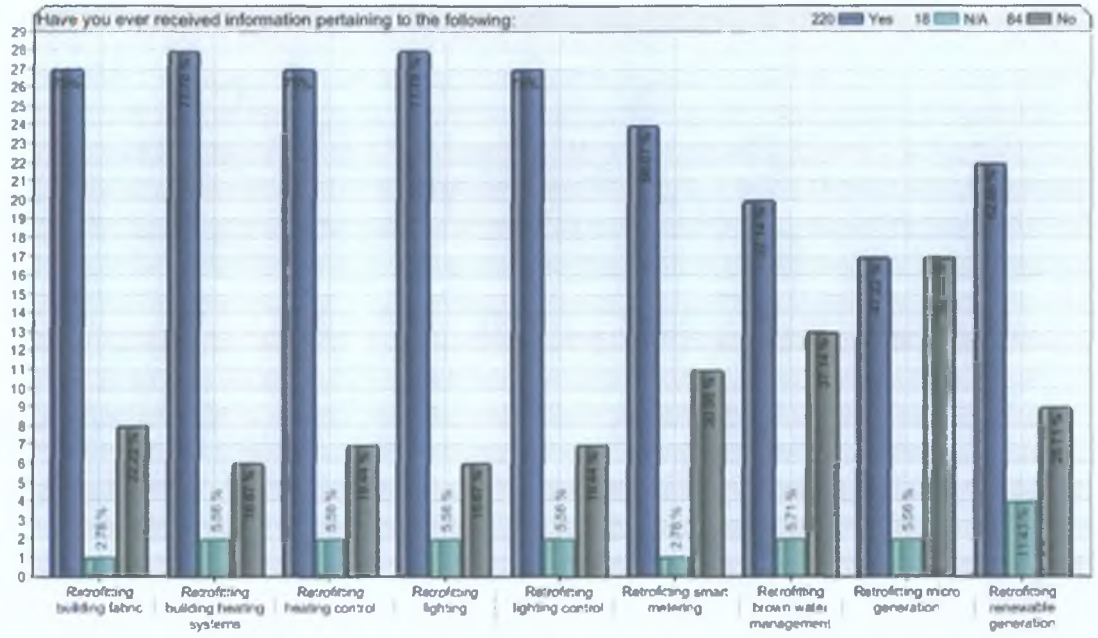


Figure 63: Survey Question 32 Response

Asked whether they had ever received information pertaining to the following:

- Retrofitting building fabric: Y 75%, N/A 3%, N 22%
- Retrofitting building heating systems: Y 77%, N/A 5%, N 18%
- Retrofitting building control: Y 75%, N/A 5%, N 20%
- Retrofitting lighting: Y 78%, N/A 5%, N 17%
- Retrofitting lighting control: Y 75%, N/A 5%, N 20%
- Retrofitting smart metering: Y 67%, N/A 3%, N 30%
- Retrofitting brown water management: Y 57%, N/A 6%, N 37%
- Retrofitting micro generation: Y 47%, N/A 6%, N 47%
- Retrofitting renewable generation: Y 62%, N/A 11%, N 27%

Interesting to note that relatively speaking; a reasonably high proportion of respondents have never received information pertaining to retrofitting smart metering, brown water management, micro generation and renewable generation.

6.2.3.6 Question 33

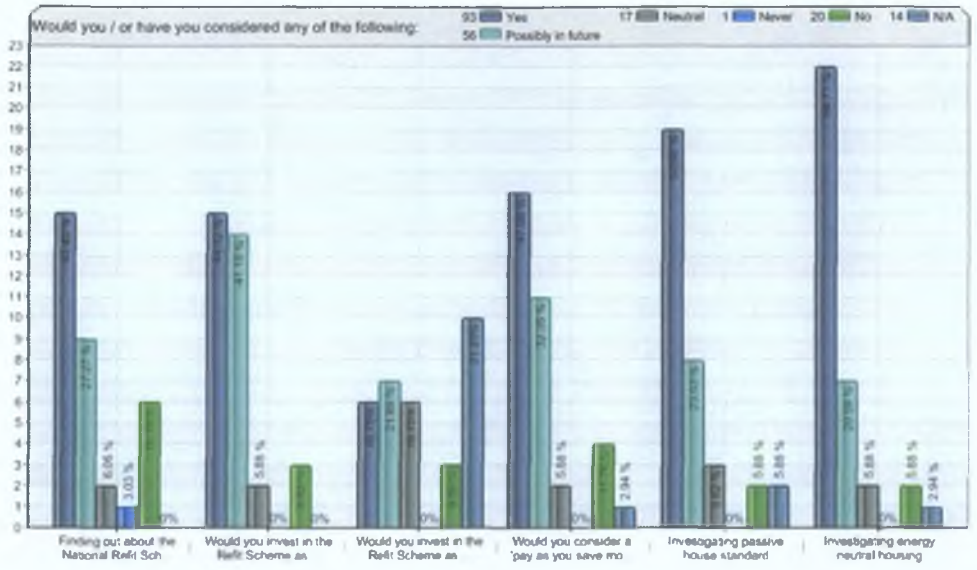


Figure 64: Survey Question 33 Response

Asked whether they had or would consider any of the following:

- Finding out about the national retrofit scheme: Yes (Y) 46%, Possibly (P) 27%, Neutral (N) 6%, Never 3%, No 18 %, N/A 0%
- Would you invest in the retrofit scheme as an owner: Y 44%, P 41%, N 7%, Never 0%, No 8%, N/A 0%
- Would you invest in the retrofit scheme as a landlord: Y 19%, P 22%, N 18%, Never 0%, No 10%, N/A 31%
- Would you consider a pay as you save model: Y 47%, P 32%, N 6%, Never 0%, No 12%, N/A 3%
- Investigate passive house standard: Y 56%, P 23%, N 9%, Never 0%, No 6%, N/A 6%
- Investigate energy neutral housing: Y 65%, P 20%, N 6%, Never 0%, No 6%, N/A 3%

Interesting to note a high proportion of positive feed-back across the entire spectrum, albeit for retrofit as a Landlord, this could be due to the fact that most respondents do not own investment properties, however, as the question posed asked whether the schemes might be considered, one might also say that landlords / or would be landlords are seemingly more reluctant to invest in retrofit and energy saving schemes.

6.2.3.7 Question 34

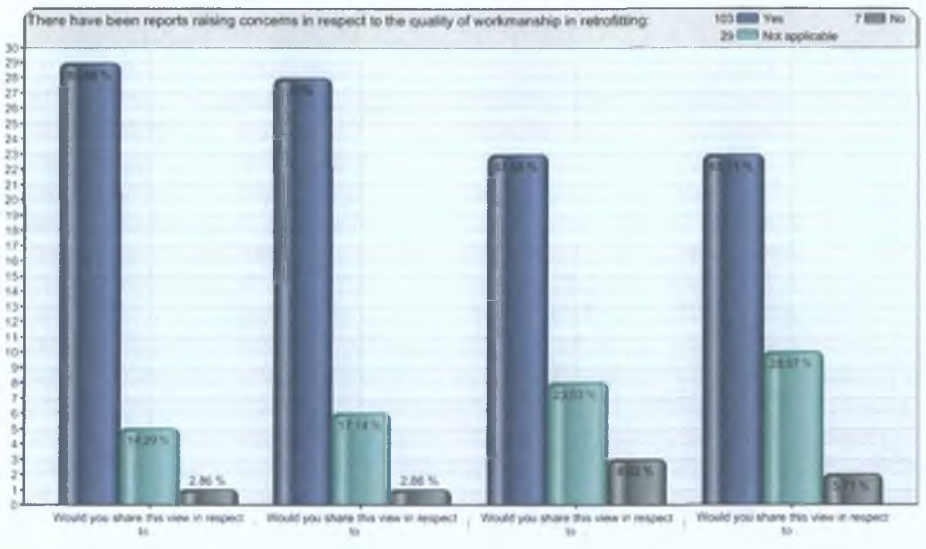


Figure 65: Survey Question 34 Response

Asked whether respondents have concerns in respect of retrofit quality under the following:

- Building Fabric: Yes (Y) 83%, N/A 14%, No (N) 3%
- Building Services: Y 80%, N/A 17%, N 3%
- Consultancy Advice: Y 68 %, N/A 24%, N 8%
- Other Retrofit: Y 66%, N/A 29%, N 5%

Interesting to note; a very high percentage of respondents confirmed concerns in relation to retrofit quality, with minor dips under consultancy and other retrofit.

6.2.3.8 Question 35

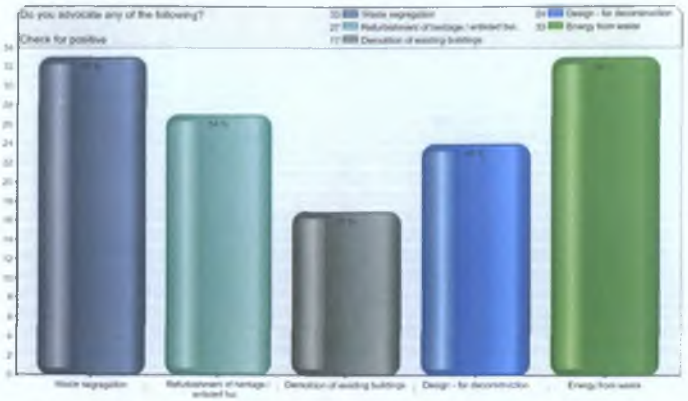


Figure 66: Survey Question 35 Response

Asked whether respondents advocated any of the following:

- Waste segregation: 66%
- Refurbishment of heritage buildings: 54%
- Demolition of existing buildings: 34%
- Design for deconstruction: 48%
- Energy from waste: 66%

It is interesting to note a high proportion of respondents confirmed waste segregation and energy from waste as a priority, whilst fewer advocated demolition of existing buildings.

6.2.3.9 Question 36

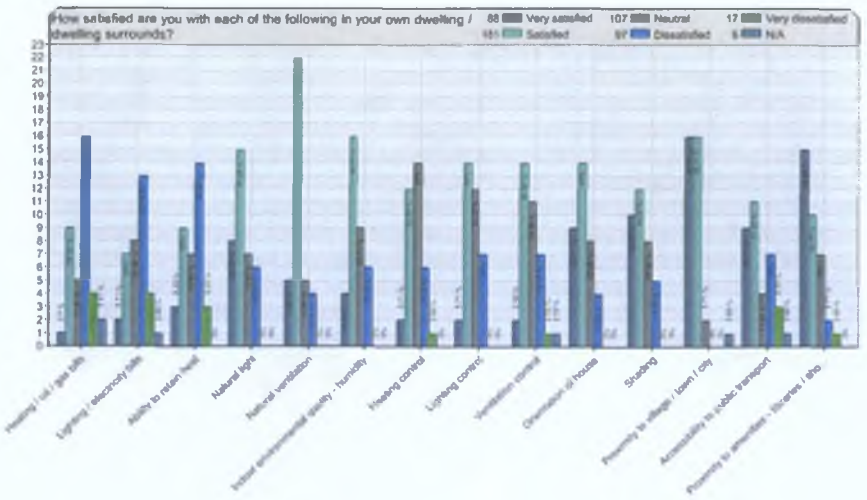


Figure 67: Survey Question 36 Response

Asked how satisfied with each of the following in their own home / dwelling surrounds:

- Heating / oil / gas bills: Very satisfied (VS) 3%, Satisfied (S) 24%, Neutral (N) 13%, Diss-satisfied (DS) 43%, Very Diss-satisfied (VD) 11%, N/A 6%
- Lighting / electric bills: VS 6%, S 20%, N 23%, DS 37%, VD 11%, N/A 3%
- Ability to retain heat: VS 8%, S 25%, N 20%, DS 39%, VD 8%, N/A 0%
- Natural light: VS 22%, S 42%, N 20%, DS 16%, VD 0%, N/A 0%
- Natural ventilation: VS 14%, S 61%, N 14%, DS 11%, VD 0%, N/A 0%
- Indoor environmental quality / humidity: VS 12%, S 46%, N 26%, DS 16%, VD 0%, N/A 0%
- Heating control: VS 6%, S 34%, N 40%, DS 17%, VD 3%, N/A 0%
- Lighting control: VS 6%, S 40%, N 34%, DS 20%, VD 0%, N/A 0%
- Ventilation control: VS 6%, S 39%, N 31%, DS 19%, VD 3%, N/A 2%
- Orientation of house: VS 26%, S 40%, N 23%, DS 11%, VD 0%, N/A 0%
- Shading: VS 29%, S 34%, N 23%, DS 14%, VD 0%, N/A 0%
- Proximity to village: VS 46%, S 46%, N 6%, DS 0%, VD 0%, N/A 2%
- Accessible to public transport: VS 26%, S 32%, N 11%, DS 20%, VD 8%, N/A 3%
- Proximity to amenities / libraries / shops / schools: VS 42%, S 29%, N 20%, DS 6%, VD 3%, N/A 0%

The following interesting trends stem from the analysis, namely:

1. A relatively high proportion of respondents are Dissatisfied and Very Dissatisfied (combined, approximately 50%) with their respective Heating and Electricity Bills and the dwellings ability to retain heat.
2. A high proportion of respondents are Neutral and Satisfied (combined, approximately 60%) with the following: Natural light, Natural ventilation, Indoor environmental quality, heating control, lighting control, ventilation control.

3. A high proportion of respondents are Very satisfied and Satisfied (combined, approximately 70%) with the following: Orientation of house, Shading, Proximity to village / town / or city and proximity to amenities, with a dip down in satisfaction (combined, approximately 60%) on accessibility to public transport.

6.2.3.10 Question 37

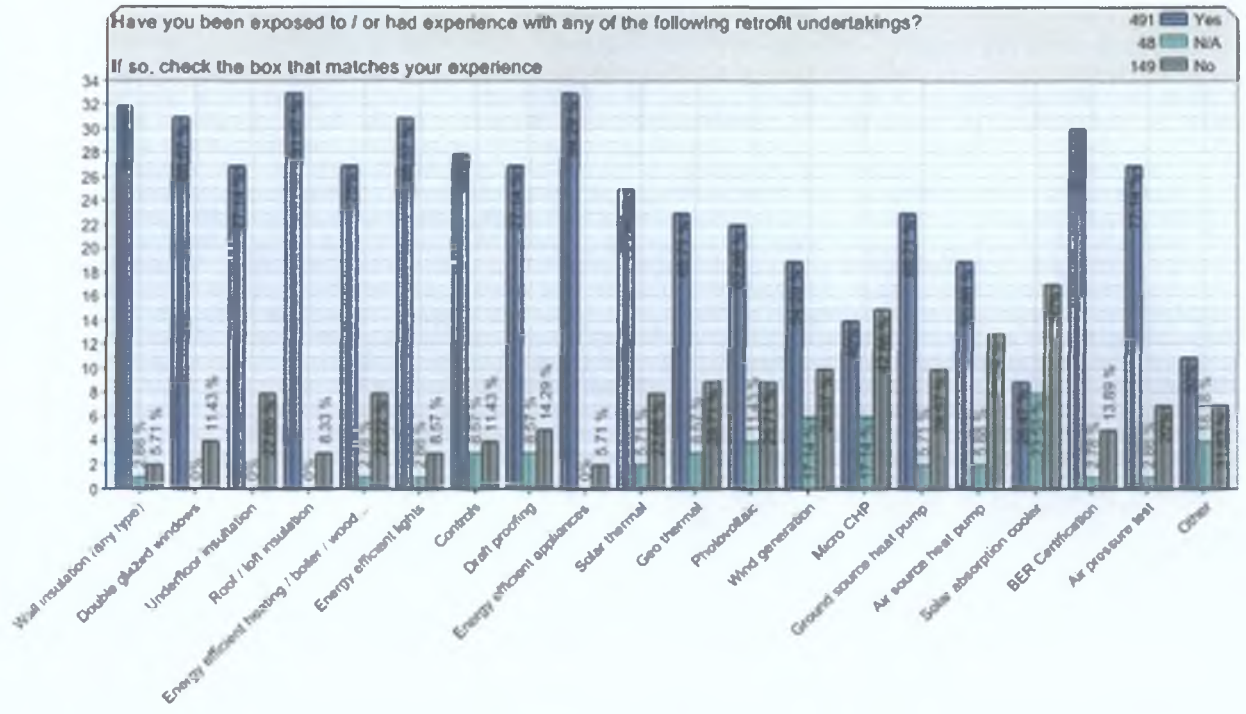


Figure 68: Survey Question 37 Response

Respondents were asked whether they had been exposed to / or had experience with any of the following retrofit undertakings:

- Wall insulation: Yes 91%, N/A 3%, No 5%
- Double glazed windows: Yes 88%, N/A 0%, No 11%
- Underfloor insulation: Yes 77%, N/A 0%, No 23%
- Roof / Loft insulation: Yes 92%, N/A 0%, No 0%
- Energy efficiency heating / boiler: Yes 75%, N/A 3%, No 22%
- Energy efficient lights: Yes 89%, N/A 3%, No 9%

- Controls: Yes 80%, N/A 9%, No 11%
- Draft proofing: Yes 77%, N/A 9%, No 14%
- Energy efficient appliances: Yes 94%, N/A 0%, No 5%
- Solar thermal: Yes 71%, N/A 6%, No 23%
- Geothermal: Yes 66%, N/A 9%, No 26%
- Photovoltaic: Yes 63%, N/A 11%, No 26%
- Wind generation: Yes 54%, N/A 17%, No 29%
- Micro CHP: Yes 40%, N/A 17%, No 43%
- Ground source heat pump: Yes 66%, N/A 6%, No 29%
- Air source heat pump: Yes 56%, N/A 6%, No 39%
- Solar absorption cooling: Yes 26%, N/A 24%, No 50%
- BER certification: Yes 83%, N/A 3%, No 14%
- Air pressure test: Yes 77%, N/A 3%, No 20%
- Other: Yes 50%, N/A 18%, No 32%

Interesting to note that whilst most activities scored high amongst respondents; the following items scored notably lower, namely: wind generation, micro CHP, ground source heat pump, air source heat pump and solar absorption cooling

7. OVERALL DISCUSSION AND CONCLUSION

7.1 Preface

National policies have targeted many industry sectors but have failed to directly tackle GHG emissions associated with construction activity (Acquaye and Duffy, 2010) specifically in material specifications, embodied energy and waste.

By retrofitting existing houses to Passive Standard and the employment of a sustainable Whole Town Strategy, it is perceivably viable that small rural towns can become a net energy exporters and Carbon Zero with economical, social and environmental benefits. Self-sufficiency through energy generation, water harvesting, sewage treatment, locally sourced materials, reuse and recycle is possible via a bottom up approach within a community. Social and cultural reform is necessary whilst awareness and incentives such as water metering, smart metering, carbon tax / credits (Trading Scheme) and the display of an Energy Certificate will all facilitate to motivate the community

A framework to low-carbon, low-impact, community-based sustainable housing and living can be invoked by the community from grassroots up. "Recognising the innovative nature of green niches at the policy level could lead to new approaches to governance of bottom-up community action for sustainable development." (Seyfang, 2010)

"Zero-carbon" homes are defined as zero net carbon emissions from all energy use in the home over a year, and applies at the level of the development, not the individual home, and at present does not permit offsetting to achieve the targets."(Seyfang, 2010)

Seyfang argues that the term 'sustainable' should not only equate to the energy use but also to the environment. Self-sufficiency through energy generation, water harvesting and sewage treatment (Singh et al., 2010), design also capitalised on solar gain, a resurgence of interest in traditional building materials which could be locally sourced from renewable or recycled materials such as straw bale, wood, cob (mud and straw mixtures), reed and thatch, as well as alternative formulations of concrete using natural materials such as 'papercrete' and 'hempcrete', innovation such as housing cooperatives and co-housing where facilities such as laundry and gardening are shared.

Most of the Zero Carbon strategies can be employed in retrofitting existing dwellings; where according to Williams, the Zero Carbon housing growth programme could offer an opportunity for accelerating the deployment of decentralised renewable energy systems (DRES) in the UK. (Williams, 2010) The definition for Zero Carbon (ZC) is subject to wider consultation and consensus; however Xing advocates a simple three step hierarchical approach to ZC refurbishment, namely: (Xing et al., 2011)

- Step 1: Reduce energy demand by retrofitting building fabrics to a higher standard.
- Step 2: Install energy efficient equipment
- Step 3: To establish on-site low and zero carbon energy supply technologies with smart grid connections and control. (Decouple building energy systems from fossil fuels)

7.2 Conclusion to Supposition

7.2.1 Embodied Carbon in Construction

Energy inputs need to be carefully considered when a decision is made to produce a product; moreover, the extraction of raw materials and the effects to the environment require meticulous scrutiny. (3.1)

It is now clearly apparent that a global embodied database is not possible, as raw materials extracted from different locations by different companies with different equipment, work methodologies and efficiencies will embody different coefficients for the same or similar product. (3.1)

In the Research Survey of this thesis; it is interesting to note that 24% of respondents stated that they had never heard of embodied energy whilst 14% had never given thought to embodied energy. The majority portion of respondents (56%) stated that they had never heard of or been exposed to an embodied energy database, whilst only 16% confirmed that they had exposure.

Life cycle assessment needs to associated to specific geographical confines where specific raw materials are being extracted and processed, this process needs to be audited and vetted to ensure the inventory of relevant energy, work and material inputs including environmental releases are accurate. It is important to note characterisation factors depend on gases different potencies and life spans in the atmosphere, so impact assessment must clearly state time horizon assumed calculations. (3.2) In addition, renewable energy flows and the toxicity of waste products needs to be taken into account in LCA, currently these are not accounted for.

All Life Cycle assessment procedures need to be in accordance with internationally standardised method (ISO 14040:2006) so as to ensure scope definition, inventory analysis, impact assessment and then the interpretations and conclusions are conducted on the same basis throughout the world. Practitioners should not rely on industrial average data, which may come from sampling of manufacturers, from trade organisations, or from pre-existing databases. Data from these sources, which includes electricity, fossil fuels and raw materials will vary in accuracy and exacerbates problems when trying to compare alternatives. It is now apparent that whilst LCA portrays results, the details of the information used to generate the results needs to be standardised; (3.2) where inventory flows can number in the hundreds depending on system boundaries, these system boundaries also need to be agreed and standardised, such as defining whether a product will be used for energy / recycled or disposed of after its useful life.

In the Research Survey of this thesis, it is interesting to note that 30% of respondents stated that they have given consideration to the LC of a product and 33% confirmed that they considered LCA to be worthwhile. In contrast, only 14% of respondents have been involved in LCA and 22% stated that they had not been involved in LCA.

This research has identified severe deficiencies in LCA associated with construction and low carbon methodologies, from the system of principals and terms, classification and naming through to ISO quality criteria which encompasses but is not limited to documentation extent, ILCD format, nomenclature compliance, data quality, technological and time-related representative-ness, quantitative criteria for accuracy and completeness, methodological consistency, data process compliance, registered independent external review through all processes, accounting procedures, computer integrated modelling and IT integration between computer calculators and inventory data bases.

In the Research Survey of this thesis; thirty seven percent of respondents stated that they had heard of / or been exposed to a carbon management system, whilst 42% answered 'no' to this question. Thirty one percent stated that it was possible to successfully manage carbon (35% sometimes) whilst 54% stated that in their opinion, carbon management is plausible.

Low carbon LCA associated with building and refurbishment is currently found to be a fragmented and haphazard undertaking with an ad-hock approach and little or no consistency in terms of the ISO quality standards and procedures as stipulated by the European Commission Joint Research Centre.

In the Research Survey of this thesis; the following 'yes' answers from respondents:

- Manufacturers should be audited in respect of a products embodied carbon and a certification process should be mandatory. (Yes - 59%)
- Construction materials manufactured from healthy plastics originating from 'say' corn (not oil), organic compounds or recycled material should be VAT exempt (Yes - 42%)
- Carbon management systems should be made mandatory in company Quality Assurance and Pre Qualification tender registers. (Yes - 39%)
- Robust guides for Boundary Critique and Boundary Judgement in Embodied Carbon inventories is critical to ensure statistical information relating to construction material is accurate and consistent. (Yes - 42%)
- Minimising the carbon footprint of a building creates awareness of the environmental impacts of material selection, product development and the manufacture process. (Yes - 73%)
- All construction materials should have visible labelling – confirming source and carbon footprint at source of dispatch. (Yes - 71%)

Whilst the response received was predominantly positive; again, it may also be said that a greater a proportion of respondents were unsure, with a large spread of results across: possibly, neutral and uncertain. It is interesting to note the high percentage marked against awareness and also material labelling, 73% and 71% respectively.

7.2.2 Sustainability

There is a growing realization in governments and multinational institutions that it is impossible to disconnect economic development from environmental issues, many forms of development displace and erode environmental resources upon which they are founded, where environmental degradation can in turn undermine economic development. (4.1) Environmental issues can therefore not be viewed without a broader perspective which encompasses factors such as poverty, international inequality and the various social and economic aspects occurring in the micro fabric of sustainable strategy. (Brundtland, 1987)

According to a NASA Goddard Institute for Space Studies (GISS); the solar increases do not have the ability to cause large global temperature increases, greenhouse gases are indeed playing the dominant role; that is; human activities are the primary factor in global climate change. (NASA, 2012)

There is now a direct correlation between GHG emissions, the burning of fossil fuels due to human activity and global warming which may have far reaching and devastating effects on all human kind.

7.2.2.1 Sustainable Development

Bio-energy deployment is therefore not straightforward, where the myriad of different options result in different GHG savings, savings depend on how land use is managed. Assuming sustainability and policy frameworks to secure good governance of land use and major improvements in agricultural management, the resultant resources could be substantial. (PIK, 2012)

In the long term, the potential for fossil fuel scarcity and decreasing quality of fossil reserves represents an important reason for a transition to a sustainable world wide RE system. Given the interdependence of economic growth and energy consumption, access to a stable energy supply is a major political concern and a technical and economic challenge facing both developed and developing economies.

In the Research Survey of this thesis; respondents (59%) stated that in their opinion, Bio-energy is a viable source of renewable energy into the 21st century and beyond. There were 15 comments received from 39 respondents, comments varied, from: 'a balance between food and the production of bio-fuels' to 'land for food growth and not energy crops'.

The composition of age class of the building stock of a country influences its future energy demand, especially for heating and cooling. Many buildings in developed countries have average life spans of 120 years and above, hence energy efficiency measures and the integration and deployment of RE technologies will need to result mainly from retrofitting of existing buildings. Developing countries have stock turnover rates of 25 to 35 years on average with relatively high new building construction growth, offering good opportunities to integrate RE technologies through new designs. (PIK, 2012)

7.2.2.2 Energy in Buildings

The UK is Ireland's closest neighbour; where it is reported that the most important energy end-use in the building sector is space heating, which is responsible for 25% of carbon emissions and accounts for over 60% of delivered energy and over 40% of energy costs in the residential sector. The thermal requirements projected by the SEAI 2009 Report titled 'Energy forecasts for Ireland to 2020', depicts an increase in energy consumption associated with heating, which correlates to the study and findings in the UK. The SEAI advocates the decarbonisation of electricity in Ireland by the implementation of the 'smart grid' which will cater for greater integration of indigenous renewable energy sources together with intelligent monitoring, control, communication and self healing technologies.

Excess morbidity and mortality in Ireland due to poor housing standards is amongst the highest in Europe; it was found that considerable long-term economic, environmental, health and social benefit could be realised if the thermal efficiency of Irish housing stock was to be increased to the requisite level (4.2.3.1). Further, it was noted that the level of income impacts on the ability to make capital investments in retrofitting a home; (4.2.3.2) whilst a study conducted by the Urban Institute Ireland at the University City Dublin (UCD) 2001, found that the highest numbers experiencing fuel poverty were occupying homes built between 1940 to 1970's and are therefore in the greatest need of retrofitting for a minimum of thermal efficiency. (4.2.3.4)

There are many factors characteristic with Energy in Buildings; some of which are housing conditions, income, thermal efficiency, dwelling age and the ability to retrofit to minimum standards; these also correlate to the alleviation of fuel poverty and GHG emissions and have direct influence on Government Policies, Sustainable Development, Economic and Social implications as well as the National Climate Strategy. (4.2.4)

In the Research Survey of this thesis; 100% of respondents stated that in their opinion, significant energy savings can be achieved by increasing the energy efficiency of the built environment. Again, 100% respondents stated that retrofitting renewable energy systems is a worthwhile undertaking, there were a total of twelve comments levied, see Figure 79: Survey additional comments Q.21. Approximately 95% of respondents agreed to the statement: 'retro-fitting the Irish housing stock to improve thermal standards will have substantial social, economic, environmental and health benefits to society'.

7.2.2.3 Sustainable Networking

Sustainable networking is pivotal to developing local employment initiatives, labour market integration and social inclusion. Initiatives encouraging shared use of human resources and facilities for research, development, education, culture, communication, health, environmental protection, improving energy efficiency and renewable energy cooperation through legal, administrative and institutional strategies

7.2.2.4 Harmonisation

National initiatives are linked to regional sustainable development priorities (4.3.2); harmonisation is essential to coagulate sustainable networking in shared human resources and development, whilst decoupling economic growth from environmental pressures to coincide with best international practices.

7.2.2.5 Sustainable Accounting

Social performance indicators are difficult to measure in quantitative units; more-over, absent is any guidance as to how competing elements are prioritised (economic, environmental and social), whilst it is doubtful whether continued economic growth is compatible with ecological sustainability.

In the Research Survey of this thesis; 84% of respondents reside in the ROI; yet 42% stated that they had not been exposed to or heard of SEC (4.2.4) which is by nature designed to promote social cohesion and economic development. Dundalk (Figure 25) was expected to have a radiating influence, yet 55% of respondents confirmed that they had no knowledge of SEZ. As all respondents targeted are construction professionals or affiliated to construction and environmental services, it is surprising that 60% have not heard of or been exposed to Sustainable Networking (Interreg).

7.2.3 Refurbishment

Space heating accounts for approximately 50% of the household energy use in the UK, and in the EU27, this figure averages closer to 70%. The Total Primary Energy (TPE) use is increasing due to the increasing number of households and larger dwelling size; with a direct relationship between GHG emissions and space heating, this area is contributing to climate change (4.1.2) and global warming.(Galvin, 2010)

> ***"The main barriers to progress are located in policy, process and availability of humane resources, rather than in technology as narrowly defined." (Lowe and Oreszczyn, 2008)***

According to Mullally; decoupling of economic activity and environmental degradation, requires greater economic efficiency; whilst Woodward opposes this view by stating that an efficient economy is not necessarily a sustainable economy, and that when considering policy alternatives, economic principals may not necessarily realise the required result.

The EU ETS (European Union Emission Trading Scheme, June 2012) provides economic incentives for abatement at a marginal cost (see 5.1), Woodward argues that carbon taxes are the justification for the use of a tax policy which again is based on the theory of market

efficiency, taxation uses the market mechanism to allocate adjustments to GHG emissions and does not sufficiently address the implications associated with sustainability.

In the Research Survey of this thesis; respondents were asked whether they had heard of Energy Performance Indoor Environmental Quality Retrofit (EPIQR) as an evaluation tool; 89% stated that they had not. Interesting to note that relatively speaking; a reasonably high proportion of respondents have never received information pertaining to retrofitting smart metering, brown water management, micro generation and renewable generation. Asked whether respondents would consider retrofitting in the capacity as a Landlord, most answered negatively, where this could be due to the fact that most respondents do not own investment properties, however, as the question posed asked whether the schemes might be considered, one might also say that landlords / or would be landlords are seemingly more reluctant to invest in retrofit and energy saving schemes. Interesting to note; a very high percentage of respondents confirmed concerns in relation to retrofit quality, with minor dips under consultancy and other retrofit. Also interesting to note, a high proportion of respondents confirmed waste segregation and energy from waste as a priority, whilst fewer advocated demolition of existing buildings.

There is now much greater awareness in the value of conserving our Architectural Heritage and the built environment in the refurbishment of older buildings and ensuring retention of detail and character which revitalises cities and towns, supporting the aesthetic value and promoting a distinctive identity. According to Davies, there are a significant number of dwellings within the UK existing housing stock which have great historic value, and are therefore protected by multiple public interest groups and heritage conservation orders which have inadvertently prevented the adoption of LCHR principals and strategies. Davies suggests

that architectural conservation bodies can facilitate the current impasse (Davies and Osmani, 2011b) and points out that conversion and extension projects of Listed and Victorian dwellings have increased during the current economic climate, whilst demolition and new building activities have decreased. Power argues that upgrading stock to a high environmental standards can actually be achieved more cheaply than demolishing, and with significant carbon reduction. Experience on Continental Europe suggests that retrofit costs to the full Passivhaus Standard, (5.4.4) typically equate to approximately 60% of what it would cost for to build the same dwelling completely from new.

Evidence suggests (5.4.9) that retention to refurbish has an important role in improving a communities health (Blackman et al., 2001) whilst community involvement coupled with low carbon programmes (SEAI, 2008), VAT incentives and information to education programmes facilitate up-take and create local momentum. (Davies and Osmani, 2011a)

7.3 Synopsis

Jones, Leach (2000) and DEFRA (2005) identify that there is no single solution to achieving a sustainable existence; a holistic approach is needed to reach the established CO_2 reduction targets. (Davies and Osmani, 2011b)

This holistic approach connotes that every aspect is considered; including the water consumption per capita per day in Ireland, which as it stands, is one of the highest in Europe. The use of domestic rainwater harvesting and greywater treatment systems has the potential to supply nearly 94% of domestic water in Irish households. (Li et al., 2010) Refurbishment undertakngs should take account of this.

Rural development policies are being undermined by other policy instruments (specifically transport) which have a contradictory impact. (McDonagh, 2006) Economic sustainability is best secured by the creation of local or regional self-reliant, community economies. Local currencies, community corporations, regional food economies and other locally oriented efforts, eco-local theory presents a new analysis of the "economy of place". (Curtis, 2003)

Eco-effectiveness and cradle-to-cradle design present an alternative design and production concept to the strategies of zero emission and eco-efficiency. (Braungart et al., 2007) To achieve high levels of renewable energy generation, similar distributed wind/hydrogen hybrid systems could reduce the need for curtailment of wind farms, save wasted energy, reduce backup power, reduce transmission losses, generate large revenue by selling power at peak times, ensure security of supply and reduce the need for costly interconnects to Europe. (Carton and Olabi, 2010)

7.3.1 Greenfield development

With poignant planning and research into demands, trends and technologies, coupled with the advantage to consider a 50 year time horizon, Greenfield development can be sustainable in those instances where additional requirements need to be met and the land-take is justified in terms of the use designated.

Regulation, legislation and building codes need to be espoused and rigorously imposed with the aid of suitably qualified building inspectors and grant agencies taking full yield of the benefits to modern methods of construction (Monahan and Powell, 2011) and Greenfield development opportunities in context of reliable data to enable instructive decisions in a local context.

It is imperative that Greenfield development takes cognisant of (Brundtland, 1987) statement that ***"Development is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs."*** Specifically in materials selection, interface and construction methods where design for de-construction should be adopted as standard practice to ensure the copious reuse of our ailing resources.

Renewable, recycled and composite products and materials to be adopted in building codes governing Greenfield development; whilst design offices should be made to take account and publish the energy needed to manufacture the material specified and validate this against carbon efficiencies anticipated. (Szalay, 2007)

Greenfield developments with renewable energy generation to grid should be granted elevated incentives with emphasis on waste to energy generation from the effluent on site, such as AD (IrishFarmersJournal, 2010) to complete self sufficiency.

New services and infrastructure should be designed and installed so as to facilitate flexibility, expansion and maintenance, whilst ensuring high installation quality and the incorporation of smart metering and BMS technology. (Pitts, 2008a)

7.3.2 Regeneration and Brownfield site

Demolition and regeneration to Brownfield sites are a necessary undertaking in specific instances once a careful, selective and balanced approach to all considerations has been rigorously employed.

Table 11: Demolition and Brownfield Development. (Thornton et al., 2007)., (Power, 2008)., (Yates, 2006)

DEMOLITION & BROWNFIELD	
Barriers	**Drivers & Enablers**
Loss of a home & Cost of replacement	Opportunity to increase urban density whilst making use of existing infrastructure.
Designated demolition areas do not attract investment, can lead to disrepair, vandalism and neighbourhood blight	Opportunity for choice of materials, high standards and high BER Ratings
Demolition is difficult to execute on a restricted house by house basis, usually entire streets or neighbourhoods are demolished with viable properties being destroyed.	Opportunity for better solar orientation, new technology and low carbon heating / cooling systems
Socially disruptive, complex and slow in re-housing terms. This generates opposition especially in areas where there is a high percentage of occupancy.	Opportunity for Socio-economic and urban regeneration including green spaces and smart metering.
Hardship to residence as schools, shops, banks and other provisions vacate designated area long before re-housing.	Opportunity to address planning issues and create whole life Town Centres with modern amenities
Loss of viability and investment may lead to ugly refuse-strewn sites affecting a far wider area.	Increased local market activity, employment and ultimately investment
Facilities, meeting places and social infrastructure may be lost for decades.	Opportunity to address contamination and hazardous materials which would have been required, perceived to be a better Health and Safety proposition.
Young people may become disorientated when properties are expropriated for demolition.	Opportunity to rejuvenate idle, abandoned and underused real estate back to beneficial use with a positive effect on the wider community.
Re-housing creates an additional housing demand, whilst demolition reduces housing capacity.	Opportunity for new innovation and technology to present better re-use and recycle from demolition
Slow legal processes, the whole process may take up to 20 years	Opportunity for innovative thinking in system building, life cycle and use analysis coupled with design for deconstruction and re-use
Survey has shown that demolition drives sprawl and mostly blights poorer areas, this may contribute to urban exodus.	Opportunity for market and economic stimulation driving new high technology materials solutions and alternatives.
Environmental aspects such as loss of valuable materials, impact on landfill, increased transport, Health & Safety aspects, embodied carbon in replacement, etc	Opportunity for Case Study research driving new legislation and socio-economic and environmental policy.

7.3.3 Retention to Refurbishment

Reliable research identifies that retention and refurbishment displays the most viable argument to the scenarios raised in this research; especially over the short to medium term where refurbished homes can perform as well as new homes over a 60 year period (Power, 2008); however, behaviour change, education, retraining and standardised assessment techniques need to be invigorated at national level.

Table 12: Retention to Refurbishment. (Gorgolewski et al., 1996)., (Davies and Osmani, 2011a)., (Power, 2008)

RETENTION & REFURBISHMENT	
Barriers	**Drivers & Enablers**
Data base knowledge on exact embodied energy values of materials, manufacture & installation	Improvement to communities health coupled with social grounding and a reduction in fuel poverty
Case study research on environmental impacts and associated costs.	Economic, environmental and cultural benefits including architectural, historic and aesthetic merits
Limited engagement with manufacturers and key stakeholders	Retention and protection of valuable archaeological assets including the inhabitable transformation of enlisted buildings
Limited practitioners with adequate knowledge on material specification, correct solution and use	Sustainable use of resources, reduced transport and substantial environmental benefits including reduced landfill
Lack of adequately trained and resourced building inspectors to monitor building code, legislation and local by-laws	Sustainable development model with retention to character and quality of local street scapes, coupled with enhanced appearance
Lack of wide spread and accessible education programmes to facilitate up-take and local momentum	Maximum use of existing infrastructure both permanent, fixed and movable services.
An inert human trait adverse to change	Small scale local contractors, labour and local market stimulation
Lack of suitably skilled and qualified tradesmen and shop stewards in the correct installation and sequence of new technology and materials	Case studies prove economic viability and a substantial monetary saving in contract to Brownfield or Greenfield development
Limitations to possible energy reduction based on existing orientation, funds available and structural repair	Legislation, policy, incentives and grants available such as the warmer homes scheme and greener home scheme in Ireland
Limited regeneration and scale of densities, trade off to valuable real estate, maximum use of existing infrastructure and business development to future trends	Integrated phased solutions are preferred with less disruption and upheaval of community.
Limited green space expansion with retention; limited green technology employment such as Green Roofs	Structural, aesthetic and general building upgrade can coincide with integrated energy upgrade solutions
Limited life cycle use with retention, may require expansive alterations in future to apprise evolving trends and movement	Gains and benefits are quickly realised and contribute towards up-take momentum, the benefits feed to the local and wider spread environment

7.4 Recommendations

7.4.1 Embodied Carbon in Construction

Not every factor taken in LCA can be reduced to a number and inserted into a model, where social implications are generally lacking from Life Cycle Analysis and evaluation on how LCA models attempt to describe an infinite complex real world with a series of categories and numbers; this needs to be reappraised.

Boundary critique is critical to professional propositions considered with the results of LCA; therefore if different boundary judgement exists, different statistical information and different product use and end use can sway LCA validity due to these varying parameters. Detailed appraisal and consideration to boundary parameters through the LCA process needs to be meticulously thought through and standardised so that results can be used without reservation when considering options.

7.4.1.1 Construction Materials

There is a high level of uncertainty on the results of the 'as-built / or as-planned' LCA due to the fact that whilst a specific material may have a durable service life, it may be replaced relatively quickly for aesthetic or market / economic reasons. The recommendation to 'as-built' LCA should include a mandate for specific service life on vetted materials, including how such materials are removed, re-used and or disposed of.

Carbon Management and the Embodied Carbon Ladder which tracks embodied carbon from inception through to construction, operating or in-use carbon, and then deconstruction should be made mandatory for any building or refurbishment project from planning to client hand over and then operation. The facilities management should be enlisted to track the in-use carbon during the life span of the installed product within the building, such as repair,

maintenance, restoration, refurbishment and the replacement of materials and components which have been installed. This information should be collected by a government body and used as a centralised data base for in-use embodied carbon on materials, products and working systems so as to facilitate future thinking, planning and decision making.

There are many various Carbon Calculators available to practitioners; the analysis is subject to the usual critique associated with the availability, quality, consistency and accuracy of data including the validity of data to a specific region. A recommendation is that the Central Statistical Office should provide one standardised carbon calculator for a particular region or county, in this way aggregate sector data will not be used to evaluate environmental aspects and impacts; whilst a centralised calculator can also be used as a management tool and bespoke solutions to a specific region which may have local resources. The calculator and used coefficients can then also be adjusted from a central source so that practitioners are making use of the same system boundaries when evaluating materials and making decisions in selecting the best materials to minimise the carbon footprint of a building, both during construction and during operational use to re-use or disposal. Local knowledge and construction skill can also feed into such calculator facilitating decisions relating to techniques and aggregate supply alternatives, in that way shoring up a robust and long term management and reporting carbon tool where authentic Key Performance Indicators (KPI's) for a region or county can be established.

7.4.1.2 Research Survey

In the Research Survey of this thesis; it is clearly apparent that a high proportion of respondents had never heard of embodied energy or given thought to embodied energy. The majority portion of respondents stated that they had never heard of or been exposed to an

embodied energy database; the recommendation here would be to include these areas of exposure and expertise in future education, instruction and degree courses.

7.4.2 Sustainability

The Intergovernmental Panel on Climate Change (IPCC) fourth assessment report on climate change 2007, summary for policymakers notes the following significant influences due to global warming, namely: rise in sea level (15-95 cm by 2040), altered rainfall and temperature patterns, change in agriculture / ecosystems and human habitation patterns, decline in global food production, gulf stream shut down; secondary effects could lead to migration, poverty, famine and regional conflict. Recommendations include sustainable design to mitigate the emissions of GHG's, planning to take account of 'pending' affects such as increasing floor level heights above NGL, increasing minimum threshold heights from 150 mm to 250 mm, designs to cope with increase rainfall, greater emphasis on passive cooling and also greater emphasis on food production and sustainable land and site use.

7.4.2.1 Sustainable Development

Bio-energy has complex and dynamic interactions among society, energy and the environment including climate change impacts and various spatial and temporal scales on all resource uses for food, fodder, fibre and energy. Biomass resources need to be produced and managed in sustainable ways as their impacts can be felt from micro to macro scales by increasing carbon stocks in the biosphere, reducing carbon emissions from unsustainable forest use and by replacing fossil fuel based systems in the generation of heat, power and modern fuels. It is therefore imperative that a coordinated approach between food and fuel is adopted in conjunction with detailed assessments on land use in context of the micro region. Good governance will also include sustainable frameworks that generate effective policies that lead to sustainable ecosystems whilst providing opportunities for regional economic development.

Historically, economic development has been strongly correlated with increasing energy use and growth of GHG emissions, renewable energy (RE) can help decouple that correlation, contributing to sustainable development (SD). In addition, RE offers the opportunity to improve access to modern energy services for the poorest members of society, which is crucial in addressing concerns about relationships between human society and nature.

A well-implemented Feed in Tariff (FIT) as adopted in Germany helped guarantee high investment security due to a combination of long-term fixed price payments, network connection and guaranteed grid access on all renewable generation. Well designed FITs have encouraged both technological and geographic diversity and have been found to be more suitable for promoting projects of varying sizes.

7.4.2.2 Sustainable Energy Community

A Sustainable Energy Community (SEC) offers a wide range of benefits to all stakeholders where new working partnerships are formed between the community, SME's, providers, consumers and householders whilst allowing national policy to be delivered at local level. The recommendation is therefore to include and promote retrofitting of existing buildings within the SEC, this combined with low carbon and renewable energy will lower the environmental impact of the community, facilitate demand side management through greater self sufficiency and increase security of energy supply. A further recommendation is to include retrofitting of existing buildings as a focal point, where a SEC has critical mass and is converging into a Sustainable Energy Zone (SEZ) and the community is striving for sustainable development and energy through diverse techniques and technologies.

7.4.2.3 Sustainable Networking

Interreg is an initiative that aims to simulate cooperation between regions within the European Union and involves collaboration among authorities of two or more Member States. A recommendation would be to develop a retrofit programme capitalising from collaborative knowledge and diverging this Sustaining Small Expanding Towns (SusSet) thus also bolstering local development and strengthening the spirit of enterprise.

A further recommendation is that the barriers as described by Petzel (4.3.2.3) 'in a networked world', are carefully elucidated and resolved so that the wider benefits gained through collaboration may be amassed for a European wide database and capitalised upon in the short term.

7.4.2.4 Sustainable Accounting

Research linking accounting to the emerging concept of sustainability surfaced in the early 1990's; where it is difficult to understand the breadth, complexity and enormous challenges which require significant commitment of resources to achieve and implement a sustainable accounting framework successfully. The recommendation is therefore to establish, resource and maintain a National Sustainable Accounting framework, using a series of performance indicators to measure the economic, environmental and social (employee, consumer, human rights) dimensions. Further, the EU needs to ascertain and institute guidance on how 'social' performance indicators are to be quantified and prioritised, greater emphasis on retrofitting and refurbishment will most certainly facilitate in off-setting growth from ecological sustainability.

7.4.2.5 Land rights and sustainable development

Agenda 21 addresses virtually every aspect of life and devises many policy recommendations that Member States are expected adopt. The recommendation is therefore that a harmonized

effort to coordinate national strategies, plans, policies, and processes are considered, specifically in relation to social and economical dimensions, management of resources for development and refurbishment, and then also on the question of individual land rights in terms of leaving the land in a better state than that which the owner found it in at the time of acquisition. (ref: construction and demolition sector, which produces contaminated soil, 5.1.1)

7.4.2.6 Efficiency and Sustainability

Ireland has identified several weaknesses in the National Development Plan 2007 – 2013; the recommendation is (4.3.3) that the State focuses on the deficiencies identified with emphasis on achieving sustainable and balanced development, contributing optimal performance economically, socially and environmentally through correct and good policy governance.

7.4.2.7 Research Survey

It can be said that the construction professionals who responded to the survey are not well informed in relation to Sustainable initiatives; specifically in relation to SEC and SEZ, the recommendation is that the SEAI and other affiliates should institute Master Classes for all construction professionals and endorse active involvement in Sustainable Networking.

7.4.3 Refurbishment

Xing states that space heating accounts for the largest building energy use (about 40% of final energy consumption and about 85% of domestic energy consumption); where external wall insulation and improving air tightness greatly reduces energy bills. (Xing et al., 2011) According to Motherway; implementing simple building efficiencies in lighting, appliances and electronics, almost 1 million tCO_2e can be saved; however with a negative cost of approximately €40 per tCO_2e in retrofitting residential building envelopes, such as double glazing, external wall insulation and roof / attic insulation measures, a further 2 million tCO_2e

can be saved. The EU appliance energy consumption labelling scheme is a key component of efforts to increase the diffusion of energy-efficient household appliances. (Mills and Schleich, 2010) (O'Doherty et al., 2008) (Leahy and Lyons, 2010) In the technical appendix; Motherway argues that a further 4 million tCO_2e can be achieved via behavioural measures. DEFRA claims that behavioural change is as much needed as regulation and enforcement, whilst Dobson recommends fiscal incentives. Corporate Social Responsibility (CSR) has the potential to be a commanding driver with reduced operational costs coupled with potential for higher rents and sales for energy efficiency. (Davies and Osmani, 2011a)

The over-optimistic projections by the SEAI (SEAI Strategic Plan 2010-2015) such as the acceleration of renewable electricity from 15 per cent in 2010 to 40 per cent in 2020, the fast tracking of ocean energy deployment and the support of micro generation development and deployment would be more readily realised through policy proposals around a growing suit of new energy positive buildings complimented by strong energy retrofitting of all existing buildings through robust new standards and regulations to support retrofitting with emphasis on quality and a leadership position demonstrated by public sector policies.

Jones and Leach (2000) and DEFRA (2005) identify that there is no single solution to achieving a sustainable existence; a holistic approach is needed to reach the established CO2 reduction targets. (Davies and Osmani, 2011a) The Whole House Approach (5.4.5), is where the approach considers a households energy needs and carbon dioxide impacts as a whole, thereby establishing a tailored but comprehensive package of measures to address them, this also ensures that adopted measures happen in the right order with minimum disruption. The Decent Homes programme (UK) is be considered to be a positive evolution in the retrofitting methodology, especially in the current economic climate (5.4.5) where defined grades of up-lift are implemented over a defined time period, this is not all measures at once and also not all measures to the highest standards first time.

"It is found that the lowest standard is an order of magnitude more cost-effective than the highest, in terms of both energy saved per euro invested, and return on investment over the lifetime of the renovations, regardless of fuel prices", (Galvin, 2010)

There are a great many variants which need to be considered prior to undertaking a building's refurbishment, including: cost of refurbishment and the pay-back time, effects to health and the environment in respect to materials employed, annual fuel economy and cost of maintenance, aesthetics and functionality, comfort levels associated with heating, cooling, sound and air quality and then the longevity of the building fabric and improvements. (Brager, 1996) The recommendation is therefore that Multivariant design and multiple criteria analysis which allows for a broad spectrum of data to be processed and evaluated; is refined and made available as a standardised tool to designers from inception stage to refurbishment.

Jaggs and Palmer note that a successful approach to refurbishment can result in improved structural conditions, improved living conditions and reduced energy costs whilst also informing and encouraging future retrofit projects.

In a study conducted in the UK; the respondents defined the 'lack of a uniform approach for applying sustainable strategies' as a hindrance for successful LCHR design and implementation, where it was suggested that there should be a 'Code for Sustainable Housing Refurbishment' (CSHR) addressing the lack of clarity surrounding Building Regulations for refurbishment, whilst it was also noted that Part L of the Building Regulations is not stringent enough in terms of compliance obligation in regard to refurbishment, and that non-retrospective principal behind the Building Regulations is a serious LCHR obstruction (Davies

and Osmani, 2011b). The recommendation is therefore to address this issue at policy level and implement a National Code for Sustainable Housing Refurbishments.

In the Research Survey of this thesis; generally a positive response to retrofitting albeit for little if any experience in wind generation, micro CHP, ground source heat pump, air source heat pump and solar absorption cooling

1. A relatively high proportion of respondents are Dissatisfied and Very Dissatisfied (combined, approximately 50%) with their respective Heating and Electricity Bills and the dwellings ability to retain heat.
2. A high proportion of respondents are Neutral and Satisfied (combined, approximately 60%) with the following: Natural light, Natural ventilation, Indoor environmental quality, heating control, lighting control, ventilation control.
3. A high proportion of respondents are Very satisfied and Satisfied (combined, approximately 70%) with the following: Orientation of house, Shading, Proximity to village / town / or city and proximity to amenities, with a dip down in satisfaction (combined, approximately 60%) on accessibility to public transport.

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9. APPENDICES

9.1 House of Tomorrow: list of technology options

House of Tomorrow – List of Technology Options

Technical Requirements

Feature/ Item	Tick below as appropriate	Comments/Notes
INTEGRATED SITE PLANNING		
1. Appropriate site development strategy with links to wider community/ commercial developments		
2. Energy efficient transport link(s)/ Pedestrian and bike friendly		
3. Provision for Household/Garden/Sanitary waste management		
4. Group or district heating with efficient distribution		
5. Other positive ecological features (please specify)		
TOWARDS LOCAL ENERGY AUTONOMY		
1. *Energy from local biomass or waste*		
2. *CHP*		
3. *Wind energy source*		
4. *Photovoltaic electricity*		
5. *Other renewable energy sources*		
LANDSCAPING & SHELTER		
1. Use of site contours		
2. Reduce site exposure via earth berming, shelter planting, or wind barriers		
BUILT FORM, DESIGN & ORIENTATION		
1. Compact built form to minimise surface area for heat loss		
2. Orientation and internal zoning to facilitate passive solar heat gain and day lighting / optimised glazing to the south and west		
3. Design for natural cooling and ventilation / appropriate thermal mass for passive solar heat storage		
4. Sunspaces and collector walls/ floors		
5. Design for spatial/ functional adaptability		
FABRIC ELEMENTS		Must surpass elemental u-values at a minimum
1. Pitched Roof insulation at ceiling (U-value ≤ 0.16 W/m^{2}K) or on slope (U-value ≤ 0.20 W/m^{2}K)		
2. Flat Roof (U-value ≤ 0.22 W/m^{2}K)		
3. Wall insulation (U-value ≤ 0.27 W/m^{2}K)		
4. Floor insulation (U-value ≤ 0.25 W/m^{2}K)		
5. Windows, doors and roof lights (U-value ≤ 2.2 W/m^{2}K)		
6. Detailing to minimise cold bridging		

9.2 House of Tomorrow: energy technology specifications

House of Tomorrow – List of Technology Options

VENTILATION & AIR QUALITY CONTROL		
1 Draught lobby (single or double)		
2 Comprehensive ventilation strategy to include:		
• Planned ventilation paths and openings		
• Underfloor draught supply or balanced flue to all fireplaces and heating appliances		
• Controllable trickle ventilation		
• Mechanical air extract from kitchens & bathrooms, with humidity activation		
• Draught sealing of all openings and joints		
or equivalent.		
3 *Comprehensive structural sealing against air leakage*		
4 *Balanced mechanical ventilation with heat recovery, or equivalent*		
5 Allergen & asthma reduction measures		
6 Radon reduction (where applicable)		
HEAT GENERATION SOURCE (single or group)		
1 Low emissions appliance with seasonal thermal efficiency over 75%		
• Condensing boiler (natural gas, LPG or oil)		
• Combi boiler (natural gas, LPG or oil)		
• Wood burning stove with low emissions (preferably auto-feed)		
• Low emission solid fuel appliance (preferably auto-feed)		
2 Innovative heating system		
• *Active solar space and/or water heating installation*		
• *Heat pump installation (gas or electric)*		
• *Micro – CHP installation*		
3 SECONDARY HEATING APPLIANCE (if applicable) High efficiency, low emissions, stove or equivalent .		
HEATING DISTRIBUTION and CONTROLS		
1 Insulation of all heating pipes and ducts in unheated locations		
2 Separate space & water heating circuits		
3 Minimum seven day programmable controller or Optimum start/stop programmer		
4 Thermostatic radiator valves or Zoned space temperature controls		
5 Zoned and timed temperature controls		
6 Weather compensating temperature control		
7 Remote access computer compatible controls		
8 Computerised energy management system (Group Heating)		
9 User friendly heat metering *Except solid fuel fired (Group heating)		
SANITARY H&C WATER & WASTE FACILITIES		
1 Combi boiler		
2 Instantaneous gas fired water heating		
3 Gas fired hot water storage cylinder		
4 Water economy measures (mixer taps, economy flush toilets, grey water capture, etc.)		
BUILDING MATERIALS		
1 CFC and HCFC free materials		
2 Sustainable materials selection:		
• Low toxicity materials		
• Materials from sustainable sources		
• Local materials		
• Low embodied energy materials		
• Materials with recycled content		
APPLIANCES: REDUCED ELECTRICITY USAGE		
1 Low energy lighting/appliances		
2 Provision for natural clothes drying		

9.3 Whole House Approach

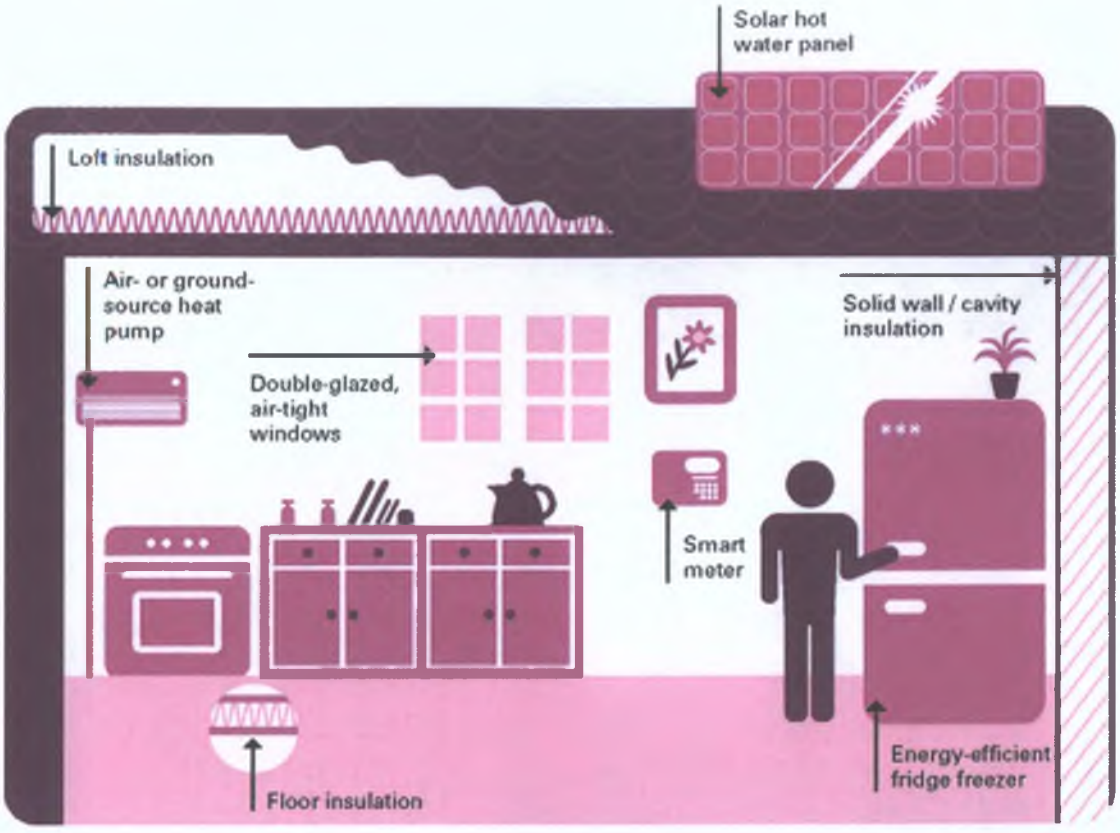


Figure 69: The Whole House Approach, UK. (Central Government, 2009)

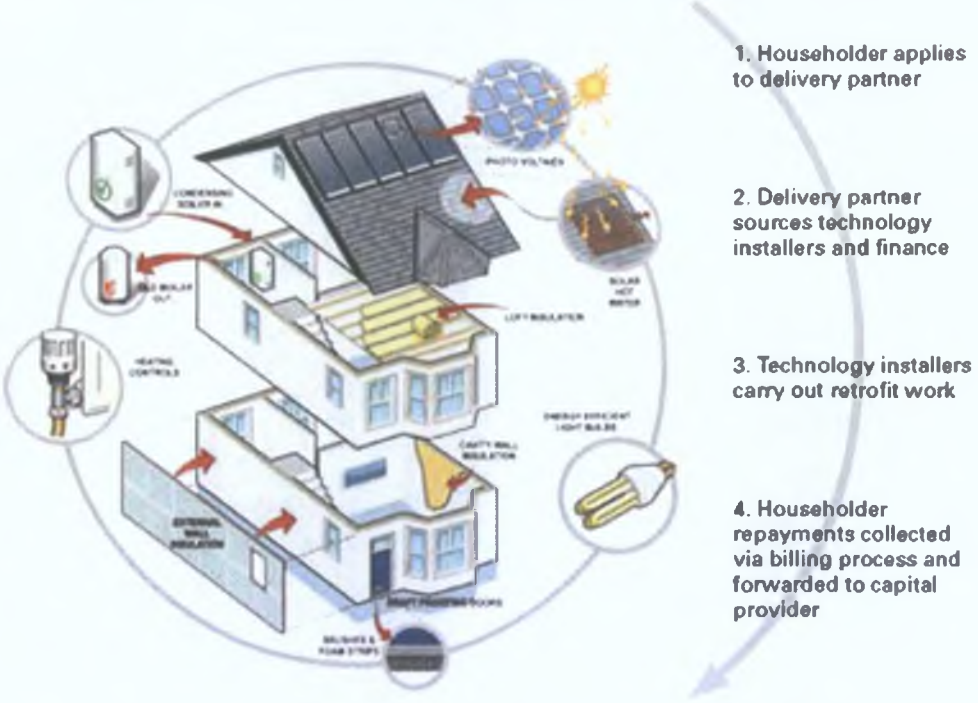
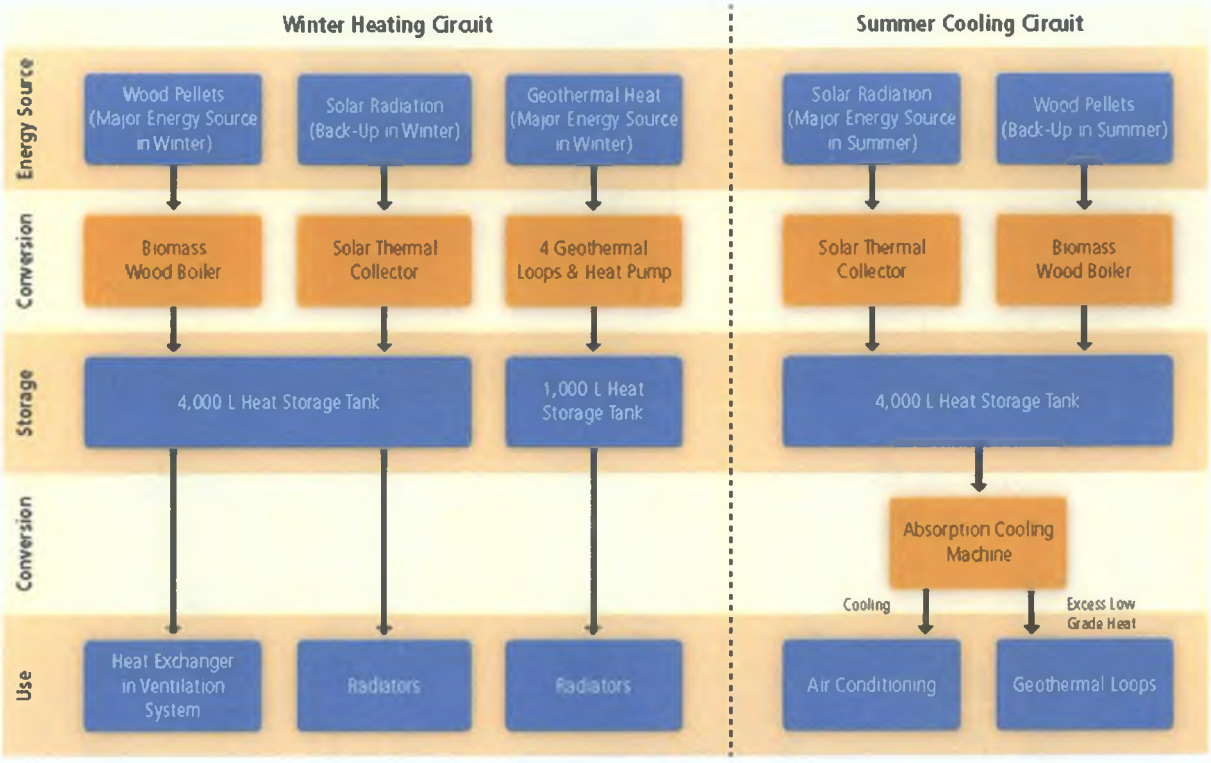


Figure 70: Possible Pay as you Save Model, UK. (Central Government, 2009)

9.4 Integrated Heating and Cooling Systems

Table 13: Integrated RE heating and cooling systems installed in a 120 year old building. (PIK, 2012)



9.5 House completions Qtr 1 and Qtr 2 2006-2008

Table 14: House completions 2006-2008 (CSO, 2008)

	Unit	2006[1]	2007	2008
Completions				
Private housing units	No.	36,795	36,567	24,497
Local authority housing units	No.	1,345	1,891	2,352
Voluntary housing units	No.	528	520	887
Total completions	**No.**	**38,668**	**38,978**	**27,736**
Share of Completions				
Private housing units	%	95.2	93.8	88.3
Local authority housing units	%	3.5	4.9	8.5
Voluntary housing units	%	1.4	1.3	3.2

Source: DEHLG Housing Statistics

[1] Incorporating downward adjustment by CSO to 2006 housing completions estimate.(see note)

Note: House completions data series are based on the number of new dwellings connected by ESB Networks to the electricity supply and may not accord precisely with local authority boundaries. These represent the number of homes completed and available, and do not reflect any work-in progress. ESB Networks have indicated that there was a higher backlog in work-in-progress in 2005 than usual (estimated as being in the region of 5,000 units). This backlog was cleared through the connection of an additional 2,000 houses in Quarter 1 2006 and 3,000 houses in Quarter 2 2006.

9.6 Urban Consolodation Priorities

Table 15: Urban Consolidation Priorities. (Central Government, 2002)

1: Identify Opportunities for Re-Use	Through the development plan process, identify under-utilised, derelict or undeveloped lands within towns and villages.
2: Realise Options for Re-Use	Realise identified opportunities using, for example, the Derelict Sites Act and acquisition of key sites.
3: Identify Extension Options	Where sufficient development opportunities within the urban area are not available, consider appropriate extension options to the village or town.
4: Realise Extension Options	Follow up on options for extensions to the built up area using the tests in Box 5.2.

9.7 Proposed steps in retrofitting rural Ireland (1 of 2)

Table 16: Proposed Retrofitting to Passive House Standard in Rural Ireland (1 of 2) (SEAI, 2007) (SEAI, 2009c) (GreenSpec, 2010)

No	Element	Passivhaus Standard U-Values	Estimated Current Standard U-values	Retrofitting Notes & Ref to Calculations	Action Task	Primary Energy (Space Heating) kWh/m2a	Total Primary Energy kWh/m2a
1	Survey		After the Survey: devise Retrofit Strategy, see Strategy below			Passive House Threshold: 15 kWh/m2a	Passive House Threshold: 120 kWh/m2a
A		Thermal Performance	Heat Loss Permeability Energy Usage Occupancy		Thermal Imaging Air Tightness Test Meter Readings *Not in Passivhaus Standard (see DEAP / BER)		
B		Physical Inspection	Damp		Absorption / Evaporation or Impermeable Materials		
C		Exposure	Orientation		30 SE / S / 30 SW / Wind / Rain / Solar Gain / Shade		
D		Structure	Structural Integrity		Roof & Floor Timbers / Superstructure / load bearing capacity of roof trusses, etc		
E		Typology	Existing Materials		No windows & doors / material performance / dimensions / hazardous materials / Ventilation		
2	Super Insulation		Steps Taken to Reduce Primary Energy (Space Heating) & Total Primary Energy (All Energy regardless of source)			Estimated Current Performance 200 kWh/m2a	Estimated Current Performance 427 kWh/m2a
A	Insulation Walls	U ≤ 0,175 W/M2K	U ≤ 0,55 W/M2K	see Appendices 1: Masonry Cavity Wall Dry Lined requires 110 mm external insulation and render	External insulation either stuck or mechanically fixed directly to external face complete wrap around to below Floor Slab / Reduction of possible thermal bridging / Cavity wall also filled with bead insulation to avoid thermal looping / complete system including render to have Agreement Certificate. *[U ≤ 0,17 W/M2K]*		
B	Insulation Roof	U ≤ 0,15 W/M2K	U ≤ 0,35 W/M2K	see Appendices 2: Thermal Transmittance (U-Value Calculation Report)	Install 300 mm insulation between rafters @ 600 mm c/c and 30 mm cross insulation between battens (at 90 deg). As this house typology has a vaulted sloping ceiling, insulation will be fitted between roof trusses, this will have the added advantage of creating a heated attic at the apex of roof void for service runs and location for heat recovery ventilation equipment and possibly a solar hot water tank, thereby reducing transmission heat losses. *[U ≤ 0,12 W/M2K (Better than required, however may necessitate removal and re fitting of existing roof slates, see Survey)]*		Estimated Reduction based on PHPP Calculation on Similar House Type & age in the SEAI Guidelines for Upgrading an Existing Dwelling
C	Insulation Ceiling	U ≤ 0,09 W/M2K	U ≤ 0,45 - 0,60 W/M2K	see Appendices 3: Thermal Transmittance (U-Value Calculation Report)	Install 200 mm Glass Fibre Quilt between joists at 400 mm c/c and 100 mm Glass Fibre Quilt over joists; we suggest the use of Rockwool as opposed to Glass Fibre given that there will be no cold bridge for intermediate floor ceiling due to external insulation wrap around, Rockwool has a lower insulative coefficient but greater sound proofing and fire resistance factor. *[U ≤ 0,12 W/M2K (Does not achieve the desired Standard, but does not take effect no cold bridging)]*	46	166
D	Insulation Floors	U ≤ 0,15 W/M2K	U ≤ 0,45 - 0,60 W/M2K	None: see PHPP Calculation based on similar house (Ref)	To externally insulate ground floor slab would require removing the existing concrete slab and hardcore before placing a damp-proof (or Radon) membrane, insulation and new floor screed. This would be costly and disruptive to homeowners. To compensate for this; the external wrap around insulation (Item A) should be excavated and applied to the external walls as far as the foundation layer. In addition, rooms with ceiling heights in excess of 2,4M with no built in elements may consider raised floor with insulation and batten. In any event; as the existing structure in dry lined internally, all junctions (skirting / cornice, etc) will be sealed. *[Unknown (see Action Task)]*		
E	Window Glazing	U ≤ 0,80 W/M2K	Windows U ≤ 1,85 W/M2K Doors U ≤ 3,00 W/M2K	None: see PHPP Calculation based on similar house (Ref)	Change from double to triple glazed windows & doors (PHPP estimate from 1,85 to 0,91 W/M2K / doors estimate from 3,00 to 0,80 W/M2K) With increased glazing there will be a decrease in potential solar & light gains. The junctions between windows / door frames & structure need to be sensibly detailed with 65mm insulation overlap at reveal, head & cill to reduce potential thermal bridges. Shading devices may be considered to prevent overheating in summer. *[Estimated overall reduction U ≤ 0,80*	33	143
F	Structural Air Tightness	n50≤0,6 /air changes per hour	n50≤ 6,39 /air changes per hour	None: see PHPP Calculation based on similar house (Ref)	Compared to current Part L, this level of air tightness is quite a high performance standard. The airtight membrane should always be located on the warm side of the insulation and should be continuous around the building fabric. For practical Retrofit purposes, we propose special attention to all building material interface junctions be suitably addressed, i.e. EPD Membranes bonded to window / door frame and cavity, draught proofing attic and hot press openings, sealing of all junctions such as floor / wall / ceiling, etc. It Should be noted that the wrap around external insulation and render as per Item A will address a greater portion of the required air tightness. *[n50≤0,6 /air changes per hour (This can be achieved with Retrofitting, see Action / Task.]*	27	135
G	Thermal Bridges	Linear heat coefficient Ψ≤ 0,01 W/mK	Unknown	None: see PHPP Calculation based on similar house (Ref)	Repeating thermal bridges (such as studs / rafters) are typically accounted for in the quoted U-values; whilst Linear thermal bridges will be mitigated by the employment of wrap around external insulation and render from foundation level to roof eaves. The junctions of internal / external elements such as windows / door frames, etc will be mitigated by correct detailing and execution of sealing and insulating. *[Unknown (see Action Task)]*		

9.8 Proposed steps in retrofitting rural Ireland (2 of 2)

Table 17: Proposed Retrofitting to Passive House Standard in Rural Ireland. (2 of 2) (Build, 2010) (GentleDescent, 2010) (SEAI, 2009c)

No	Element	Passivhaus Standard U Values	Estimated Current Standard U values	Retrofitting Notes & Ref to Calculations	Action / Task	Primary Energy (Space Heating) kWh/m2a	Total Primary Energy kWh/m2a
3	*Heat Recovery / Air Quality*		*Steps Taken to Reduce Primary Energy (Space Heating) & Total Primary Energy*			Continued from Table 6A	Continued from Table 6A
A	Mechanical Heat Recovery Ventilation (MHRV)	Heat Recovery Efficiency ≥ 75%	NIL	Appropriate air change rate is between 0,3 - 0,4 times the volume of the building per hour at normal pressure	A high level of air tightness is required in order to minimise heat loss. It is recommended that a mechanical heat recovery system is retrofitted to existing house, this maintains high indoor air quality whilst ensuring a comfortable level of humidity and maximising energy savings. The efficiency of the heat exchanger in the MHRV is determined by the amount of heat that can be recovered from the exhaust air.		
B	Minimal Space Heating	Low temperature heating	Limited	Water to air exchanging / upgrade of HW cylinder for triple coil	Hot / warm water may be circulated through the fresh air intake device when / if additional heating occupancy is required. An upgraded HW cylinder to incorporate a third coil which either extracts heat from the insulated cylinder or provides heat to the cylinder once radiators are in operation		It is estimated that Standard is achieved after Step 3 in accordance with the PHPP software based on Estimated current standard.
C	Efficient small capacity heating system	Biomass, condensing gas boiler for DHW. Efficiency 80 - 90 %	Oil Fired, approximately 14 years old.	Electric emersion only for emergencies	The equipment must be appropriately sized to the heat load of the house, a typical retrofit house in Ireland will require just 7kW output for space heating and DHW needs. An independent combustion air supply must be provided. The practical suggestion for the 'chosen' house in Killucan would be a wood pellet boiler with 80 - 90% efficiency as gas main is not available. A suitable storage volume for feed stock is recommended from an economic and carbon footprint perspective, i.e. transport of feed stock.	15	118
D	Air Quality through ventilation rate	Min 0,4 air changes per hr or 30 m3 per person per hr.	Windows, doors, air vents and air leakage	Different standards PHPP vs. Building Regulations Part: F	BR Part F calls for a higher exchange rate which will lead to greater energy consumption, however it is important to note that different room uses / types require different rates, i.e. kitchen 60m3/h / bath room 40m3/h / shower & WC 20m3/h, but such supplies must be balanced.		
E	Insulate Ventilation ducts	6 - 10 cm for ductwork	NIL	Mostly air ducting but can also be UFH or Rads	It is important to adequately insulate air ducting and locate ducting within the thermal envelope and try keep pipe runs short. Vents are usually placed in the ceiling to spread air horizontally minimising downward draughts (exhaust vents negative pressure, supply positive pressure)		
4	*Passive Solar Gain*		*Secondary Measures*				
A	Window Glazing	Solar energy transmittance g ≥ 50%	Estimated to be higher due to larger opening sizes and less window structure	Solar and light gains will be reduced through frame and mullion proportions for triple glazing whilst openings will also reduce with increase insulation	Sun is high in the sky in summer, whilst in winter the sun is low in the sky and passive solar gain will be provided by the sun's rays passing underneath a shading device such as overhangs, balconies or bris soliel.		Estimated
B	Solar Orientation	South facing or 30 deg SE / SW	Current orientation NE & SW	Orientation can not be altered.	The larger portions of glazing are at the rear of the property which is shielded by a boundary wall and foliage; this façade faces SW. This is not ideal, as the winter sun is interrupted whilst the summer sun is not shielded. Suggest lowering the boundary wall and installation of metal trellised and aggressive trimming / cutting back of the foliage to take effect of the low winter sun.	14	118
C	Thermal Mass within Envelope	Recommended	As existing	Effectiveness determined by potential solar gain	The existing house has concrete floors and dry-lined masonry walls internally. Suggest transference of solar gain via a system of tubes in the ground that pre-heat the air fresh air intake (the ground is warmer than the air in winter, but cooler than the air in summer) during winter and pre-cool air in summer.		
5	*Electrical Efficiency*		*Low Cost: Recommended Upgrade*				
A	Household Appliances	A Rated Appliances	Various	Energy labelled Household appliances	Once appliances can no longer be economically serviced and maintained, correct disposal for recycle and replacement with A+ / A++ / A+++ rating		
B	Hot water connections	Low Cost	NIL	Connect hot water to dishwasher / washing machine	Low cost mechanical plumbing Tee's and valves to connect appliances using existing hot water source thereby reducing high energy / electricity usage by appliance to produce own hot water		Estimated
C	Lighting & Other	CFL or LED recommended	NIL	Replacement of existing bulbs / fittings	Suggest phased replacement of light fitting to take account of low energy bulbs. All fans, pumps, etc used in retro fit must be energy efficient type.	13	98
D	Controls	Medium Cost	NIL	Integrated Controls	Building Regulations Part: L require minimum levels of control. Phased inclusion of the following controls, suggested: Automatic control for space heating via room temperature stat / Auto control of heat input to HW cylinder via temp stat / Separate automatic control to shut down boiler or heat source when there is no demand / individual room temperature control / weather compensation control / automatic intelligent valve control to direct heat to required source, etc		Maintenance of filters, system, etc will be required
6	*On-site Renewable*		*High Cost: Long Term Upgrade*				
A	Solar Thermal	Recommended	NIL	Occupancy dependent	Typically 5m2 Solar Panel can provide 300 lt of hot water storage, energy reduction in electricity and oil.		
B	Other	On a case by case basis	NIL	On a case by case basis	It would be prudent to bring the dwelling to standard whilst being cautious not to over-invest. Other mooted renewable energies should be considered on a case by case basis, such as: Micro Wind / Photovoltaic and geothermal.		Consider on a case by case basis.

9.9 Survey Email

From: Bernhard Funke
To: "bernhard.funke@bigpood.com"
Subject: Low Carbon Housing Refurbishment Challenges in Ireland, a Discussion
Date: 21 January 2013 00:01:00

Dear ____,

You are invited to take part in a research study as part of an MSc dissertation at the Institute of Technology Sligo, Ireland. Please take time to read the following information carefully.

The research questionnaire should not take longer than _20__ minutes to complete.
Please 'click' on the Link below, note – the survey does have a 'save & resume' function

http://www.surveymethods.com/EndUser.aspx?87A3CFD685C7DAD58C

The purpose of the study –

Aim:

The overall aim of this research is to examine the barriers and enablers to retrofitting and refurbishment vs. rebuilding in the current Irish market.

Objectives:

- To better understand what is meant by the term 'Embodied Carbon'
- To evaluate the impact of building materials in construction, in terms of Carbon Management
- To ensure that the literature review presents an overview of the relevant research
- To evaluate the term 'sustainability' in terms of the built environment, energy and harmonisation.
- To obtain an in-depth understanding of refurbishment and the challenges in the Irish context.

I would like to thank you for taking the time to complete this survey. Your participation is valuable for the success of this research study.

Thank you,
Bernhard Funke

Figure 71: Sample Survey Enquiry Email

9.10 Survey questions

Low Carbon Housing Refurbishment Challenges in Ireland, a Discussion

The purpose of the study:

Aim:
The overall aim of this research is to examine the barriers and enablers to retrofitting and refurbishment vs. rebuilding in the current Irish market.

Objectives:

- **To better understand what is meant by the term 'Embodied Carbon'**
- **To evaluate the impact of building materials in construction, in terms of Carbon Management.**
- **To ensure that the literature review presents an overview of the relevant research**
- **To evaluate the term 'sustainability' in terms of the built environment, energy and harmonisation**
- **To obtain an in-depth understanding of refurbishment and the challenges in the Irish context**

I would like to thank you for taking the time to complete this survey. Your participation is valuable for the success of this research study.

It is imperative to fill out the following survey in full

1. Please indicate your age category

- ○ Under 35 Years
- ○ 35 to 65 Years
- ○ 65 + Years

2. Please indicate your occupation, you may check multiple boxes

- ☐ Architect
- ☐ Engineer (structural)
- ☐ Engineer (Building Services)
- ☐ Quantity Surveyor (PQS)
- ☐ Quantity Surveyor (Contractor)
- ☐ Environmental Engineer
- ☐ Facilities Manager
- ☐ Contracts Manager
- ☐ General Contracting
- ☐ Developer
- ☐ Specifier
- ☐ Other
- ☐ If other, please specify

Figure 72: Survey Questionnaire

3. **Please check the duration in occupation**

- ○ 10 Years
- ○ 10 to 20 Years
- ○ 20 + Years

4. **Please state your current resident Country**

[--Please Select--]

5. **Please confirm your resident City / or the closest major City to where you reside**

Embodied Carbon in Construction

Please check the box that best matches your responses to each statement

6. **A definition of Embodied Energy can be given as the sum of energy inputs that are used in work to manufacture and produce a product, from the point of extraction and refining of the materials, to manufacture of the product, bringing it to market including the disposal and recycling of the material.**

	Yes	Sometimes	Neutral	Not sure	No
Have you heard of Embodied Energy ?	☐	☐	☐	☐	☐
Have you given thought to Embodied Energy ?	☐	☐	☐	☐	☐

7. **Have you heard of or been exposed to an Embodied Energy database ?**

- ○ Yes
- ○ Sometimes
- ○ Neutral
- ○ Not sure
- ○ No

8. **It has been suggested that Embodied Energy is a concept for which scientists have not yet agreed absolute universal values because there are so many variables to take into account.**

In your view, is it possible for an Embodied Energy database to take all / or sufficient coefficients into account.

- ○ Yes
- ○ Sometimes
- ○ Neutral
- ○ Not sure
- ○ No

9. **It can be said that Life Cycle assessment is a technique used to assess environmental impact associated with all the stages of a products life from raw material extraction through materials processing and refining, manufacture, distribution, use, maintenance and repair and disposal or recycling.**

	Yes	Sometimes	Neutral	Not sure	No
Have you ever given consideration to the Life Cycle of a material or product?	☐	☐	☐	☐	☐
Have you ever been involved in Life Cycle assessment of a material or product?	☐	☐	☐	☐	☐
Would / or do you consider the Life Cycle assessment of a material or product to be worthwhile?	☐	☐	☐	☐	☐

10. **Which option best matches your response to the following statements in relation to Life Cycle assessment:**

	Yes	Sometimes	Neutral	Not sure	No
Life Cycle assessment is relevant to t					

he choice of materi als specified in a gi ven design?	❑	❑	❑	❑	❑
The service life of a product is significa nt in terms of that products environm ental profile?	❑	❑	❑	❑	❑

11. **Carbon Management, whilst simple in form, has been proposed as an effective and functional tool to facilitate designers, specifiers, architects, engineers, property managers and developers.**

	Yes	Sometimes	Neutral	Not sure	No
Have you heard o f / or been expose d to a carbon man agement system?	❑	❑	❑	❑	❑
In your opinion, is i t possible to succe ssfully manage car bon?	❑	❑	❑	❑	❑
In your opinion, is carbon manageme nt plausible?	❑	❑	❑	❑	❑

12. **The Carbon Calculator in effect, makes use of the values extracted from a carbon inventory and ideally translates these values into a constructed product including deconstruction, thereby affording designers a full assessment of the proposed design whilst prompting questions and specification changes.**

In your opinion, are such calculators relevant to the fast pace of modern day design, specification and construction?

- ○ Yes
- ○ Sometimes
- ○ Neutral
- ○ Not sure
- ○ No

13. **In terms of your knowledge, experience and exposure:**

Rate the following:	Yes	Possibly	Neutral	Uncertain	No	N/A
A robust carbon & energy invent ory associated t o building mater ials is imperativ e for Policy mak ers, designers, Specifiers, Engin eers and the lik e	❑	❑	❑	❑	❑	❑
A carbon & ener gy inventory sh ould be paired t o zoned local co nditions - in ord er to accurately reflect carbon in a particular juris diction	❑	❑	❑	❑	❑	❑
Carbon calculat ors should be ut ilised throughou t the constructio n process, from i nception to tes t / commission a nd client hand-o ver files	❑	❑	❑	❑	❑	❑
Projects should be categorised and benchmark ed at planning s						

tage to a maximum limit / amount of calculated embodied carbon tCO2/m2	❑	❑	❑	❑	❑	❑
Construction techniques, aggregate supply and alternatives should be mandated in tender / procurement schedules	❑	❑	❑	❑	❑	❑

14. **In terms of your knowledge, experience and exposure:**

Rate the following:	Yes	Possibly	Neutral	Uncertain	No	N/A
Manufacturers should be audited in respect of a products embodied carbon and a certification process should be mandatory	❑	❑	❑	❑	❑	❑
Construction materials manufactured from healthy plastics originating from 'say' corn (not oil), organic compounds or recycled material should be VAT exempt	❑	❑	❑	❑	❑	❑
Carbon management systems should be made mandatory in company Quality Assurance and Pre Qualification tender registers	❑	❑	❑	❑	❑	❑
Robust guides for Boundary Cntique and Boundary Judgement In Embodied Carbon inventories is critical to ensure statistical information relating to construction materials is accurate and consistent	❑	❑	❑	❑	❑	❑
Minimising the carbon footprint of a building creates awareness of the environmental impacts of material selection, product development and the manufacture process.	❑	❑	❑	❑	❑	❑
All construction materials should have visible labelling - confirming source and carbon footprint at source of dispatch	❑	❑	❑	❑	❑	❑

15. **In 2012 the United Nations convened in Brazil, Rio de Janeiro as a 20 year follow up to the historic 1992 conference on Environmental Development, the conference has two themes agreed upon by member states:**

In your view - Rate the following two statements

	Very relevant	Relevant	Neutral	Not that relevant	Not at all relevant	Not sure
Green Economy within the context of sustainable development and poverty eradication	○	○	○	○	○	○
Institutional framework for sustainable development	○	○	○	○	○	○

16. **According to a NASA Goddard Institute for Space Studies (GISS, 2012); the solar increases do not have the ability to cause global temperature increases. Greenhouse gases are indeed playing the dominant role; that is, human activities are the primary factor in global climate change.**

○ Yes ○ No

Additional Comments

17. **There is a direct correlation between GHG emissions, the burning of fossil fuels due to human activity and global warming which may have far reaching and possibly devastating effects on all human kind.**

○ True ○ False

Additional Comments

18. **Electrical generation is our most obtainable source of energy for households, buildings and manufacture.**

(A) In 2008 Bioenergy accounted for 1.1% / Wind energy accounted for 1.1% / whilst Photovoltaics, Geothermal and Ocean energy accounted for 0.37% in World Electrical Generation.

(B) Coal, Oil and Nuclear energy accounted for 60.2% of World Electrical Generation.

Question:
In your opinion, will it be possible to increase renewable global electrical generation by 20% by 2020?

○ Yes ○ No

Additional Comments

19. **Bio-energy has complex and dynamic interactions among society, energy and the environment; including climate change impacts and various spatial and temporal scales on all resource uses for food, fodder, fibre and energy.**

In your opinion, is Bio-energy a viable source of renewable energy into the 21st century and beyond?

Briefly state any reasons for your answer / or - what about developing countries where the greatest population increase will occure over the next 37 years?

○ Yes ○ No

Additional Comments

20 **It is anticipated that increased urbanization will continue and that 50% of the 6.4 billion world population living in cities and towns today, will rise by 60% in 2030 to 8.2 billion people (UNEP, 2011)**

In the UK, space heating is responsible for 25% of carbon emissions and accounts for over 60% of delivered energy and over 40% of energy costs in the residential sector.

In this context:
Do you think that significant energy savings can be achieved by increasing the energy efficiency of the existing built environment?

❍ Yes ❍ No

Additional Comments

21 **The building sector in 2008 accounted for about 92 EJ, or 32% of total global final energy consumption.**

It is assumed that buildings have an average life span of 120 years in developed countries and approximately 35 years life span in developing countries.

In this context:
In your opinion, is retrofitting renewable energy systems a worthwhile undertaking on existing buildings?

❍ Yes ❍ No

Additional Comments

22 **Retro-fitting the Irish housing stock to improve thermal standards will have substantial social, economic, environmental and health benefits to society.**

❍ True ❍ False

Additional Comments

23. **Have you ever heard of / or been exposed to any of the following?**

	Yes	Not sure	No	N/A
A sustainable energy c ommunity (SEC)	❑	❑	❑	❑
A sustainable energy z one (SEZ)	❑	❑	❑	❑
Sustainable Networkin g - INTERREG	❑	❑	❑	❑
Sustaining Small Expan ding Towns (SusSET)	❑	❑	❑	❑
Sustainable Accounting	❑	❑	❑	❑

24. **What is your understanding of the following statement:**

,... whilst it is doubtful whether continued economic growth is compatible with ecological sustainability.

❍ True ❍ False

Additional Comments

25. **What is your reaction to the following statement:**

,... to enforce owners to use their land so that sustainability can be achieved, must be a consideration for future development,....

❍ Yes ❍ No

Additional Comments

26. **What is your reaction to the following statement:**

,...Agenda 21 cites that private land decisions are often driven by strong economic incentives that result in several ecological or aesthetic consequences, and that the key to overcoming this is through public policies,...

❍ Yes ❍ No

Additional Comments

27. *,...Woodward argues that carbon taxes are the justification for the use of the tax policy which again is based on the theory of economic efficiency. Taxation uses the market mechanism to allocate adjustments to the GHG emissions problem and does not sufficiently address implications associated with sustainability,...*

What is your reaction to this statement?

❍ True ❍ False

Additional Comments

28. **There are two main European Directives influencing the environmental, cultural and financial drivers on Low Carbon House Refurbishments (LCHR)**

Respond to the following:

Have you had experience with / heard of / or been exposed to

	Yes	Possibly	Neutral	Not sure	No	N/A
(1) the EU Renewables Directive - which sets binding targets on energy from renewable resources	❑	❑	❑	❑	❑	❑
(2) the Energy Performance Buildings Directive (EPBD) - which is focused on the improvement of energy efficiency	❑	❑	❑	❑	❑	❑

29. **In the Sustainable Energy Authority Ireland (SEAI) abatement potential on emissions in Ireland 2030 - the top levers for building emission abatement are:**

Respond to the following:

Have you had experience with / heard of / or been exposed to

	Yes	Possibly	Neutral	Not sure	No	N/A
(1) New build efficiency package residential	❑	❑	❑	❑	❑	❑
(2) Retrofit building envelope package 1 - residential	❑	❑	❑	❑	❑	❑
(3) Retrofit building envelope package 2 - residential	❑	❑	❑	❑	❑	❑
(4) House of Tomorrow (HOT)	❑	❑	❑	❑	❑	❑

30. ***There are a great many variants which need to be considered prior to undertaking a building's refurbishment, including:***

cost of refurbishment and the pay-back time, effects to health and the environment in respect to materials employed, annual fuel economy and cost of maintenance, aesthetics and functionality, comfort levels associated with heating, cooling, sound and air quality and then the longevity of the building fabric and improvement.

With regard to your knowledge, experience and exposure - do you agree with the above statement

○ Yes ○ No

Additional Comments

31. **An evaluation tool referred to as the Energy Performance Indoor Environmental Quality Retrofit (EPIQR) is:**

a decision tool combining financial, technical, energy and comfort analysis, and enables rapid low cost acquisition of all data and comprehensive analysis taking over 800 parameters into account.

Have you heard of / used / or been exposed to EPIQR / or similar?

○ Yes ○ No

Additional Comments

32. **Have you ever received information pertaining to the following:**

	Yes	N/A	No
Retrofitting building fabric	❑	❑	❑
Retrofitting building heating s ystems	❑	❑	❑
Retrofitting heating control	❑	❑	❑
Retrofitting lighting	❑	❑	❑
Retrofitting lighting control	❑	❑	❑
Retrofitting smart metering	❑	❑	❑
Retrofitting brown water man agement	❑	❑	❑
Retrofitting micro generation	❑	❑	❑
Retrofitting renewable gener ation	❑	❑	❑

33. **Would you / or have you considered any of the following:**

	Yes	Possibly in futu re	Neutral	Never	No	N/A
Finding out abo ut the National Refit Scheme	❑	❑	❑	❑	❑	❑
Would you inves t in the Refit Sch eme as an own er	❑	❑	❑	❑	❑	❑
Would you inves t in the Refit Sch eme as a landlo rd	❑	❑	❑	❑	❑	❑
Would you consi der a 'pay as yo u save model'	❑	❑	❑	❑	❑	❑
Investigating pa ssive house sta ndard	❑	❑	❑	❑	❑	❑
Investigating en ergy neutral ho using	❑	❑	❑	❑	❑	❑

34. **There have been reports raising concerns in respect to the quality of workmanship in retrofitting:**

	Yes	Not applicable	No
Would you share this view in respect to workmanship to b uilding fabric	❑	❑	❑
Would you share this view in respect to workmanship on b uilding services	❑	❑	❑
Would you share this view in respect to consultancy advice	❑	❑	❑
Would you share this view in respect to other retrofit expe rience	❑	❑	❑

35. **Do you advocate any of the following?**

Check for positive

- ❑ Waste segregation
- ❑ Refurbishment of heritage / enlisted buildings
- ❑ Demolition of existing buildings
- ❑ Design - for deconstruction
- ❑ Energy from waste

36. **How satisfied are you with each of the following in your own dwelling / dwelling surrounds?**

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied	N/A
Heating / oil / gas bills	❑	❑	❑	❑	❑	❑
Lighting / electricity bills	❑	❑	❑	❑	❑	❑
Ability to retain heat	❑	❑	❑	❑	❑	❑
Natural light	❑	❑	❑	❑	❑	❑
Natural ventilation	❑	❑	❑	❑	❑	❑
Indoor environmental quality - humidity	❑	❑	❑	❑	❑	❑
Heating control	❑	❑	❑	❑	❑	❑
Lighting control	❑	❑	❑	❑	❑	❑
Ventilation control	❑	❑	❑	❑	❑	❑
Orientation of house	❑	❑	❑	❑	❑	❑
Shading	❑	❑	❑	❑	❑	❑
Proximity to village / town / city	❑	❑	❑	❑	❑	❑
Accessibility to public transport	❑	❑	❑	❑	❑	❑
Proximity to amenities - libraries / shops / schools, etc	❑	❑	❑	❑	❑	❑

37. **Have you been exposed to / or had experience with any of the following retrofit undertakings?**

If so, check the box that matches your experience

	Yes	N/A	No
Wall insulation (any type)	❑	❑	❑
Double glazed windows	❑	❑	❑
Underfloor insultation	❑	❑	❑
Roof / loft insulation	❑	❑	❑
Energy efficient heating / boiler / wood pellet	❑	❑	❑
Energy efficient lights	❑	❑	❑
Controls	❑	❑	❑
Draft proofing	❑	❑	❑
Energy efficient appliances	❑	❑	❑
Solar thermal	❑	❑	❑
Geo thermal	❑	❑	❑
Photovoltaic	❑	❑	❑
Wind generation	❑	❑	❑
Micro CHP	❑	❑	❑
Ground source heat pump	❑	❑	❑
Air source heat pump	❑	❑	❑
Solar absorption cooler	❑	❑	❑
BER Certification	❑	❑	❑
Air pressure test	❑	❑	❑
Other	❑	❑	❑

9.11 Survey Comments

2. Please indicate your occupation, you may check multiple boxes

Response	Comments
1	Energy Assessor and Air tightness Application- Blowerdoor Testing
2	MD of BIM / Project Controls Consultancy
3	Environmental and ecological consultant
4	Engineering Recruiter
5	Safety Manager
6	Education & Research
7	HEALTH AND SAFETY MANAGER
8	Heating and plumbing merchant
9	PROJECT MANAGER - STRUCTURAL PRECAST
10	safety
11	Construction Consultant
12	Company Director
13	Subcontractor
14	electrical contractor
15	energy Manager
16	Contracts Consultant
17	Project Manager
18	Dispute analysis / consultant
19	Mechanical engineer employed in wind development
20	Building Physics Engineer

Figure 73: Survey occupation comments Q.2

Response	Additional Comments
1	I agree, but prior to getting materials right the Auto & Oil Industry must get its fuel right and suspend diesel engines and introduce liquid gas engines and the fuel stations to drive them
2	This is extremely relevant causing rising ice cap destruction and rising sea levels
3	I believe human activity is the dominant player and it is only human activity which we have complete control of

Figure 74: Survey response comments Q.16

Response	Additional Comments
1	Not entirely sure
2	Climate change has cycles - but Mother Nature should not be abused the way humans are at this time
3	Reduction is necessary - elimination is impossible
4	Destruction it appears is a slow process but in real time destruction in rapid i.e. the last 100years has seen huge changes

Figure 75: Survey response comments Q.17

Response	Additional Comments
1	especially not in Ireland with a tariff of 3000 units on supply
2	Absolutely
3	Stop subsidising the oil, gas and coal producers and move the money to renewable
4	Only because the machinery and tax incentives are not there to make it happen
5	This is possible but will be offset by emerging nations using more electricity etc.
6	lack of will rather than lack of possibilities
7	If the political willpower exists to achieve this target
8	Just do it
9	Subject to measures being introduced and countries pro-actively addressing any issues with planning/grid in a sustainable manner. Likelihood is that this wont happen in time
10	The potential is there but government will is at least questionable. I'm afraid when the necessity arrives, then we will have no choice and then action will be taken.

Figure 76: Survey additional comments Q.18

Response	Additional Comments
1	Growing energy requires energy and has a carbon footprint. Agriculture is for food.
2	Financially viable for large business, not financially viable for 'joe public'.....
3	Balance required between food production and Bio-fuels
4	We have to use land for food growth not energy crops
5	Food prices are currently too high for emerging economies and so bio-energy will only raise food prices more
6	However underdeveloped countries will be decades behind developed countries
7	Needs to be handled carefully to avoid adverse effects on the environment
8	Financial cost will be too high
9	Providing its development is micro grown locally on a large scale as opposed to a large scale development by conglomerates
10	solar and wind power will aid developing countries when the cost of production is reduced
11	Very labour intensive and also produce emissions to cultivate though a substitute for oil is required
12	more feasible to have electric vehicles
13	lack of food generating land would be a problem
14	It's not going to be possible to provide enough I think for the world's needs.
15	Technology exists and if demand patterns are managed then there is no doubt it can be used. Demand/consumption must change

Figure 77: Survey additional comments Q.19

Response	Additional Comments
1	But has to be greater than 70% up take
2	however existing domestic stock not retrofit friendly
3	Future proofing is essential. All building should be efficient and refrain from fossil fuel as there energy generation
4	Space should not be heated. persons should be heated and space kept above 2 degrees , ie Thermal body heat and radiant heat controlled by body sensors
5	This could be done but in the UK for example many building have a very high carbon footprint and it is very costly to upgrade these properties
6	This should be incentivised
7	Housing new build and retrofit can reduce energy demand. but it can not be left to the market to deliver this, legislation funding mechanisms quality control and enforcement must be put in pace urge

Figure 78: Survey additional comments Q.20

Response	Additional Comments
1	But mostly in cities
2	As above answer20. Society has to endeavour to be aware of LCA, carbon sinks, embodied energy, product origin, in every aspect if their life. Designers r responsible 4their creations cradle2cradle
3	Although there may be some exceptions
4	Provided lifecycle costs prove its worth, also it is an area which can produce employment in suffering economies
5	It will reduce energy consumption and extend building life
6	Large swathes of buildings are under performing in terms of heat loss savings from lack of retrofit heat saving design, materials, appliances and techniques
7	This is possible in many cases but some properties are not worth upgrading
8	but it may be more useful to upgrade the building fabric to reduce the overall heat required
9	only on buildings that were well built originally, most pre 1970 domestic were not
10	Non domestic retrofit is the challenge
11	Distributed generation needs to implemented/ It also serves the dual purpose of educating people and raising awareness
12	BUT ONLY if fabric losses are addressed first with greater insulation levels, reduced thermal bridging and improved air tightness and ventilation methods!

Figure 79: Survey additional comments Q.21

Response	Additional Comments
1	creating work installing products, and greater comfort levels with reduced bills
2	as 20 above
3	Yes without a doubt
4	When the housing stock has reached a sensible value possibly 2015 , it will be economic to retrofit solutions for low cost living
5	Yes in many cases
6	renovation is a rich mans pastime
7	Though I know little about the Irish housing stock in fact.
8	Deep retrofit is required, golden re approach is a waste
9	But only if done with care. In some cases where a "quick fix" solution is used, this may lead to mould growth, IAQ issues and structural problems

Figure 80: Survey additional comments Q.22

Response	Additional Comments
1	There is a conflict
2	I believe when in recessionary mode we look for saving measures
3	Cycles. Everything has a cycle; economies, seasons and climate, etc
4	The type growth we have at the moment would just lead to more carbon
5	Growth itself is not the only criteria. Sustainability is essential if growth is necessary in the long run.
6	Full scale ecological sustainability (its true) but legislation must start with the worst offenders and with the assistance of tax incentives commence the process.
7	Continued global growth will increase the Carbon footprint to dangerous levels overtime
8	Nothing is impossible we need to think differently
9	Technology fix required and consumption patterns to change

Figure 81: Survey additional comments Q.24

Response	Additional Comments
1	Individual land rights
2	enforcement is 'police state'.....incentive & encouragement is better.
3	Enforcement has no role in todays world, perhaps incentivise?
4	But in a measured and sensible, managed approach
5	To enforce with accountability where its possible and not a burden
6	Not enforce-Educate or should I say Re-educate
7	Incentivising as opposed to enforcing. Educate them and make it worthwhile
8	I agree to an extent with the statement but applying force is not a sustainable solution. there must be carrot and stick approach.

Figure 82: Survey additional comments Q.25

Response	Additional Comments
1	Within limits
2	http://www.globaldashboard.org/2012/02/06/agenda-21-is-evil/
3	Public consultation is not exercised properly in Ireland
4	But public policies are not enough on their own
5	The citation is correct but the 'key' is not necessarily through unmanaged controls
6	Big discussion
7	Money is the root of all evil!
8	The value of land should be determined by its sustainable use
9	Possibly

Figure 83: Survey additional comments Q.26

Response	Additional Comments
1	think property tax should be based on the building energy rating of the building
2	True
3	Carbon taxes are seen as general tax when no viable alternatives are available. Carrot rather than stick should be employed to encourage sustainability
4	Carbon taxes are justification in growing economies but these tax policies must be fare and industry should contribute far more.
5	Taxing with offering an alternative path will not work. Besides politicians cannot agree long enough for something like that to work and wont implement a full program

Figure 84: Survey additional comments Q.27

Response	Additional Comments
1	Too complicated
2	I sell the retrofit package not in terms of pay-back rather in a reduction in energy costs and again higher comfort levels
3	Conceptual macro BIM will overcome this
4	As said , a great many variants which will differ in environments and regions
5	I have refurbished properties myself and agree that insulation is still not being properly used to reduce heat losses in new and existing buildings.
6	Payback as a means of establishing viability is wrong

Figure 85: Survey additional comments Q.30

Response	Additional Comments
1	have with a colleague of mine from German my own retrofit excel tool
2	D-Profiler
3	Yes, but not used it. similar to HIPs in the UK
4	Can you send me info on this

Figure 86: Survey additional comments Q.31