Research

Climatic Risk Toolkit

The impact of climate change in the Non-Domestic Real Estate sector of eight European countries

March 2015

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Climatic Risk Toolkit:
The impact of climate change in the Non-Domestic Real Estate sector of eight European countries

Report for Royal Institution of Chartered Surveyors

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Abbreviations

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (French Environment and Energy Management Agency)
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BPIE	Buildings Performance Institute Europe
BR	Building Regulations
BS	British Standards
BRE	Building Research Establishment
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CIBSE	Chartered Institution of Building Services Engineers
CMIP5	Coupled Model Intercomparison Project Phase 5
CRC	Carbon Reduction Commitments
CRT	Climatic Risk Toolkit
DECC	Department of Energy & Climate Change
DEFRA	Department for Environment, Food & Rural Affairs
DENA	Deutsche Energie-Agentur GmbH (German Energy Agency)
DIW	Deutsches Institut für Wirtschaftsforschung (German Institute for Economic Research)
DATSAV	Surface Climatic Database
EEA	European environment Agency
EERE	Office of Energy Efficiency and Renewable Energy
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ESPON	European Observation Network
EU	European Union
FNR	Fachagentur Nachwachsende Rohstoffe e.V. (Agency for Renewable Resources)
GBP	Great Britain Pounds (£ Sterling)
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographic Information Systems
HadCM3	Hadley Centre Coupled Model, version 3
HVAC	Heating Ventilation and air conditioning
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPCC DDC	IPCC Data Distribution Centre
IPCC TAR	IPCC Third Assessment Report
IWEC	International Weather for Energy calculation
MS	Member States (of the EU)
NZEB	Nearly Zero-Energy Buildings
SEAI	Sustainable Energy Authority of Ireland
SCP	Sturgis Carbon Profiling LLP
UKERC	United Kingdom Energy Research Centre
WEC	Weather for Energy Calculation

Foreword

The effects of climate have always been a major consideration when planning and designing effective and efficient buildings. Until recently buildings were planned with an underlying expectation that local climatic conditions would hold to historical patterns. Now with mounting evidence of unprecedented climate changes, and growing frequency of disruptive weather events, such assumptions are no longer sufficient. Finding new ways of planning and adapting buildings for a much more dynamic future climate is challenging and complex, but also imperative if buildings are to remain effective and efficient for the duration of their intended lives.

This report provides thoughtful insight into the impacts of climate change on our built environment, and creates tools which may be very helpful to industry participants in refining their strategies for their properties looking forward. Of particular note is the finding that even well prepared buildings may still be at risk depending on their sources of energy; so while carbon emissions may actually fall over time, the impact of climate change on fuel supply and prices may still result in higher operational costs.

The authors correctly point out that although a number of the factors used to predict impacts are uncertain, the report nonetheless provides thorough insight into the issues which will drive the changes, and how these will affect different kinds of buildings. It provides a framework applicable across a widely varied European climatic geography, including eight countries, as well as a practical toolkit for how to assess and mitigate building specific risks. These two components make this study a welcomed and important step forward in advancing critical, long term risk management within our industry.

Michael P.M. Spies
Tishman Speyer,
Senior Managing Director Europe, India and Turkey,
Chair of Investment Committee

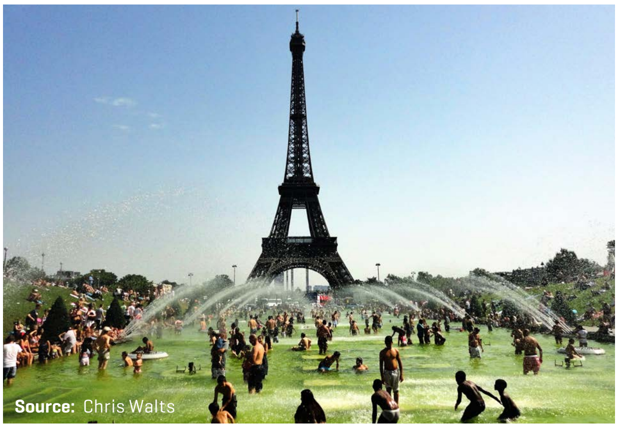
Ensuring a property is sustainable, with reduced carbon emissions and energy usage in order to minimise the impact of climate change effects has become the policy across EU member states, driven from the centre by the European Commission requirement to reduce carbon emissions by 80% by 2050. However the effects of climate change are already being felt, with extreme climate change events occurring on an ever more frequent basis.

For the property and construction industries, forecasting how to future proof new and existing buildings to meet these tightening targets is becoming ever more problematic, so this report is a welcome addition to the body of knowledge that will help to inform stakeholders today about the future trends in climate.

The interactive toolkit is especially welcome, providing a simple means of forecasting the likely outcomes up until 2050, enabling clients and design teams to make more informed decisions about the measures most likely to be effective over the design life of a building, rather than opting for short term solutions, which this report ably demonstrates could actually make matters worse in the long term, rather than better.

We hope that this report will be expanded in the future to cover all 28 member states in the EU so that they all may benefit from this important research paper.

Martin Russell-Croucher FRICS
Director for Sustainability and Special Projects RICS


Source: Chris Walts

Source: Bob Embleton

Executive Summary

Climate change is primarily caused by greenhouse gas emissions released to the atmosphere, and its most significant effect is an increase in temperature globally. However, the impact of climate change extends beyond temperature increase. Weather is becoming unpredictable and more volatile: Extreme events are predicted to be more frequent, stronger and lasting for longer periods of time. These changes are happening worldwide and European countries are also vulnerable: Drought cycles hit Mediterranean countries more recurrently; in 2003 France recorded 15,000 extra deaths in a period of 15 days due to an extreme heat wave that swept all western Europe, and last winter, whole regions of south-west England were flooded for months.

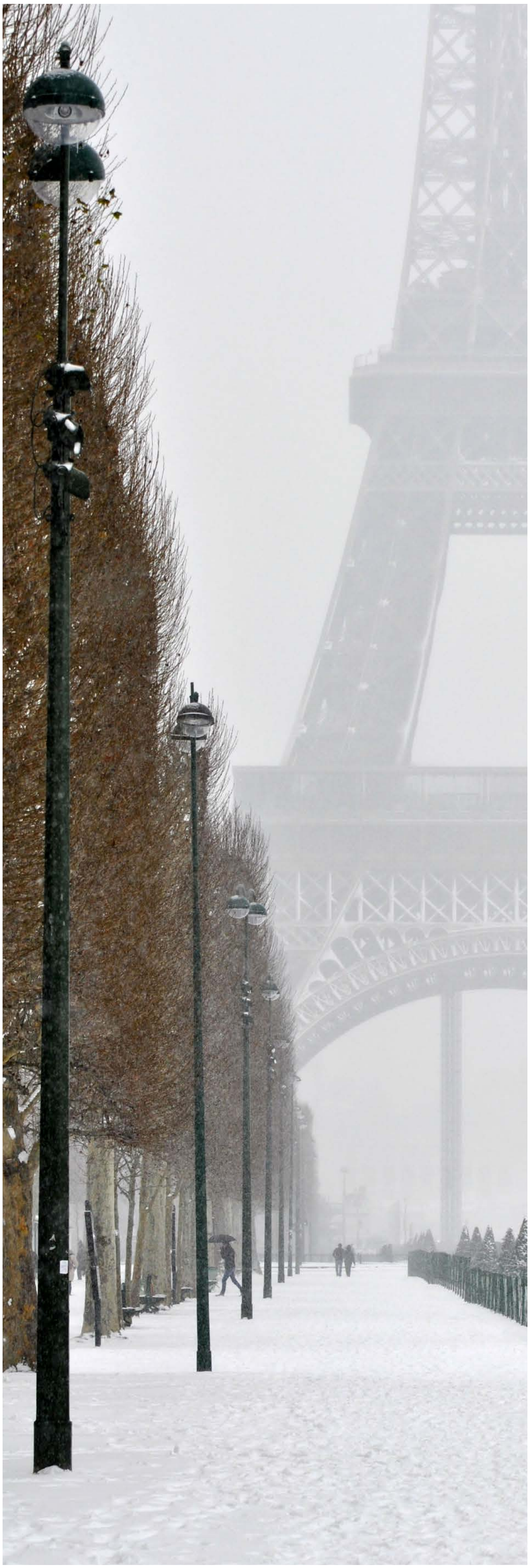
Nevertheless, climate change represents both a hazard and an opportunity for the Real Estate sector. Not every country or every building will be affected negatively or with the same intensity. Pre-existing conditions will determine whether climate change will be beneficial or devastating for each single asset. This research appraises the risk that buildings in eight European Countries face due to climate change, identifying the most vulnerable assets and quantifying the potential cost or benefit in energy bills.

Cost of climate change

How much money are we talking about? Our results estimate that the impact of climate change on energy consumption and running costs is huge. The cumulative cost of temperature increase over the next 40 years (2010-2050) in the non-residential stock of the eight European countries studied in this research could reach 450 billion GBP (550 billion EUR) if no retrofitting action is taken. This is more than the current annual GDP of Sweden and Greece combined, two of the countries included in the study.

The impact of climate change is not equally distributed. This is a story of winners and losers at many levels: Some regions are under higher climatic risk; certain building types will be benefited by climate change, but others will be challenged by growing energy prices; finally, the particular construction quality and thermal characteristics of every particular building might sentence them to market death, too inefficient to lease and too expensive to retrofit.

Where are those buildings? How can they be identified? How many of them are hidden in a property portfolio?



Distribution of risks

Let's start looking at countries: The distribution of the potential GBP 450 billion bill will not be paid equally by each country. Actually, Germany would pay half of it (Figure 1).

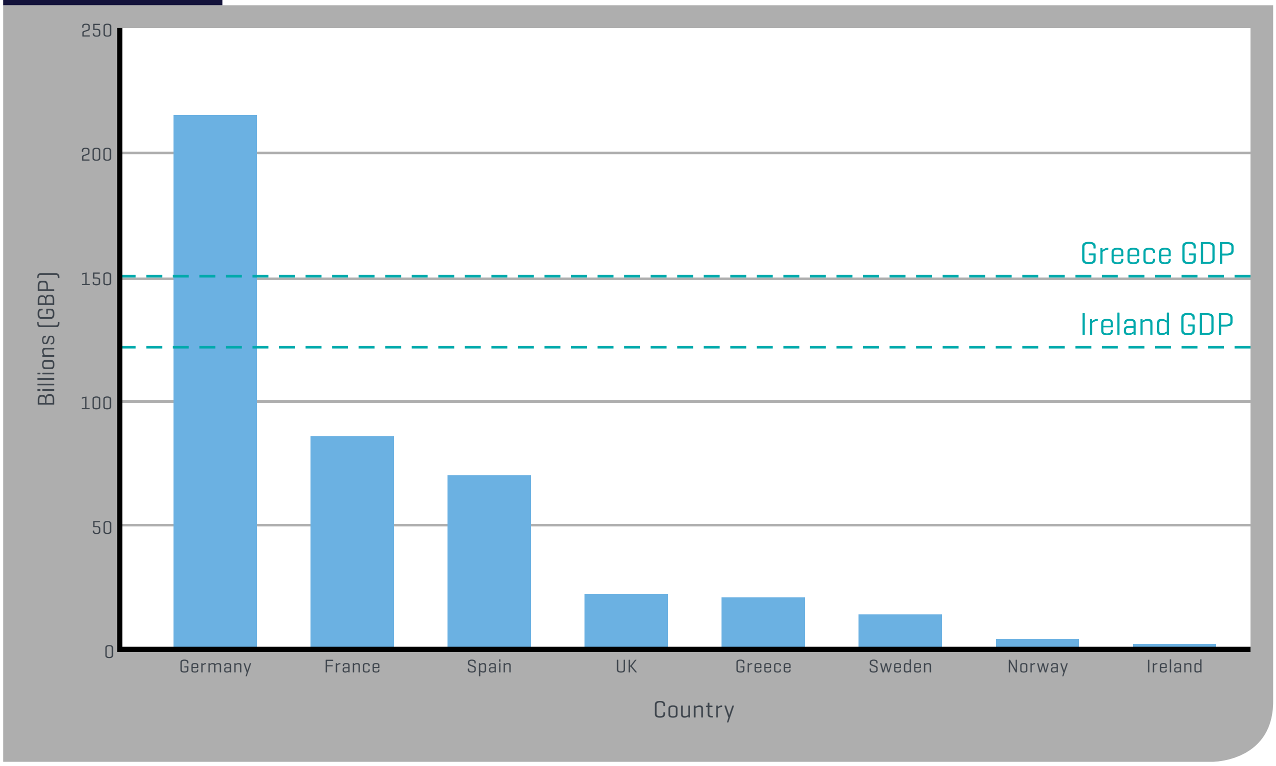
However, absolute numbers do not provide an accurate picture due to the different sizes of the economies and the distribution of the non-residential building stock across countries. The following graph (Figure 2) displays the cumulative cost of climate change in each country over the next 40 years compared with their annual GDP (2012 data). This is a much more representative factor for the economic risk that climate change will pose in each country's non-domestic real estate sector.

Greece, Germany and Spain are under higher climatic risk and face more severe challenges. On the other hand, UK, Ireland and Norway are the winning areas, mainly because the impact of climate change in their climates will be milder.

The roots of inequality in the distribution of the impact of climate change are deeper in the building stock. Different building types and uses face an uneven distribution of potential costs because their energy demand and bills respond to different requirements. The energy bills of building types more dependent on cooling systems, like retail will soar, while schools will generally be able to reduce their energy costs. Figure 3 displays the expected increase in energy bills from 2010 to 2050. Retail buildings in some regions will need to face an increment in their bills of GBP 35.00 per square metre, while some schools may find their energy bills reduced by up to GBP 15.00 per square metre.

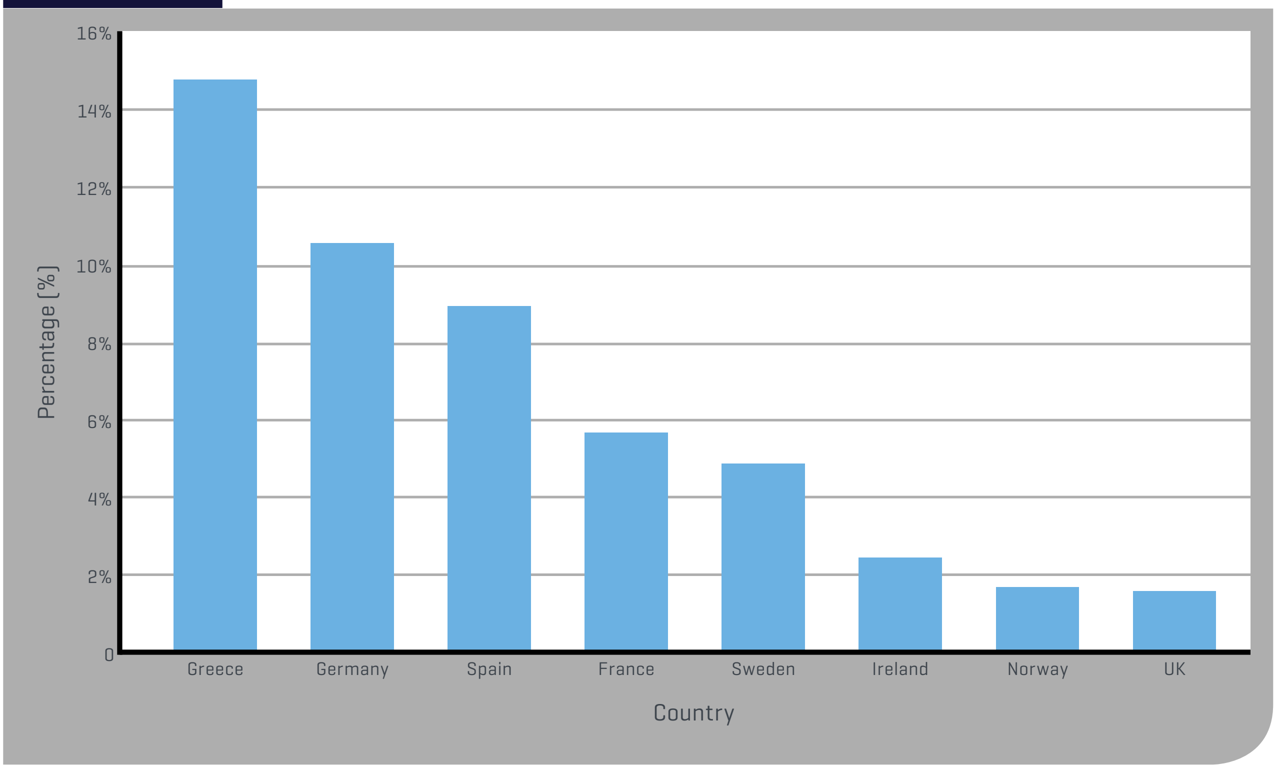
Differences in running costs can also vary within the same building type category, depending on the asset's characteristics. The quality of construction, efficiency of heating and cooling systems, and the thermal properties of the envelope play a critical role in the energy performance of buildings and subsequently to their energy bills. Figure 4 shows the predicted energy costs across Europe in 2050 for two types of air conditioned office buildings. The building geometry, use intensity and fuel prices for both buildings are the same. The only difference is the characteristics of the thermal envelope: the map on the left shows the performance of a building completed in 1961, while the building on the right was finished in 2010.

Figure 1 Breakdown of cumulative climatic cost per country (billion GBP)



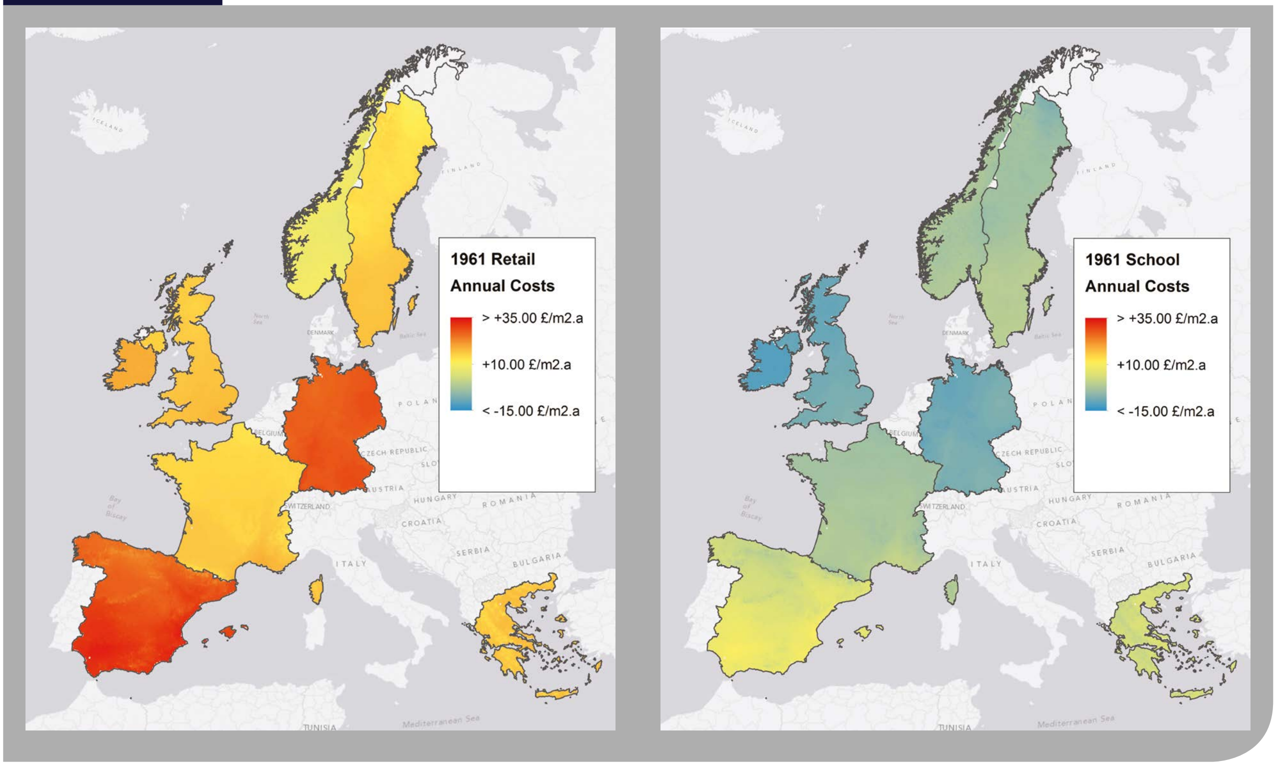
Source: Sturgis Carbon Profiling LLP, with additional data from the World Bank (2012)

Figure 2 Cumulative climatic cost (40 years) / annual GDP in each country



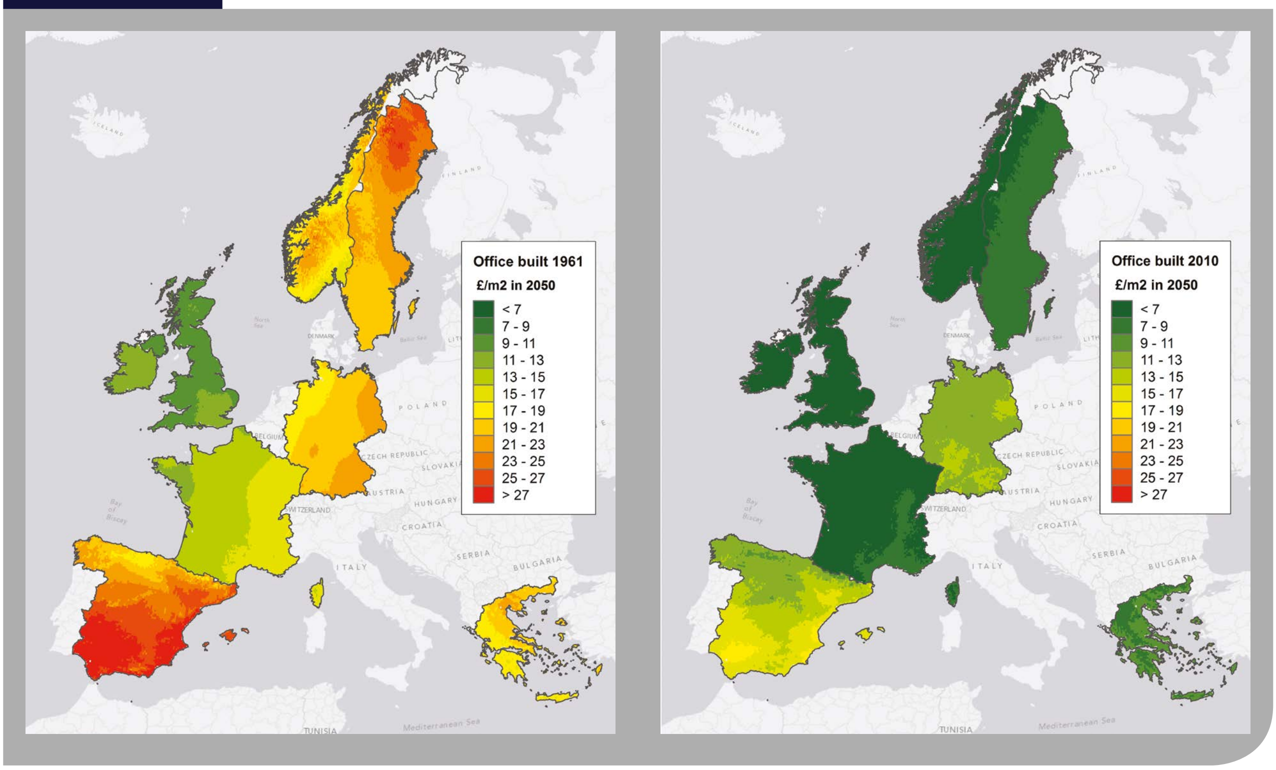
Source: Sturgis Carbon Profiling LLP, with additional data from the World Bank (2012)

Figure 3 Impact of climate change on bills. Retail and Schools



Source: Sturgis Carbon Profiling LLP

Figure 4 Energy cost per m^2 for office buildings of different ages



Source: Sturgis Carbon Profiling LLP

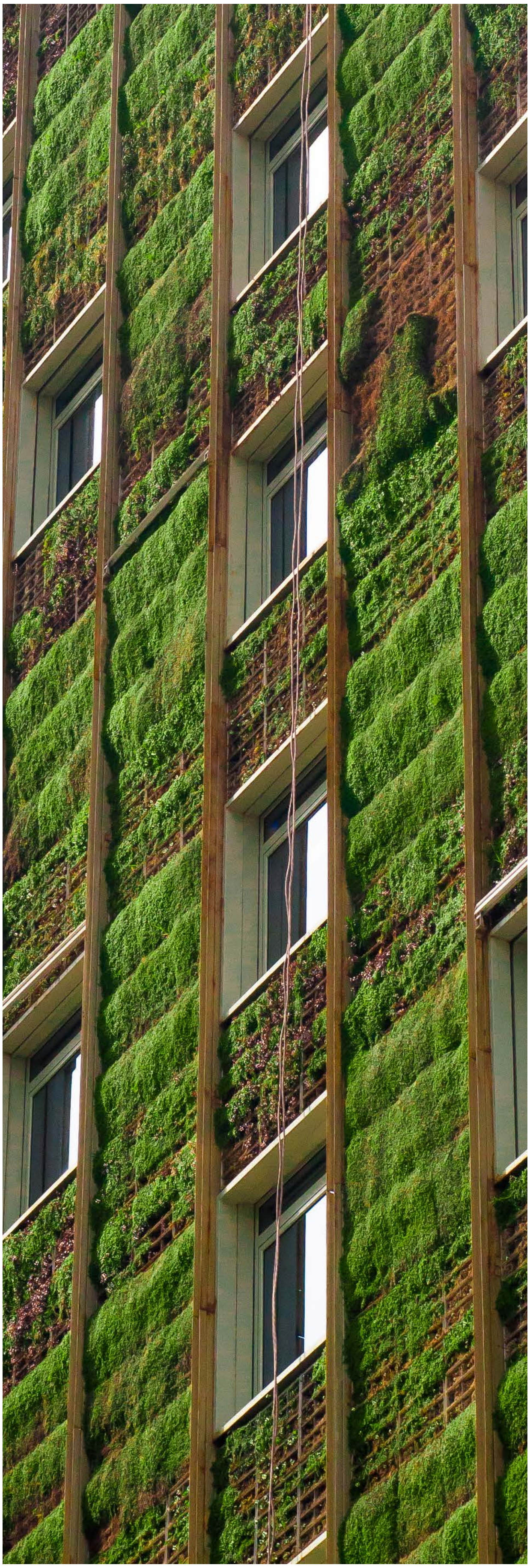
Building's obsolescence

The costs in Figure 4 only account for the impact of global warming. The likelihood of extreme climatic events poses a threat to the asset itself, and that risk will have an impact on its transactional and insurance value: for instance, the value of any building located in an area expected to suffer more frequent and more intense floods will be depreciated and the associated insurance premium will rise.

To summarise, the study's calculations show that if retrofitting to reduce energy consumption is not carried out, up to 25% of the current non-residential constructed area could be at risk of obsolescence or may face unsustainable increases in energy bills.

How can the most vulnerable buildings be identified? How much risk is any particular building facing? Together with this research report, the authors have developed the Climatic Risk Toolkit: a high level prediction model that simulates the likely evolution of energy demand, costs and carbon emissions for any office building in the eight researched countries. The model will also provide the indicative climatic risk level for the specific characteristics of a building. The Climatic Risk Toolkit is described in Annex II of this report.

The model and instructions for its use are available to download at the RICS research website (rics.org/research). This model has been developed to primarily benefit Building and Valuation Surveyors and is simple and friendly to use. The required data is easy to collect and mainly refers to building location, areas according to IPMS Standards and energy bills. Preliminary estimates require very little input, but the accuracy of the predictions will improve when more data is introduced.



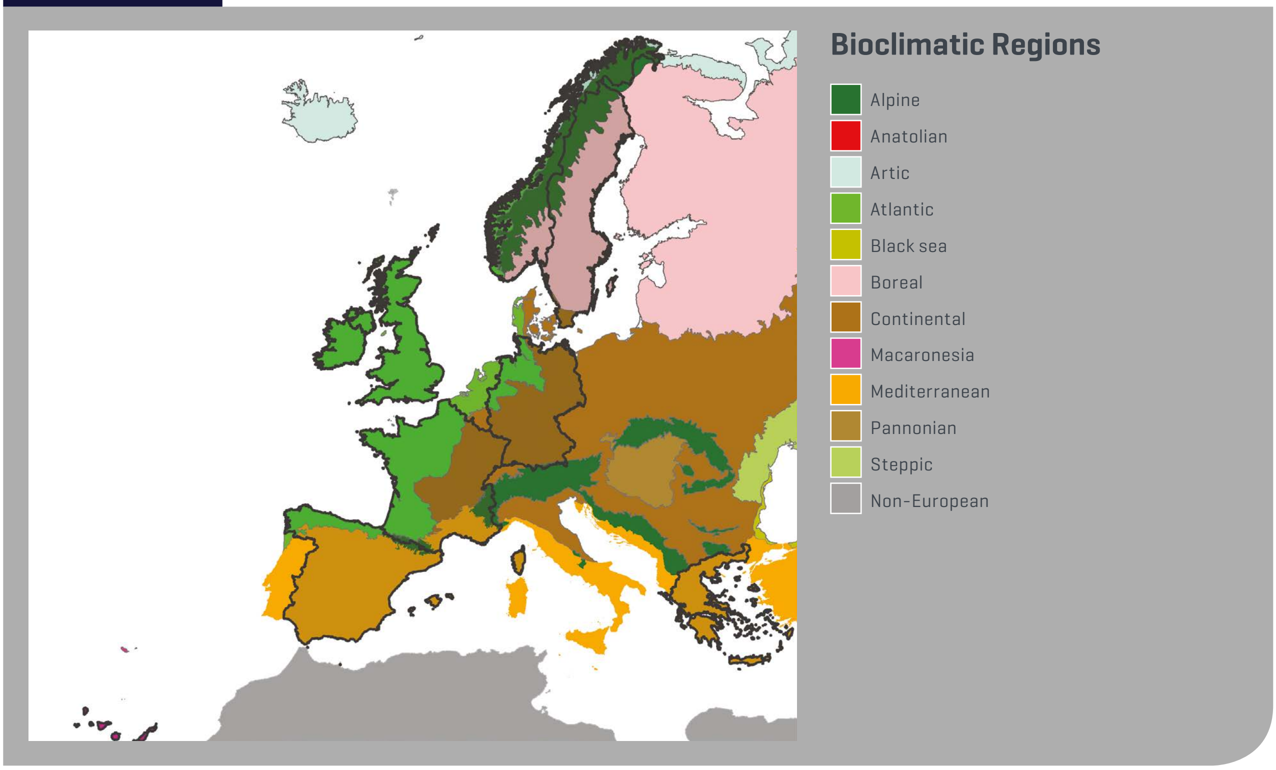
1.0 Introduction

1.1 Aims

This research aims to shed light on the risk that climate change poses to non-domestic buildings. The Real-Estate sector needs to understand how climate change will affect energy demand and running costs of buildings in order to correctly appraise the current value of assets. The current value of any building will be higher if it is more resilient to climate change and succeeds in keeping the energy bills lower than other buildings in the same area. Understanding the amount of investment that any building will require to endure climate change is also critical. Finally, future regulations will probably impose more stringent requirements to cut emissions in the built environment, which might in turn lead to an additional economic burden on underperforming assets.

This report explores all of these issues and compares results from eight European countries: Germany, France, the United Kingdom, Ireland, Spain, Greece, Norway and Sweden. These countries encompass a wide range of European climatic regions. The research analyses four main areas in order to understand how climate change will affect energy demand, operational costs and carbon emissions for six types of buildings: offices, retail, schools, hospitals, warehouses and leisure.

Figure 5 **European bioclimatic regions and scope of research**



Source: Sturgis Carbon Profiling LLP with additional data defined by the Habitats Directive (92/43/EEC) (EEA, 2006)

I. Energy Performance and Labelling

According to the Energy Performance in Buildings Directive (EPBD) developed by the European Parliament and Council in 2002 (revised in 2010 with stricter requirements), the energy efficiency and carbon emissions of non-residential buildings must be assessed and limited. The EPBD also requests the registration of the energy efficiency of buildings in public databases and the development of suitable labelling systems for communication purposes, which each Member State develops, following national requirements (Figure 6). However, some governments have questioned whether or not labelling is beneficial for the industry.

Subsequently, the EPBD has had a direct impact on the building regulations of each member state to achieve the ambitious objective of 'Near Zero-Energy' (NZE) for new buildings by 2020. This report provides an insight into the policy background and the level of success of the regulations to foresee what is likely to happen in the future.

II. Identify Risks

Climate change can be illustrated as encompassing a wide range of risk factors, direct and indirect, that will affect a building's value and should be addressed by policy makers at a European trans-climatic level. Risk can come from different origins, including fuel prices, insurance costs, comfort conditions and user satisfaction, obsolescence of assets and envelope characteristics, amongst many characteristics. The identification of these risks emerges as one of the most important aspects when evaluating the fluctuations in an asset's potential value and running costs.

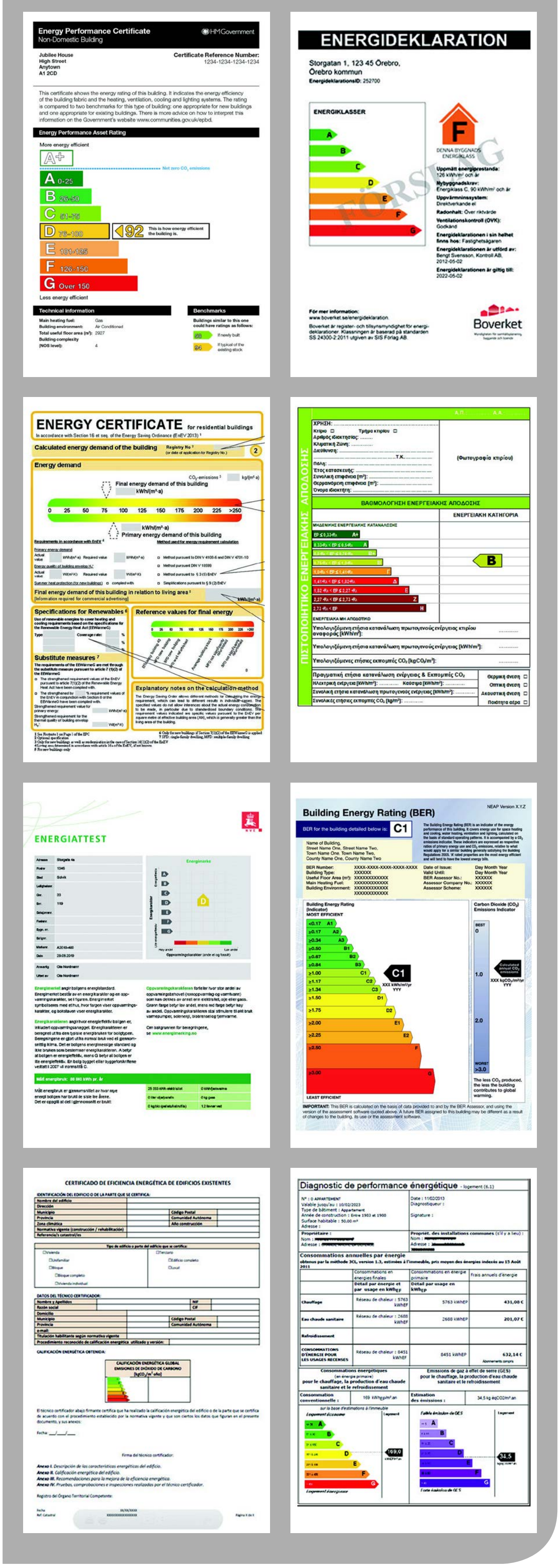
III. Mitigating Strategies

Risk control requires successful solutions. This report takes a practical approach and recommends mitigating tools depending on climatic risk. It proposes an extensive array of currently available strategies that can be implemented in existing or new buildings. The aim is to provide practical measures to 'future-proof' portfolios in order to keep or increase their future value in comparison with other assets in the same region. These strategies (see examples in FIgure 7) are illustrated with reference to successful case studies to help understand the scope and effect of each strategy. All the strategies and case studies can be found in Appendix 2.

IV. Climatic Risk Toolkit

This report is supported by a practical Climatic Risk Toolkit (CRT) – see Appendix 2. This tool is available online and has been developed to predict the impact of climate change in the eight researched European countries, and includes proposed mitigating strategies. It also includes a Microsoft Excel® software-based Climatic Risk Calculator and a supporting document which explains clearly how it works. Using current bills and building characteristics, this model predicts energy loads, operational costs and carbon emissions in 2050. The model is based on building performance simulation software that analyzes present and future weather conditions. It has been tested with data from existing buildings across Europe.

Figure 6 Energy Performance Certificates. Layout in all research countries



Source: CA-EPBD (2012)

Figure 7 **Mitigating strategies – comparing technologies**

LIGHTING

Low Energy Lighting

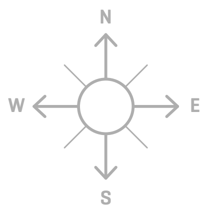
Design Stage | Retrofit | £ | ☺

Lighting: 10% of the energy bill	UK1
Switch to CFLs & LEDs: **electricity reduction**	UK2
Cooling reduction due to fewer internal gains	UK3
CFLs use less electricity and have longer lifetime than regular bulbs	EL1
LEDs last longer than most CFLs	SWE1
LEDs: full brightness without warm-up time	ES2
	ES4

LAYOUT

Orientation

Design Stage | Retrofit | £ | ☺



Daylight is maximized	
Heating demand reduction	
Restricted artificial lighting: **cooling reduction**	FR1
carbon emissions reduction	
User comfort is enhanced	

Source: Sturgis Carbon Profiling LLP

Figure 8 Climatic Risk Toolkit

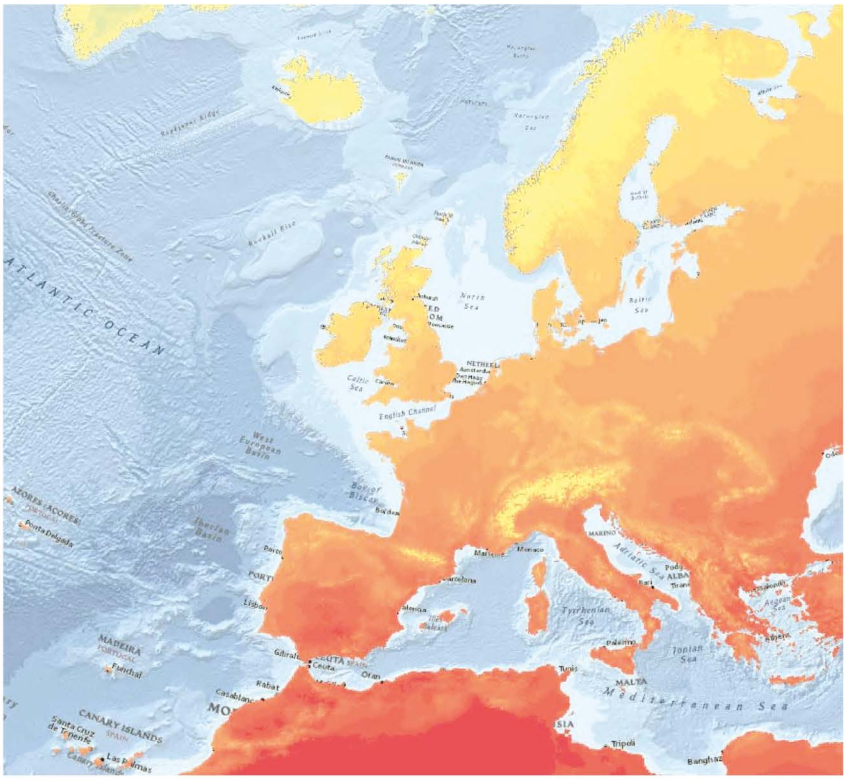
This toolkit calculates an individual asset's climate change risk profile through three simple steps. Its intention is to help guide investment and active assets management strategies tailored to a building's unique characteristics. Specifically, it quantifies:

> future running costs
> future energy demands
> carbon impact of climate change

To input data, please click in the blue areas: Sample input

Surveying Institution	Surveyor Name
Surveyor	Surveyor Name
Date	Mar-14

Building Name	Building name	City	City
Building Address	Address 1	Country	Country
	Address 2	Currency	GBP - British Pound
Postcode	Postcode		



Source: Sturgis Carbon Profiling LLP. Available at rics.org

1.2 Why is the Climatic Risk Toolkit Relevant?

Predicting the evolution of energy bills and anticipating which specific retrofitting measures are needed in a building will be critical in order to define and increase the value of assets.

In the short term, investment in retrofitting measures needs to double to meet EU energy efficiency targets for 2020 (EIU, 2013). In the long term, the efforts might need to increase even more to achieve stricter targets. However, some buildings will require much more investment to reduce their carbon emissions. Finding them early is key to minimising future costs.

Role of building surveyor and building engineer

Building surveyors and engineers are involved in all aspects of property and construction, from supervising large mixed-use developments to planning domestic extensions. This varied workload can include everything from the conservation and restoration of historic buildings to contemporary new developments and encompasses most real estate markets.

Existing buildings
Building surveyors and engineers determine the condition of existing buildings, identify and analyse defects and prepare proposals for repair. They also give advice on factors such as alterations, renovations and extensions. Information on the most effective retrofitting measures to be implemented to guarantee good energy performance and low bills in the future once applied will assist with the reduction of building obsolescence. Understanding cost and carbon implications will help plan retrofitting works for the most suitable time.

New buildings
New projects of any scale will need to consider future climatic challenges at very early stages. Issues such as orientation, availability of natural ventilation or glazing ratios will have a huge impact on the building's future performance. Building regulations control the maximum emissions rate for current conditions, but as climate changes these rates, and their associated costs might change if appropriate measures are not implemented.

Environment
Building surveyors and engineers often work on preventative measures which keep buildings in good condition, whilst also improving sustainable features. They advise on energy efficiency, environmental impact and sustainable construction. The most sustainable strategies to be implemented today may not be the right answer in the future. Considering that the average lifespan of a building is sixty years, knowing the challenges buildings will need to face will help to future-proof them today and reduce carbon emissions.

Feasibility studies
Predicting the evolution of operational costs following climate change, and understanding which factors drive these changes in a specific location might highlight the difference between a feasible project and an erroneous calculation.

Valuation surveyors

Property surveyors are involved in the purchase, sale, management and leasing of real-estate assets; negotiations between landlords and tenants, and strategic management of corporate property portfolios. They provide the basis for performance analysis, financing decisions, transactional or development advice, dispute resolution, taxation and various statutory applications.

Valuation
The value of a real estate asset depends on the current operational costs and the future investments that the asset will require to keep running expenses under control. The definition of this value today needs to take into consideration the future circumstances that will challenge the building. Assets with a more adaptable response to climate change are already increasing their value. On the other hand, the value of buildings more vulnerable to climate change and with a requirement for extensive improvements will soon be devalued.

Managing portfolios
The option to lease or rent any premises will also be affected by climate change. Buildings with increasing bills and comfort issues will face a reduction in desirability and prospective value. On the other hand, buildings with a green rating are already worth higher premiums (European Commission, 2013), and this tendency will probably continue in the future as energy prices rise.

If part of a portfolio does not comply with the minimum energy performance conditions defined by policies, large retrofit investment might be required. Being able to predict which buildings will require more retrofitting works will facilitate making decisions about which assets should be included in a portfolio and which sold before global warming raises bills.

1.3 The CRT tested by building and asset surveyors

Alongside the development of the Climatic Risk Toolkit, one of the most important objectives of the project was to create a useful application for surveyors. During the process, four of the leading UK and Europe Real-Estate investors and managers were contacted to obtain their feedback on preliminary versions of the toolkit and to appraise their needs (Land Securities, Tishman Speyer, Argent, Grosvenor).

Surveyors judged the usefulness and accessibility of the tool and provided their impressions of the research scope, what they would expect from it and what future steps would be useful for the sector. This dialogue provided invaluable feedback, which can be summarised in the following essential features:

- Determine which areas of Europe are under higher climatic risk
- Make the toolkit useful for both new and existing buildings
- Focus on the economic impact of climate change in the real estate sector
- Availability of reference case studies to illustrate the options to mitigate the risks.

All of the above feedback has been incorporated in the research objectives, methodology and structure.

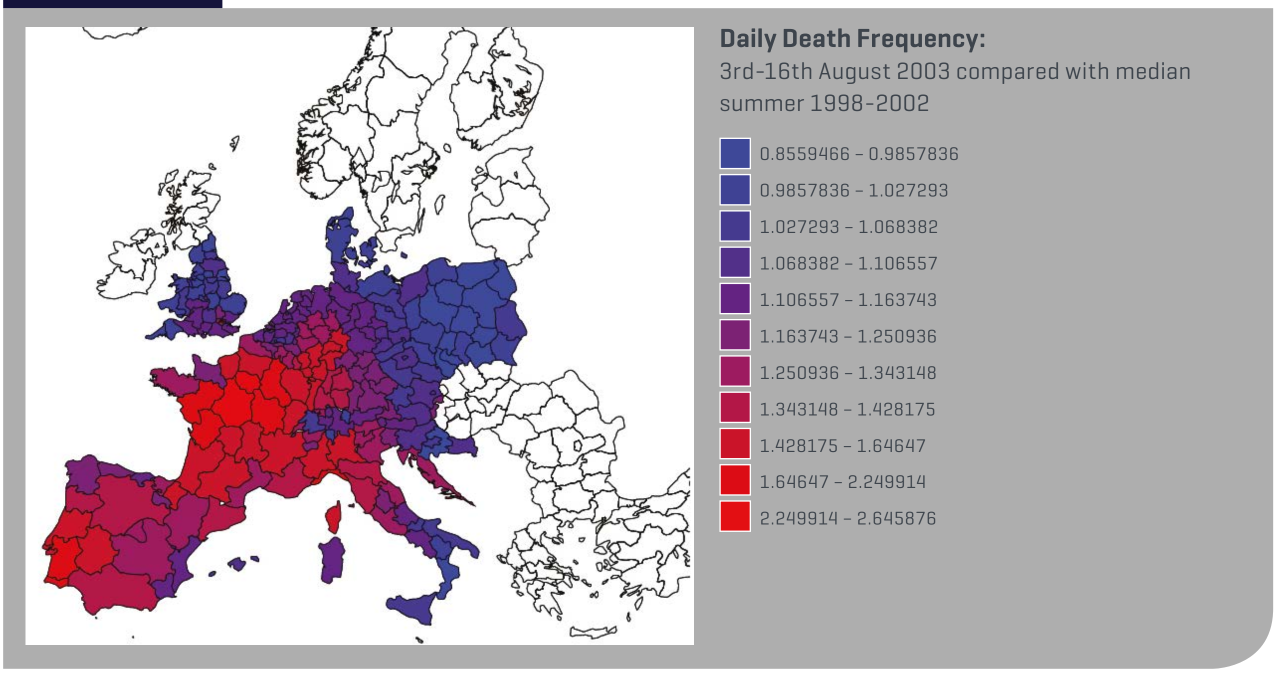
Surveyors also provided anonymous data relating to real buildings to test and calibrate the toolkit and its projections. Details on how this has been carried out can be found in Appendix 1 of this report.

2.0 Background

Climate change is already happening. Every year more frequent extreme weather conditions hit many areas within the European Union. A severe heat wave struck Western Europe in 2003. It has been estimated that this event claimed 80,000 extra lives. Robine (2007) compared the average death rates of 2003 with previous years during the same period. 15,000 of the extra deaths happened only in France. Recently, some areas of the British region of Somerset flooded for months and countries like Spain suffer recurrent draught cycles. These events impose a severe burden onto local and national economies. The built environment also suffers these effects and they will affect the future performance and value of real-estate assets.

Temperature is rising globally (IPCC, 2103), but local effects in each region will not always follow this global pattern. Latitude, climatic region, precipitation patterns, level of urbanization and height above mean sea level are some of the parameters that will modulate local variations. Besides, the characteristics of the buildings will also be of critical importance. A building that performs well and is energy efficient under current climatic conditions might not be the right answer following climate change. Therefore, building regulations will need to be adapted to new climatic conditions, and for some regions the direction of changes might change current trends.

Figure 9 **2003 Heat wave. Excess mortality rate in Western Europe.**



Source: Robine (2007)

Global warming will have a crucial effect on the value of real estate assets. Energy prices are expected to rise (DECC, 2013b) and may increase a building's running costs. However, this relationship is not evident because even though cooling loads and costs will increase, heating loads are expected to decrease. Besides, many naturally ventilated buildings will suffer from severe overheating and will require retrofitting strategies or the installation of active cooling systems to cope with summer temperatures. Local conditions and building characteristics are the key factors which will define how climate change will affect any building.

This gloomy scenario also presents an opportunity to add value to any portfolio or new project. This report and the complementary Climatic Risk Toolkit (CRT) in Appendix 2 have been developed to help understand how climate change will affect buildings and businesses. This is a complex topic where multiple layers interact, but the study presents the research in simple language and uses a simple tool that provides consistent and comparable climate change predictions for eight countries across the European Union.

2.1 Non-Domestic Climate Change Model for England and Wales (2011)

In 2011, RICS published a research report on climate change modelling in the non-residential sector, also developed by Sturgis Carbon Profiling (2011). The scope of this original research project was England and Wales and a hedonic model was developed based on the statistical regressions of a wide range of variables including climate, asset characteristics, building use, type of HVAC system, type of fuel and time trends. The database was obtained from the release of 65,000 Display Energy Certificate (DEC) records following a Freedom of Information request.

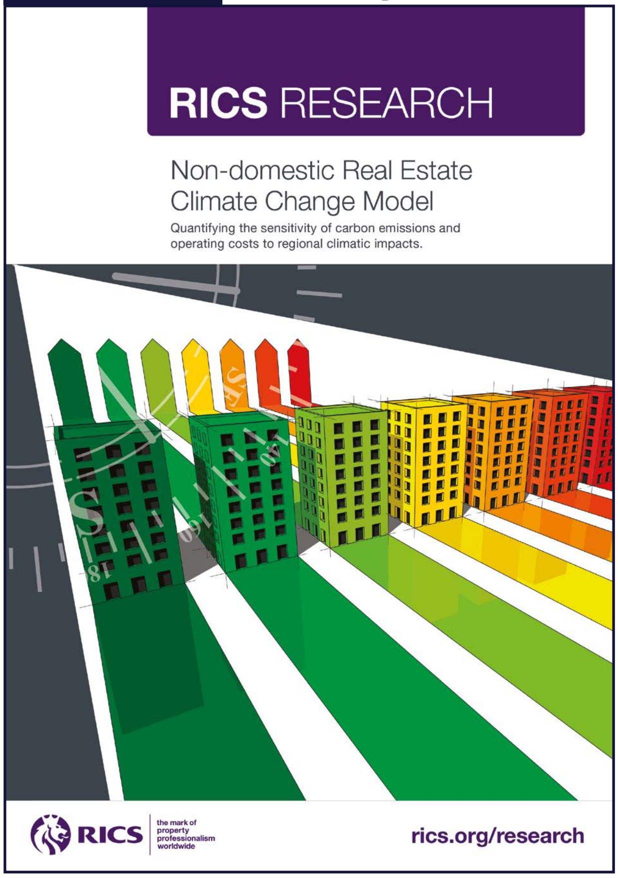
The regression analysis results, together with UKCP09 (DEFRA, 2009) temperature data for a medium emissions scenario, allowed the model to predict how climate change will affect energy demand, costs and carbon emissions throughout these regions by 2030. Findings from the analysis showed the geographical distribution of expected variations, depending on the use of the building. It is already apparent that the effect of climate change on real estate assets at a regional level is not linear and that it is affected to a greater or lesser degree by multiple variables.

The results in England and Wales for 2030 are positive: energy demand, operational costs and carbon emissions are all expected to be reduced following climate change by 2030. However, it was also evident that the scope of the research should be widened both in time and geographic areas. Further global warming and escalating fuel prices beyond 2030 might modify or revert these trends because higher cooling loads and costs might exceed energy savings in heating. Buildings in other European climatic regions are also likely to be challenged differently by climate change.

The previous report for England and Wales (RICS, 2011 *Non-Domestic Climate Change Model for England and Wales)* laid the foundations for this current, wider research. The timescale for the current research has been extended to 2050 and eight European countries have been selected in order to analyse the variations between the most important climatic regions of the continent.

The new model is based on building performance simulation software, but it also considers the findings and methodology from the 2011 report, based on statistical regressions for more consistent and reliable projections. The extension of the report to other European States added the variable of different thermal characteristics of buildings as defined in each country's building regulations, and it included the opportunity to assess both the implementation of the EPBD directive in each country and their building regulation's approach and history. Calculations can be tailored to the general characteristics of most non-domestic buildings within the geographic scope to obtain the impact of climate change.

Figure 10 **Non-Domestic Climate Change Model for England and Wales**



Source: Sturgis Carbon Profiling LLP

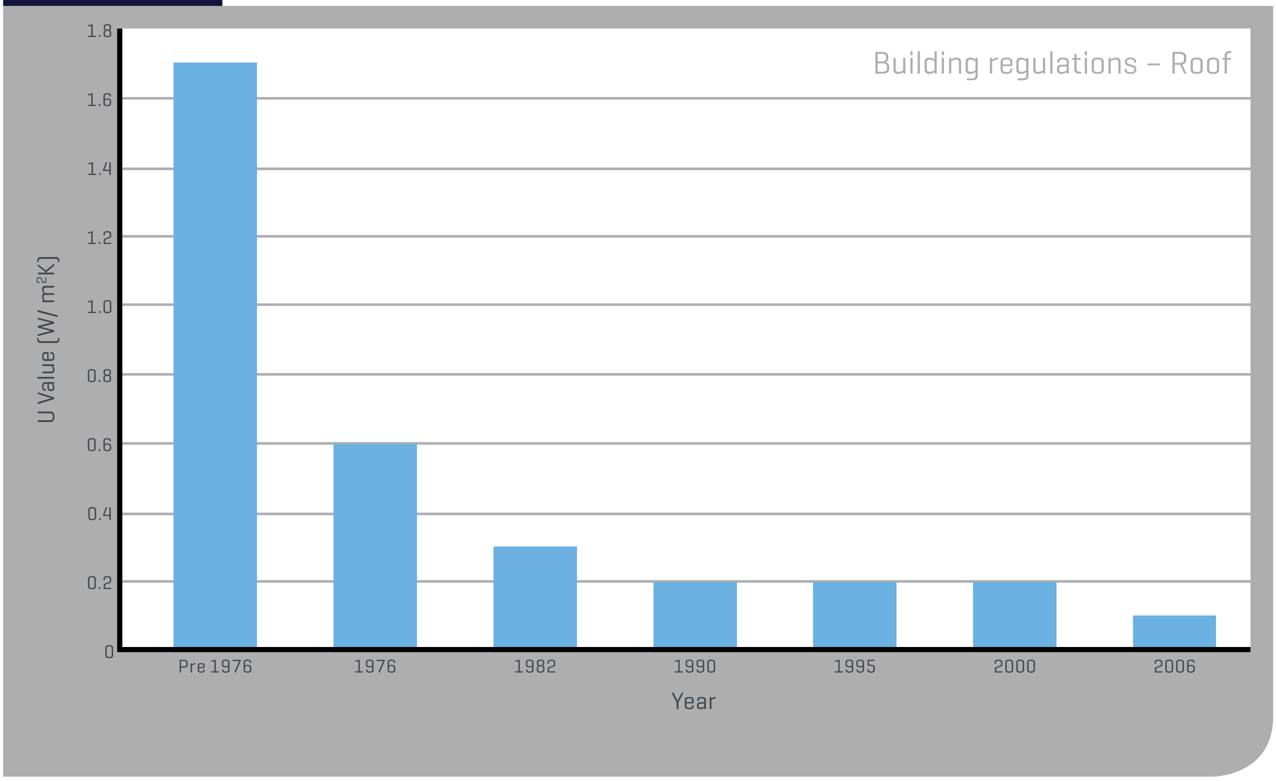
3.0 Policy Review

The future thermal performance of buildings and carbon emissions mainly depends on the characteristics of their envelope and HVAC systems. Historically, building characteristics have been defined by traditional construction systems, and developed according to local climate and resources available. In the 20th century, building regulations were developed at national levels to control interior comfort conditions and energy consumption to achieve different objectives. More recently, directives at a European level have set energy consumption and carbon emissions reduction targets, which have been incorporated into national legislation. The analyses of regulations, their targets and strategies is critical to an understanding of how current and past codes defined building characteristics, and to predict how they will perform in the future following changing climatic conditions.

One of the most important factors to consider when aiming to reduce carbon emissions is how to raise awareness. In the built environment clear communication of the energy performance of a building is achieved by the use of energy labels reporting the energy consumption and carbon emissions of the building. Energy labelling is enforced at a national level following the European Union's directives. Therefore, Member States have developed their own labels and reporting methodologies, which share some elements and approaches, but also show wide divergences.

Finally, future targets for all of the energy consuming sectors, including the built environment, are being discussed at national and European levels. The level of success of currently enforced regulations is also being reviewed, to assess whether or not regulations need to become stricter, and in which direction, to achieve carbon reduction commitments.

Figure 11 **Historic evolution of the thermal requirements for roofs in the United Kingdom**



Source: Sturgis Carbon Profiling LLP

3.1 EPBD: The Framework

3.1.1 EPBD 2002

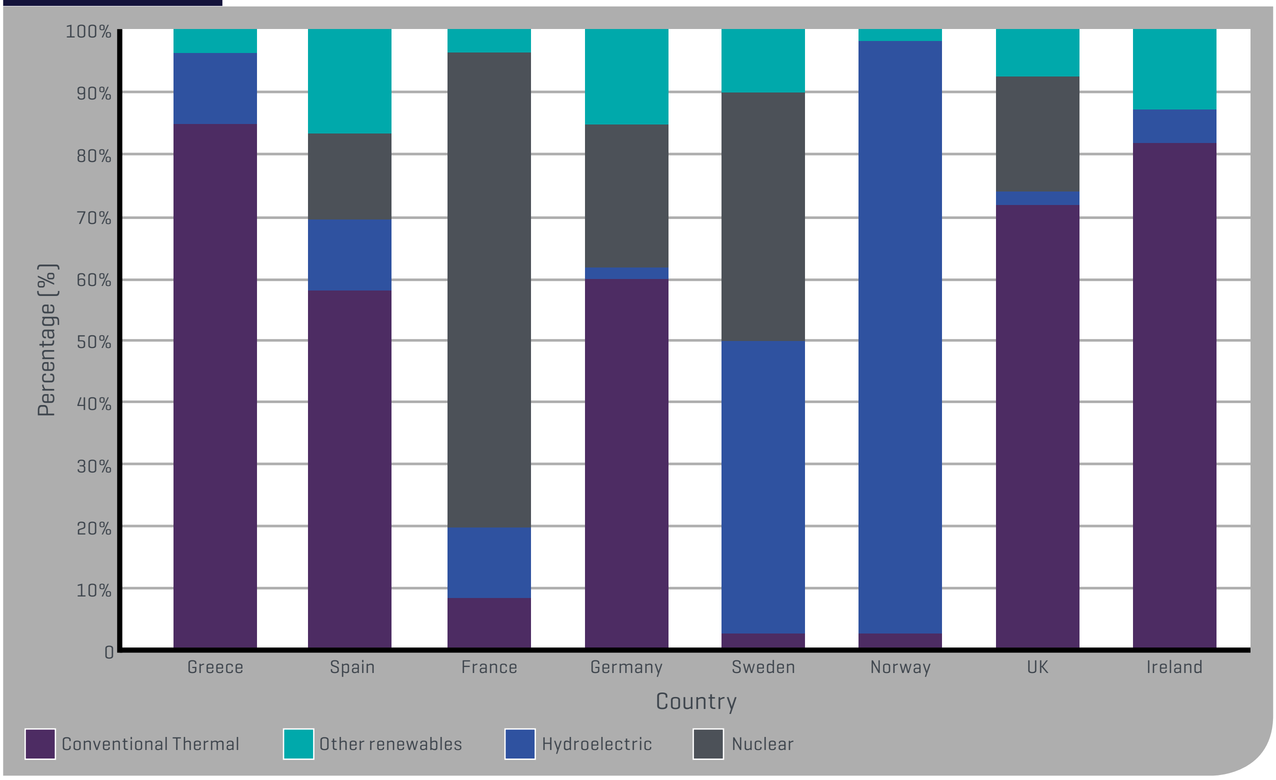
At the European level, the main policy driver is the Energy Performance of Buildings Directive (EPBD, 2002/91/EC). The EPBD is a framework legislation: it defines high-level targets and outlines the methodologies that Member States (MS) need to further develop. They integrate the directive into their national policies according to specific cultural, policy background and political circumstances.

Objectives

The original EPBD aimed to achieve two particularly high-level objectives:

- **Set the grounds for all MS to meet Kyoto's Carbon Reduction Commitments**
  Requirements, aiming for a 20% reduction in EU greenhouse gas emissions from 1990 levels by 2020.
- **Reduce EU's energy dependency from foreign markets.**

Figure 12 **Current carbon emissions impact of electricity generation**



Source: Sturgis Carbon Profiling LLP, with data from World Energy Council (2013)

3.1.2 EPDB Recast 2010

Originally implemented in 2002, EPBD defined the minimum energy performance of buildings and established the basic calculation methodology. It also set the grounds for energy certification of buildings through Energy Performance Certificates (EPC) and required the inspection of boilers and air conditioning systems. Later EU programs (Asiepi, 2008) assessed the directive in all Member States and pointed out some limitations to be overcome. The main areas of improvement related to the differences between countries in Energy Performance requirements and implementation levels. This lack of harmonization, together with the different climatic requirements that Member States face made it difficult to find a fair and effective comparison method to assess the achievements of each country.

Objectives

Subsequently, the Directive has been recast in 2010 (EPBD recast, 2010/31/EU) with more ambitious provisions incorporated for the built environment to achieve the target known as “20-20-20” (European Commission, 2014):

- **20-20-20 by 2020:**
  - 20% reduction in EU greenhouse gas emissions from 1990 levels
  - 20% energy consumption from renewable sources
  - 20% improvement in EU’s energy efficiency.
- **Energy dependency:**
  The objective to reduce the EU energy dependency from foreign markets remains in the political background.

To achieve these targets, the EPBD’s scope of action can be summarised in three main areas of development (BPIE, 2013): energy performance, financial factors and Nearly Zero-Energy Buildings (NZEB).

A - Energy Performance

Definition: Introduce minimum energy performance requirements for buildings, building elements and technical building systems.

Provisions include the development of a suitable calculation methodology for Energy Performance, building certification and labelling as well as the inspection of building services.

The transposition of the directive into national regulations and administrative provisions still depends on each Member State. The recast has significantly improved the harmonization of available data. The differences between countries, their legal and regulatory systems, cultural aspects and political views lead to a significant variation in the implementation of the directive, with considerable differences in impact, compliance, quality and control.

B – Financial factors

Definition: Set the above requirements, based on a cost-optimal methodology, taking into account the lifetime costs of the building, availability of financial incentives and market barriers.

The introduction of financial criteria and cost-optimal strategies is a new and necessary milestone to determine the actual economic feasibility (and sustainability) of the whole process. The development of reference buildings and a calculation methodology is still a challenge for each MS and reflects the characteristics of local stocks. In addition to the performance gap, the difference between predicted emissions and actual emissions affects the efficiency of cost-optimal strategies and jeopardizes the achievement of targets.

All in all, raising awareness of the importance of economic criteria in the process has been critical to the assessment of targets and to the development of suitable implementation tools (EPBD, 2012).

C - Nearly Zero-Energy Buildings

Definition: Construct only Nearly Zero-Energy Buildings [NZEB] from 2020 onwards.

The main challenge of this change is the ambiguous nature of the word ‘Nearly’, which is left to interpretation under local conditions in each country. Therefore, the application in each MS has led to a wide range of definitions of NZEB. In March 2013, six Member States had already defined NZEB in their building regulations. However, strategies, methodologies, time frames, calculation methodology and reporting values (energy or emissions) vary. The Commission will evaluate the national plans, will periodically report on the progress and will issue recommendations.

In conclusion, although the EPBD recast has resulted in greater harmony, the Directive is still far from placing Member States in a comparable position. This situation is inherent in the European Union’s definition. This comparable position might only be achieved in the long term, but coordinated actions to mitigate Climate Change cannot be delayed. Details of the energy performance of buildings, target achievement and public awareness can be found in the transposition of the Directive at national levels:

- **Building Regulations** include minimum energy performance details, calculation methodologies and emissions targets in each Member State.
- **Energy Performance Certification** systems account for and communicate the Energy Performance of existing and new buildings. EPCs normally enforce the cost-optimal approach of the Directive in their recommendations for retrofitting and improvement. EPCs are also key elements to open many financial programmes and incentives.

3.2 Building regulations: The framework in practice

National Building Regulations (BR) are the guidelines to be adhered to in order to convert the EPDB's objectives into reality. They include minimum Energy Performance requirements for new and existing buildings in each Member State and they mainly define the characteristics of the envelope and the Heating Ventilation and air conditioning (HVAC) systems of the building.

3.2.1 Achieving the targets

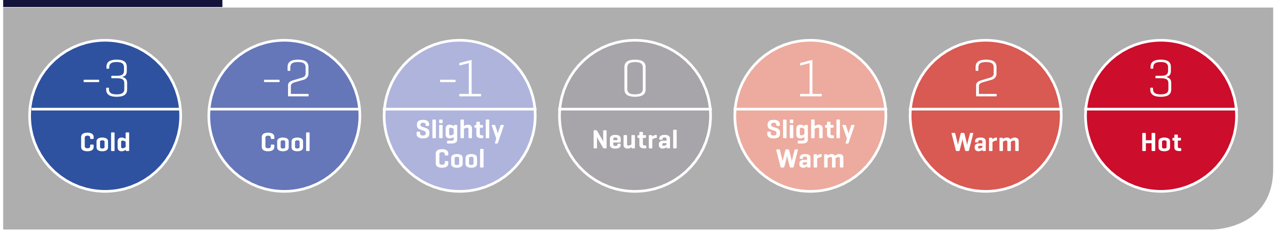
Building regulations are introduced to control the energy requirements in buildings. The requirements are driven by a complex number of factors that have changed through the course of history. Historically, the main reasons for the development of Building Regulations (BR) can be summarized in three headings, all of them linked to economic factors:

Comfort

The first significant focus of the regulations is comfort. Buildings are constructed to maintain interior conditions within comfortable levels throughout the year. Historically, traditional construction had technical limitations which prevented the achievement of this for the general public. In the 20th century, both technical improvements in the built environment and occupants' growing expectations led to a relative increase in the construction quality, but in most countries this was not regulated and comfort was maintained in winter with active measures dependent on fossil fuels.

However, in some extreme climates, meeting comfort expectations required so much energy that it was not affordable. As a result, buildings had to be constructed under certain technical standards that are capable of providing these desired conditions at a low price. Therefore, there is no surprise that Scandinavian countries led the way on promoting comfort conditions: Sweden and Norway had their first BR in 1946 and 1949 respectively.

Figure 13 Fanger's seven point thermal comfort scale



Source: Sturgis Carbon Profiling LLP

Figure 14 Flag policy during oil crisis in 1973 in Oregon, US and Automobiles lining up for fuel at a service station in Maryland US in 1979

Source: Library of Congress US

Energy consumption

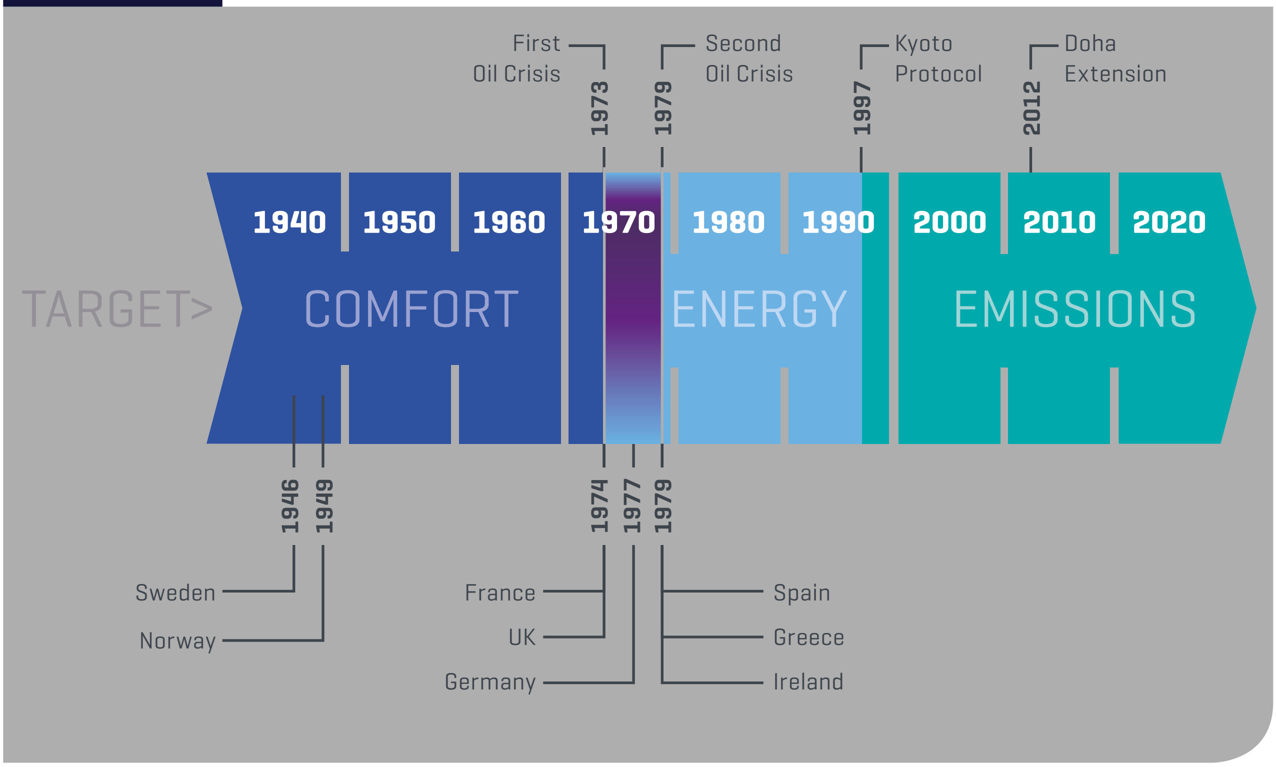
The first oil crisis in 1973 raised serious concerns about future fuel price increase and highlighted the fragility of the European Economic Community (EEC) because of its energy dependence on other countries and the economic consequences. Hence, political and economic reasons led France and Germany to develop their BR in 1974. Awareness of declining reserves of fossil fuels also grew in developed societies. After the second oil crisis in 1979, energy availability was proven unstable. Fearing a potential upcoming crisis, Ireland, Greece and Spain, developed their first Building Regulations: 33 years after Sweden.

Building regulations aimed for a more rational use of energy in the built environment, but emissions and climate change were not yet part of the agenda.

Emissions reduction

The final factor that forced countries to have stricter building regulations is environmental concerns. Climate change is a fact; and the continuous rise of emissions due to human activity has led all European countries to sign the Kyoto Protocol, which is an international treaty that sets binding obligations on industrialized countries to reduce their carbon emissions. As a result, major energy reduction must occur in order to reduce carbon emissions.

Figure 15 Implementation of first energy related building regulations



Source: Sturgis Carbon Profiling LLP

3.2.2 How Building Regulations aim to reduce carbon emissions?

The first step is to **reduce energy losses**. The target is to control heat transfer between the building and the environment. This is achieved by improving the building's envelope:

- **Insulation:** External surfaces can reduce their heat transfer coefficients (U-values): walls, roofs, floors, doors and windows.
- **Infiltration:** Air leakage must be controlled and reduced so that undesired heat losses are minimized. However, adequate controlled ventilation will provide a healthy environment.
- **Protection:** Excessive sun radiation must also be avoided in summer, but solar gains are promoted in winter. The objective is to reduce heating demand, but also to avoid overheating.

The second step is to **reduce the energy demand** of the activities that happen inside the building.

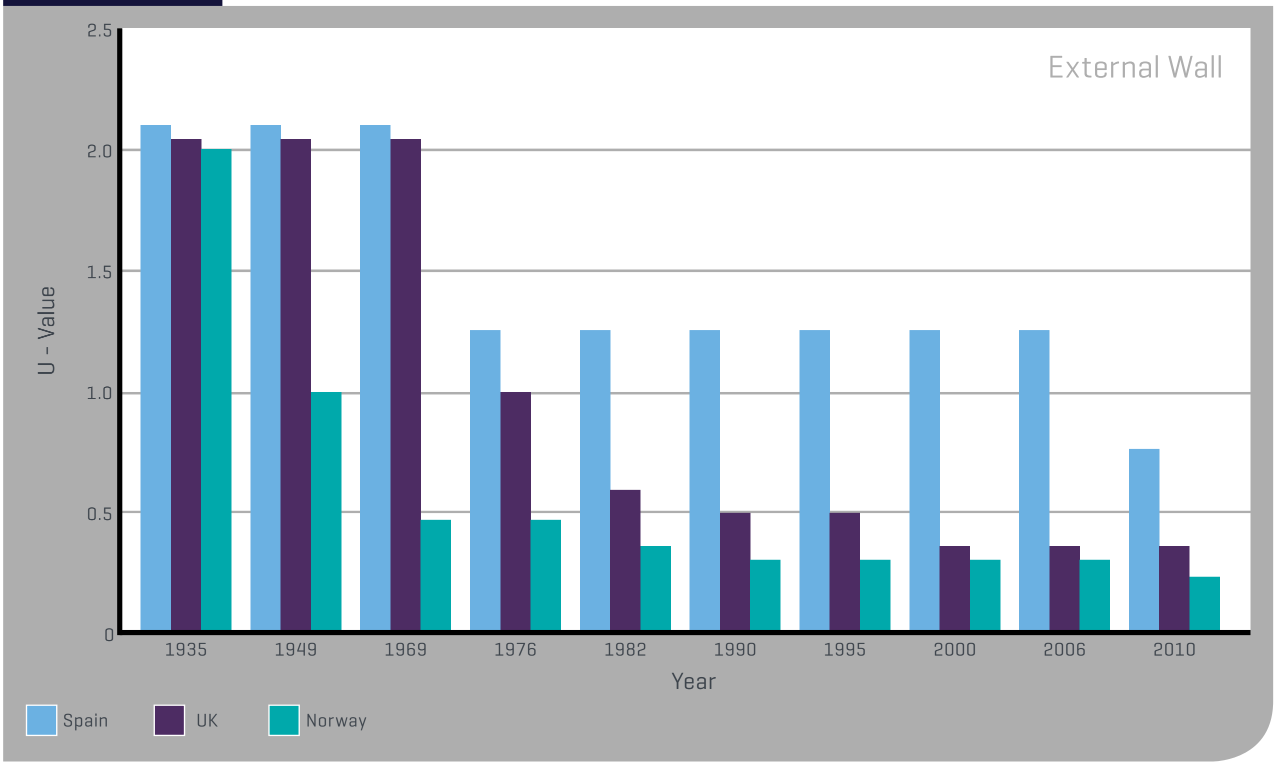
- **Ventilation:** It is a major contributor to the total energy consumption in buildings. Where applicable, natural ventilation should be considered as a carbon free and zero energy strategy.
- **Lighting:** To further reduce energy demand, daylighting must be maximized and controls should be considered to reduce the use of artificial lighting. Electricity consumption and cooling demand will thereby be reduced.

Finally, the production of **renewable energy** on site may be required to meet emissions targets, avoiding the use of fossil fuel and its associated carbon impact.

3.2.3 Building Regulations in different countries

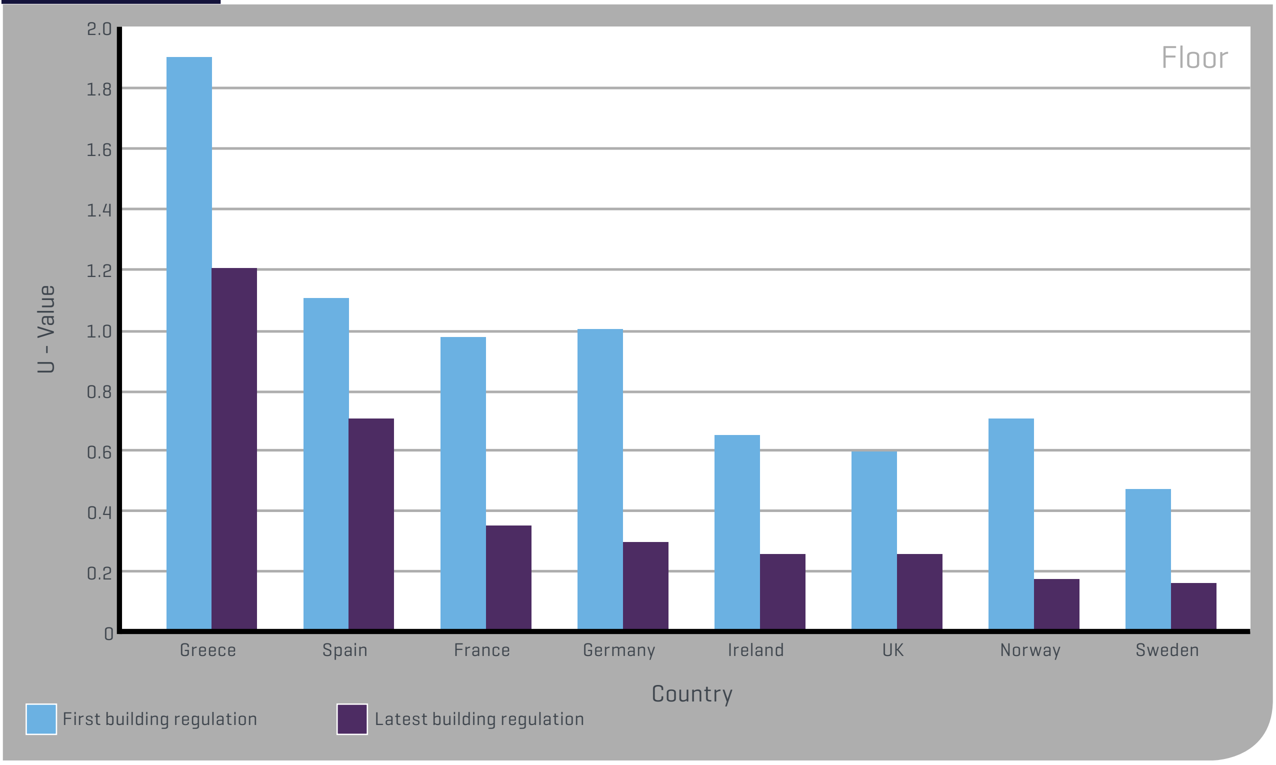
Building Regulations have improved buildings' performance throughout recent decades. The thermal requirements for the individual components have been improved in every revision, meeting each BR's targets. The minimum requirements for walls, roof and floors were defined by the first regulation of every country. Windows' characteristics and maximum air infiltration rates were introduced in later standards.

Figure 16 National building regulations: Historic evolution of minimum thermal requirements for external walls



Source: Sturgis Carbon Profiling LLP

Figure 17 **First and most recent building regulations: Minimum thermal requirement for floors**



Source: Sturgis Carbon Profiling LLP

There are major differences between the evolution of Building Regulations in northern and southern countries due to climatic conditions:

- **Northern, and colder countries seek to isolate buildings from their environment.** Unfavourable exterior conditions in winter lead to regulations that require very well performing envelopes. The objective is to minimize energy losses through energy transfer or air infiltration. Sun protection and heat dissipation in summer are not the priorities.
- **Southern, and warmer countries seek to control the relationship between buildings and their environment.** The main climatic risk in warmer climates is overheating. The aim is to avoid unwanted sun radiation and dissipate internal heat gains in summer. All lighting, people and equipment emit heat. Regulations focus both on sun protection and adequate ventilation as well as envelope improvement. Southern countries have heating requirements in winter too, but milder winters require less energy input to meet requirements. Therefore, the characteristics of the building envelope (thermal conductivity and air tightness) are much less strict than in northern countries.

Building standards are focused on reducing energy consumption and carbon emissions in current climate conditions. However, many have overlooked the fact that climate is changing and it might affect cooling and heating demand. Making building regulations stricter will be beneficial for the next few years, but in the long run, electric consumption due to cooling demands, and overheating levels will increase, which might result in buildings not achieving their emissions targets. Whether or not buildings are ready to meet future expectations in a changing climate is not clear.

3.3 Energy Performance Certificates (EPC): Beyond a Communication tool

EPC is, most of all, a communication tool that informs owners or tenants how their buildings perform, or can be expected to perform.
(EPBD-CA, 2012).

EPCs are not just a formal certification document, they have become a flexible tool that each EU country is using to promote good energy performance, to communicate results and to engage stakeholders in the emissions reduction process. The EPBD 2010 recast sets a limited amount of minimum targets which all Member States must comply with. Compulsory requirements focus on:

- Control of issuing conditions, EPC content and reference values
- Development of suitable calculation methodologies
- Cost-efficient retrofit recommendations
- Display requirements.

However, EPBD allows flexibility to Member States to add further information, customise labels or develop calculation methodologies that are more suitable for local building stock and existing policies. This flexibility widened the capacities of the EPC, but it has reduced the possibility of making comparisons between countries.

This customisation of the document at a national level follows differences in policy background together with cultural and political aspects. Even though these differences set limitations, when comparing building performance at a trans-national level, they also may have positive impacts. The latest EPBD's Concerted Action report assessing the Implementation of the EPBD directive in member States (2012) describes the differences between countries. The following section summarises the most relevant factors for surveyors.

3.3.1 Content of the EPC

Key factors

The reference values displayed in the EPC and the methodologies to calculate them are not consistent throughout all EU countries. EPBD proposes a framework methodology which refers to national building stock characteristics and benchmarks to display relative performance of buildings. In absolute numbers, the minimum energy performance requirements may also vary from country to country.

- Energy performance indicators can be expressed in different units: kwh/m^2 per annum, kgCO_2/m^2 per annum
- Calculation methodologies might also be different. Energy performance factors referring to the same scope might not be comparable between countries.

To make possible comparisons between assets at a transnational level, EPCs should include at least one building performance reference indicator, calculated in every country according to the same methodology and expressed in the same unit. Including this in the available calculation methodologies and software might be difficult because it may lead to oversimplification of calculations, but actions towards meeting this objective should be undertaken.

On the other hand, national customisation of EPC contents, including amount and type of indicative values, different ways to display labels, energy bands and ratings, also generates positive impacts. Display methods are always intuitive and if benchmarks and display values are adapted to local markets and culture, it will be more beneficial for surveyors and residents to understand the content and apply them to the relative value of an asset within the local market.

EPC recommendations

One of the most important changes in the recast of the EPBD is the inclusion of cost-effective methodologies to assess the feasibility of the strategies recommended in the EPC. If a retrofit strategy or energy related recommendation is not economically feasible, it should not be included in the document.

Again, methodologies and calculation methods vary, but the implementation of any retrofit action in the building (improving the façade, renovation of the air conditioning, or improving the air tightness) will normally be sourced in the local market. The use of local economic and climatic databases to assess the feasibility of the recommendations is much more useful than keeping the cost-effective rating at the European level.

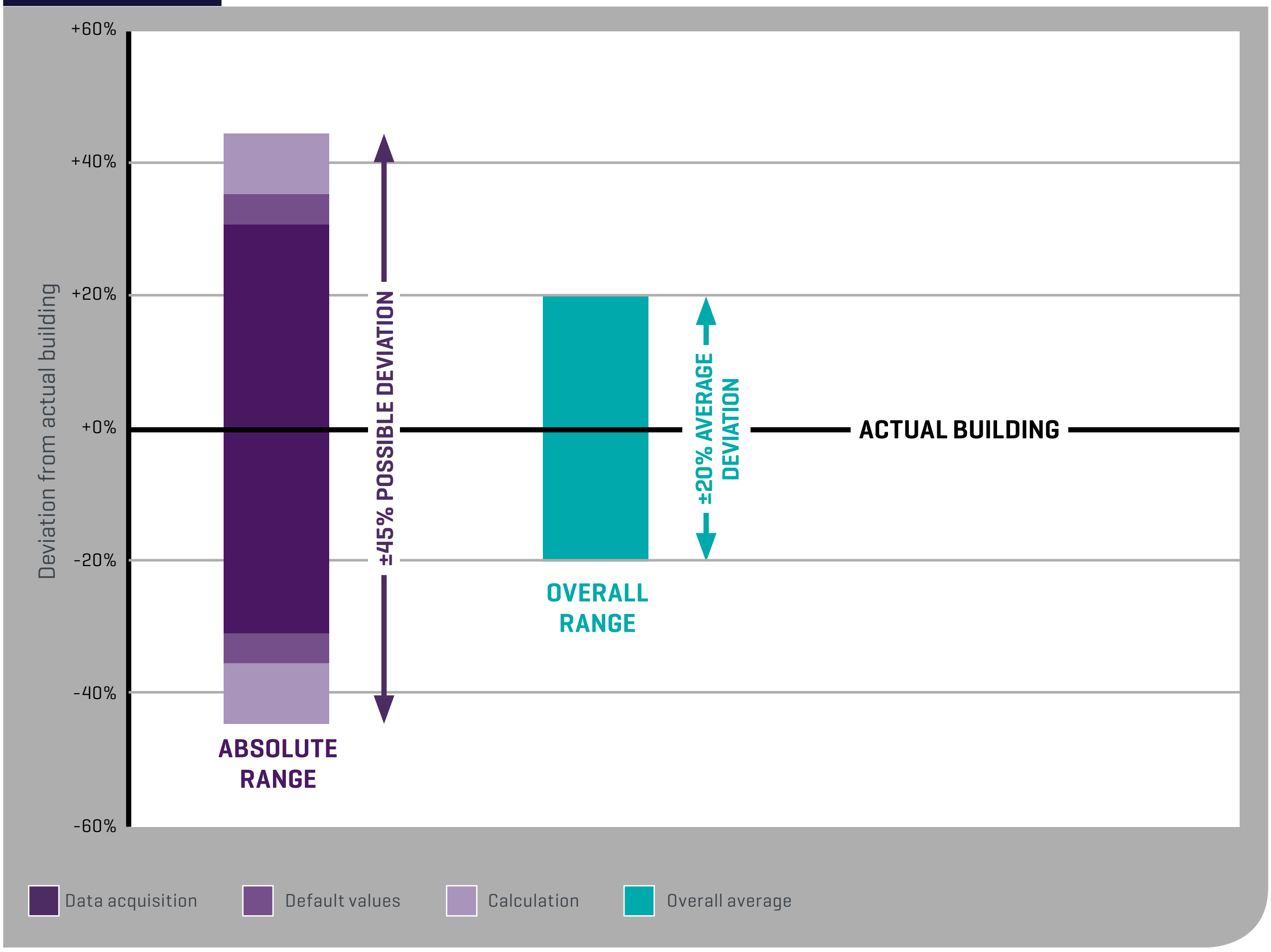
3.3.2 Process and Quality

There are also differences in the processing of collected data as well as the process of development and issuing of EPCs. These include training/accreditation requirements and the availability of different methodologies at national levels for different building types or uses. These differences have an impact on the final cost to issue the EPC document and the quality of the results.

Real estate firms managing international portfolios might consider using the same accreditation team to obtain comparable results at European levels. However, different methodologies, software, scopes and accreditation schemes for energy assessors make the setting up of these teams difficult.

Multiplicity of methodologies at national levels has also had an impact on the quality of results. Concerns have already been raised about the accuracy of the results in the process of developing an EPC, and how results from different assessors may differ up to 40% (BPIE, 2010) for the same building (see deviations in accuracy levels, shown in Figure 18). At a transnational level, this difference may be even higher. The control of the quality of delivery also varies greatly depending on the experience of each Member State in the implementation of energy performance tools. The reputation of the directive and the reliability of the EPC's indicators depend to a great extent on quality, so the recast EPBD introduced the mandatory independent control system. Most member states are implementing centralized electronic databases at national or regional levels for monitoring and data quality checks.

Figure 18 **Deviation resulting from the accuracy level of the three-part assessment procedure**



Source: Sturgis Carbon Profiling LLP with data from BPIE (2010)

3.3.3 Usability, Public Acceptance and Financial Impact

The primary function of an EPC is the advertising of any building offered for sale or rent (generally of large public buildings). EPCs are a source of information and an indicator of the building's energy performance. The public acceptance of the EPC greatly depends on how much they cost to be prepared. Are EPCs a burden or a benefit? How intuitive and friendly are EPCs and what information do they display? The level of attention of Member States towards the promotion of EPC awareness in the general public also has a significant impact. The adaptation of the design and required content of the document at a national level to meet cultural, professional and economic expectations will have a beneficial impact on the use and public acceptance of the document. However, different stakeholders (tenants, buyers, real estate agents) may have different requirements for how the data is to be displayed and this might affect the document's usability.

The potential usability of the document is much wider and it is extending outside the original objectives.

Building and market performance data

Most EU countries are setting up centralised databases of EPC ratings and assets' energy characteristics for quality assurance purposes. These data will become an invaluable source of information for building and valuation surveyors, who will be able to calculate the average performance of assets in a certain area, compare similar assets or undertake statistical analyses of larger databases. However, different constraints are holding back the availability of the information, including: privacy and data protection concerns, paywalls (webpage content only available with a paid subscription), difficulties with downloading large amounts of data and access restrictions (to researchers or policy developers for example). National legislation is also used to regulate the process and therefore wide differences between Member States are found in terms of data accessibility.

Financial eligibility

Governments and administrations are increasingly requiring minimum and maximum EPC ratings to become eligible for different financial instruments and programs. EPC ratings are also used to promote retrofitting to further reduce emissions. Poorly performing assets might not be allowed to be let or sold. Therefore the EPC rating already has an impact on the value of real-estate assets. An example of this is the latest British Energy Act (Crown, 2011), which from 1st April 2018 would make it unlawful to let residential or commercial properties under a certain energy performance level as defined by the Energy Performance Certificate. This limit will be defined by energy efficiency regulations that are currently under debate, but which the Government has yet to define in detail. However, it is expected that the minimum standard required for England and Wales will be based on an E-rated EPC.

Impact in the asset value

The impact on the rental and transactional values of a real-estate asset has started to be calculated. Recent studies using hedonic regressions confirm different tendencies: Brounen and Kok (2010) identified a premium increase between 2.8-3.6% in Dutch dwellings with EPC ratings A, B, C. Also Kok, with Chegut and Eichholtz (2012) studied the British commercial sector with good results for green neighbourhoods, and surprisingly negative premiums for green certified buildings (e.g. LEED, BREEAM ratings).

The most recent and widest research study about the financial impact of EPC was carried out in different EU countries by the European Commission (Bio Intelligence Service, 2013). Results claim that in most countries premium value will increase between 2-6% per level (designated by a letter) of improvement in EPC rating. The exception is the United Kingdom, where Energy Rating resulted in a negative impact on the value of the asset, but this result may have been caused by either age as an omitted variable, or the small sample size available for analysis.

Figure 19 UN Climate Change Conference 2012, Doha

Source: UNFCCC

3.4 Future

The transposition of EPBD into each Member State's building regulations and EPC implementation system responds to the EU's current carbon reduction commitments following the Kyoto Protocol. These objectives may seem strict and difficult to achieve, but they are likely to become even more stringent in the future.

3.4.1 Objective 30%

The European Union is actively pursuing further engagement from major economies in the developed and developing world to ratify commitments to reduce GHG emissions. Many countries have not ratified the Kyoto Protocol yet or are not bound to reduce their emissions in spite of being huge growing economies. The 2012 United Nations Climate Change Conference reached an agreement to extend the life of Kyoto Protocol to 2020, but the EU believes that further international action needs to be undertaken (European Commission, 2014). The EU is ready to increase their commitment in reducing carbon emissions to 30% by 2020 in order to engage additional countries. This will further curtail requirements in built environment, and it will have additional consequences in the short term.

3.4.2 Energy Efficiency Plan 2011

This plan was developed by the European Commission (2011) to ensure the achievement of the 20% emissions reduction in every energy consuming sector, including the built environment. One of the objectives was to assess the impact of the current policy framework in each of these sectors. Specifically, in the built environment, low renovation rates in the existing stock suggest that committed reductions by 2020 will not be achieved.

The document makes clear the fact that the current policy framework does not and cannot oblige property owners to renovate their buildings and it also cannot require any Member State to provide financial and fiscal assistance and training. However, the plan calculates the impact for different scenarios, adopting new instruments which range from raising awareness, training or voluntary commitments to regulatory instruments with very stringent measures, or setting up new financial instruments. Results were considered by Member States to further develop and enforce measures at national level. Some countries are already implementing measures that directly or indirectly address these shortcomings. An example of this would be how in some countries it is now almost impossible to rent or sell assets with very low energy performance rating.

Figure 20 **Sustainable retrofit of commercial building in Farringdon, Central London 2006-2009**

Source: Sturgis Carbon Profiling LLP

Most of 2050's building stock has been already built. Depending on the evolution of the carbon emissions, further measures will need to be implemented in existing buildings. Figure 20 provides an example of how existing stock can undertake successful sustainable retrofit.

3.4.3 Roadmap 2050: Towards A Stricter Future

In the long term, the European Commission is aiming towards more ambitious targets. The objectives are the same as those that drive the EPBD: to mitigate climate change and reduce energy dependency. However, the targets are much more ambitious. The Roadmap 2050 (European Climate Foundation, 2010) targets 80% reduction of carbon emissions by 2050 from 1990 levels in all sectors of the EU. The study scope still remains very high level, but it already suggests policy recommendations.

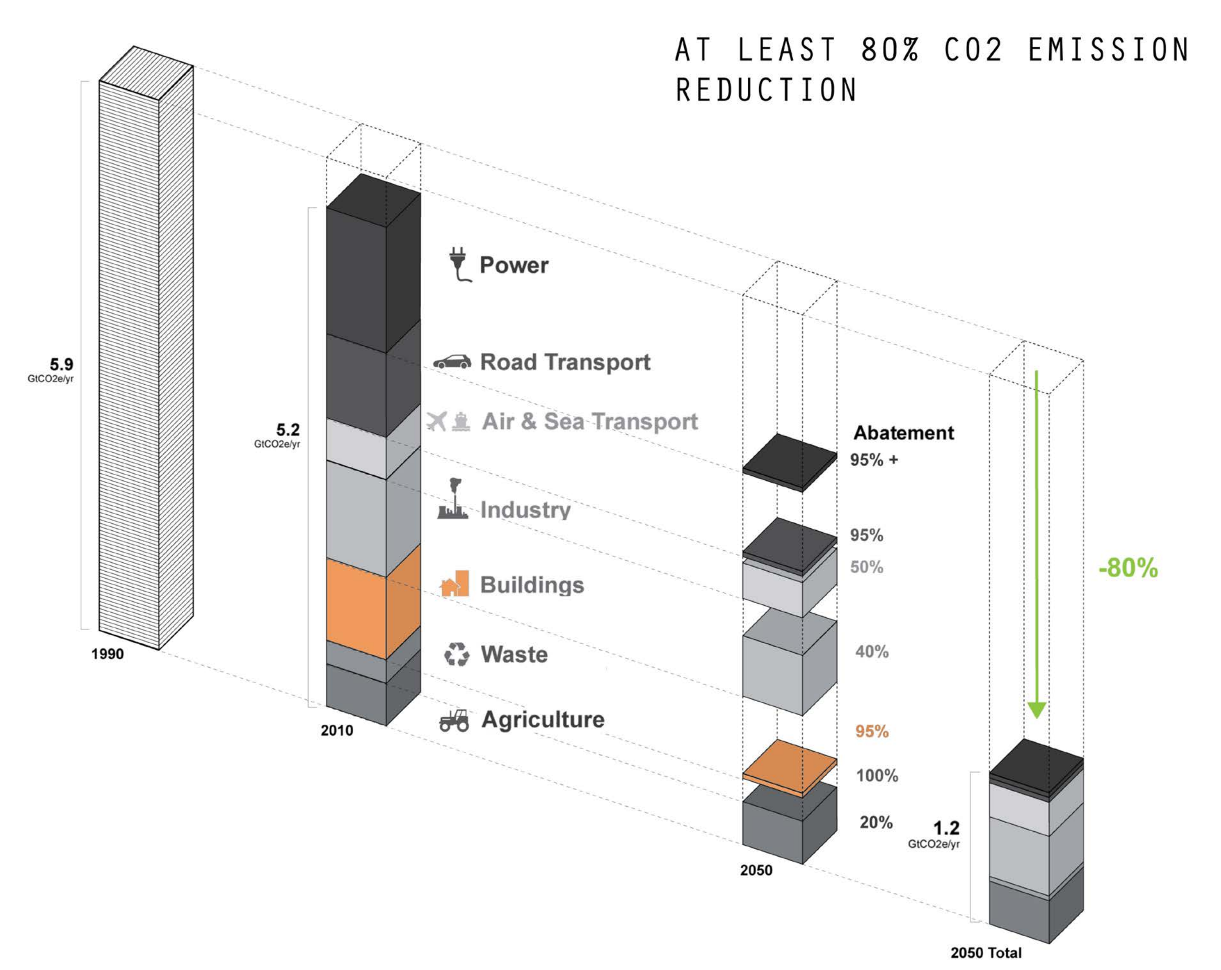
In the built environment, this target would equate to 95% emissions reduction from 1990 levels. This could only be achieved with the total decarbonisation of power generation and an almost total rehabilitation of the existing building stock (probably including buildings that are currently being built). The roadmap defines itself as a cost-effective pathway to keeping global warming below 2°C, but the financial implications need further development.

The decarbonisation of electricity generation will not be cheap. Recent research has calculated that the total cost will vary between EUR 139 – 633 billion (Jägemann, 2013). The broad scope of this estimate and the uncertainty of how the process will be funded adds further unpredictability to the evolution of electricity prices in the medium and long terms.

3.4.4 Climate Change

Finally climate change itself is a source of uncertainty in the long term. The impact of the warming climate might further constrain emissions requirements. Buildings currently under construction are required to achieve emissions rates that respond to current climatic conditions. In 30 years' time the climate will have changed, and the strategies being currently implemented in new and existing buildings might not be the appropriate ones to keep emissions low in warmer climatic conditions. Whether or not buildings are being designed and retrofitted to endure climate change and keep their emission levels low still needs to be addressed. This climatic risk toolkit aims to shed light on this issue and evaluate if current assets are future-proofed.

Figure 21 Carbon emission targets by 2050



Source: Original from Roadmap 2050 (European Climate Foundation, 2010). Format modified by Sturgis Carbon Profiling LLP

4.0 Methodology

The Climatic Risk Toolkit and Calculator predictions are based on building performance simulations calculated with EnergyPlus Energy Simulation Software package (EnergyPlus, Version 8.1.0, 2014). Simulation software can predict the interior conditions and the energy requirements of buildings. The input required by the software to perform simulations includes the building characteristics and the environmental conditions throughout the year.

4.0.1 Environmental Conditions

The environmental conditions for simulations are defined by weather files that contain hourly data of all relevant environmental factors for a complete typical year – temperatures, humidity, sun radiation levels, wind intensity and direction. Whilst there are many complete weather file databases available for present conditions, weather files predicting future projections are scarce and scattered. They are normally developed at a national level, few countries have developed them, and methodologies vary between countries. To maintain the consistency of results in all the predictions, the Climate Change World Weather File Generator developed by the University of Southampton (2014) has been used. This tool generates reliable future weather projections from present weather files which have been collected from one single database. These future projections have been used to simulate how buildings will perform in 2050.

4.0.2 Building Characteristics

Building simulation software also requires the definition of the building to be simulated. The data to input includes:

- Building geometry
- Properties of the thermal envelope: walls, roof, floors, windows…
- Internal loads: people, equipment, lighting – for every element that produces heat inside the building
- Heating, ventilation and air conditioning systems and controls
- Building use schedules for occupants, windows and HVAC systems…

The geometry of a typical representative building which can accommodate all of the researched uses has been defined as a default for the purposes of this study. The thermal characteristics of the envelope components have been modified in different models to comply with the current and historical building regulations of all the countries in the scope of the study. The internal loads and schedules have been adjusted to represent the typical operation of each building use.

4.0.3 Simulation and Output

Full building performance simulations for 2010 and 2050 have been carried out in the 39 locations marked in Figure 22.

In each location, different models have been developed and re-simulated to comply with all the building regulations historically enforced by each country. This applies to both naturally ventilated and air conditioned scenarios. In total more than 1,500 simulations have been carried out.

The simulation output includes:

- energy demand for electricity, heating and cooling
- hourly interior conditions
- number of hours when comfort criteria according to BS EN 15251 (CEN/TC 156) were not met (Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics)

4.0.4 Regressions and Building Adaptability

Actual characteristics of buildings will very rarely exactly match the geometry and size of the indicative building that has been simulated. Further research has been carried out to find the most suitable method of adapting simulation results to the conditions of most buildings.

The attributes that drive this adaptation have been found to be:

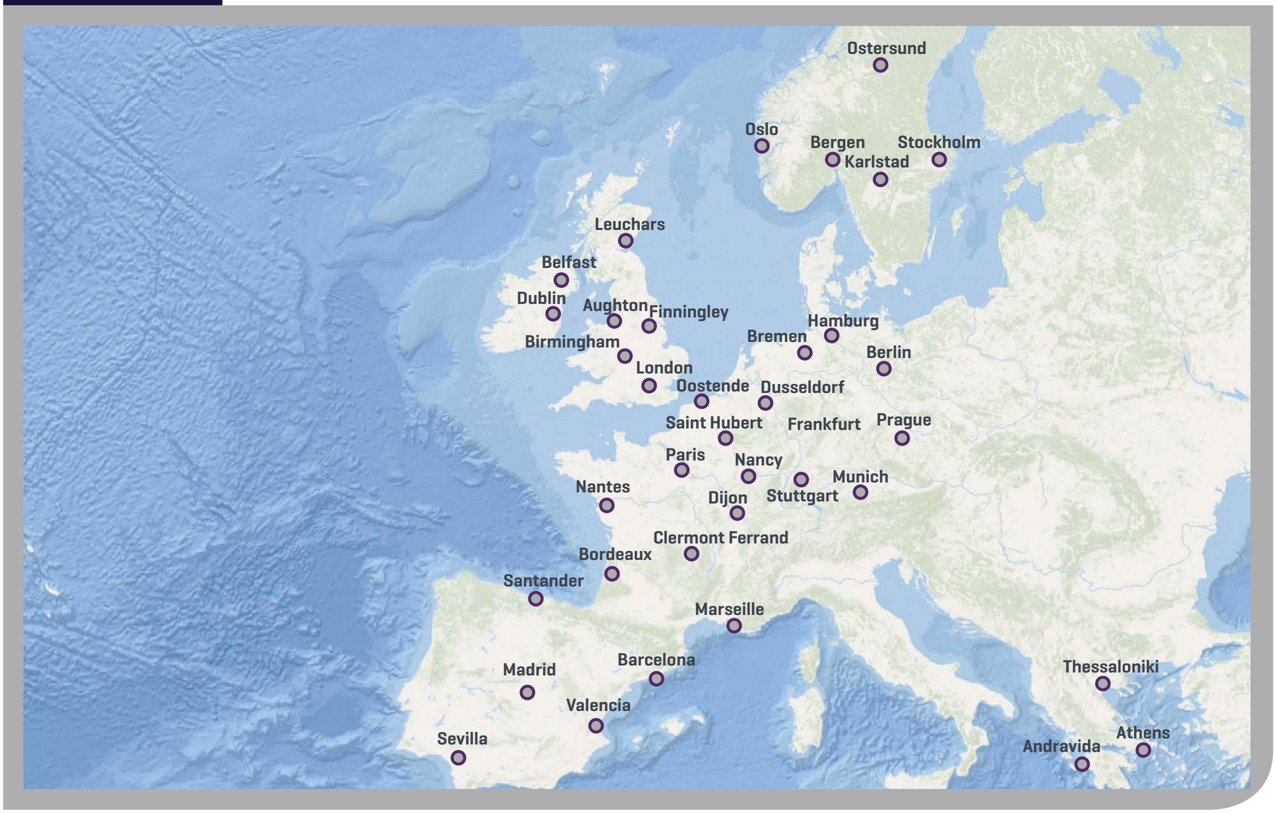
- Size of the building
- Relationship between building gross internal area and perimeter
- Façade glazing ratio
- Retrofitting levels
- Occupancy ratios
- Elevation above sea level.

4.0.5 Maps

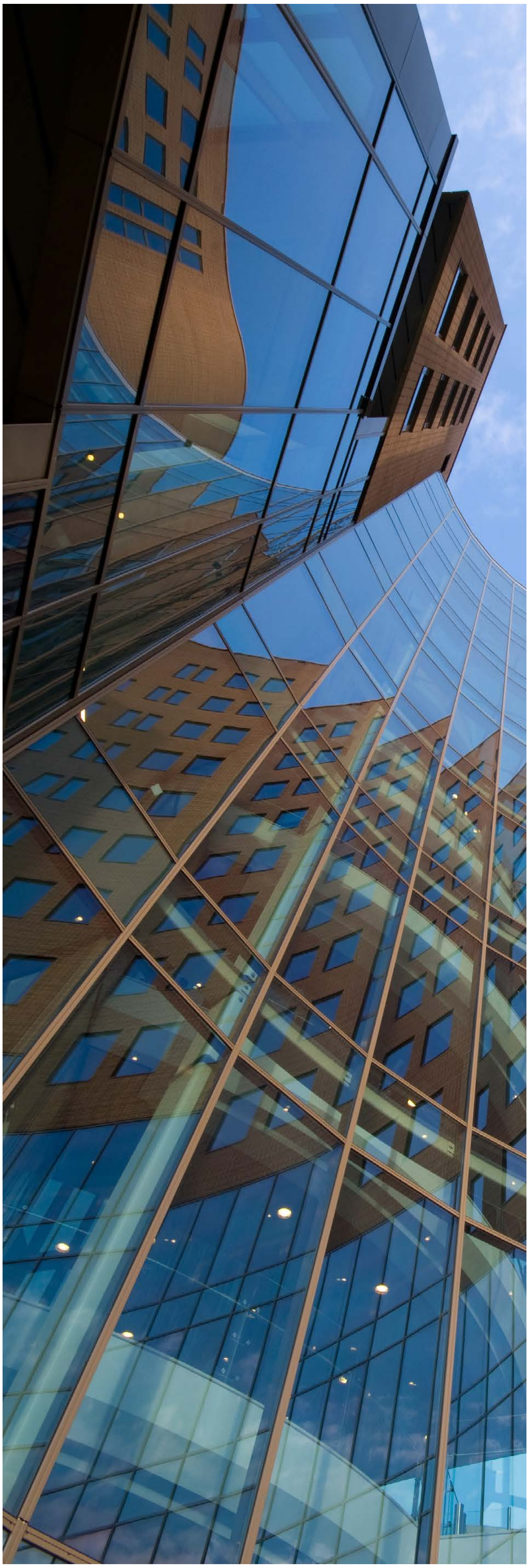
Finally, Geographic Information System (GIS) software has been used to determine how climate change will affect assets in the countries within the research scope. Together with the results of the simulations, local weather and geospatial data have been collected to calculate the impact of climate change at a regional level and to define which areas are facing higher climatic risk.

Further detail relating to the research methodology, sources of data, calibration and assumptions can be found in Appendix 1.

Figure 22 **Locations of simulated buildings**



Source: Sturgis Carbon Profiling LLP



5.0 Findings

The following sections outline the most critical findings according to the model calculations and literature research. They show clear tendencies and indicative risk areas, but they need to be read with a critical approach: The suggested examples, geographical areas and scopes are necessarily statistical, generic and non-specific. They cannot be assumed to be true of every building within the suggested range. Surveyors are expected to apply the recommendations after considering the specific characteristics of the surveyed building.

5.1 Surveying a building – Risks based on building characteristics

Many of the climatic risk factors can be deduced from the characteristics of the building's geometry and layout, building quality or the properties of the construction materials. The main objective for the surveyor is to analyse building conditions to minimise the risk of obsolescence. A building becomes obsolete when it cannot meet the occupant's comfort demands, or meeting them is not economically feasible. When this happens, some building owners/users can embark on undertaking retrofitting works to preserve or increase the building's value. This might require a significant investment, but is not always feasible due to statutory limitations or economic factors. If this is the case, the building owner or occupant will be required to consider more drastic decisions, which might include a change of use, demolition, or accepting a significant depreciation in the building's transactional or rentable value.

Following climate change some buildings that currently meet standards might become obsolete. The following sections describe the most relevant areas to be considered to identify the risk and how these factors interact.

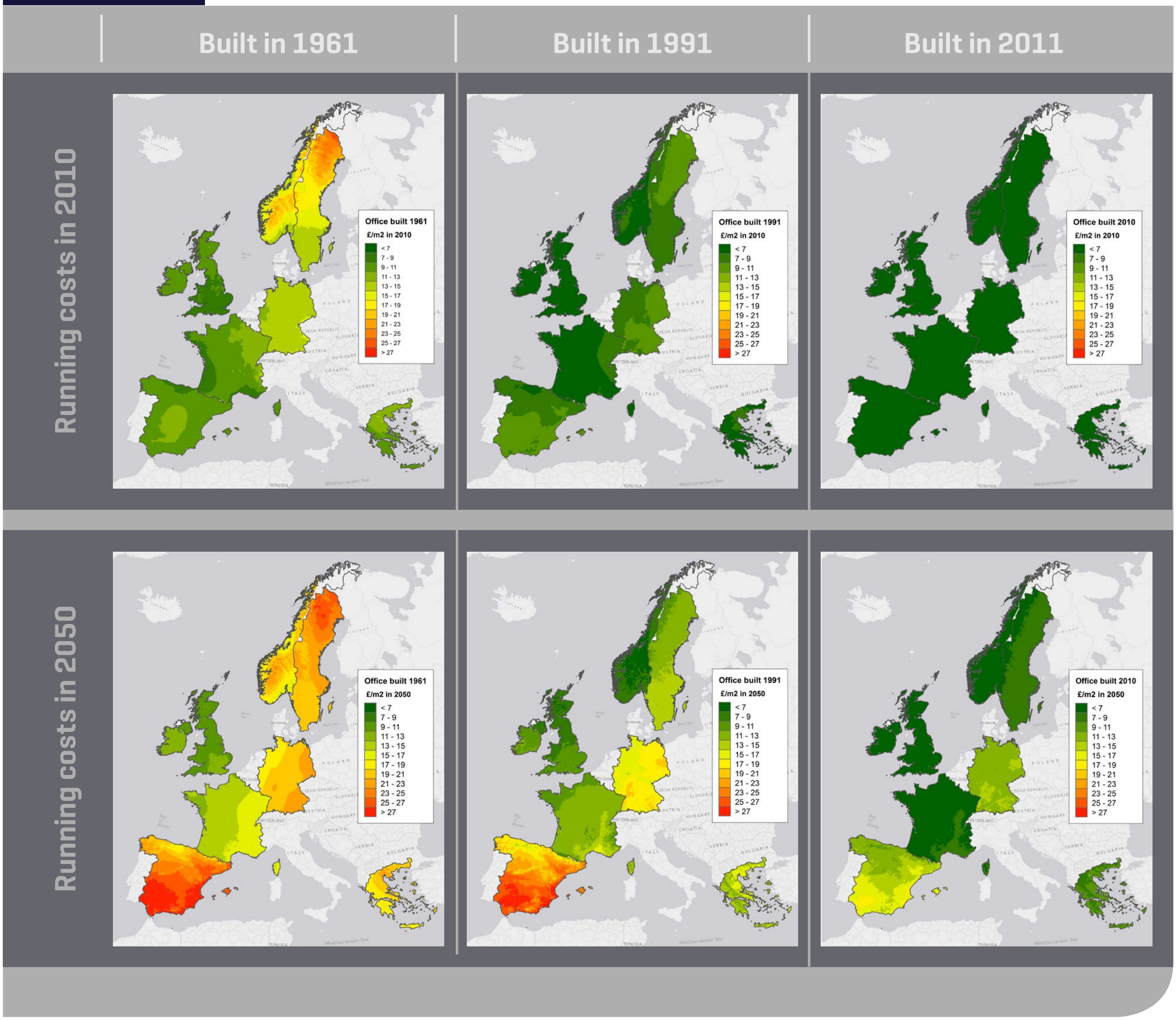
5.1.1 Building and HVAC Age

Building regulations have equipped buildings with better and more energy efficient technology in both building envelopes and HVAC systems. Newer buildings perform better than older buildings under current climatic conditions, and will generally perform better following climate change too.

In 2050, energy demand and carbon emissions of any building will be lower, but that will not be the case for the running costs. Maps as shown in Figure 23 illustrate the evolution of running costs in buildings built at different times.

The same air conditioned office buildings have been simulated in 2010 and 2050 with the typical characteristics defined in building regulations at each time. Newer buildings pay lower bills, but costs will be higher in the future due to increasing cooling loads and fuel prices.

Figure 23 **Present and future energy costs in buildings of different ages**



Source: Author/Sturgis Carbon Profiling LLP

5.1.2 Glazing Ratio

Global warming will increase cooling loads in all European countries during the summer months. Buildings with higher glazing ratios in their envelope are more vulnerable to climatic change. There are two main reasons for this:

Solar gains

If not suitably protected, glazed areas will let more solar radiation into the buildings. Even though this is beneficial in winter, in summer these loads will need to be dissipated through natural ventilation, thus increasing the risk of overheating, or by air conditioning, leading to higher energy bills and carbon emissions. Buildings with unprotected glazed areas might need to undertake deep retrofitting works in the façade or add protection elements to reduce loads.

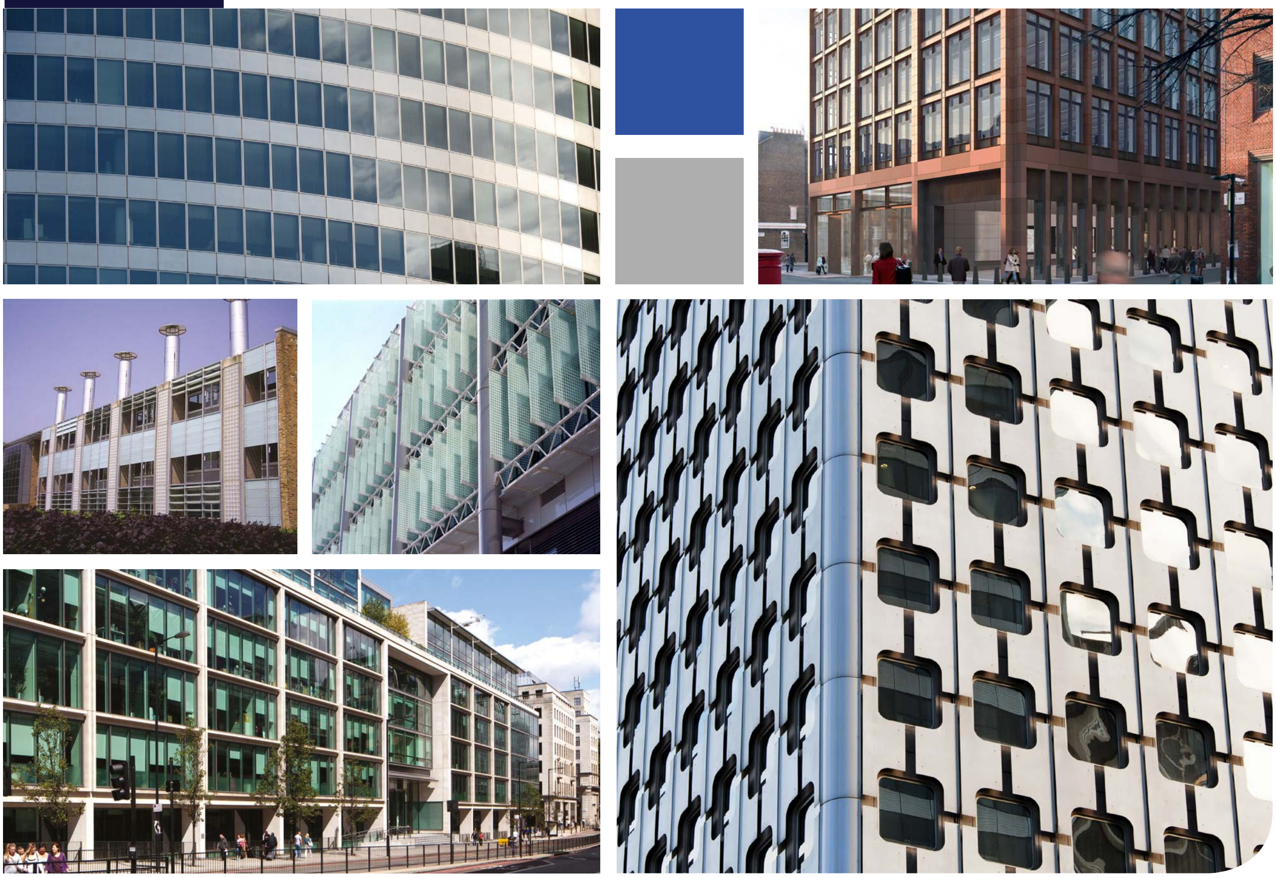
Heat losses / gains

The thermal properties of windows are less efficient than the rest of the envelope components. Façades with higher glazing ratios will lose or gain more energy.

Southern countries are exposed to higher sun radiation levels and solar gains through unprotected glazing.

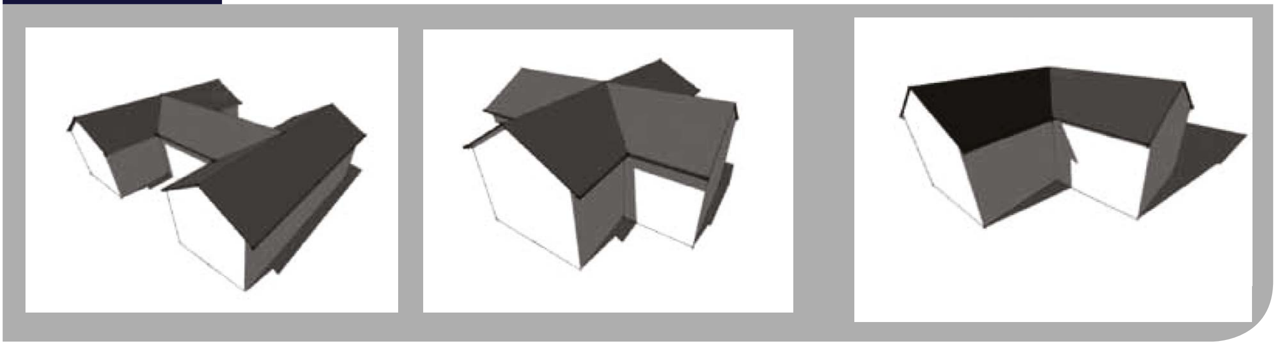
Glazing ratios are directly related to natural light availability, so any change in the glazing areas will need to be balanced with the availability of daylight and the energy consumption and internal loads caused by artificial lighting. Different levels of glazing ratios are illustrated in Figure 24.

Figure 24 Different levels of glazing ratios



Source: Grosvenor / Euleb.info

Figure 25 Different levels of compactness



Source: BRE (2014)

5.1.3 Perimeter to Area Ratio: Compactness

The simple relationship between the surface of the building envelope and the volume that it protects (see Figure 25) defines part of the building's vulnerability. The risk level will depend on the quality of the envelope and the type of ventilation system used in summer.

Mechanical ventilation

Buildings with mechanical ventilation or air conditioning are more efficient if they are compact. The ratio between envelope surface and volume is lower and there are fewer energy losses or gains through the envelope.

Natural ventilation

Naturally ventilated buildings need to find a balance between reducing energy losses in winter and dissipating extra heating loads in summer. Compact buildings perform better in winter, but less compact buildings will have more opportunities to achieve good ventilation rates in summer. This balance is defined by the environment of the building and the risk of overheating that it poses. If the risk of overheating is low in the present and future climate, then a compact building will perform better.

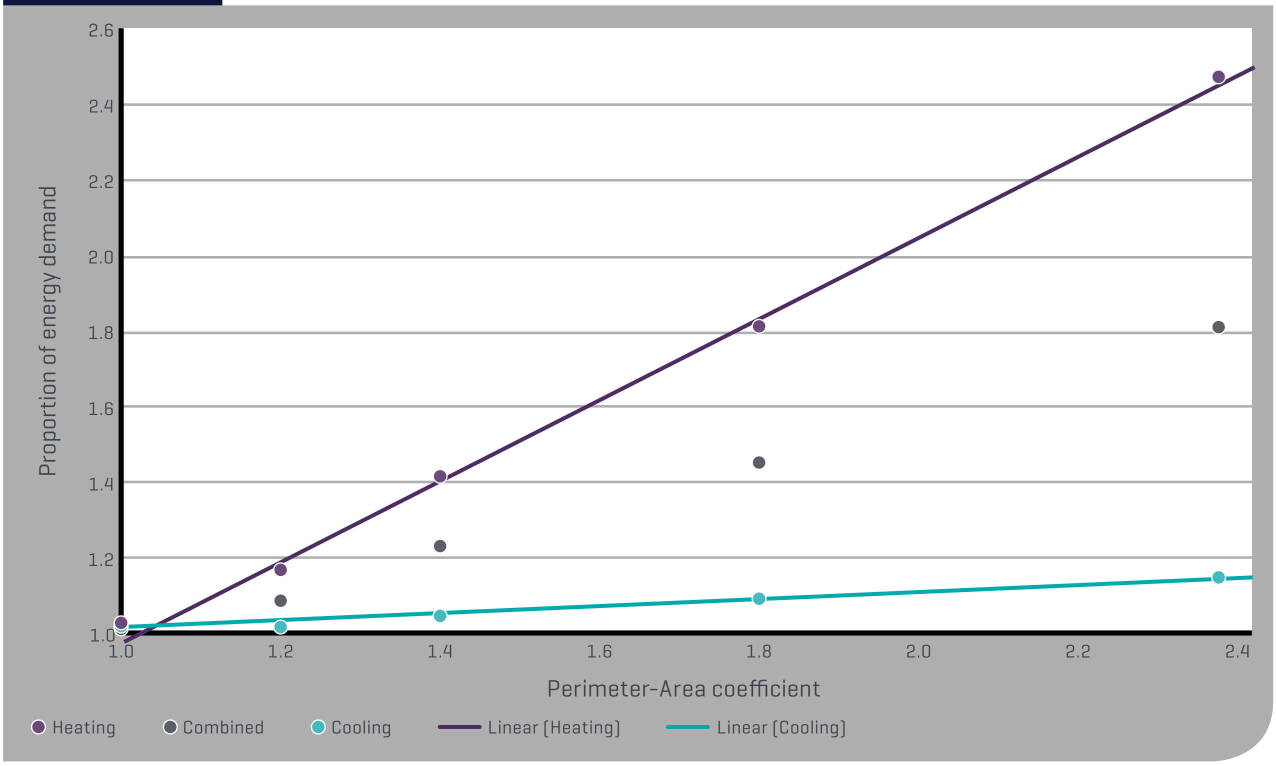
Quality of the envelope

If the envelope of the building is very permeable, a compact layout will always perform better. In winter, this low quality envelope will increase heating demand and depending on the level of energy losses, retrofitting measures might be required. In summer, air infiltration will enhance heat dissipation, but this should be achieved by controlled natural ventilation systems. Newer buildings tend to have lower infiltration rates, but there are exceptions: buildings built just after the World War II can be more permeable than older buildings, because construction quality was inferior. Also, some countries did not define air tightness limitations in their building regulations until very recently. Air tightness will depend on local traditions and construction techniques.

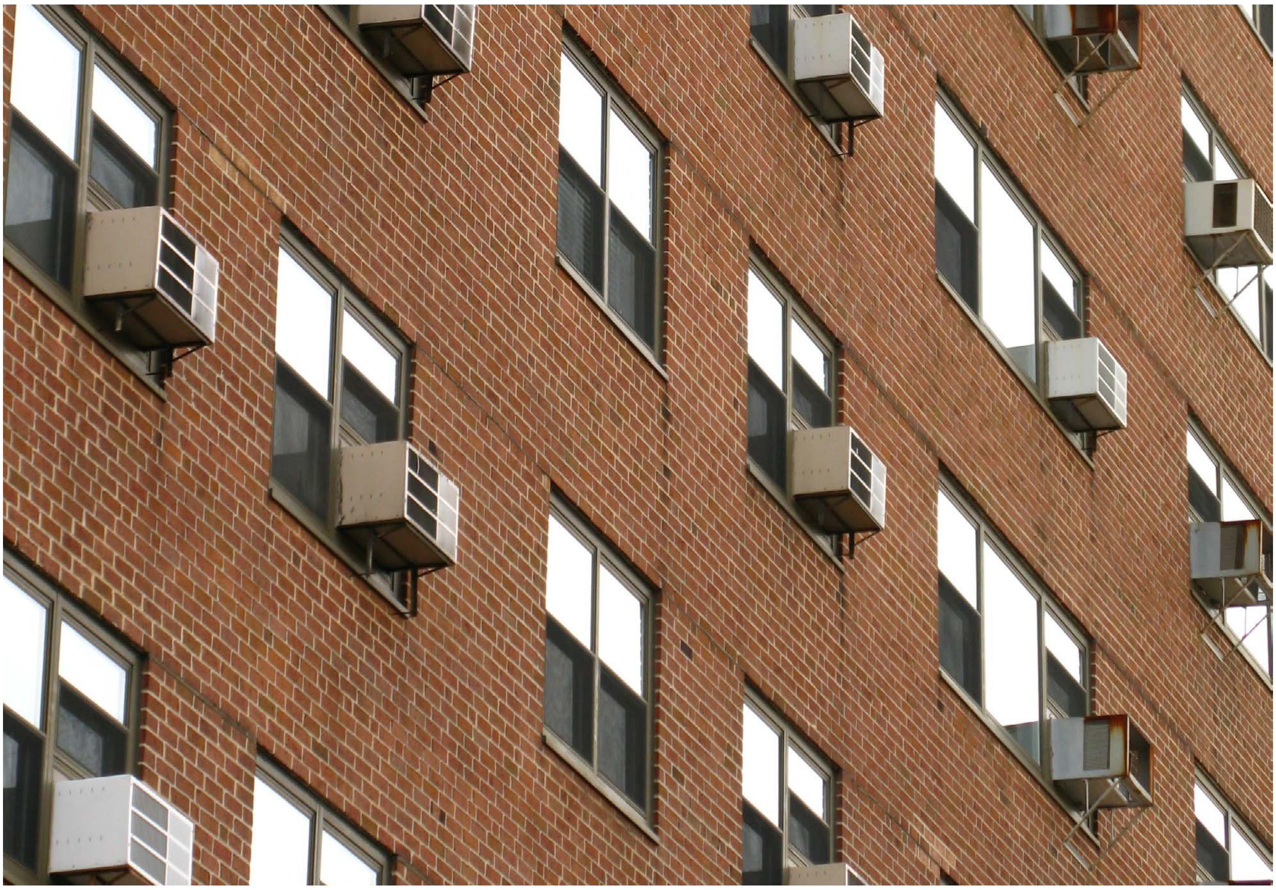
Alongside cooling demand in summer, another factor to be considered when dealing with compact layouts is the effect of the availability of daylight. Compact buildings with deep distance between windows cannot provide suitable daylight levels in the interior areas and will be more dependent on artificial lighting. If suitably planned, low energy artificial lighting will not consume as much energy as the lack of compactness, and extra heating loads will not be very high. However, occupants generally prefer natural lighting and availability of views, which also affect the perceived value of a building. In some building types, for example warehouses, this is not an issue.

Results obtained by regressions of simulating results (Figure 26) indicate that there is a direct relationship between perimeter to area ratio and energy demand.

Figure 26 Linear regression: Perimeter-Area and Energy Demand



Source: Sturgis Carbon Profiling LLP



5.1.4 Air Tightness and Active Ventilation Systems

The combination of high air tightness levels and the impossibility of dissipating heat through natural ventilation or passive strategies will increase energy demand.

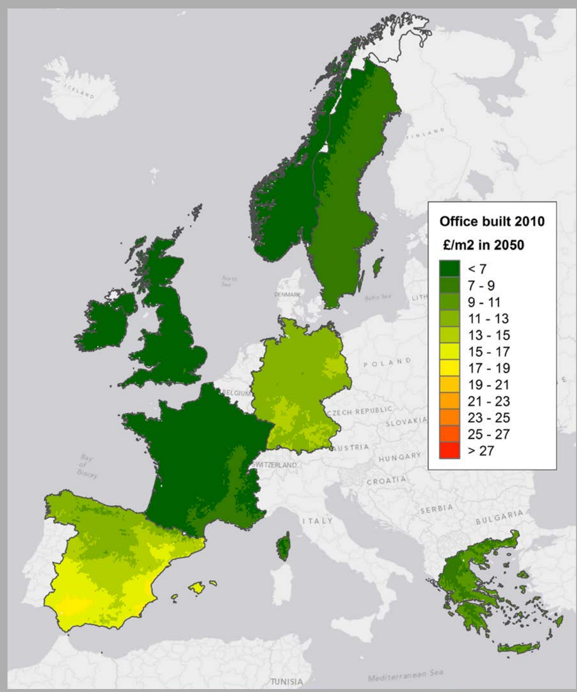
Air tightness requirements for newer buildings have gradually become stricter in order to reduce uncontrolled energy losses through the envelope. This strategy is very beneficial to the reduction of heating demand in winter and to the avoidance of unwanted heat gains from the environment in summer. However, activities in buildings are also a source of heat – occupants, lighting, and equipment. In summer, the extra heat loads need to be dissipated to keep interior conditions at comfortable levels. Heat can be dissipated through natural ventilation and passive strategies that do not consume energy, or by mechanical ventilation / air conditioning, which does.

Global warming will increase cooling demand and if the extra energy needs to be dissipated with active strategies (air conditioning), bills will escalate. Increasing energy prices will also increase the financial impact of climate change.

The problems outlined above are not caused by buildings being too air-tight, but by the unavailability of suitable ventilation systems. The assets at higher risk are buildings designed to achieve high airtight levels, but which are not provided with suitable natural or passive ventilation. The clearest examples are buildings in Germany, built according to the most recent building regulations, or ultra-airtight mechanically ventilated buildings, fulfilling standards like PassivHouse. However, the same will apply in any other area where building regulations demand stricter air tightness levels but do not require buildings to provide suitable ventilation strategies.

The map in Figure 27 shows the energy costs by 2050 in new air conditioned office buildings that do not allow natural ventilation. Germany's air tightness requirements are stricter than any other European country, and buildings are less adaptable to climate change if natural ventilation is not provided. As a result, bills will be higher than in other countries, unless natural ventilation strategies are provided. Bills for running costs in Spain will also be higher. However, the reasons for this are the stronger impact of climate change in Spain and the inferior quality standards of construction that make buildings less resilient to climate change.

Figure 27 **New air conditioned office buildings. Energy costs per square meter in 2050**



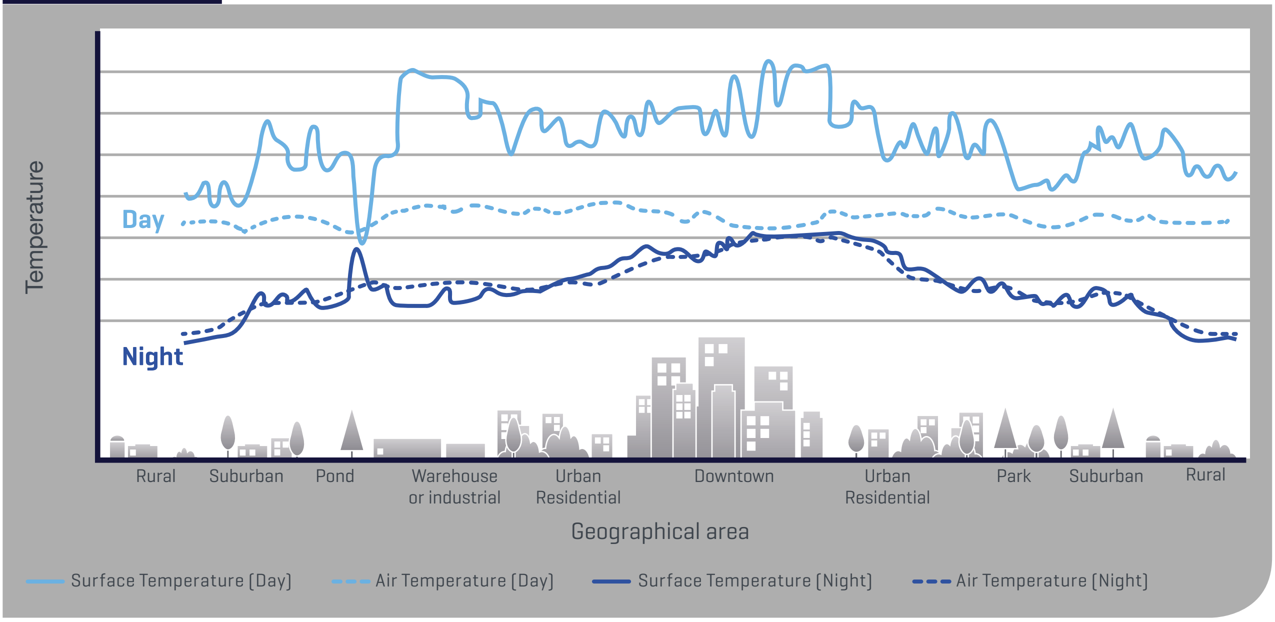
Source: Author/Sturgis Carbon Profiling LLP

5.1.5 Overheating

The risk of overheating mainly affects naturally ventilated buildings. Air conditioned or mixed mode buildings should always be able to maintain comfortable interior levels in summer. As climate is getting warmer, buildings that currently can dissipate heat in summer through natural ventilation might not be able to keep comfortable levels in the future. Some buildings will need to be retrofitted with sun protection or new mechanical ventilation systems. Electricity bills will then be affected, or the value of the asset will be reduced.

The areas expected to be more affected by this change are mid European latitudes: northern France, Germany, southern areas of the United Kingdom and even the south of Sweden and Norway. Greece, Spain and the south of France already suffer from overheating in summer, but their conditions will become worse. The risk of overheating in naturally ventilated buildings in Ireland and northern Britain is much lower.

Figure 28 Urban Heat IslandTemperature fluctuation over different land use areas



Source: DEFRA

5.1.6 Urban Related Factors

Urban Heat Island

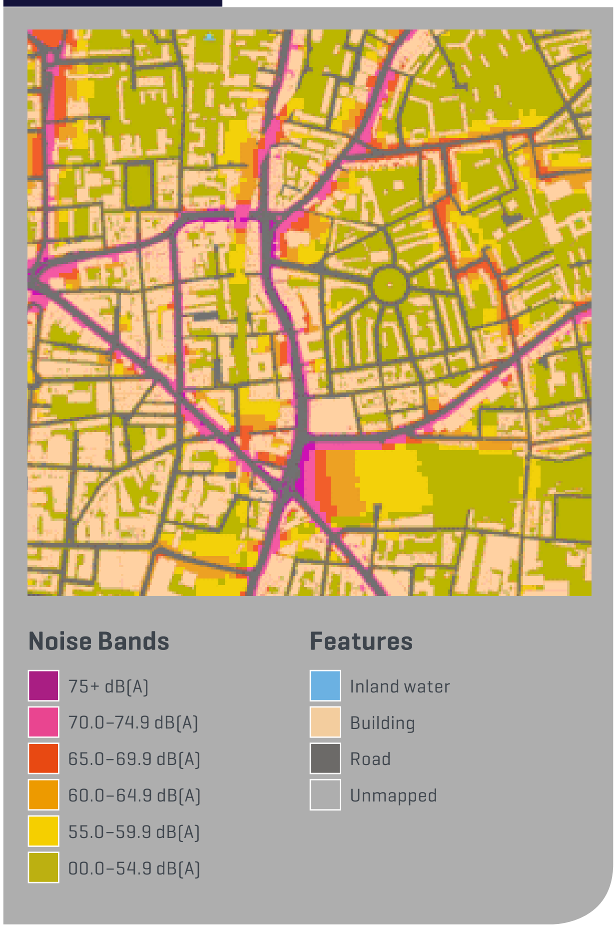
The "urban heat island" is the effect that causes city centres to be warmer than their suburban and rural surroundings (Oke, 1987). Existing buildings already reflect this effect in their bills and overheating levels. However, new projects in city centres will need to consider their urban context when assessing the overheating risks, or expected impact on cooling demand. Buildings in city centres are more prone to overheating and higher cooling bills (see Figure 28).

Noise and Pollution

Some urban areas suffer from high levels of noise and pollution (see Figure 29). Besides the acoustic discomfort and potential health issues, these conditions make it impossible to appropriately use natural ventilation to avoid overheating. These buildings can be almost entirely dependent on mechanical means to achieve comfort levels during the summer. Growing electricity prices and the difficulties encountered when attempting to dissipate heat through natural ventilation will boost electricity bills following global warming. Ironically, older and less air tight buildings will be less affected, but their performance in winter will also be worse.

As previously discussed, the unavailability of strategies to dissipate heat through natural ventilation is one of the factors that will cause higher energy demand and pose economic risks to buildings.

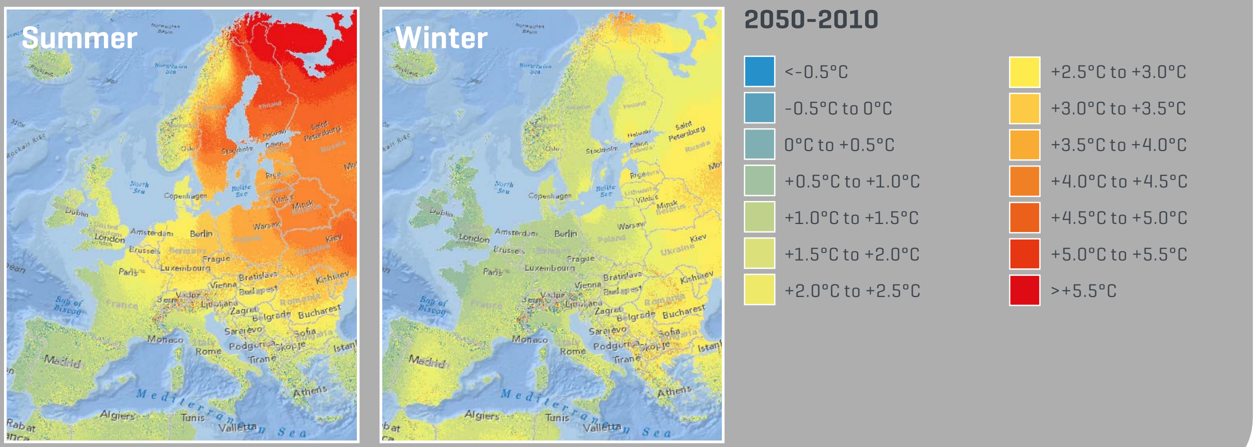
Figure 29 Noise pollution levels, Shoreditch, London



Source: DEFRA

5.2 Where to invest? – Region based risks

Figure 30 **Summer and winter temperature changes across Europe: Predictions 2010-2050**



Source: Sturgis Carbon Profiling LLP with data from IPCC

5.2.1 Risks Due to Expected Temperature Changes

The map above (Figure 30) shows the seasonal average temperature changes expected in Europe due to climate change between 2010 and 2050. Maps have been obtained using GIS raster calculations from weather projections obtained from IPCC's databases for their medium emissions scenarios.

Winter

Climate change will reduce heating loads in all European countries. Proximity to the wet oceanic winds will reduce the impact of global warming, so the western part of the continent (Portugal, Spain, Ireland and Britain) will experience lower temperature increases (of 1-2ºC). Mediterranean countries will also be affected at lower levels. However, temperature will rise gradually in the interior of the continent, as the influence of the ocean is lower. Temperatures will rise in some areas by more than 4ºC, and therefore their heating loads will be reduced more significantly.

Summer

Similar patterns are expected in summer in the western and interior areas of the continent. However, climate change will affect southern countries negatively because they will experience the highest increase in temperature. The south of Scandinavia will be less affected by climate change in summer than in winter.

Climate change will pose a higher risk to southern countries. Their already hot summer will become hotter, and overheating levels will increase. Heating loads in winter will not be significantly reduced. On the other hand, climate change might be positive for Scandinavian countries when considering temperature patterns. Their winter temperatures will rise and heating loads will decrease. Summer temperatures will also rise to a lesser degree, keeping the risk of overheating to a reasonable level. Temperature will also increase on the western coasts of the continent, including Portugal, Ireland and Britain, but it will not pose a severe risk of overheating in most buildings.

5.2.2 Risks due to Extreme conditions

Not only will climate change affect temperature, but it will also impact the prevalence, intensity and frequency of extreme weather conditions, which also pose a severe risk to assets. Events can be followed every year world-wide: intense cold waves in winter in the United States, longer hurricane seasons and the 'el Niño' effect, caused by warmer ocean water temperatures. At European level, natural hazards are more likely to happen in particular regions, and they affect both the value of the asset and insurance costs.

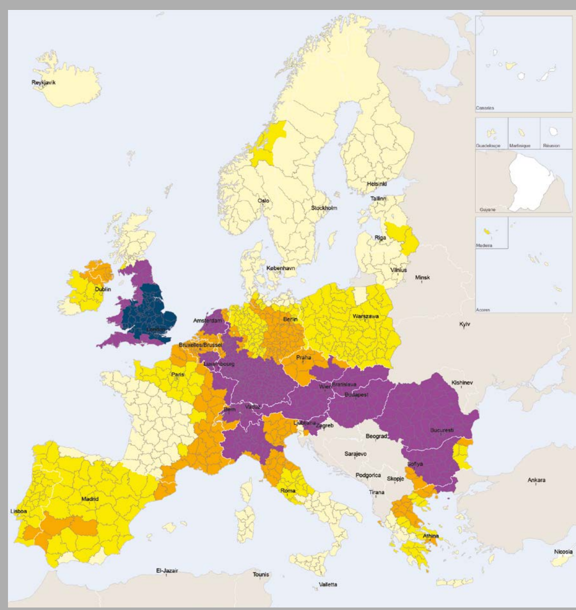
The following maps (Figures 31–35) show the impact of the three factors that are most likely to affect the European Union. Some of this data has been extracted from ESPON (2013), a study commissioned by the European Union to assess Natural Hazards and Climate Change.

Floods

Risk of flooding is directly linked to the major European river basins: the Danube, Rhine and Po. However, the area with highest risk of flooding is England. The following map (Figure 31) outlines the locations of floods in Europe over the last 30 years. The risk of floods is expected to increase.

Surveyors should pay special attention to locally researching the probability of floods and the historic evolution of flood maps when considering the purchase or rent of any asset in the regions that pose a higher risk.

Figure 31 **Average count of floods per year and river basin (1985-2012)**



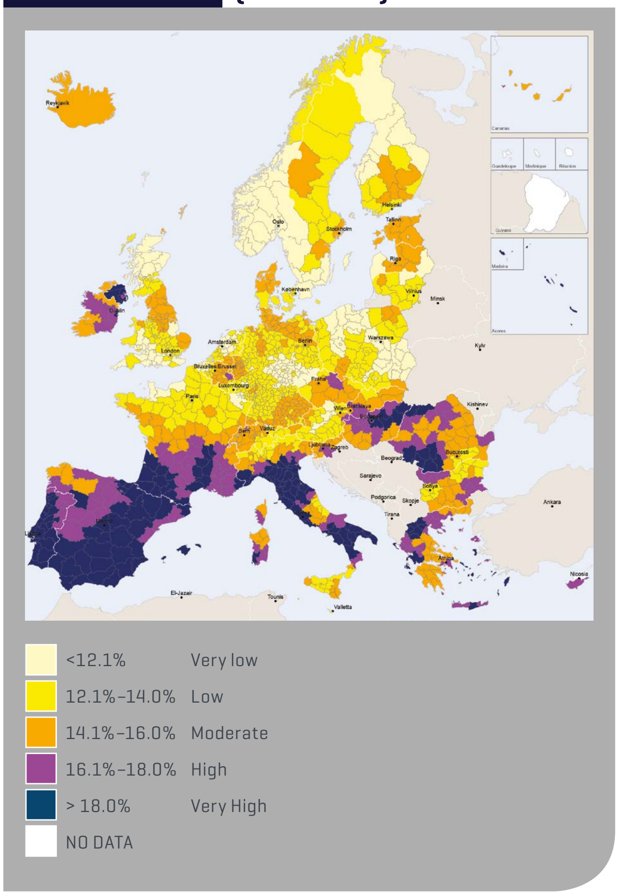
Source: Original from European Union (2013).
Format modified by Author/Sturgis Carbon Profiling LLP

Droughts

The South of Europe is more likely to suffer from droughts. The accounts from the last 20 years show recurrent patterns in Italy and Spain, but also in some areas in the Carpathian regions. Desertification in the southern countries will increase this risk and restrict the availability of water. Figure 32 maps drought frequency in the last decades.

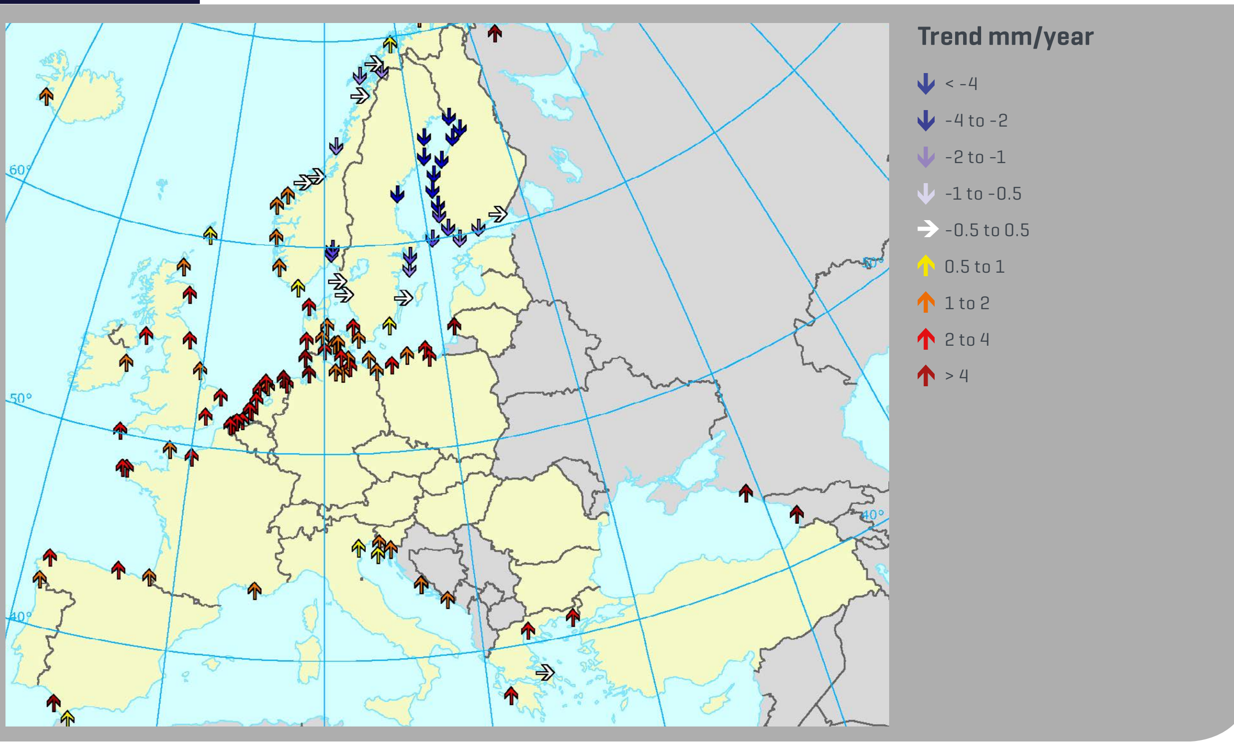
Droughts do not pose a severe risk to the integrity of assets but value may decrease if there is no guarantee of water supply, or if this may be restricted during certain times of the year. Surveyors should research local infrastructure and water policies to develop a complete understanding of the local situation and administrative awareness of the risk.

Figure 32 **Drought hazard and frequency (1991-2010)**



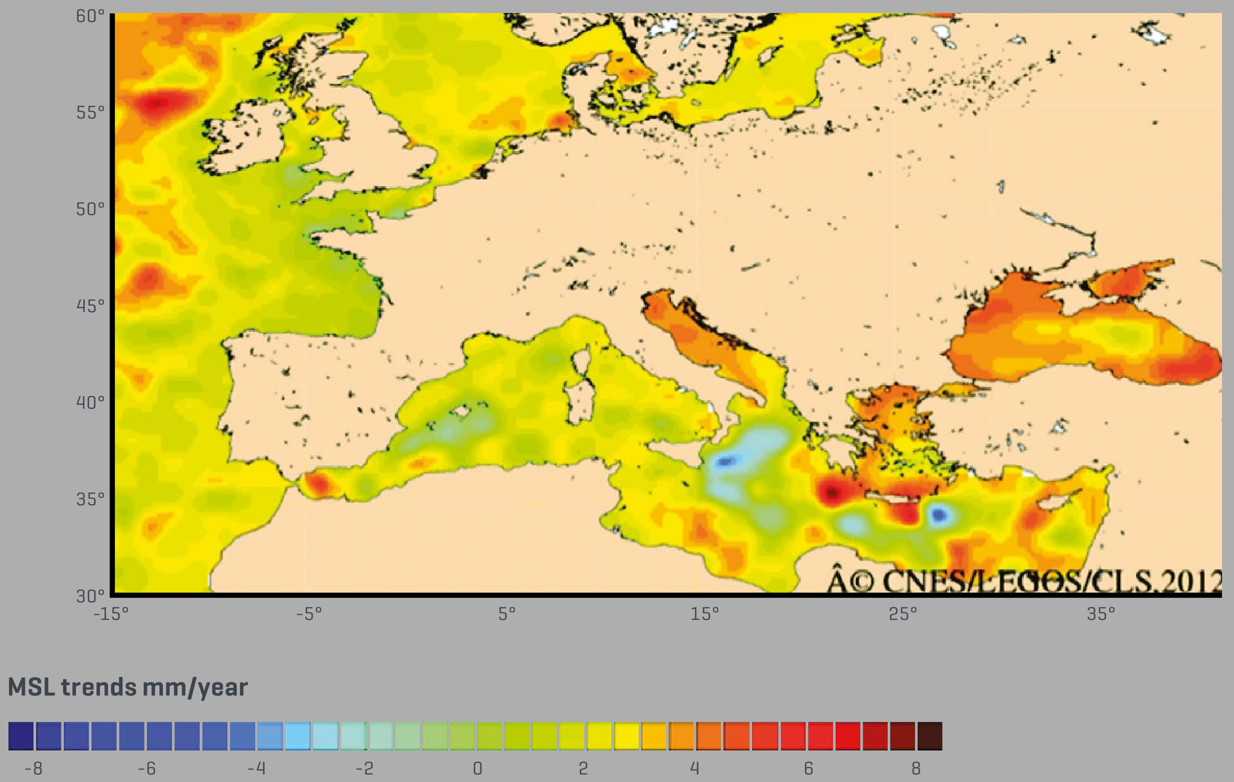
Source: Original from European Union (2013).
Format modified by Author/Sturgis Carbon Profiling LLP

Figure 33 Trend in relative sea level at selected European tide-gauge stations 1970-2010



Source: Robine (2007)

Figure 34 Trends in absolute sea level across Europe based on satellite measurements 1992-2011



Source: Robine (2007)

Rising sea level

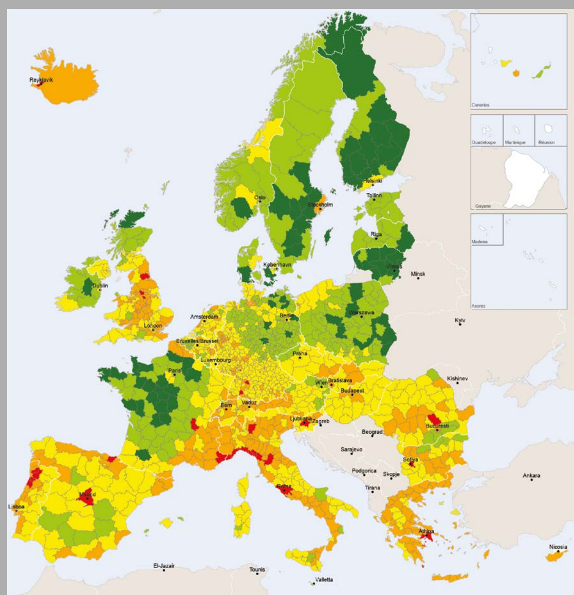
In coastal areas the rise of the sea level poses a further risk to the severity of storms and the necessity of implementing and maintaining coastal defences. How much the sea level will rise still remains highly uncertain and depends on the evolution of carbon emissions into the atmosphere (EEA, 2014). The results from different studies collected by the EEA range between 12 cm to 140 cm, and levels are also subject to regional variations. EEA's indicators on past trends of sea level identify certain European areas which are more likely to suffer higher sea level rises (Figures 33 and 34).

The vulnerability of any area to sea level rise depends more on local geographic conditions and distribution of assets than on any absolute figure. Areas built below sea level or at very low elevation are at higher risk. If the severity of storms and winds is higher, the risk also increases. Following this, the coasts of the North Sea, including the Netherlands, Germany and Denmark, the coast of the Veneto in Italy, the Greek islands and some river Estuaries, for example the Thames, are more vulnerable to sea level rise.

General vulnerability

Total vulnerability to climate change is a function of exposure, sensitivity and response capacity to particular hazards. The following map (Figure 35) collates all the factors described in the previous sections, including both temperature changes and natural hazards, and it also defines the European areas which are more vulnerable to climate change. This map also considers the distribution of assets and their value. Urban areas are more vulnerable than their surrounding regions.

Figure 35 **Vulnerability to climate change**



Vulnerability

- Very low
- Low
- Moderate
- High
- Very High
- No data

*Integrated Sensitivity and Response Capacity

Intensity of Hazard \ Degree of (IS&RC)*	1	2	3	4	5
1	11	12	13	14	15
2	21	22	23	24	25
3	31	32	33	34	35
4	41	42	43	44	45
5	51	52	53	54	55

Source: Original from European Union (2013). Format modified by Author/ Sturgis Carbon Profiling LLP

5.3 The cost of climate change

5.3.1 Economic Impact Per Use

The main impact of climate change on the built environment is that it affects the running costs of buildings, and this cost is different in each building type.

The following maps (Figures 36–40) quantify how much energy bills will be affected by climate change per square metre in old and new buildings. The maps have the same scale within the same building type in order to compare the impact of climate change in buildings of different ages; values represent the difference in pounds per square metre per annum (GBP/m^2.pa) in the energy bills; energy bills predicted for 2050 minus energy bills calculated for 2010.

The impact of climate change on bills is building specific. These maps show the impact on an indicative 2,400 m^2 air conditioned building with a glazing ratio of 40% and rectangular floor plans measuring 20m x 40m. To calculate the impact on buildings with other characteristics, use the Climatic Risk Toolkit and Calculator provided with this report (see Appendix 2).

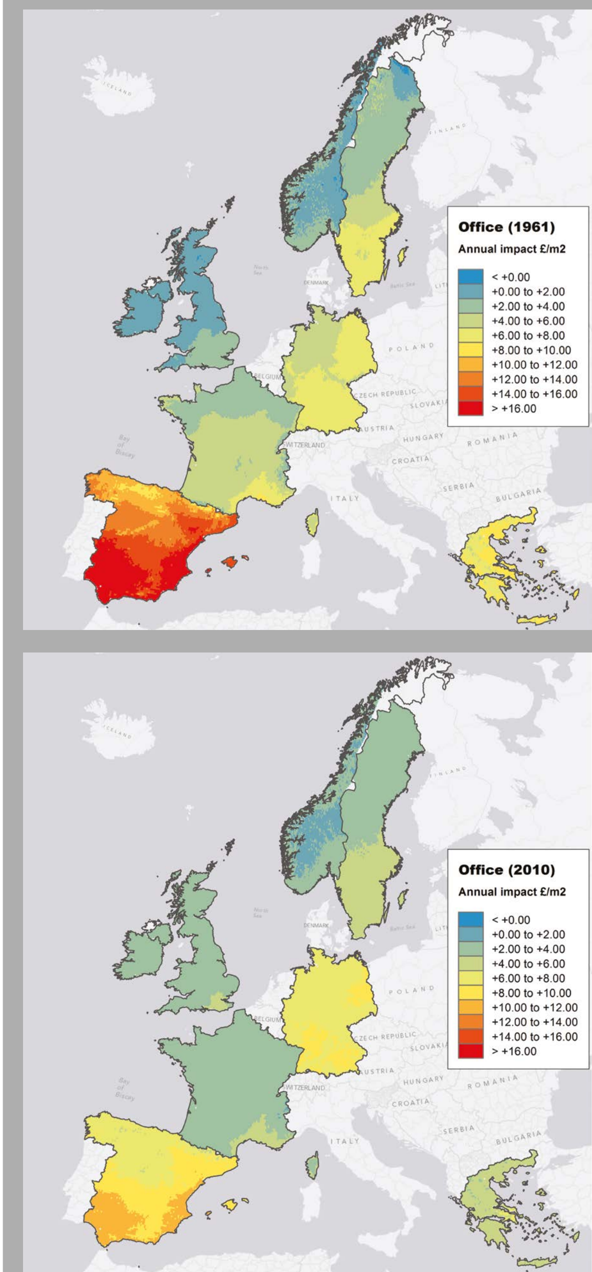
The following findings affect all building types:

- Climate change will impact energy bills on very different levels: some building uses will reduce energy bills by GBP 15.00/m^2 per annum while other buildings will increase their energy bills by GBP 35.00/m^2 per annum
- Newer building regulations make buildings more resilient to climate change and the impact on bills is lower. The differences between countries are also less extreme
- Countries in South Europe, especially Spain, will suffer greater impact on their bills due to growing cooling demand
- Energy bills in buildings with high air tightness levels in some countries will increase at a higher rate than their neighbours unless they provide natural ventilation strategies. Results for air conditioned buildings show that global warming will negatively affect German buildings, which have been designed for high performance under current climatic conditions.

Offices

- The impact of climate change on office buildings is relatively high
- Energy bills for older in southern countries will increase at a higher rate.

Figure 36 **Impact of climate change:** Air conditioned **offices** built in 1961 and 2010. Predicted variation on energy bills by 2050



Retail

- Dependency of retail on cooling systems makes this building type more vulnerable to climate change
- Energy costs will increase more than in any other use, and buildings in some areas are under risk of climatic obsolescence
- Natural ventilation will help to significantly reduce these costs in northern and central European countries, but southern countries will not be able to dissipate most of this demand.

Schools

- Climate change will have a mild or positive impact on energy bills of school buildings
- Excessive air tightness reduces this impact in newer buildings because a school's heating demand is lower than for other uses. However, interpretation of results needs to be carefully considered as the modelled indicative building does not allow for natural ventilation. This is not the normal scenario for schools. These results are valid for a small range of real buildings.

Figure 37 **Impact of climate change:** Air conditioned **retail** built in 1961 and 2010. Predicted variation in energy bills by 2050

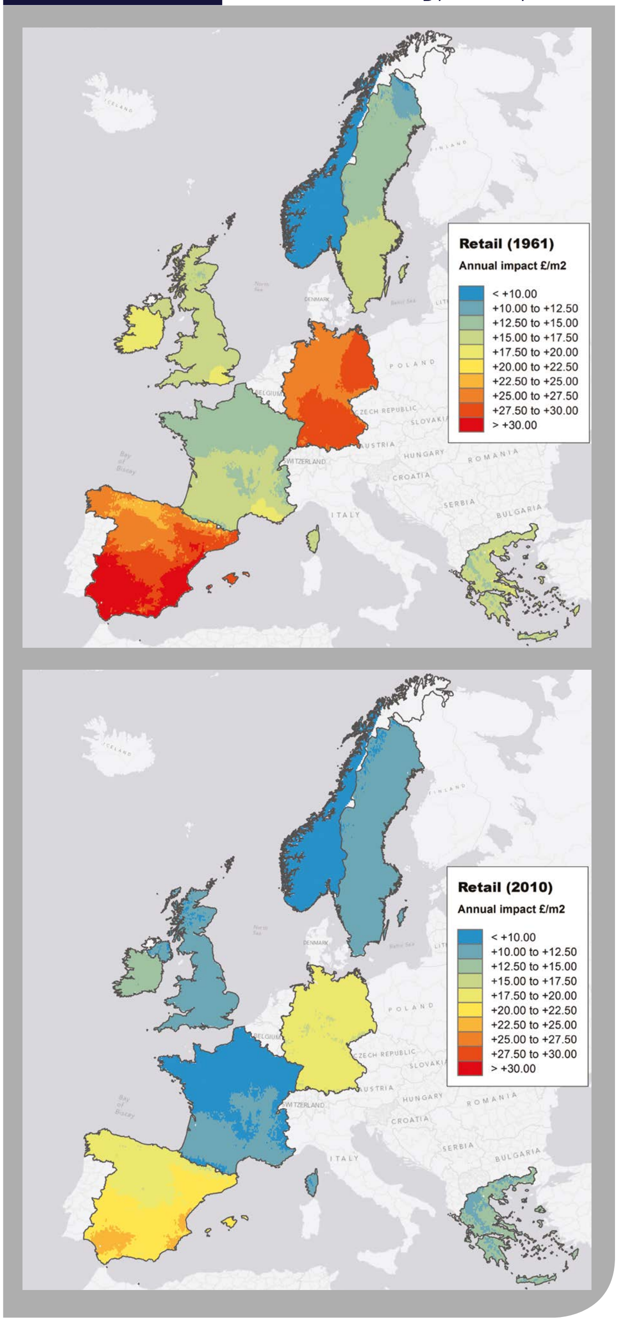
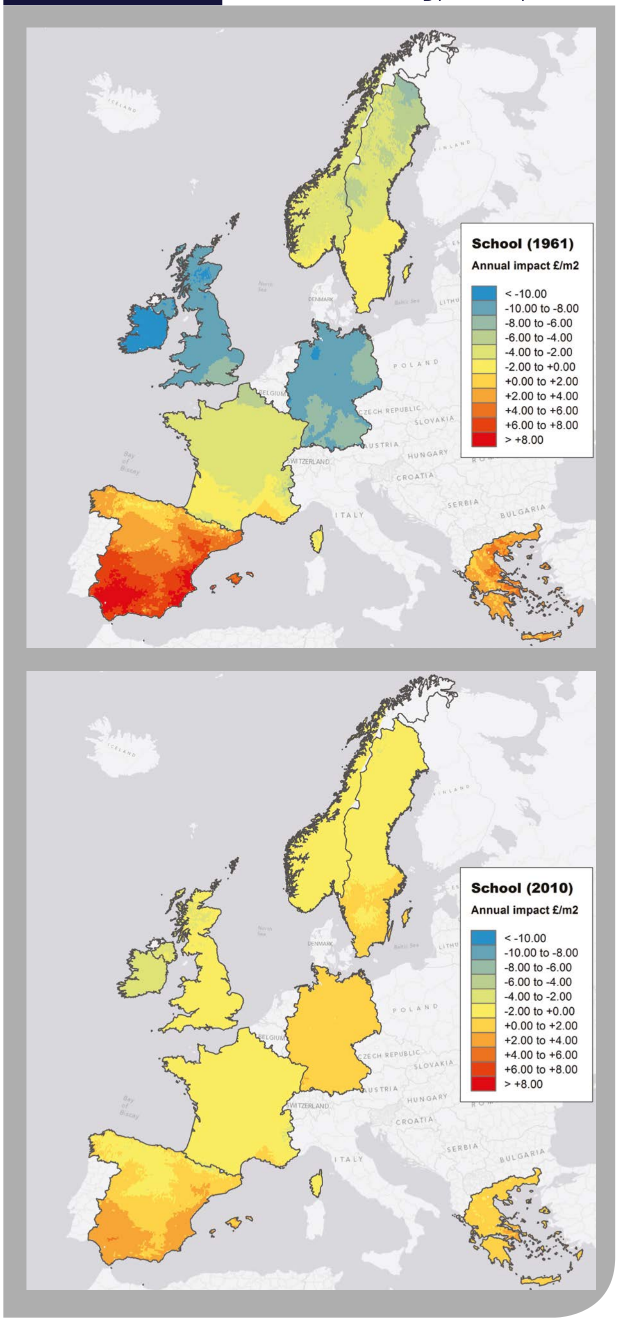


Figure 38 **Impact of climate change:** Air conditioned **schools** built in 1961 and 2010. Predicted variation in energy bills by 2050



Hospitals

- Comfort requirements for hospitals are very strict and they influence their heating and cooling loads and expenses
- Heating and cooling demands are high in southern regions, but close to zero in northern countries.

Warehouses

- Comfort and energy requirements in warehouses are very low. Therefore, climate change will reduce or have very little impact on the energy bills of most buildings of a variety of ages and regions
- In southern regions and for buildings with high airtightness levels, the effect of climate change will be slightly more negative.

Figure 39 **Impact of climate change:** Air conditioned **hospitals** built in 1961 and 2010. Predicted variation on energy bills by 2050

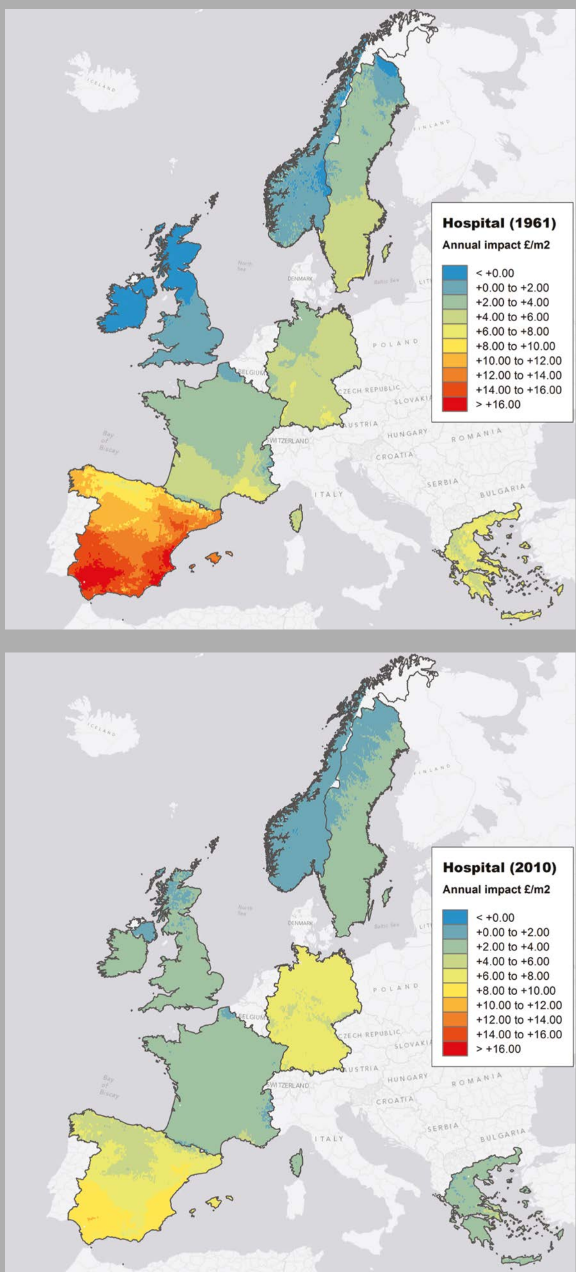
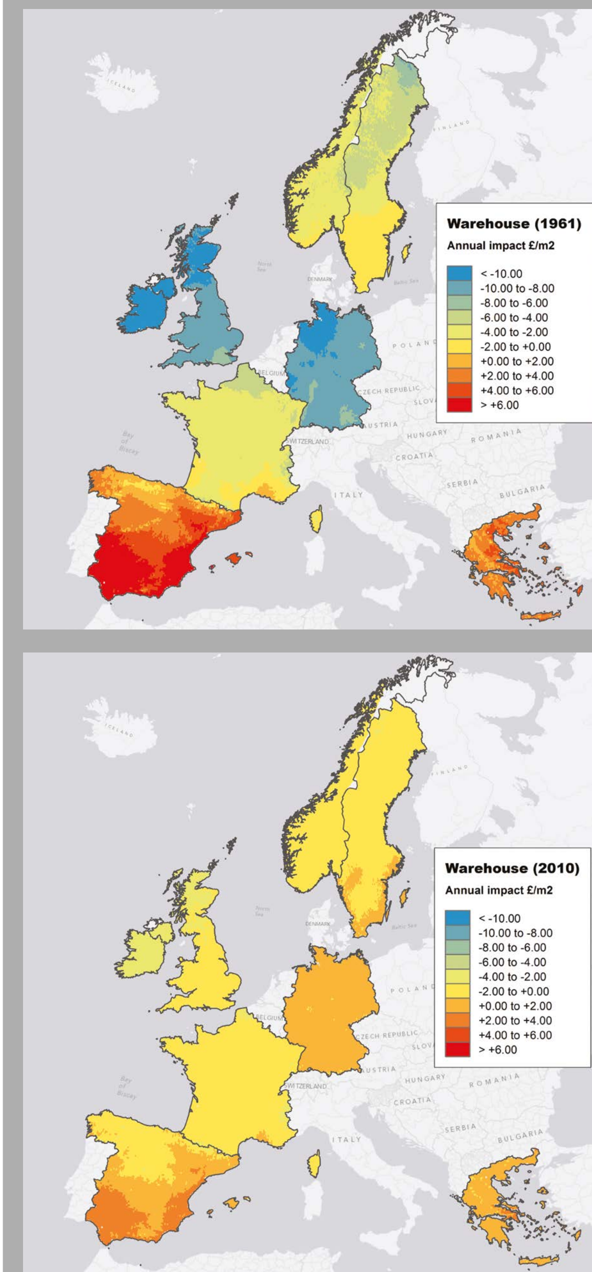


Figure 40 **Impact of climate change:** Air conditioned **warehouses** built in 1961 and 2010. Predicted variation on energy bills by 2050



5.3.2 Indicative Cost per Country

The total cost increase in energy bills was estimated for all 8 countries for the period between 2010 and 2050. This helps us to understand the impact of inaction towards climate change. The following assumptions have been considered in making the calculation:

- To reflect the typical conditions, the average climate location has been selected for each country
- The indicative construction period selected is 1981-1990 because most building codes were developed or updated following the second oil crisis
- A straight linear cost function increase was assumed, to calculate the total cost for the 40 year period. This cost calculation assumes that no mitigating strategies will be implemented in any building.

The total cost has been estimated considering each building stocks' profile (see Figure 41), future energy prices and projections on future consumption (BPIE, 2011).

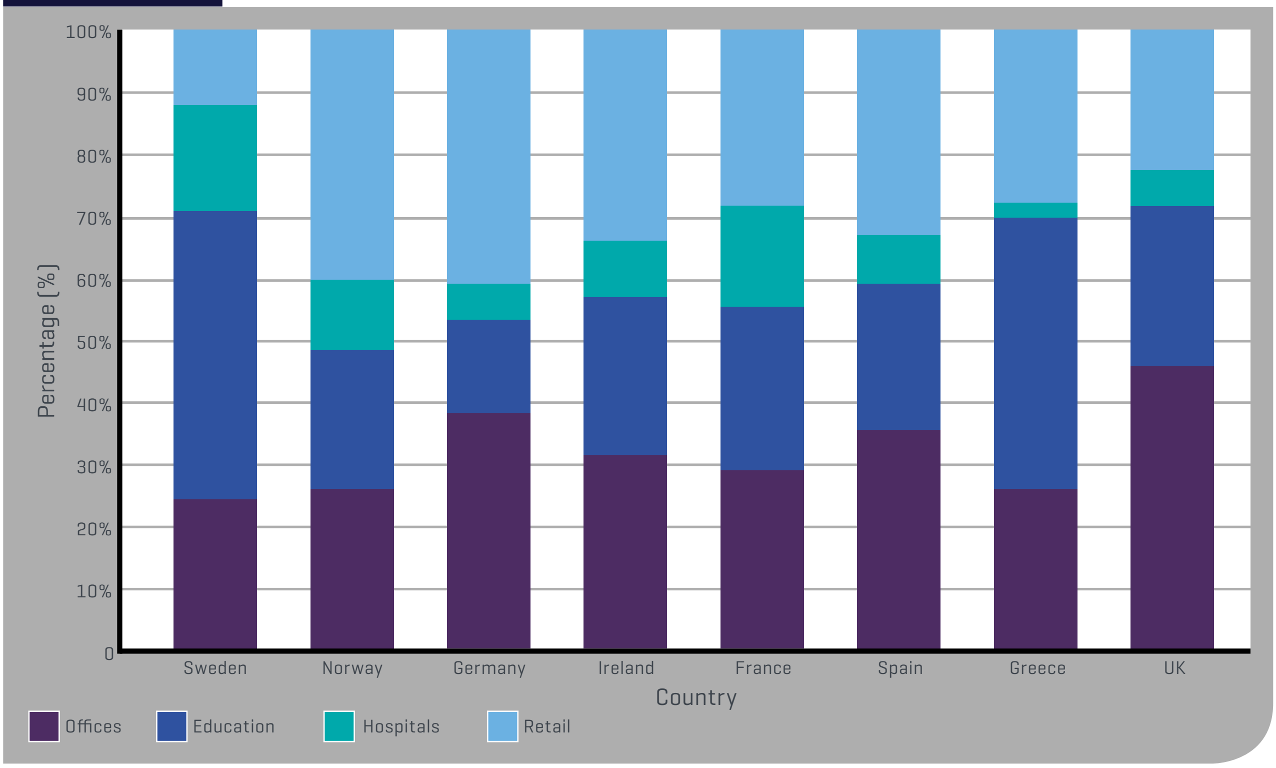
To understand just how much this cost increase could be, the total climate change cost over the 40 year period has been compared with the Gross Domestic Product (GDP) of each country in 2012 (World Bank). This factor defines the climatic risk level of each of the researched countries from an economic perspective.

Results show that the cost of climate change in Germany, Spain and Greece is more than 8% of their GDP. At the other end of the scale, the cost in Norway and UK is less than 2% of their GDP (see Figure 42).

The total cost of forty years of climate change in the eight researched countries reaches a staggering GBP 457 billion. This figure is equivalent to:

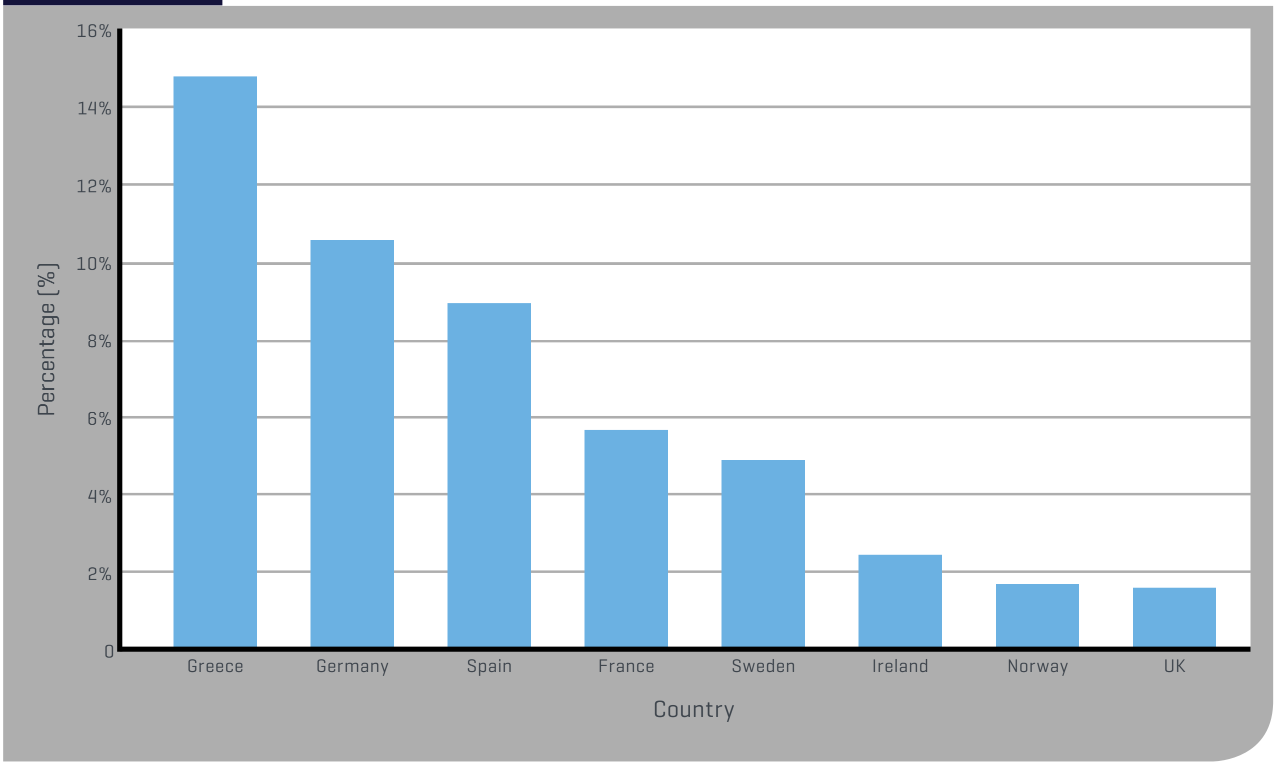
- The annual GDP of Greece and Sweden combined
- The global investment in renewable energy for the period between 2011 and 2013.

Figure 41 **Non-Domestic Building Stock profile breakdown**



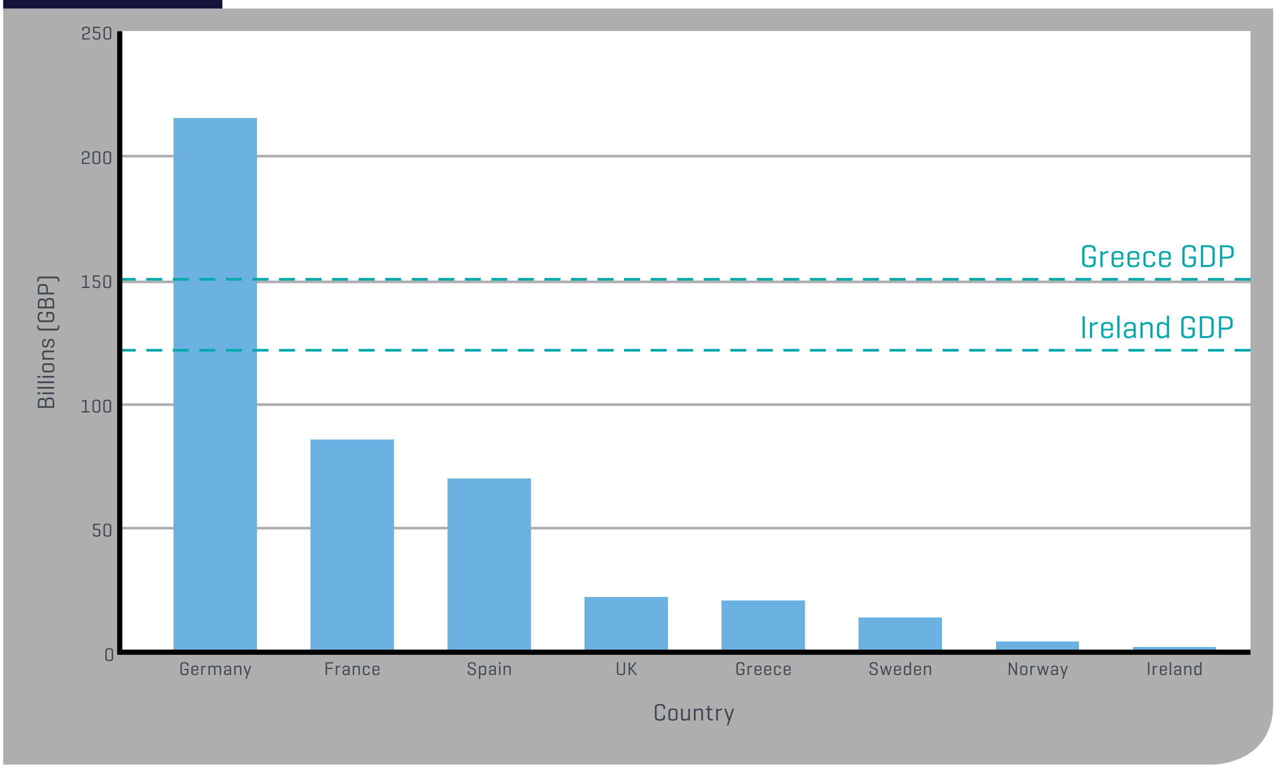
Source: Sturgis Carbon Profiling LLP with data from BPIE (2011)

Figure 42 Cumulative climatic cost (40 years) / annual GDP in each country



Source: Sturgis Carbon Profiling LLP with data from the World Bank 2012

Figure 43 Breakdown of cumulative climatic cost per country (billion GBP)



Source: Sturgis Carbon Profiling LLP with data from the World Bank 2012

The absolute figures in the graph on page 53 (Figure 43) add together the total amount that each country might need to pay as cumulative climatic costs.

- The most severe impact of climate change is anticipated in Germany. The increase in energy bills in 40 years will reach GBP 223 billion. This is more than half the total cost of climate change in the eight studied countries
- France and Spain follow Germany, with GBP 90 billion and GBP 74 billion increases respectively if no mitigation strategies are implemented
- Climate change will be milder in the UK and this corresponds to a relatively low impact on energy bills of GBP 24 billion
- The least affected countries are Ireland and Norway with a less than GBP 5 billion increase.

The figures from the two previous graphs are detailed and expanded in Table 1 below. The extra cost per capita illustrates the combination of climate change a impact, size of the building stock and population.

- In Spain, Ireland and United Kingdom, relatively small size of the building stock compared with their population reduces the cost of climate change per capita
- On the other hand, the proportionally larger size of the building stock in Sweden, Norway and Germany increases this cost
- Germany and Greece are the countries where the impact of climate change per capita is likely to be the highest.

Table 1 Cost of Climate Change: Extra annual cost and cumulative cost in 40 years – Comparison with GDP and per capita

Country	TOTAL NIA[1] (office, hospital, retail, education)	Extra cost of climate change[2]	Cumulative cost in 40 years[2]	GDP[3]	% GDP annual[4,5]	Extra cost per capita[4,5]
	m²	million GBP per year	million GBP	million GBP per year		GBP per year
Sweden	111,100,000	18.98	15,600	312,000	5.0%	2.06
Norway	74,070,000	6.24	5,100	297,000	1.7%	1.22
Germany	1,110,700,000	271.77	222,800	2,040,000	10.9%	3.31
Ireland	32,770,000	3.86	3,200	125,000	2.5%	0.86
France	718,000,000	109.14	89,500	1,554,000	5.8%	1.70
Spain	236,100,000	89.87	73,700	802,000	9.2%	1.96
Greece	100,160,000	27.38	22,500	148,000	15.2%	2.45
UK	310,000,000	29.48	24,200	1,448,000	1.7%	0.48
Total	**2,692,900,000**	**556.70**	**456,500**	**6,726,000**	**6.8%**	**1.96**

Source: [1]BPIE (2014) [2]Sturgis Carbon Profiling LLP [3]World Bank (2012) [4]European Union (2014) [5]Statistics Norway (2014)

5.4 Areas of uncertainty

The results described in this section and the projections provided by the Climatic Risk Toolkit depend on a wide range of factors. The evolution of some of these factors in the future remains uncertain and should be taken into account when interpreting the results and introducing any necessary modifications.

Fuel prices

Future fuel prices have been estimated following current projections from the British Department of Energy and Climate Change (2013). However, the medium and long term projections of these factors and their fluctuation are highly uncertain. The Climatic Risk Calculator allows overriding present and future fuel prices to adjust them to specific local conditions.

Decarbonisation of the electric grid

Roadmap 2050 (European Climate Foundation, 2010) predicts that by 2050, the electric grid should be decarbonized by 95%, and that the built environment should reduce emissions to 0. The calculation of the emissions by the CRT considers this ratio of decarbonisation of the electric grid. If in the future the decarbonisation happens at a lower rate, the emissions projections will need to be adjusted accordingly.

Policy evolution and enforcement

As described in the Policy Review section of this report, stricter policies are expected to be enforced in the future, affecting both building regulations and setting retrofitting incentive schemes. The reason for this is that the current renovation rate of the existing stock is very slow. Many of the currently enforced regulations have only affected new buildings, but the existing stock is the key opportunity to reduce emissions in the built environment. Stricter conditions should improve building performance.

Another reason to enforce further policy requirements is the performance gap between estimated and real building emission rates. This gap is already being quantified in some countries with schemes like Carbon Buzz (2014). There is a significant difference between the amount of carbon that buildings are designed to emit and the amount that they are really emitting. This difference does not necessarily require the modification of the targets defined in building regulations, but would affect the quality of construction and users' performance. New policies will probably be enforced to reduce this gap, but at the moment the main consequence is that real emissions are not reduced at the rate that they should be. This will affect future targets in the medium and long term, which might be translated into new, tougher regulations to meet commitments.

Success reducing emissions

The results provided in this report consider a medium-term emission's scenario. The evolution of emissions depends on the performance of all sectors of the economy, all of which are expected to meet their targeted requirements. However, if anomalies such as the 'Performance Gap' in buildings are happening in other sectors, the CO_2 emissions reduction will not decrease at a desirable rate. On the other hand, if emissions are satisfactorily reduced throughout all of the economy sectors, the EU might need to consider aiming to even lower emissions scenarios for future calculations.

Different emissions' scenarios for 2050 will require the use of other weather projections in the calculation of future energy demand, cost and emissions.

Source: Andrius M / Shutterstock.com

6.0 Conclusions

The conclusions of the research have been combined in groups addressed to different stakeholders, including recommendations for further action. The Climatic Risk Toolkit calculator and guidance document (Appendix 2) included in this report expand on these recommendations with further details.

6.1 Valuation Surveyors

Climatic risk

Countries

- Buildings in south and central Europe will be at higher climatic risk. Their bills are expected to increase considerably because many of them will not be able to dissipate heat to their environment or produce enough electricity on site to take on growing cooling demand
- Ireland, United Kingdom and Norway will be the countries less affected by climate change. Heating costs in these countries will be considerably reduced and even though electricity cost will also increase, it will occur at a slower rate.

Sectors

- Due to their dependence on air conditioning, retail buildings will be challenged by higher energy bills and demand
- On the other hand, climate change will tend to reduce energy bills in many schools and warehouses.

Buildings

- Newer buildings will generally perform better than older ones in the future. Stricter building regulations have improved the general quality of the newer stock
- The provision of natural ventilation strategies to dissipate heat in summer will be critical to reduction of energy demand and costs. Buildings that depend exclusively on mechanical HVAC systems to dissipate heat are at high climatic risk. If their envelopes are very air tight and have high glazing ratios, the risk is much greater. Newer buildings are more likely to be affected.

Cost of climate change

Total cost

- The cumulative cost of climate change on energy bills over the next forty years will reach more than GBP 450 billion if no retrofitting actions are taken to improve the current stock. This amount equals the combination of the annual GDP of Greece and Sweden.

Energy prices

- In spite of lower energy demand, bills will increase in the future for most buildings. Energy prices are expected to rise at a higher rate than consumer price indexes and they will lead to higher operational costs for most buildings, especially for those dependent on electricity
- Buildings in the retail sector will be the most affected. Their energy bills will increase up to 35 GBP/m^2 depending on building conditions and location.

Carbon emissions in 2050

- The targets defined by the European Roadmap for 2050 aim for 100% emissions reduction in the built environment. To meet this target, only renewable energy sources can be used
- The decarbonisation of the electricity grid will need to be completed. This process will probably need to include nuclear generation as well as renewable energy sources. However, the economic impact of the cost of decarbonisation will increase energy bills.

Cooling loads

- A warmer climate throughout Europe will expand the use of cooling systems to maintain comfort within buildings. This cooling energy is most likely to be supplied by electricity. If this electricity is not produced on site, it will be expensive and will significantly impact on energy bills.

Natural ventilation

- Heating demand can be brought down to almost zero by improving the envelope of a building, but cooling demand is more difficult to reduce because it involves the dissipation of heat to the environment. Natural ventilation strategies in buildings will become critical to help reduce cooling demand and cost
- Some European regions, mainly in southern countries, will be too hot in summer and will not be able to use natural ventilation to dissipate interior heat. Buildings will rely on air conditioning for the greater part of the cooling season
- Buildings in central and North Europe will need to combine mechanical and natural ventilation. Buildings that already combine both systems are more resilient to climate change.

6.2 Building Surveyors & Architects

Mitigating strategies

Reducing energy demand becomes the priority for all regions. Building regulations help to reduce this demand in current conditions, but they might not be sufficient to do so in the future.

Heating

- Heating demand will still be an issue in older buildings, mostly in northern latitudes. Building regulations have greatly reduced this dependency in most regions. However, more restrictive carbon emissions targets will force buildings that still require heating to change their fuel supply to carbon neutral options such as electricity (considering grid decarbonization) or biomass.

Cooling

- Reducing cooling demand will become critical for both new and existing buildings. Due to increasing electricity prices, lower demand will not guarantee lower running costs, but will nevertheless reduce them significantly. The implementation of retrofitting strategies to minimize external heat gains is recommended: sun protection, insulation, natural ventilation or passive cooling. To reduce internal heat production, strategies like the reduction of artificial lighting or adding control systems in lighting and equipment should be sought.

Retrofitting buildings

- With the existing stock, architects, building surveyors and other designers should appraise options to improve the air tightness and insulation levels of the envelope and the HVAC efficiency. This should be achieved by keeping or improving the building's capacity to use natural ventilation
- Buildings with high glazing ratios will be much more difficult to protect against direct sun radiation. Even though there are inexpensive systems to reduce gains like coatings, in the long term and depending on the region, these buildings will need to undertake deep retrofitting works
- If a building has been designed to high air tightness standards but with limited or no natural ventilation systems, the risk of obsolescence is high. The building will require much more energy to dissipate internal heat. HVAC systems may need to be upgraded and bills will increase.

New buildings

- New buildings should be designed considering future climate. Even though strategies to reduce cooling demand might not seem to be required at present, building surveyors and architects should assess the impact of global warming and the building's future risk of overheating.

6.3 Policy

EPC: Local flexibility and international incompatibility

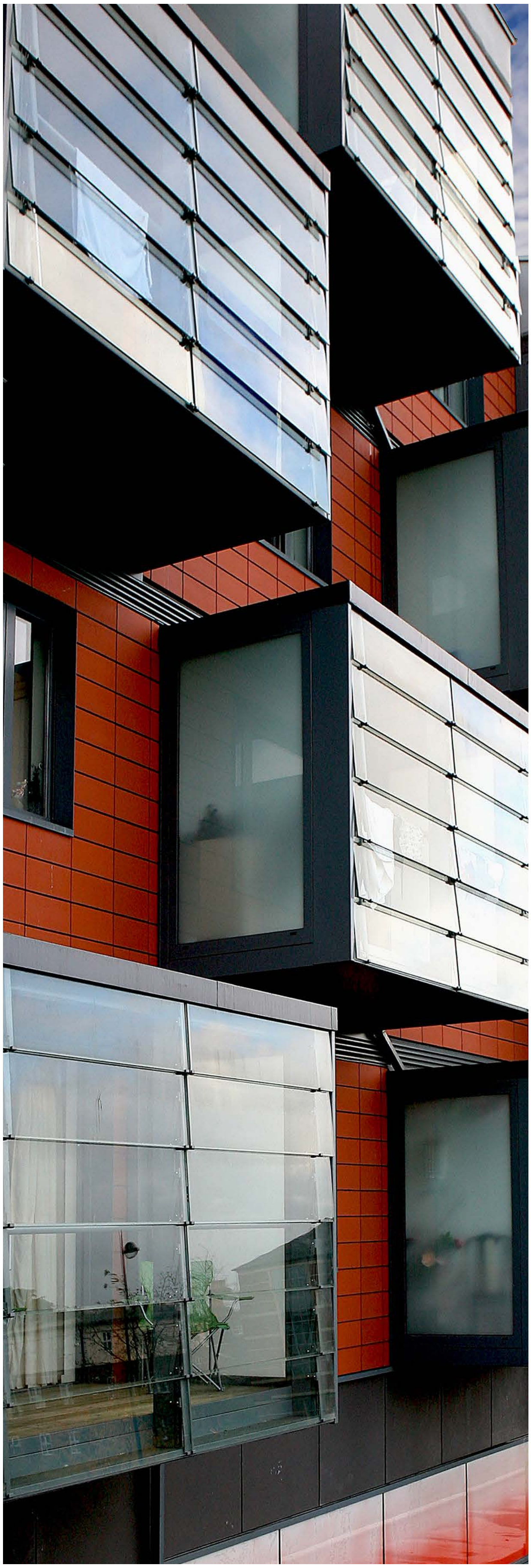
As the communication instrument of the EPDB Directive, EPCs have become a flexible tool that each country is customizing to promote good practice, communicate results and to engage stakeholders in the reduction of carbon emissions.

In this process, EPCs' structure and content, including cost-effective retrofitting strategies have been adapted to national culture, policy backgrounds, calculation methodologies and markets. One of the disadvantages of the 'nationalisation' of this document is the loss of common grounds of comparison amongst different Member States. Energy rating bands follow different benchmarking databases, nationally based, and even factors that might seem comparable ($kgCO_2$ / m^2) in most cases are calculated using different methodologies. Surveyors can usually use EPC results and content when comparing buildings within the same country but they have to be much more careful when comparing assets within an international portfolio.

Building Regulations

Building regulations are the instrument that Member States use to enforce the maximum emission rates defined by the EPBD. All new buildings and buildings being retrofitted within the EU are adopting these values and complying with emissions' rates for the current climate. The problem is that climate is changing and building regulations are not considering the impact that future climate will generate on buildings currently being built. These buildings might not perform well in the future.

One example of this is Germany: at present, Germany's building regulations promote high standards of insulation and air tightness. Their current heating loads are the lowest in Europe and cooling loads are also quite low. However, in 2050 climate in Germany will be much warmer. Cooling demand will increase and overheating levels will rise in many regions. The cooling demand of any building which is currently being designed with no availability of natural ventilation will soar. If the country succeeds in decarbonizing the electric grid, something not yet guaranteed, carbon emissions will not be affected. However, electricity prices are expected to increase considerably, so the running costs of these buildings might become unsustainable.



7.0 Further Research Opportunities

Opportunity 1: Widen geographical scope

The conclusions of this report are applicable to a selection of eight European countries. The objective was to include a wider range of bioclimatic regions, including both warm and cold climates. However, most of these countries are affected by the wet and mild winds from the Atlantic Ocean. More continental countries in Central and East Europe will be affected by climate change in a more extreme way and the quality of their historical building stock may impose a higher climatic burden than in western countries. The same methodology can be used to expand the research to these countries, or to the whole European Union / EEA and to complete the continental map for climatic risk.

Climate change will modify all climatic regions on the planet. Subject to the availability of relevant present weather data and the reliability of future weather projections, the same methodology could also be applied at a higher level in a world-wide scope. Each climatic region will need to deal with a specific set of risks, from desertification to floods, and the mitigating strategies will need to respond to local availability and the socio-economic factors of the developing world.

Opportunity 2: Climatic Risk Calculator for other uses

The Climatic Risk Calculator included in the Climatic Risk Toolkit (Appendix 2) predicts the impact of climate change on office buildings. However, the effect of climate change on other buildings with higher comfort requirements, for example hospitals, or with higher electricity demands – leisure centres with swimming pools, will be very different. This research provided graphic representation of the impact of climate change on energy costs for all the most relevant non-residential sectors. The Calculator can be upgraded to include simulated data for other building types to predict climate change impact on a wider range of buildings within the non-domestic sector.

Opportunity 3: The residential sector

More than 60% of current European building stock is residential. The same methodology can estimate the impact of climate change on energy demand, costs, and emissions for the largest real estate sector. The most common residential typologies for each country can be researched and simulated to predict the risk and economic impact that climate change will pose on homes – most of which are still naturally ventilated. The risk of overheating, fuel poverty and increasing operational costs will become critical factors to be included in the research.

Opportunity 4: Towards the most effective cost-effective retrofitting strategies

The Climatic Risk Toolkit recommends retrofitting strategies to mitigate the effects of climate change on buildings. However, their individual or combined impact on energy demand, operational costs and carbon emissions can be quantified to find the most suitable strategies for each European region. Retrofitting strategies can be implemented and simulated in the indicative building following the same methodology used in this research. The quantification of the most effective combination of mitigating strategies for each region will provide valuation and building surveyors with a better understanding of how to evaluate and appraise assets. Indicative present and future prices of retrofitting works could also be taken into account to estimate payback periods and their evolution to define the most cost-effective moment to undertake retrofitting works.

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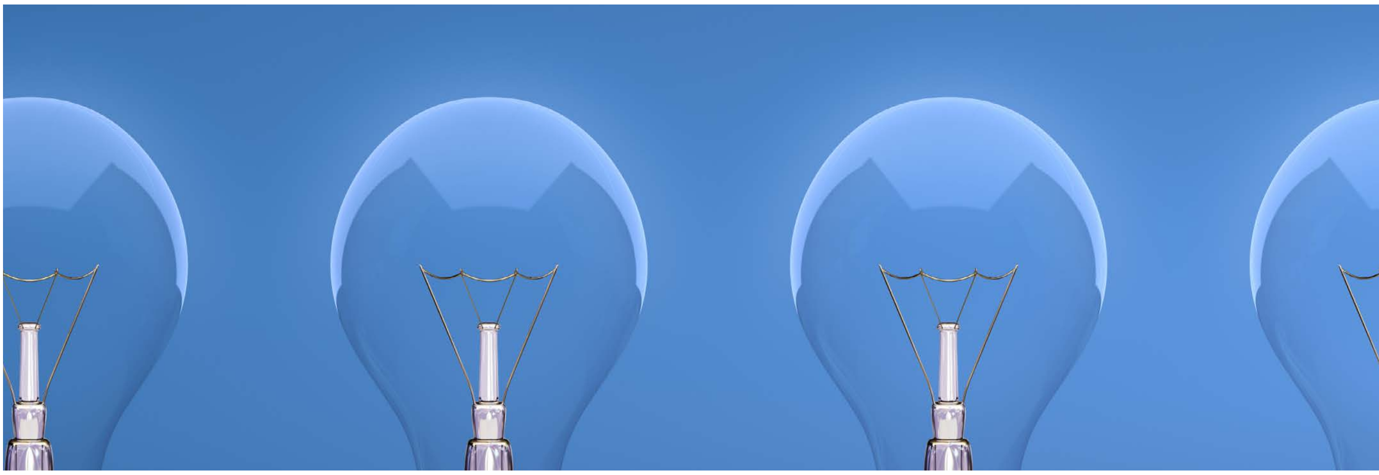

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Appendix 1 – Methodology Details

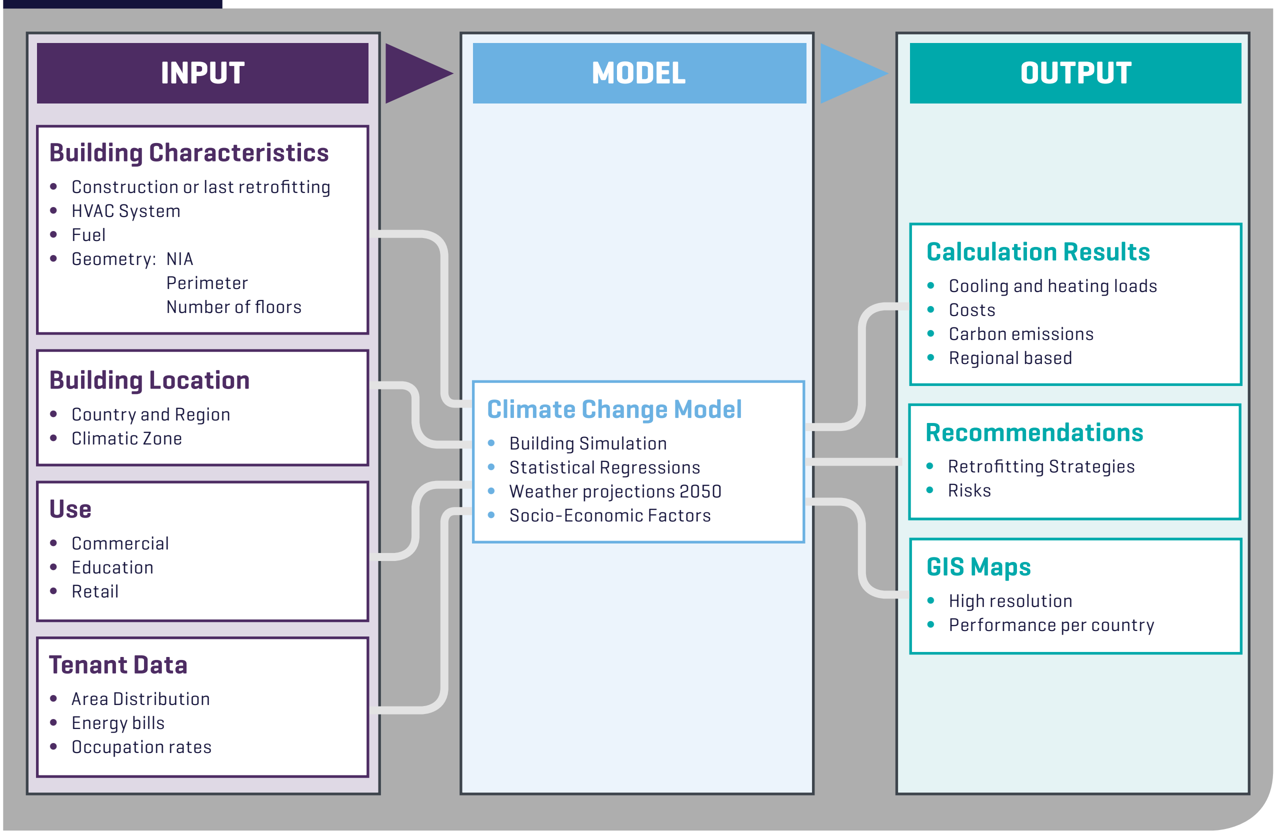
Appendix 1 – Methodology Details

This section describes the methodology for developing a high-level climate change model that predicts the energy performance of buildings across eight countries in Europe. The diagram in Figure 44 provides a general overview of the model, defining the data input that the model requires and the output that will be obtained.

The results of this model are based on the analysis of data obtained through building simulation software. The software used to simulate the thermal performance of every building is EnergyPlus (2014), which is an energy analysis and thermal load simulation program developed by the US Department of Energy. The input of the software is an architectonic model and a weather file (present or future). The architectonic model is fully defined by the thermal characteristics of its elements and internal loads.

Simulations carried out during the research study obtained results for the whole year and for every simulated model for present and future weather projections. Results include a wide range of parameters: energy performance of the building (heating, cooling, electricity, water…), hourly internal conditions (air, radiant and operative temperatures, relative humidity, ventilation and infiltration rates…) heat losses and gains, comfort levels according to BS EN 15251 (CEN/TC 156) adaptive model and other parameters such as solar radiation or extended thermal characteristics of the envelope.

Figure 44 **Climate change model – Input / Output diagram**



Source: Sturgis Carbon Profiling LLP with data from World Energy Council (2013)

A1.1 Weather files

One of the critical points to consider when obtaining comparable and robust results is controlling the sources of weather files. There are many possible sources of present and future projections of weather files. However, weather files are normally developed by national organisations following consistent methodologies for their geographical scope, but with differences between countries. Therefore, it was considered to be a more consistent approach to obtain present weather files from a single source and to calculate the future projections for each location following a single reliable methodology.

Present weather files

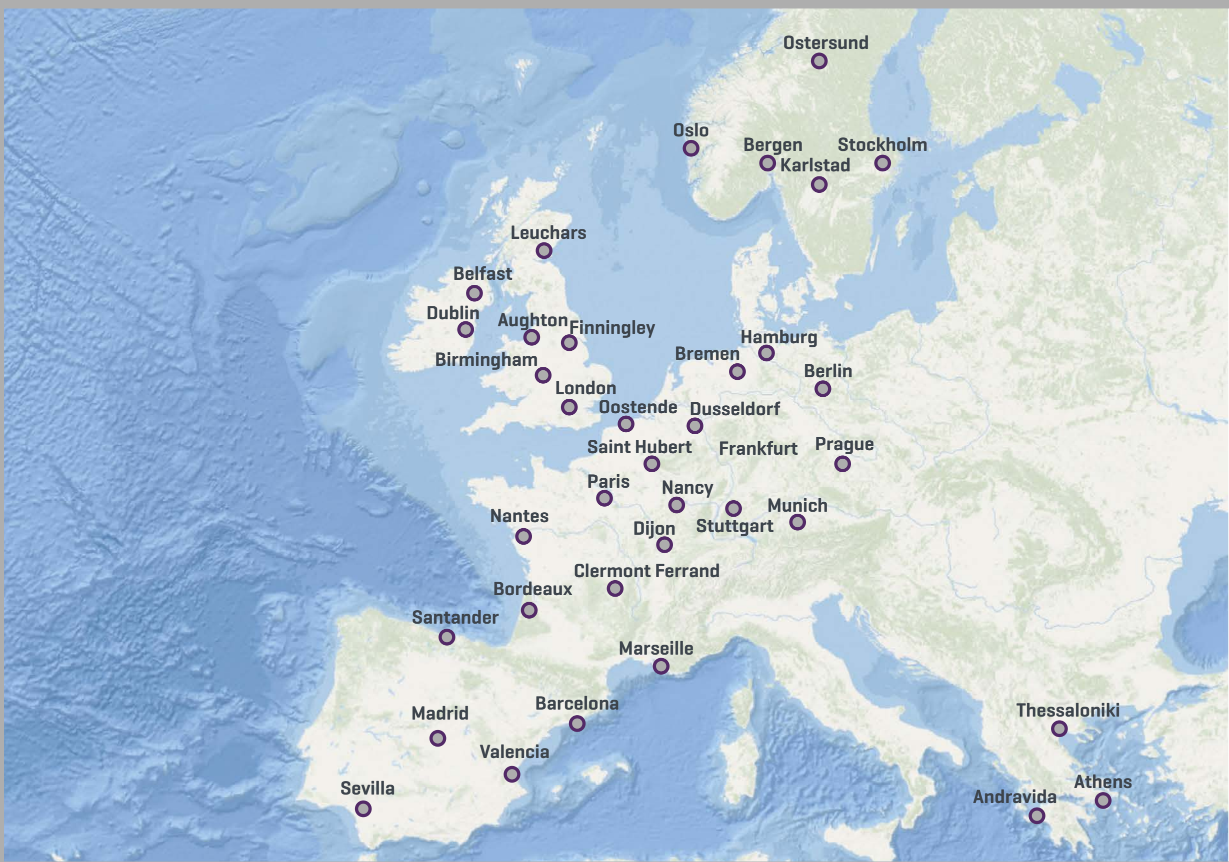
Present weather files are obtained from EnergyPlus Weather Database, also available from the US Department of Energy (2014). This database contains a large amount of weather files for different locations worldwide. Some of these files come from national sources, obtained with different methodologies. The weather data used was developed by ASHRAE from their International Weather for Energy Calculations (IWEC) database, which is an extensive database of weather files developed for worldwide locations.

The International Weather for Energy Calculation (IWEC) files are derived from up to 18 years of DATSAV3 hourly weather. The weather data is supplemented by solar radiations estimated on an hourly basis from earth-sun geometry and hourly weather elements, particularly cloud amount information (EERE, 2014). From this database, 40 locations spread over the 8 studied Member States were selected for simulations.

Future weather files

Future weather files have been obtained using the Climate Change World Weather File Generator (v1.7) developed by the University of Southampton (Jentsch et al, 2012). This tool uses IPCC TAR model summary data of the HadCM3 A2 (IPCC, 2014) experiment ensemble which is available from the IPCC DDC. The tool generates climate change weather files ready to input in building performance simulation software like EnergyPlus. The tool allows the creation of weather files for 2020, 2050 and 2080 in a medium (A2) emissions scenario. The future year generated for research is 2050: 2020 is too close to present a scenario and the results for 2080 are too uncertain and too far ahead in time to provide usable and relevant results.

Figure 45 **Locations of simulated buildings**



Source: Sturgis Carbon Profiling LLP

A1.2 Indicative Buildings

Scope

The other element to be input in the building performance simulation software is the indicative architectonic model. This model needs to accommodate the requirements of the building types and locations defined in the research scope:

Countries: United Kingdom, Ireland, France, Germany, Sweden, Norway, Spain and Greece

Building types: Offices, retail, schools, hospitals, warehouses and leisure facilities

Geometry

The indicative generic building has been defined as having three floors (one thermal zone each), so that top, middle and ground floor conditions can be monitored separately. The flat roof building is distributed in a standard rectangular plan – 20x40m – which can accommodate standard layouts for all the proposed uses. Ceiling to ceiling heights have been set at 4m. Glazing ratio of the façade is 40% in all facades. Long elevations have north-south orientation.

Different locations and policies: Thermal envelope characteristics

The simulation software can define the elements of the building envelope using a wide range of materials with their specific thermal characteristics. Current building stocks are not homogeneous. If only the buildings being constructed at present or a statistical average were simulated, the results would only offer a partial and skewed view of the building stock. In order to include the widest range of possible profiles into the model, the historic thermal characteristics of building elements (including U-values and air tightness) in all countries have been researched.

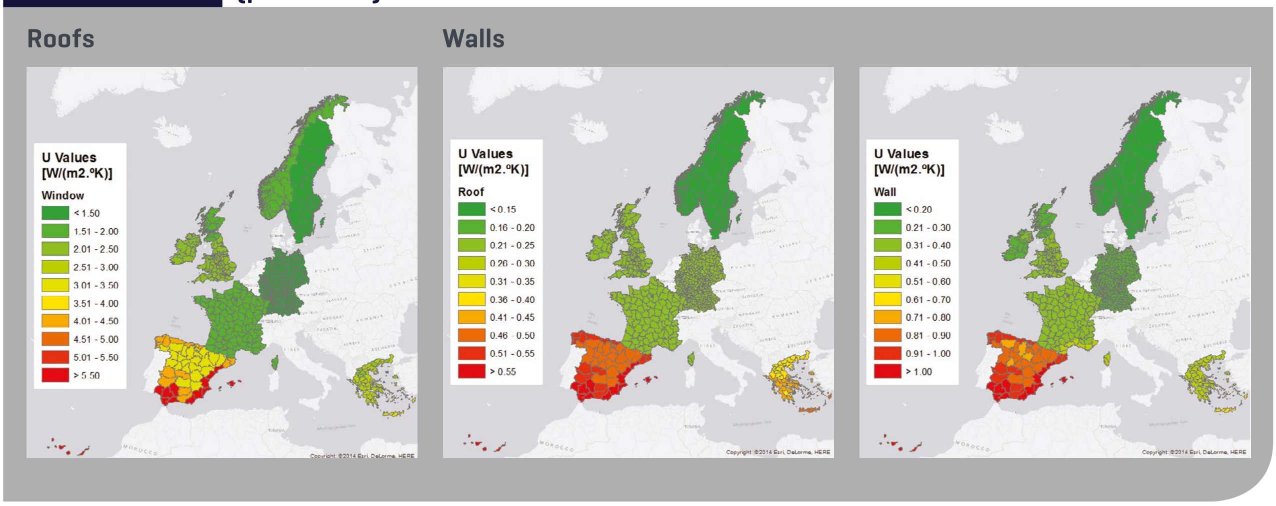
1. Traditional construction.

The research assumed that buildings in all countries had followed comparable traditional construction techniques before the first building regulations were enforced. This has been translated into a solid wall of 300mm and no insulation on the ground floor or in the roof. Therefore, all the buildings built before any building regulations (with energy efficiency requirements) were introduced or enforced, have the same thermal characteristics in every country. This common starting point allows a comparison of the impact of climate change in buildings with the same characteristics located in different European regions.

2. Building regulations

All present and past building regulations of the eight countries included in the scope have been researched. In each country, simulations of the indicative building have been run reflecting the construction requirements dictated by historical building regulations. The thermal characteristics of each building component in the model have been progressively upgraded following newly enforced building regulations. These upgraded models were simulated again for 2010 and 2050 to obtain current and future performances of buildings constructed following different building regulations. These results provide results for a comprehensive range of buildings. Figure 46 illustrates the variation in thermal requirements for walls, windows and roofs across Europe following current building regulations.

Figure 46 Thermal requirements for building components for most current building regulations (post-2010)



Source: Sturgis Carbon Profiling LLP

Building types: Internal loads

The generic building was defined as a standard rectangular conventional layout so that all the building types defined in the scope could be accommodated within it. The building's geometry and thermal characteristics are thus shared amongst all the types of building uses.

The differences between building types are therefore distinguished by their internal loads. Internal loads are defined in this research study as the amount of energy added to the model by equipment, lighting and people. Lighting and equipment consume electricity that is later partially dissipated into the space as heat. Occupants also dissipate metabolic heat into the space. The main difference between building types is the amount of equipment and people present in the building: The trading floor of an office building will generate a great deal of heat from relatively intensive lighting and equipment use and there will be numerous people in the same space. On the other hand, a warehouse uses little lighting and equipment and the presence of people is infrequent. However, both activities occur within the same envelope, defined by building regulations.

Each of the models based on historic building regulations in each country have been simulated using the characteristic internal loads of each building type. The internal loads have been defined following standard recommendations from CIBSE Guide A (2006).

Multiplicity of HVAC options: simplification to heating and cooling loads

EnergyPlus can define multiple and complex heating and cooling systems, as well as natural and mechanical ventilation options. However, the broad range of multiple possibilities, combination of systems and levels of efficiency make it impossible to simulate all the possible scenarios. Therefore, the model has been designed to provide as an output the theoretical amount of energy (kWh) that needs to be input in the building by cooling or heating systems to keep interior conditions at comfortable levels.

As a result, each model has been simulated for two possible scenarios:

Natural ventilation:
Model output provides heating loads only. Heating is switched on when interior air temperature during occupied hours falls under 22ºC. This value is higher than the usual 20-21ºC because air temperature is normally slightly higher in winter than operating temperature, which is the temperature that occupants actually feel.

Air conditioning:
Model output provides heating and cooling loads. Heating is switched on following the same pattern defined for naturally ventilated buildings. Cooling systems switch on when interior air temperature during occupied hours rises above 26ºC.

Building use: Schedules

Heating and cooling systems working times, availability of natural ventilation as well as equipment and lighting have been defined to be able to operate logically within current typical working hours (9.00-18.00):

- The buildings are occupied only during working hours and the occupancy, use of lighting and equipment follows CIBSE Guide A recommendations during those times
- During out of working hours 10% of the lighting and equipment remains switched on
- Heating operates when required all year long
- Cooling and natural ventilation controls only operate between May and October
- 10% of the glazing area in each façade can be opened for natural ventilation. Windows in air conditioned buildings cannot be opened to avoid clashing between natural and mechanical ventilation.

Calculation of comfort in naturally ventilated buildings is also important. Air conditioned buildings are always kept between the 22-26ºC range, so comfort is assumed to be achieved 100% of the time. Naturally ventilated buildings might not meet this standard in summer. EnergyPlus calculates the amount of hours of overheating according to BS-EN 15251:2007, and the risk of overheating has been estimated accordingly.

A1.3 Simulation

Present and future: simulation years

All the models have been simulated using files defining current weather conditions and projections for 2050. Comparable results for each possible indicative building have been calculated.

Output: Energy loads

Simulation output is provided in kWh/m^2 per annum for heating loads, cooling loads and electricity consumed by lighting and equipment. These results generate the basic database to calculate future impact of climate change.

Climatic Risk Calculator

The Climatic Risk Calculator considers the results of the simulation of the indicative building models to create the basic database of climate change impact. These results need to undergo further calculations to provide an output comparable with the specific characteristics and location of buildings throughout Europe.

To adapt indicative results to actual buildings, statistical regressions of multiple variables have been carried out.

The selection of variables respond to the main varying characteristics of buildings and the most statistically significant have been incorporated into the Climatic Risk Calculator. The calculator transforms the simulated results into a dataset comparable to the actual building that is being assessed.

CRT Output

The Climatic Risk Calculation provides current and future energy loads, costs and emissions by 2050. To calculate costs and emissions in each country, the following sources of data on current and future projections of fuel prices as well as the carbon impact of fuels have been considered:

Fuel Costs

Indicative present fuel prices have been obtained and calculated from data from different sources: Eurostat (2013); International Energy Agency (IEA, 2014); DECC (2013a,b,c) and DECC (2014); Kema (2005); Europe's Energy Portal (2014); SEAI (2010), Energy Saving Trust (2014); PV Parity Project (2012); FNR (2012); and E4tech (2010).

Emissions

The carbon impact of fossil fuels and biomass have been obtained and calculated using data from different sources: DEFRA (2012); DECC (2013b); Energy Saving Trust (2014); and UKERC (2013).

The evolution of both fuel prices and future carbon impact might vary considerably depending on the scenario used. Therefore, the Climatic Risk Calculator provides an opportunity to change both parameters to adopt more accurate data that might become available in the future.

A1.4 Mapping results

Finally, Geographic Information Systems (GIS) have been used to develop maps displaying the geographical distribution of climate change impacts and risks at a pan-European level. Maps are based on the simulation results of buildings in each of the study's 40 locations. Results have been extended to include other European locations within the scope of the study using present and future climatic data available from IPCC/CMIP5. Outputs are down-scaled and calibrated using WorldClim 1.4. Data, available at Worldclim (2014) and University of California (2014).

A1.5 Methodology assumptions and limitations

The model predicts changes in potentially any building in the non-residential stock across Europe. Due to the variability of factors that can affect energy demand and bills, results need to be considered at a high level and as trend definers. Detailed research into the building specific conditions would need to be carried out to provide more accurate and tailored results.

Data selection of building envelope

Many countries' building regulations define several climatic regions within the particular country, with varying thermal characteristics for the envelope components. The Climatic Risk Calculator takes into account the differences between these climatic regions. However, some countries, like France or Spain define thermal characteristics of buildings in a more complex manner:

- Different thermal regions for winter and summer with different requirements multiply the amount of models to be simulated
- Difference in altitude above sea level with a reference location incrementally modify the thermal characteristics of building elements
- Definition of single thermal factors that combine the thermal performance of all the elements.

In all these cases assumptions and simplified calculations have been made to comply with the regulations and thermal characteristics have been adapted to comply with model input requirements.

Building age / Year of construction / Retrofitting works

The enforcement of building regulations in each country does not follow similar patterns. To simplify data input in the model, users can only select the decade when the building was built. This poses two time constraints:

- Completion date and the regulations according to which the building was designed might not belong to the same decade.
- If a building regulation is enforced in the middle of the decade, buildings might have been designed according to the previous regulations.

In every country, the chronology of the building regulations has been considered to decide the most suitable way to allocate building regulations and decades. However, it is possible that the building regulation of the indicative model and the input building do not match.

Retrofitting works also challenge the simplicity and standardisation sought in the development of the model. It is impossible to predict the level of improvement that past retrofitting works have generated in a building. That depends on many aspects of the scope of works: type of materials and building components; distribution of works in the building; and retrofitting approaches used in different periods… Building regulations for retrofitting works rarely match the same requirements as building regulations for new buildings. In response to the above, the model simplifies retrofitting works using the following approach:

- If the building envelope and services have ever been completely upgraded, then the building performance is assumed to be closer to the performance and characteristics of a new building that would have built at the time of the retrofitting date
- If only the HVAC systems have been upgraded, then the building envelope will still perform according to the original construction date. However, the HVAC system's efficiency will be upgraded to the more recent average efficiency (this feature can still be overridden by the user).

Energy Price and Emission factors

Energy Prices and Emission Ratios are uncertain by definition.

Different data sources, emission's scenarios, calculation scopes and even simple factors such as varying tariffs in energy contracts challenge the choice of a single cost or emission ratio. Similar difficulties apply to the prediction of future energy prices and emission factors, decarbonisation of the grid and new technology development.

Therefore, the model makes it possible to override the indicative default factors and input more accurate values if available.

Non simulated electricity consumption and internal loads

EnergyPlus is a Building Performance Simulation software which only gauges the electricity consumption of systems that have a direct and significant impact on the total thermal performance of the building. However, there are some types of equipment that cannot be modelled and simulated, for example, lifts/elevators, computer servers and white good appliances, etc., which have a local or limited impact. This shortfall does not significantly affect results of heating and cooling loads, but it affects electricity bills. The electricity consumption of actual buildings will be higher than indicative buildings, because of this extra electricity consumption that is not accounted for. The model is able to identify and estimate these differences and reallocate them in 2050 projections, but depending on the specific characteristics of the building it might affect thermal loads supplied with electricity.

Performance gap

The use of theoretical schedules, ideal occupancy patterns and HVAC systems will affect the comparison between simulated results and real buildings. Simulations will not, amongst others, take into account issues such as inadequate commissioning of systems and maintenance, or users not knowing how to use the HVAC systems. This phenomena is known as the 'performance gap', which is widely reported in initiatives like Carbon Buzz (2014): finished buildings generally perform less efficiently than the predictions calculate. The model calibration process has used Carbon Buzz benchmarks amongst others to minimise the impact of performance gap in the results, but the unpredictable sources that lead to this effect cannot be fully modelled.

A1.6 Model calibration and validation

The model results have been calibrated following two different methodologies: Absolute benchmarks and Partial benchmarks.

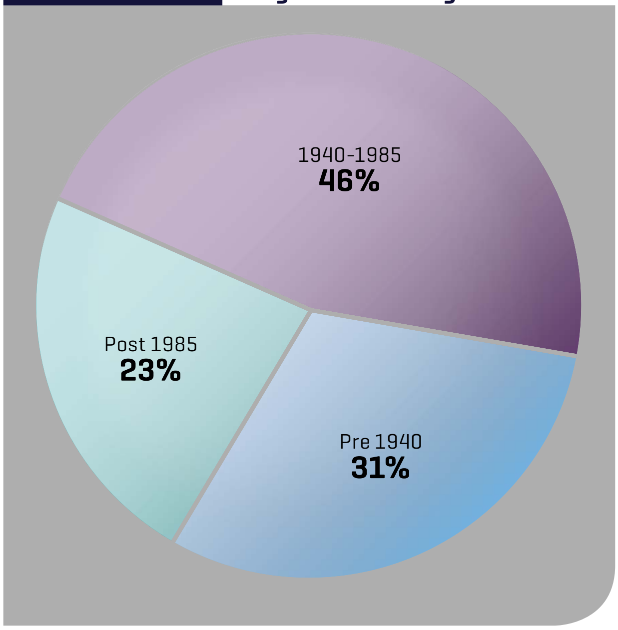
National benchmarks available for the UK stock have been used for calibration and validation:

- CIBSE Guide F (2012)
- CIBSE TM46 (2008)
- Carbon Buzz (2014)
- BRE Energy Consumption Guide (2000)

Absolute benchmarks

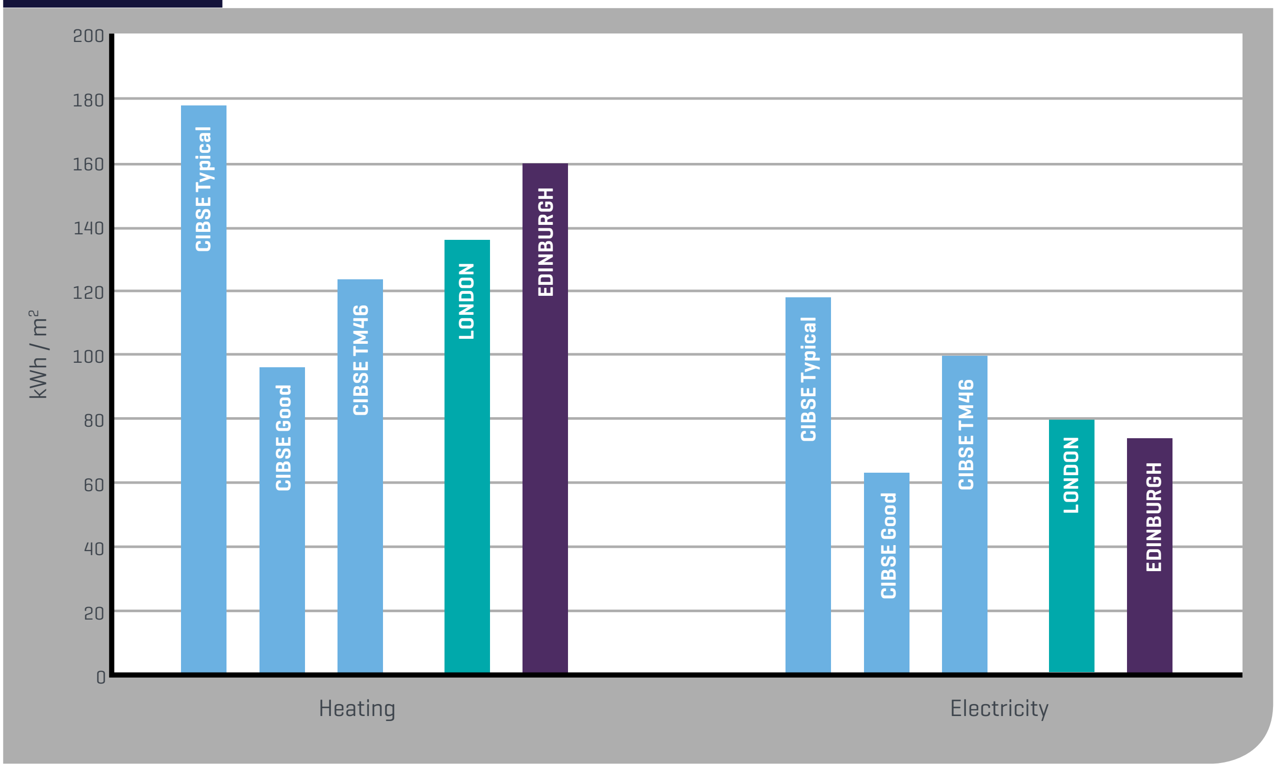
Absolute benchmarks from CIBSE and BRE consider buildings from all ages according to British non-domestic stock profile (see Figure 47). Therefore, the characteristics of UK's non-domestic stock need to be taken account of to allow comparison of simulated results against building performances (which have been proportionally weighed according to this profile). Results from buildings of different

Figure 47 Age breakdown of United Kingdom's building stock



Source: Sturgis Carbon Profiling LLP with data from Carbon Trust (2009)

Figure 48 Comparison of indicative buildings based on CIBSE's benchmarks



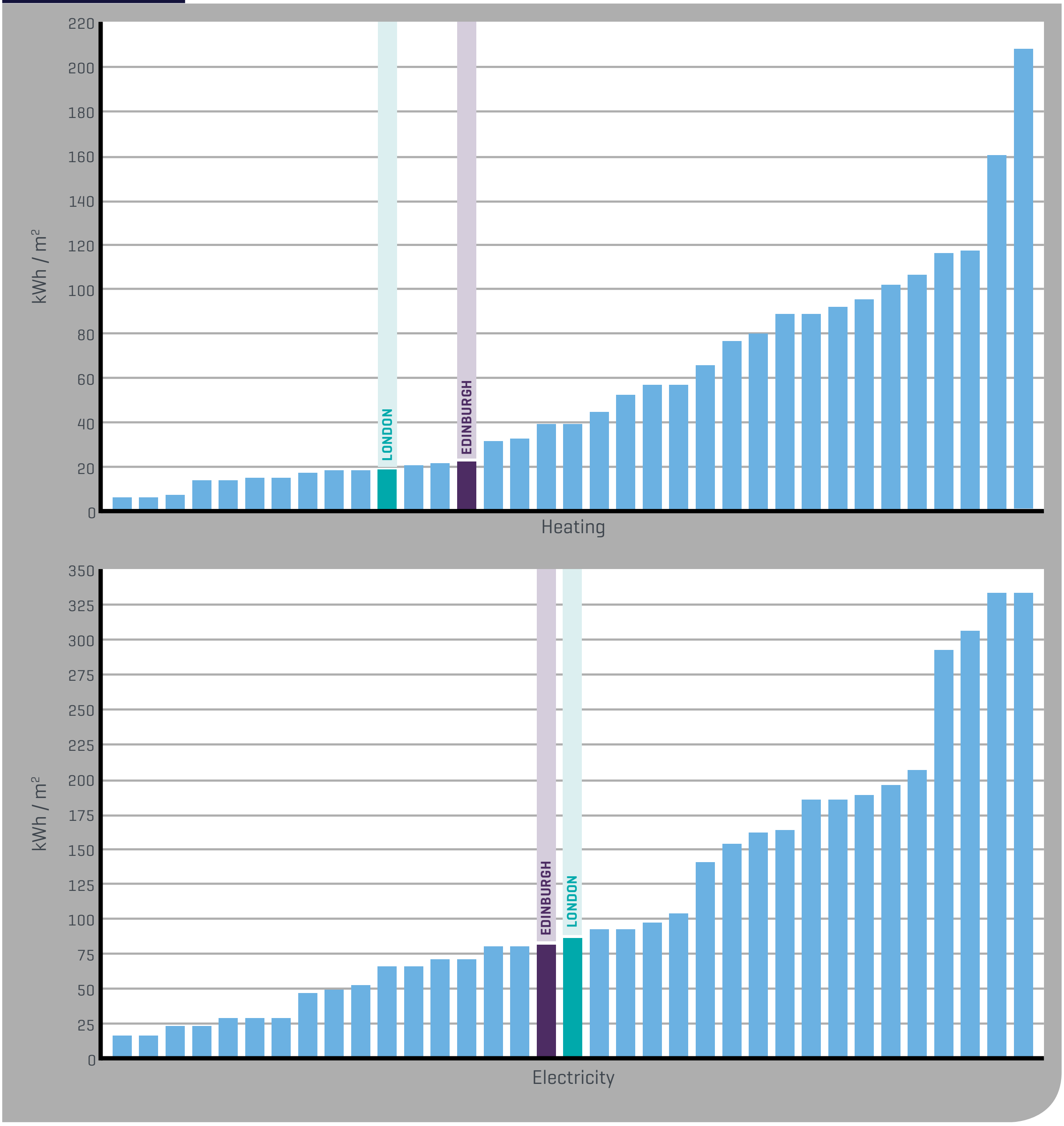
Source: Sturgis Carbon Profiling LLP with data from CIBSE (2012) ages have been used to obtain a representative energy performance value that represents the energy demand of the average British building and can be compared with benchmarks that encompass buildings of different ages.

Benchmarks are valid for all UK. Results from London and Edinburgh have been weighed according to building stock age to validate the model in different locations and climatic conditions within the UK. Figure 48 shows that simulation results for heating and electricity demand fall between typical and good practice benchmarks.

Partial benchmarks

Most buildings included in the Carbon buzz database were built after 2000. This database can be used to validate simulation results of newer buildings. In addition, Carbon Buzz provides performance data 'as modelled' and 'as built', defining the performance gap currently existing in the country. Figure 49 compares simulation results of buildings built in 2010 in London and Edinburgh with the complete Carbon Buzz database of case studies carried out within the same period.

Figure 49 **Comparison of indicative buildings with Carbon Buzz's benchmarks**

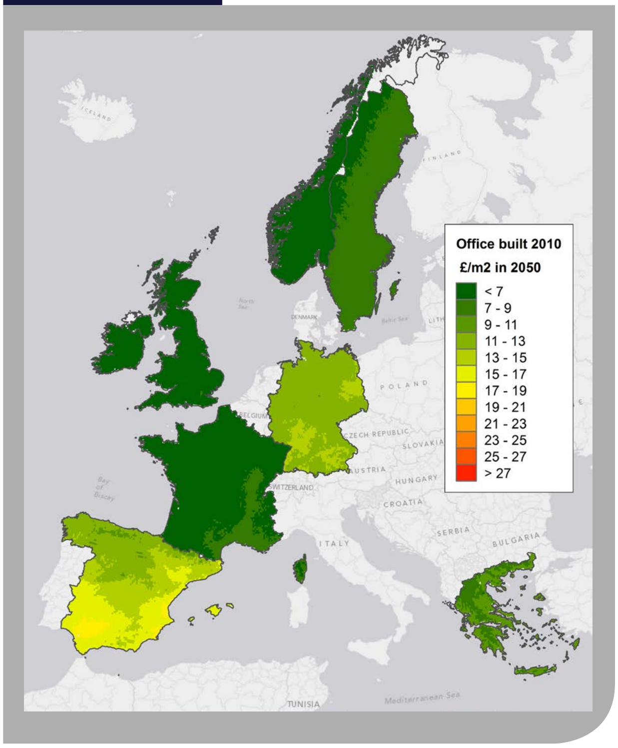


Source: Sturgis Carbon Profiling LLP with data from Carbon Buzz (2014)

Appendix 2 – Climatic Risk Toolkit (CRT)

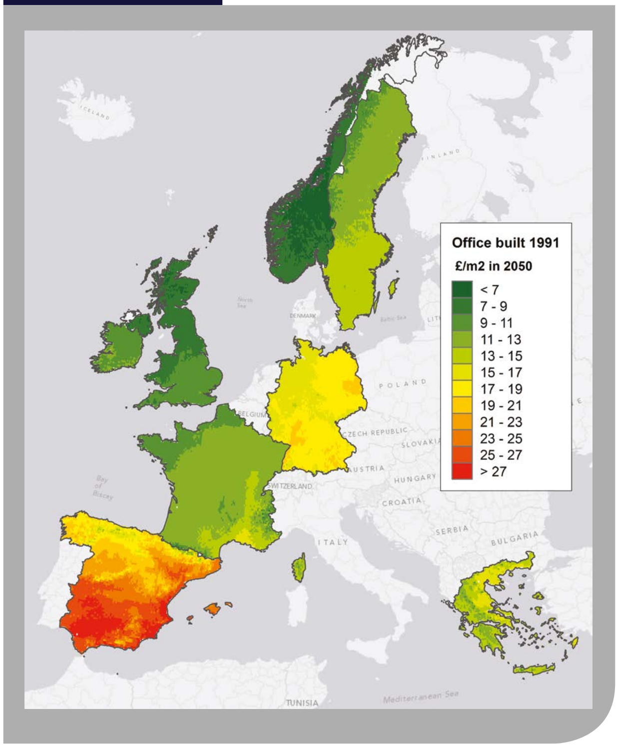
Appendix 2 – Climatic Risk Toolkit (CRT)

Figure 50 Energy use in 2010 (GBP/ m²) for offices built in 1991



Source: Sturgis Carbon Profiling LLP

Figure 51 Energy use in 2050 (GBP/ m²) for offices built in 1991



Source: Sturgis Carbon Profiling LLP

A2.1 Overview

A2.1.1 What is the CRT?

Climate change will affect future energy bills and its intensity will be different for each country (some examples are shown in Figures 50 and 51). The **C**limatic **R**isk **T**oolkit (**CRT**) helps to quantify a building's sensitivity to climate change so that mitigating action can be taken. CRT predicts the annual consumption, utility bill costs and carbon emissions variation for a surveyed building in 2050 using predicted future weather files that consider carbon emission predictions.

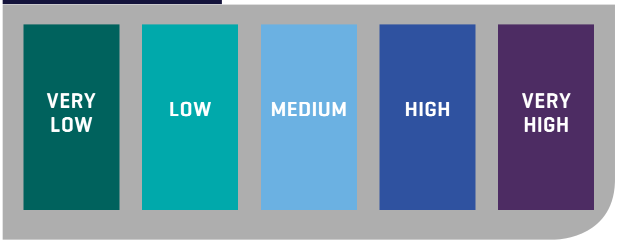
CRT was developed by the author (Sturgis Carbon Profiling llp) in collaboration with RICS and was calibrated with actual data provided by various real estate firms, whose feedback was used to define alterations and future development of the toolkit.

The Climatic Risk Toolkit is available to download from RICS Research website: Search 'Climatic Risk Toolkit' at rics.org/research. The CRT consists of:

- **Calculation tool:** Separate Microsoft Excel® based file for data input and generation of results.
- **Guidebook:** Included in Appendix 2, it presents in depth how the calculation tool works and explains how to read the outcomes.

Calculation Tool and Guidebook are to be used in conjunction with each other.

Figure 52 Risk level and associated colour



Source: Sturgis Carbon Profiling LLP

A2.1.2 Why use the CRT?

CRT is a first stage model and the results are only indicative, but are very useful as the building owner/tenant can use the model to determine:

- If the building is future climate resilient;
- Predicted carbon emissions;
- Predicted energy demand;
- Predicted utility bill cost;
- Mitigation strategies to consider to combat climate change effects; and
- If the surveyed asset will continue to be profitable in the future.

To conclude, the owner/tenant can predict if their property will be comparatively benefited or lose value as a result of climate change.

A2.1.3 How to use the CRT?

The following guide presents the outputs from the CRT Microsoft Excel® spreadsheet and provides step-by-step instructions on how to use it. The toolkit is user friendly, easy and fast to complete and produces results instantly. It consists of five tabs, the first four are to be completed and the final one presents the results.

DATA required to use the CRT:

- Location of the building
- Construction date or date of latest retrofit
- IPMS3 areas
- Service plant type and type of fuel
- Annual heating bill
- Annual electricity bill.

It is very important that the owner/tenant provides the **annual heating** and/or **annual electricity data**; otherwise the tool might not produce accurate results, the real condition of the building might be underestimated and a number of mitigation strategies might not be considered.

Generally, there are required cells to be filled in by the user and optional cells. Referring to the optional cells, if no information is defined by the surveyor, then default values will come into operation. To input data select from a scroll down list or fill in ONLY the **blue cells**.

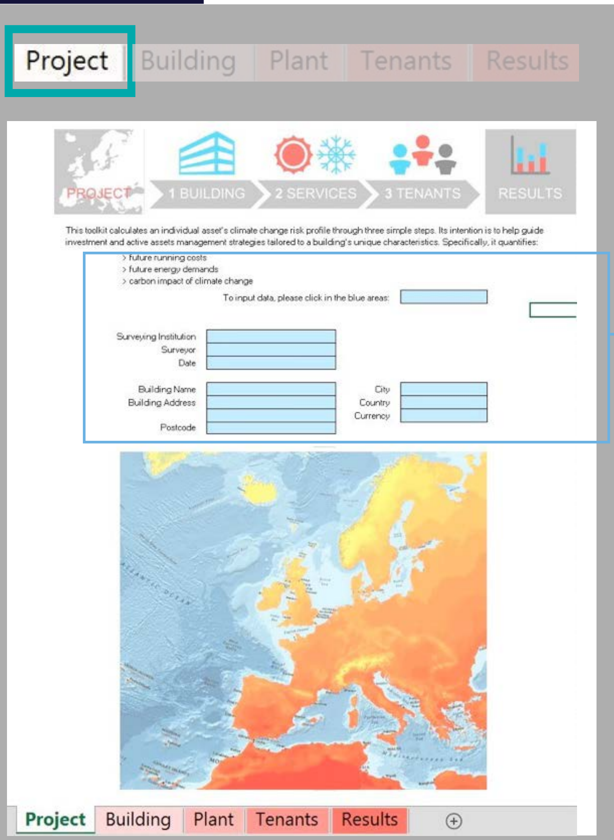
Following the data input, the toolkit can estimate the building's climate risk. There are five risk levels: Very Low, Low, Medium, High & Very High Risk that are colour coded (see Figure 52). The possible mitigation strategies are also colour coded to refer to the above five risk levels and can be found in A2.5 Strategy Cards of this guide. It should be noted that if the building's risk level is greater than Very Low Risk, then all the preceding strategies are to be considered as well.

This tool is intended to help guide decision making and predict future impacts, but specialist advice should be sought prior taking on any of the recommended strategies provided by the results.

The following section (2.0 Data Input) presents the tabs as illustrated in the CRT Microsoft Excel® spreadsheet and associated guidance, as well as the data that needs to be completed for the generation of the results.

A2.2 Data Input

Figure 53 Climatic Risk Toolkit – Project Tab



Surveyor/User Information

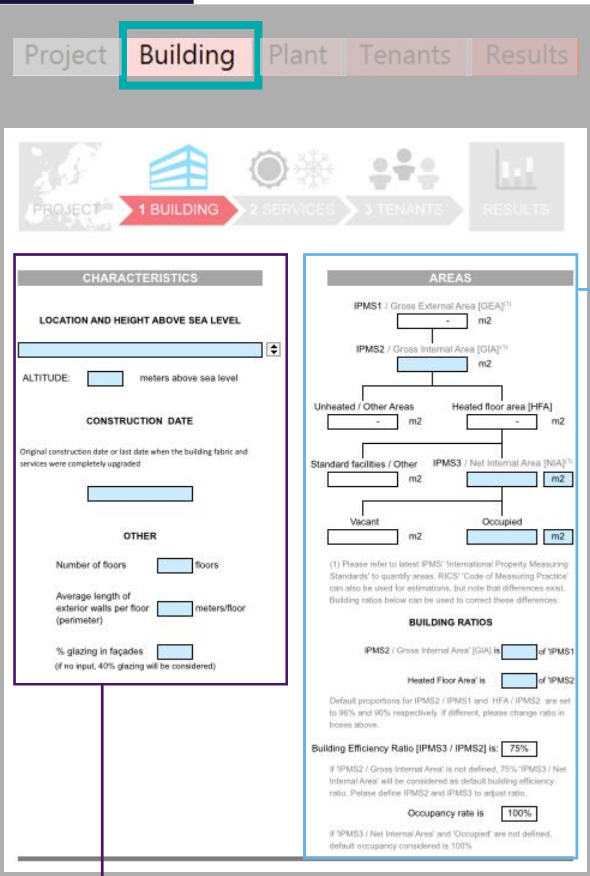
Required:

- The currency for the input data and the results.

Optional:

- The definition of any other cell is not mandatory and is mainly for presentation purposes.

Figure 54 **Climatic Risk Toolkit – Building Tab**



Building Areas

Required:

- IPMS3 Areas: m² or ft².

Optional:

- GIA and Leased Area for the calculation of HFA, Vacant, Common and Unheated areas and the building ratios (in conformity with IPMS)
- Building site ratios.

Building Characteristics

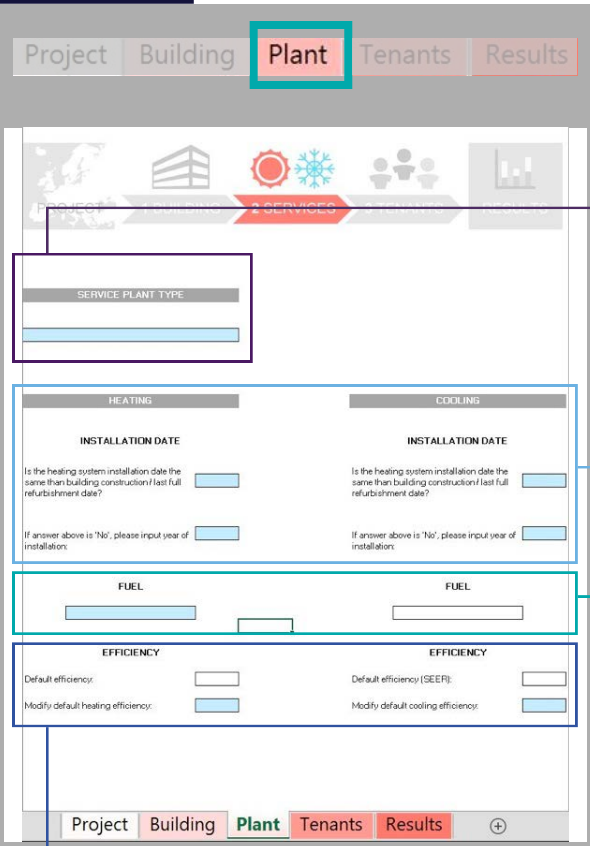
Required:

- Location of building (country / region)
- Construction date of the building or the date of the latest refurbishment.

Optional:

- Altitude (metres above sea level)
- Number of floors
- Perimeter of each floor (m run)
- Glazing ratio (%) in the facades.

Figure 55 Climatic Risk Toolkit – Plant Tab



Service Plant Type

Required:

- The plant type is selected at this stage from the drop down list.

Installation Date

Optional:

- The installation date (year) of the heating and cooling systems is required to estimate their efficiency.

Fuel Type

Required:

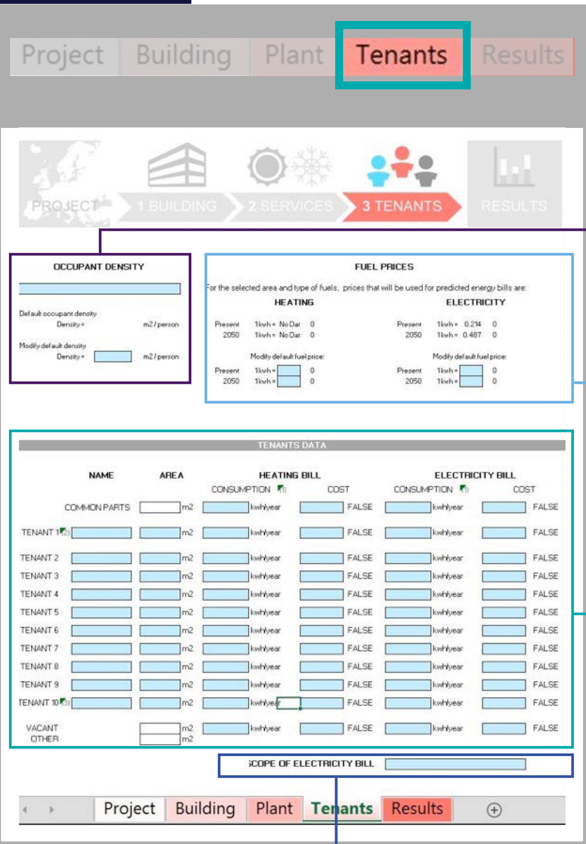
- Fuel type of heating system to estimate the system's efficiency, carbon emissions and bill cost.

Efficiency

Optional:

- The efficiency rating of the system, e.g. Sedbuk rating.

Figure 56 Climatic Risk Toolkit – Tenants Tab



Tenant Data

Required:

- Building use.

Optional:

- Occupant density.

Fuel Prices

Optional:

- The cost of the type of fuel and/or electricity.

Tenant Data

Required:

- The occupied area.

Optional:

- The annual heating and electricity bills*.

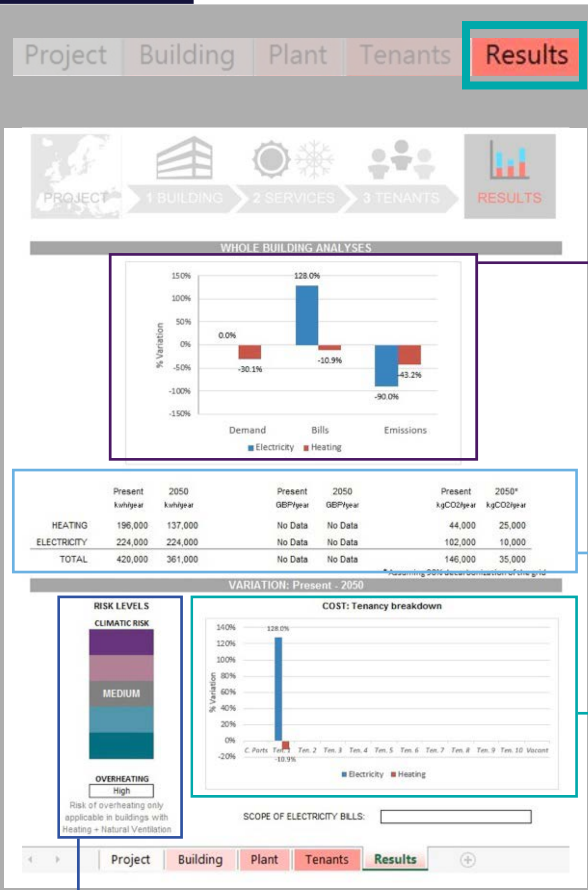
*If this information is not provided, only the % of variation between present and 2050 will be generated.

Scope of Electricity Bill

Required:

- Select from the drop down list the option that better describes your bills data.

Figure 57 Results TAB



Expected % Variation

- Energy Demand
- Bills
- Carbon Emissions.

According to location and building characteristics.

Expected Variation

- Energy Demand [kWh / year]
- Bills [currency / year]
- Carbon Emissions [$KgCO_2$ / year].

Future data only estimated if present values provided.

Cost: Tenancy Breakdown

Required:

- If data from energy bills of each tenant are provided, the expected future estimation per each tenant will be estimated.

Risk Levels

Climatic risk:

- It defines the mitigating strategies to be considered from the available range. All strategies up to the predicted climatic risk level need to be considered.

Overheating:

- High risks of overheating will require the installation of air conditioning by 2050.

A2.3 How to Read the Strategy Cards

The strategy card below (Low Energy Lighting) is an example of how the strategy cards are illustrated. The cards can be found at the end of this guide (A2.5 Strategy Cards) and according to the risk level of the surveyed building the relevant strategies can be considered. In order to read them precisely, refer to the legend below.

Figure 58 **Guide to Strategy Cards**

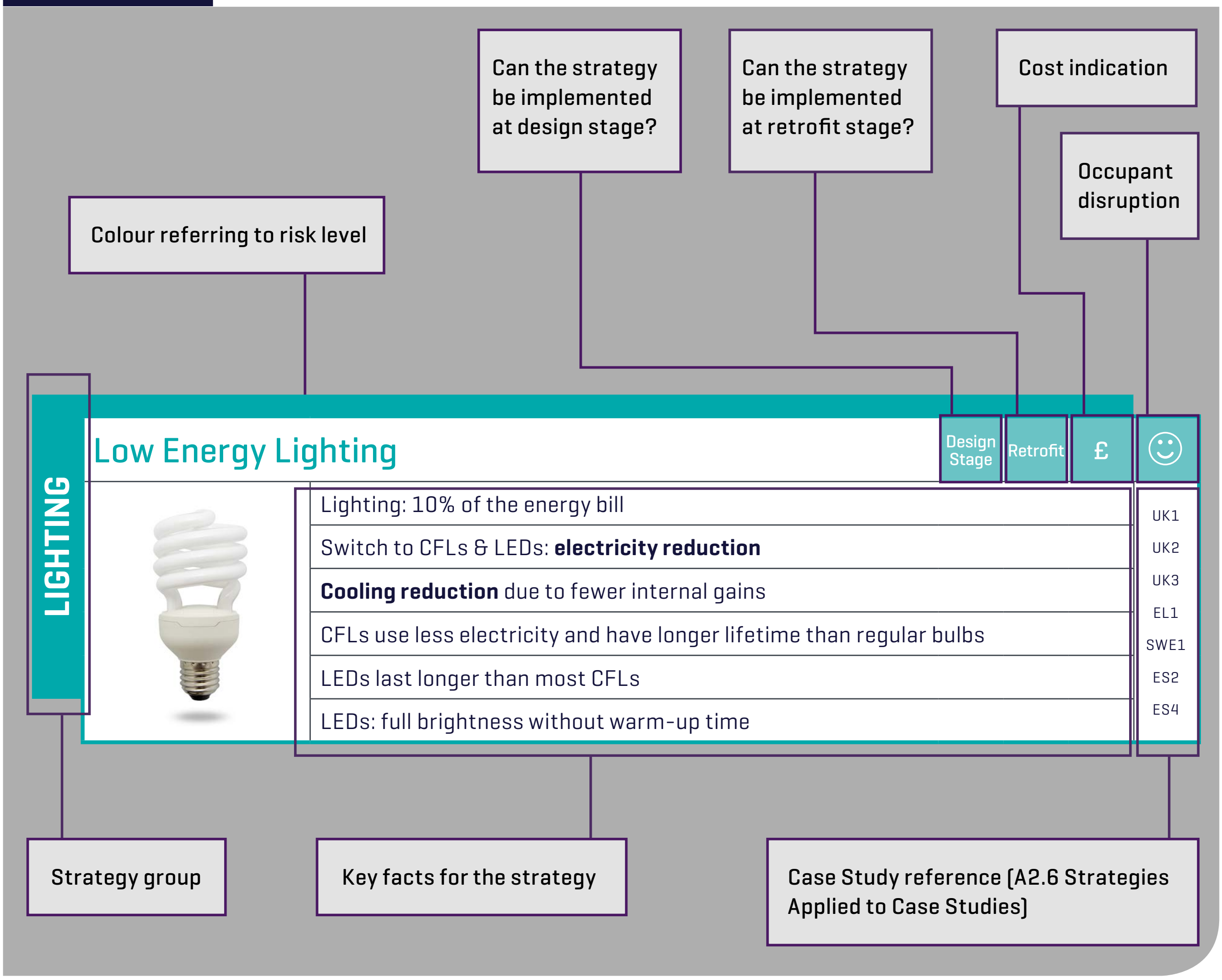


Table 2 Case Study: Input data

Country	Germany
Region	Hessen
IPMS 3 Area (m^2)	43,022
Number of Floors	7-10
Retrofit Date	2009
Heating Fuel	Natural Gas
Cooling Fuel	Electricity
Electricity consumption (kWh/year) | 2012	3,604,830
Natural gas consumption (kWh/year) | 2012	4,114,563

A2.4 CRT in Practice: Case Study

The following case study provides an example of how to use the Climatic Risk Toolkit in a real asset and what information the Toolkit generates.

The following table lists general information and energy consumption data of an office building located in Germany. The property was built in 1990 and refurbished in 2009 to good energy performance standards according to benchmark values for mechanically ventilated buildings in Germany (EPBD, 2011).

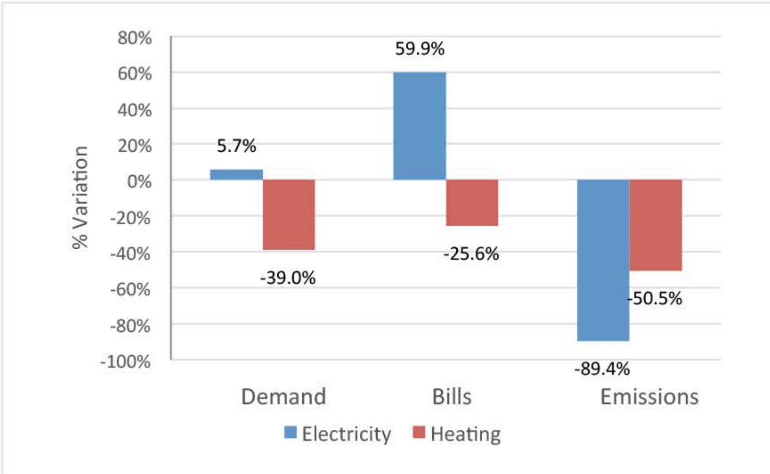
After entering the data in the CRT, the results below were generated:

- Heating demand will greatly decrease (39%) mainly due to global warming and hence, the associated gas bill will also decrease
- Carbon emissions are expected to diminish as a result of the decarbonisation of the electricity grid
- However, electricity and cooling demand is expected to increase by 5.7% due to future higher temperatures. But this figure can be misleading as a 5.7% increase in electricity, results in a surprising 60% increase in the electricity bill due to the expected rise of energy prices.

Remarkably, a good performing building in 2009 will see its bills increasing by 60% by 2050.

Figure 59 **Case Study - CRT results**

WHOLE BUILDING ANALYSES



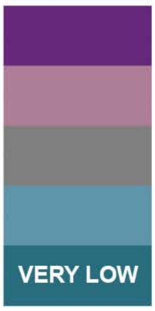
	Present kwh/year	2050 kwh/year	Present GBP/year	2050 GBP/year	Present kgCO2/year	2050* kgCO2/year
HEATING	4,115,000	2,509,000	No Data	No Data	933,000	462,000
ELECTRICITY	3,605,000	3,811,000	No Data	No Data	1,640,000	173,000
TOTAL	7,720,000	6,320,000	No Data	No Data	2,573,000	635,000

* Assuming 90% decarbonization of the grid

VARIATION: Present - 2050

RISK LEVELS

CLIMATIC RISK

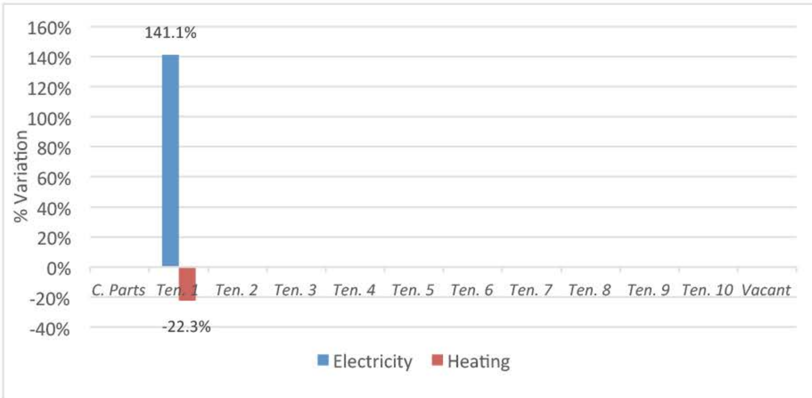


OVERHEATING

N/A

Risk of overheating only applicable in buildings with Heating + Natural Ventilation

COST: Tenancy breakdown



SCOPE OF ELECTRICITY BILLS: Cooling + Electricity

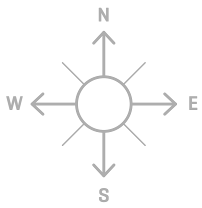
A2.5 Strategy Cards

Figure 60 **Very Low Risk Strategy Cards**

LAYOUT

Orientation

Design Stage | Retrofit | £



Daylight is maximized	FR.1
Heating demand reduction	
Restricted artificial lighting: **cooling reduction**	
carbon emissions reduction	
User comfort is enhanced	

LAYOUT

Compactness

Design Stage | Retrofit | £


1

Influence on the overall energy demand
Fewer heat gains during the day: Cooling reduction
Fewer heat losses during the night: Heating reduction

VENTILATION

Windows Opening

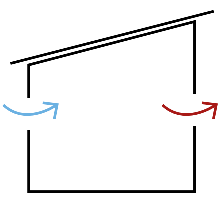
Design Stage | Retrofit | £

Greatly reduce consumption
No carbon emissions
Low running cost
Depending on wind speed
Noise pollution might be an issue
Risk of overheating

VENTILATION

Cross-Ventilation

Design Stage | Retrofit | £



Greatly reduce consumption
No carbon emissions
Low running cost
More effective than one sided window opening
Noise pollution might be an issue
Risk of overheating

continued

Source: [1]BRE (2014) Passivhaus primer: Designer's guide. A guide for the design team and local authorities. BRE (Online) http://www.passivhaus.org.uk/filelibrary/Primers/KN4430_Passivhaus_Designers_Guide_WEB.pdf

continued

HVAC

Controls/Room thermostats

Design Stage	Retrofit	£	

Controls the temperature of the room	UK.3 ES.4
Heating reduction	
Cooling reduction	
Custom temperature for parts of the building with different use	

HVAC

Controls/Room thermostats – Timing

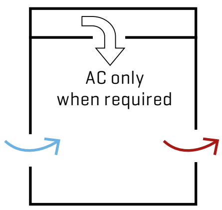
Design Stage	Retrofit	£	

Controls the temperature of the room	ES.4
Heating reduction	
Cooling reduction	
Custom temperature for parts of the building with different use	
Different temperatures for different times of the days	

VENTILATION

Mixed-mode ventilation

Design Stage	Retrofit	££	



Utilized the benefits of natural ventilation	UK.3 IT.1 SWE.1 ES.1
Back-up HVAC when the external conditions are extreme	
Fairly complicated	
Controls required	
Reduction of energy consumption	
Carbon emissions reduction	

Figure 61 Low Risk Strategy Cards

LIGHTING

Low Energy Lighting

Design Stage | Retrofit | £

Lighting: 10% of the energy bill	UK1
Switch to CFLs & LEDs: **electricity reduction**	UK2
Cooling reduction due to fewer internal gains	UK3
CFLs use less electricity and have longer lifetime than regular bulbs	EL1
LEDs last longer than most CFLs	SWE1
LEDs: full brightness without warm-up time	ES2
	ES4

SOLAR CONTROL

Heavy curtains & sealed blinds

Design Stage | Retrofit | £

Reduction of heat losses during night: Heat reduction
Not as effective as double glazing or secondary glazing
Double or secondary glazing will improve performance

ENVELOPE

Cladding

Design Stage | Retrofit | £

Controls the infiltration of weather elements
Can provide waterproof protection
Protects external insulation

SOLAR CONTROL

Low-E Coating

Design Stage | Retrofit | £

Reduction of the emissivity of the glass	
Reflects long wave infrared radiation towards the interior	
Heat losses are reduced: heating reduction	IT1
Combine with solar control coating for optimum results	

continued

Source: [1]http://commons.wikimedia.org/wiki/File:WLANL_-_Harry_--_The_Travel_--_Marmot_-_KunstHAL,_so_what's_hidden_behind_the_curtains_Rem.jpg Licence: http://creativecommons.org/licenses/by-sa/2.0/deed.en [2]http://www.scotland.gov.uk/Publications/2002/03/15098/8731 [3]Eveline Lowe School, Bermondsey" by David Anstiss - Own work. Licensed under Creative Commons Attribution-ShareAlike 2.0 Generic - http://www.geograph.org.uk/profile/29880

continued

SOLAR CONTROL

Solar Control Coating

Design Stage | Retrofit | £

Reflects short wave solar radiation	SWE2
Great reduction of solar gains: cooling reduction	PL1
Little additional thermal insulation	
Combine with low-e coating for optimum results	

SOLAR CONTROL

High Albedo Paint

Design Stage | Retrofit | £

Less solar radiation is absorbed
External surfaces have lower temperature
Lower heat transmission through the building fabric
Will slightly increase heating demand
Cooling demand reduction

SOLAR CONTROL

Awnings

Design Stage | Retrofit | £

Reduction of solar gains: cooling reduction	ES1
Integrated with new-builds	
Fitted to an existing building	
Window opening is not obstructed	
No visibility is lost	
Can be retracted if necessary	

SOLAR CONTROL

External Blinds

Design Stage | Retrofit | £


[1]

Reduction of solar gains: cooling reduction
Integrated with new-builds
Fitted to an existing building
Window opening might be obstructed
Visibility is lost
Can be retracted if necessary

continued

Source: [1]Stellladen Roll fcm" by Photographer: Frank C. Müller - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Stellladen_Roll_fcm.jpg#mediaviewer/File:Stellladen_Roll_fcm.jpg

continued

SOLAR CONTROL

Internal / Opaque Blinds	Design Stage	Retrofit	£	☺
				
Less effective than external in reducing solar gains				
Visibility is lost				
Poor daylight levels				ES2
Artificial lighting probably needed				

SOLAR CONTROL

Internal / Transparent Blinds	Design Stage	Retrofit	£	☺
 1				
Less effective than external in reducing solar gains				
Maximize daylight				
Don't stop solar glare				
Not much privacy during night				

SOLAR CONTROL

Controls / Manual	Design Stage	Retrofit	£	☺
				
Best for shared spaces				
Unlikely to satisfy everyone				
Only when building is occupied				
Less accurate than automatic				

LIGHTING

Controls / Zoning	Design Stage	Retrofit	£	☺
 2				
Electricity savings				
Better control in the space				
Improve comfort				ES4
Less intrusive than turning on/off in the whole space				
Reduce cooling demand				

continued

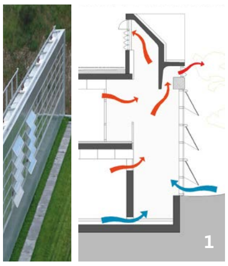
Source: [1]http://www.new-learn.info/packages/euleb/en/p17/index_s0.html [2]Sturgis Carbon Profiling, using plan from: http://en.wikipedia.org/wiki/File:Hills-DeCaro-House-First-Floor-Plan.jpg – licence: http://creativecommons.org/licenses/by-sa/3.0/

continued

VENTILATION

Stack Ventilation

Design Stage	Retrofit	£	☺

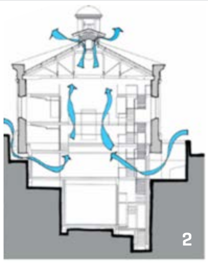


Greatly reduce consumption	UK1
No carbon emissions	
Low running cost	
Noise pollution might be an issue	
Risk of overheating	

VENTILATION

Night Ventilation

Design Stage	Retrofit	££	☺



Cools down the building	DE1
Greatly reduces cooling demand	UK1
Low running cost	EL1
Safety might be an issue	

EQUIPMENT

Controls

Design Stage	Retrofit	£	☺

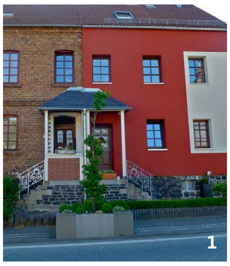
Turn off when not in use	
Fewer items of equipment on stand-by mode	
Savings in electricity	
Reduction of cooling demand	

Source: [1]http://www.new-learn.info/packages/euleb/en/p24/index_s2.html [2]http://www.new-learn.info/packages/euleb/en/p12/index_s1.html [3]Sturgis Carbon Profiling LLP

Figure 62 **Medium Risk Strategy Cards**

External Insulation

ENVELOPE | Design Stage | Retrofit | ££



Greatly reduces heat losses: Heating & Cooling reduction	
Carbon emissions reduction	
Retention of internal features	DE1
EPS, XPS, phenolic foam, mineral fibre & dense wood fibre	UK1
Front façade only in non-conservation areas	
Minimize thermal bridging	

Internal Insulation

ENVELOPE | Design Stage | Retrofit | ££

Reduces heat losses: Heating reduction
Increased thermal bridging compared to external insulation
Covers thermal mass areas
Overheating risk
Reduction of internal space

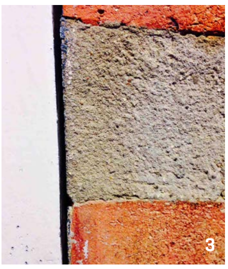
Secondary Glazing

ENVELOPE | Design Stage | Retrofit | ££

Can be fitted inside the existing window reveal
Not as well sealed as double glazing
Heating demand reduction
Low emissivity glass improves performance

Infiltration

ENVELOPE | Design Stage | Retrofit | £



High infiltration: up to 15% heat loss
Airtight membrane within each of the building elements
Proprietary tape to connect the airtight membrane to windows
Heating reduction
Health issues arise if too low
Airtightness testing

continued

Source: [1]"Wāfrmedāmmverbundsystem (WDVS) teilweise auf Altbau." by Handwerker - Own work. Licensed under Creative Commons Attribution - Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:W%C3%A4rmed%C3%A4mmverbundsystem_(WDVS)_teilweise_auf_Altbau..JPG#mediaviewer/File:W%C3%A4rmed%C3%A4mmverbundsystem_(WDVS)_teilweise_auf_Altbau..JPG [2] Sturgis Carbon Profiling LLP [3] Sturgis Carbon Profiling LLP

continued

SOLAR CONTROL

Overhangs

Design Stage	Retrofit	££	☺

Reduction of solar gains: cooling reduction
Fitted to an existing building
Window opening is not obstructed
No visibility is lost
Integrated with new-builds

SOLAR CONTROL

Controls / Automatic

Design Stage	Retrofit	££	☺

More accurate than manual
Unlikely to satisfy everyone
Occupants might complain about not having control

LIGHTING

Skylights

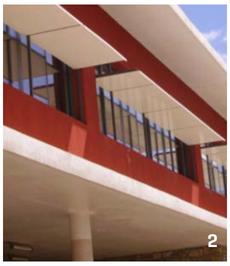
Design Stage	Retrofit	££	😐

Less artificial lighting: Electricity reduction	
Fewer internal gains: Cooling reduction	
Visually pleasing and productive environment	SWE1

LIGHTING

Light Shelves

Design Stage	Retrofit	££	😐


2

Less artificial lighting: Electricity reduction
Fewer internal gains: Cooling reduction
Visually pleasing and productive environment

continued

Source: [1] http://www.panoramio.com/photo/50644238 [2] http://www.new-learn.info/packages/euleb/en/p15/index_s0.html

continued

LIGHTING

Tubular Daylight Devices

Design Stage	Retrofit	££	

Less artificial lighting: Electricity reduction	
Fewer internal gains: Cooling reduction	
Visually pleasing and productive environment	

LIGHTING

Controls / Movement Sensors

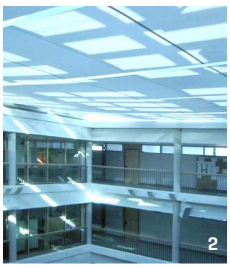
Design Stage	Retrofit	££	

Detect movement	SWE1
Reduce electricity consumption	
Improve comfort	
Reduce maintenance costs	
Reduce cooling demand	

LIGHTING

Controls / Daylight Sensors

Design Stage	Retrofit	££	



Measure natural light levels	EL1 SWE2 ES2
Determine whether artificial lighting is needed	
Improve comfort	
Reduce maintenance costs	
Reduce cooling demand	
Increased electricity savings	

LIGHTING

Controls / Dimming & Switches

Design Stage	Retrofit	££	

Measure natural light levels	DE1 UK1 EL1
Determine whether artificial lighting is needed	
Improve comfort	
Less intrusive than turning on/off	
Reduce cooling demand	
Increased electricity savings	

continued

Source: [1] "Berlin light tube" by Till Krech – http://www.flickr.com/photos/extranoise/218039747/. Licensed under Creative Commons Attribution 2.0 via Wikimedia Commons – http://commons.wikimedia.org/wiki/File:Berlin_light_tube.jpg#mediaviewer/File:Berlin_light_tube.jpg [2] http://www.new-learn.info/packages/euleb/en/p16/index_s2.html [3] Busch-Jaeger, http://commons.wikimedia.org/wiki/File:Busch-Dimmer®.jpg

continued

MATERIALS

Thermal mass

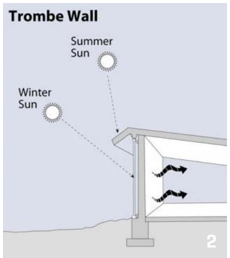
Design Stage | Retrofit | £

Absorbs internal gains during the day	DE1 UK1 EL1
Greatly reduces cooling demand	
Reduces heating demand when realising absorbed gains	
Risk of overheating	
More effective when in use with night ventilation	
Reduces peak loads and peak temperatures	

MATERIALS

Trombe Passive Solar Wall

Design Stage | Retrofit | ££



Absorbs internal gains during the day	ES1
Releases absorbed gains during night	
Reduces heating demand	
Must be shaded during summer	

RENEWABLES

Solar Thermal Panels

Design Stage | Retrofit | ££

Convert energy from the sun into hot water	DE1 UK2 FR1 ES1
Can only provide hot water during day	
Will not produce hot water on North orientation	
Roof must be fairly unshaded	
Can provide heat for space heating	

HVAC

Gas-Condensing boiler

Design Stage | Retrofit | ££

Efficiencies up to 91%	ES3
Recover any useful heat from the outgoing water vapour	
Will greatly reduce energy consumption	
Carbon emissions are reduced	
Replace old boiler with a high-efficiency condensing boiler	

continued

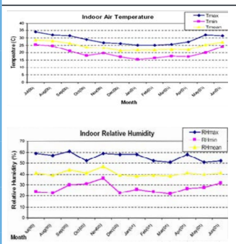
Source: [1] http://www.new-learn.info/packages/euleb/en/p21/index_s2.html [2] http://energy.gov/energysaver/articles/passive-solar-home-design [3] Atelier d'Architecture Chaix & Morel Associés, http://www.new-learn.info/packages/euleb/en/p11/index_s6.html [4] Dunnd74 at en.wikipedia – http://commons.wikimedia.org/wiki/File:Viessmann_Vertomat_Condensing_Boiler.JPG

continued

MONITORING

Environmental Monitoring

Design Stage | Retrofit | £



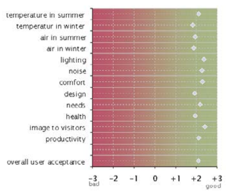
1

Provides data for the building's actual performance	
Highlights problems with the building operation	
Control of compliance with health-related standards	UK3
Control of compliance with environmental standards	ES4

HUMAN FACTOR

Post Occupancy Evaluation

Design Stage | Retrofit | £



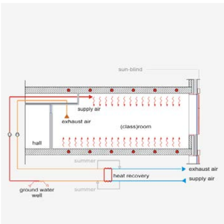
2

Provides data for the building's actual performance
Highlights problems with the building operation
Control of compliance with health-related standards
Control of compliance with environmental standards
Reduces cost by addressing potential problems
Can improve workplace productivity

HVAC

Heat Recovery

Design Stage | Retrofit | ££


3

Heat exchangers to recover heat from exhausted air	
Will greatly reduce energy consumption	FR1
Carbon emissions are reduced	SWE2
	ES2
	ES3
	PL1

HVAC

Chilled Beams

Design Stage | Retrofit | ££


4

Circulates air without noise and expense of ductwork and AHU	
Reduced fan power	
Higher chilled-water temperatures: refrigeration power is reduced	UK2
Consumption reduction	SWE2
	PL1

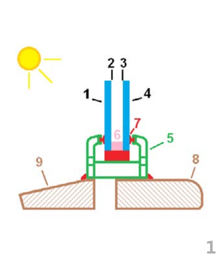
Source: [1] http://www.new-learn.info/packages/euleb/en/p19/index_s4.html [2] http://www.new-learn.info/packages/euleb/en/p19/index_s4.html [3] http://www.new-learn.info/packages/euleb/en/p1/index_s3.html [4] http://www.new-learn.info/packages/euleb/en/p5/index_s4.html

Figure 63 High Risk Strategy Cards

ENVELOPE

Double Glazing

Design Stage | Retrofit | £££

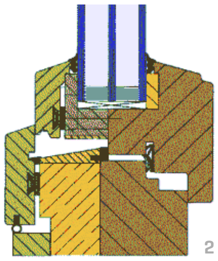


Smaller energy bills: Heating & Cooling reduction	EL1
Smaller carbon footprint: Carbon emissions reduction	
Fewer draughts and cold spots	
Soundproofing	
Reduction of condensation on the inside of windows	

ENVELOPE

Triple Glazing

Design Stage | Retrofit | £££

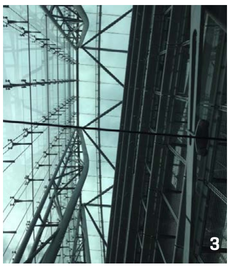


Smaller energy bills
Smaller carbon footprint
Fewer draughts and cold spots
Soundproofing
Reduction of condensation on the inside of windows
Better comfort conditions than double glazing

ENVELOPE

Double skin façade

Design Stage | Retrofit | £££



Promotes natural ventilation: carbon emissions reduction	ES2
Sound insulation	
Reduction of heat losses: heating reduction	
Shading protection: cooling reduction	
Promotes night ventilation	
Risk of overheating	

SOLAR CONTROL

Glazing Ratio

Design Stage | Retrofit | £££

The larger the window the greater daylight	IT1 SWE2 PL1
The larger the window the greater the heat losses	
Ratio between 25% and 50% is considered the optimum	
Less artificial lighting: Electricity and cooling demand reduction	
Maximize solar gains: heating reduction	

continued

Source: [1] NcLean (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons http://commons.wikimedia.org/wiki/File%3ADouble_Glazed_Fixed_Window_Diagram.png [2] Passivhaus Institut - Copied to Commons from http://en.wikipedia.org. Original source Passivhaus Institut, Germany – http://www.passiv.de. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Passivhaus_Fenster_Beispiele.png [3] Sturgis Carbon Profiling LLP

continued

RENEWABLES

Photovoltaic Panels (PV)

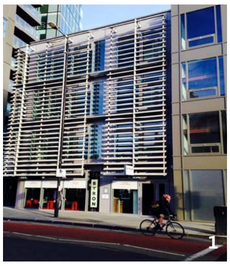
Design Stage | Retrofit | £££ | ☺

Photovoltaic panels generate only electricity	DE1
Ideally placed within 10° South but can go up to 30	
Will not generate energy on North orientation	
Roof must be fairly unshaded	
Not very efficient technology	

SOLAR CONTROL

External Louvres

Design Stage | Retrofit | £££ | ☺

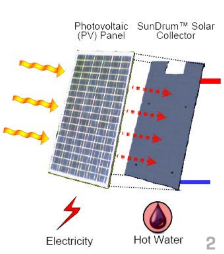


Most effective in solar shading: cooling reduction	DE1 UK1 IT1 FR1 EL1
Combats overheating	
Reduce temperature swings on sunny days	
Horizontal on equatorial facing facades	
Vertical on East and West facades	

RENEWABLES

PV-T

Design Stage | Retrofit | £££ | ☺

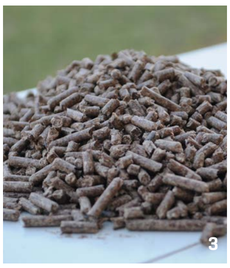


Generate both electricity and heating
Utilize PV overheating to provide heating
Increased PV capacity for electrical generation

RENEWABLES

Biomass Boiler

Design Stage | Retrofit | ££ | ☹



Biomass: wood pellets, chips or logs
Low carbon
For well insulated buildings
Sufficient biomass storage to minimize emissions transportation

continued

Source: [1] Sturgis Carbon Profiling LLP [2] http://bostonsolar.us/boston-solar-energy-blog/bid/68370/How-Does-Solar-Thermal-Technology-Work [3] "Biomass Pellets from India - White coal." by Kapilbutani - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Biomass_Pellets_from_India_-_White_coal.jpg

continued

RENEWABLES

Air source heat pump

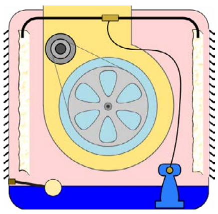
Design Stage | Retrofit | ££ | ☹/☺ neutral

Extracts heat from the air	
For well insulated buildings	
Least efficient in winter	
When there is direct electricity supply	
Hot water and space heating must be provided by other means	
Less efficient than ground water heat pumps	

RENEWABLES

Evaporative Cooling

Design Stage | Retrofit | ££



1

Hot external air is continuously moved over water-soaked pads	
Electrically driven fans are required	
Reduced efficiency when the external air has high relative humidity	
Reduced electrical consumption compared to regular AC units	
Reduced carbon emissions compared to regular AC units	

Source: [1] "Evaporative cooler" by Nevit - Own work. Licensed under Creative Commons Attribution 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Evaporative_cooler.svg

Figure 64 **Very High Risk Strategy Cards**

RENEWABLES

Micro Wind

Design Stage | Retrofit | £££

1

Generates electricity from wind	
Depending on local wind availability	
More efficient in rural areas	
Normally efficient in urban areas when higher than 15 floors[1]	

RENEWABLES

Combine Heat & Power (CHP)

Design Stage | Retrofit | ££££

2

Produce electricity from combustion of fuel	
Utilize waste heat to provide space heating and hot water	
For large space heating and hot water demand	UK4
For poorly insulated buildings	

continued

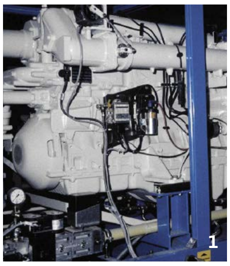
Source: [1] "Micro WindMill" by S zillayali - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Micro_WindMill.jpg [2] http://www.new-learn.info/packages/euleb/en/p3/index_s8.html

continued

RENEWABLES

Combined Cooling Heat & Power

Design Stage	Retrofit	££££



- Produce electricity from combustion of fuel
- Utilize waste heat to provide space heating and hot water
- Hot water drives absorption chillers to provide cooling
- For large space heating and hot water demand
- For poorly insulated buildings

DE1
ES3

RENEWABLES

Ground source heat pump

Design Stage	Retrofit	£££

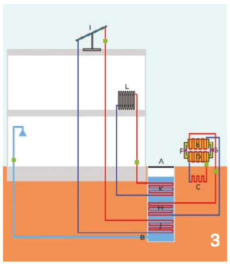
- Extracts heat from the soil
- For well insulated buildings
- Efficient throughout the year: stable soil temperatures
- When there is direct electricity supply
- Hot water and space heating must be provided by other means
- Requires a lot of space

FR1
UK2

RENEWABLES

Water source heat pump

Design Stage	Retrofit	£££

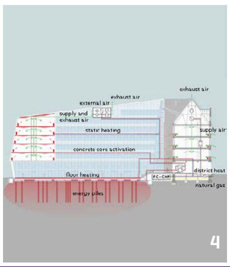


- Extracts heat from a body of water
- For well insulated buildings
- When there is direct electricity supply
- Hot water and space heating must be provided by other means

RENEWABLES

Geothermal piling

Design Stage	Retrofit	£



- For well insulated buildings
- Pipework is incorporated into the structural concrete foundation piles
- Concrete transfers heating /cooling temperatures to the heat pump
- When there is direct electricity supply
- Hot water and space heating must be provided by other means

Source: [1] © Fraunhofer ISE http://www.new-learn.info/packages/euleb/en/p2/index_s7.html [2] "3-ton Slinky Loop" by Original uploader was Marktj at en.wikipedia - Transferred from en.wikipedia; transferred to Commons by User:Teratornis using CommonsHelper.. Licensed under Public domain via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:3-ton_Slinky_Loop.jpg [3] http://commons.wikimedia.org/wiki/File:Heat_pump_system_on_rainwater_pit.png LICENCE: http://creativecommons.org/licenses/by-sa/3.0/deed.en [4] © IGS http://www.new-learn.info/packages/euleb/en/p4/index_s3.html

A2.6 Strategies Applied to Case Studies

Figure 65 **Strategies Applied to Case Studies**

DE.1

Institutsgebaude Fraunhofer ISE

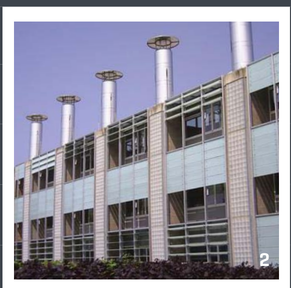
Building Data

City: Freidburg	**Use:** Office & Lab	**Heated area:** 15,130 m^2
Built Year: 2001	**Floors:** 4	

Features

increased thermal insulation	split external shutter	thermal mass & night ventilation
CCHP	20 m^2 solar thermal collectors	200 m^2 PVs

UK.1



BRE Office

Building Data

City: Watford	**Use:** Office	**Heated area:** 2,040 m^2
Built Year: 1996	**Floors:** 3	

Features

increased thermal insulation	thermal mass & night ventilation	external glass louvres
low energy lighting	natural ventilation (stack)	

UK.2

savings of 3,000 tn CO_2 in the 1st year

£ 4.4 million potential savings

King's College

Building Data

City: London	**Use:** Education	**Heated area:**
Built Year:	**Floors:**	

Features

modular boiler system	low energy lighting	ground source heat pump
solar thermal	chilled beams	

continued

Source: [1] http://www.new-learn.info/packages/euleb/en/p2/index.html [2] http://www.new-learn.info/packages/euleb/en/p6/index.html

continued

UK.3

DECC Headquarters

estimated savings of £74,000 a year

estimated savings of 327 tn CO_2 a year

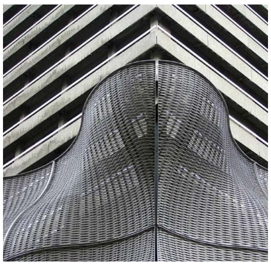
Building Data

City: Whitehall	**Use:** Office	**Heated area:**
Built Year:	**Floors:**	

Features

low energy lighting	smart meters	mixed mode ventilation
thermostat		

UK.4



Guy's and St. Thomas

savings of £1.5 millions a year

savings of 11,000 tn CO_2 a year

Building Data

City: London	**Use:** Hospital	**Heated area:**
Built Year:	**Floors:**	

Features

CHP		

EL.1

AVAX Headquarters

Building Data

City: Athens	**Use:** Office	**Heated area:** 3,050 m^2
Built Year: 1998	**Floors:** 8	

Features

vertical solar fins	double glazing	low energy lighting
automatic daylight control	thermal mass & night ventilation	

continued

Source: [1] Steph Gray, flickr [2] http://www.new-learn.info/packages/euleb/en/p19/index.html

continued

IT.1

Guzzini Headquarters

Building Data

City: Recanati	**Use:** Office	**Heated area:** 2,320 m²
Built Year: 2002	**Floors:** 4	

Features

external louvres	mixed mode ventilation	maximization of natural light
low-e double glazing		

SWE.1

Tanga School

Building Data

City: Falkenberg	**Use:** Education	**Heated area:** 6,131 m²
Built Year: 2000	**Floors:** 3	

Features

skylights	low energy lighting	movement sensors
natural ventilation [stack]		

SWE.2

26% less energy than Swedish standards

80% less energy for heating than before retrofit

Bromma Blocks

Building Data

City: Stockholm	**Use:** Retail	**Heated area:** 60,000 m²
Built Year: 1948	**Floors:** 3	

Features

glazing ratio was increased	solar control glazing	heat recovery
motion and timer controlled lighting	passive chilled beams	

continued

Source: [1]http://www.new-learn.info/packages/euleb/en/p18/index.html [2]http://www.new-learn.info/packages/euleb/en/p10/index.html [3]http://www.skanska-sustainability-case-studies.com/Case-Studies/Bromma-Blocks-Hangar-3-Sweden.html

continued

FR.1

County Hall Alsace

Building Data

City: Strasbourg	**Use:** Office	**Heated area:** 12,100 m²
Built Year: 2005	**Floors:** 5	

Features

orientation	horizontal external shading	ground water heat pump
heat recovery from the exhaust air	64 m² solar thermal	

ES.1

National Centre of Renewable Energies

Building Data

City: Sarriguren	**Use:** Office	**Heated area:** 3,580 m²
Built Year: 2004	**Floors:** 4	

Features

automatically controlled awnings	trombe wall	natural ventilation (stack)
240 m² solar thermal collectors		

ES.2

204 kWh/m² before retrofit

16% reduction after retrofit

Sede del Consorcio de la Zona Franca

Building Data

City: Barcelona	**Use:** Office	**Heated area:** 14,000 m²
Built Year: 2004	**Floors:** 5	

Features

low energy lighting	daylight sensors	blinds between the two skins of the façade
double façade	heat recovery	occupant engagement

continued

Source: [1]http://www.new-learn.info/packages/euleb/en/p11/index.htm [2]http://www.new-learn.info/packages/euleb/en/p24/index_01.html [3]http://www.panoramio.com/photo/9199939

continued

ES.3

18% energy use reduction per year

savings of € 2.7 million in 2008

Gomez Ulla

Building Data

City: Madrid	**Use:** Hospital	**Heated area:**
Built Year: Varies	**Floors:** Varies	

Features

CCHP	heat recovery	high efficient boiler

ES.4

23% reduction in total consumption

€ 60,000 savings by switching to CFLs

Escuela de Arquitectura del Vallès

Building Data

City: Sant Cugat	**Use:** Education	**Heated area:** 8,630 m^2
Built Year: 1991	**Floors:** Varies	

Features

smart meter	timing control	thermostat
zoning/ lighting	low energy lighting	

PL.1

energy consumption 32.5% lower than Polish standards

Atrium City

Building Data

City: Warsaw	**Use:** Office	**Heated area:** 18,586 m^2
Built Year: 2009	**Floors:** 7	

Features

increased glazing ratio	chilled beams	solar control glazing
heat recovery		

Source: [1]http://commons.wikimedia.org/wiki/File:HCD_GOMEZ_ULLA.jpg http://creativecommons.org/licenses/by-sa/3.0/deed.en
[2]http://commons.wikimedia.org/wiki/File:Escola_d'Arquitectura.jpg http://creativecommons.org/licenses/by-sa/2.5/deed.en
[3]http://www.skanska-sustainability-case-studies.com/Atrium-City-Poland/Project%20Introduction

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