The Historic Settlement:

Reconciling Conservation and Environmental Sustainability Through Design

Yi Lu

A dissertation submitted in
The Welsh School of Architecture,
Cardiff University

In candidature for the degree of
PHD, Cardiff University
May 2018

Abstract

Despite the comprehensive literature and guidance on the conservation of the historic settlement, little practice has put into the test of relevant guidelines for conservation in the context of sustainable regeneration of these settlements.

In the literature revealed that differing emphases and directives between current conservation legislation and codes for sustainable buildings, it was found that each agenda also has a limited perspective, which could be bonded together in certain way in order to perform a well-balanced design practice without leaving any party behind.

This study attempted to formulate and refine a design framework to guide designs within the historic settlement, embracing conservation, enhancement and environmental sustainability. The hypothetical design framework together with a point-based assessment tool is tested repeated through a series of hypothetical domestic design cases in a historical settlement to discover how different physical conditions influence building form and performance. A combination of methods including literature review, case studies and design studies has been applied.

Having tested the context of creative designs within a typical historic settlement, the research demonstrates that a reconciliation could be restored among conservation, and sustainable design in order to face inevitable interventions in the future but that there are inevitably areas of design where some tensions emerge which require a wholistic design approach.

CONTENTS

ILLUSTRATIONS

Figures

Tables

CHAPTER ONE: INTRODUCTION

1.1 Interest in 'new into old'

This study begins with the interest in historic building conservation and regeneration triggered by a project designed by Benjamin T. Wood in Shanghai, China in 2002, Project 'Shanghai Xintiandi', also known as New Heaven and Earth (Figure 1). Such project involves the transformation of an abandoned residential district into iconic tourism attraction in Shanghai. The Xintiandi project is commonly recognized as the start of contemporary 'new into old' practice in China. Chinese critics and journals identify the Xintiandi project as an example of successful urban renovation, combining Shikumen architecture and modernity artistically.

Shikumen architecture is a unique architecture style in 19th century Shanghai; it combines traditional Roman style with traditional residential building style of the southern China with stone, wood and brick altogether. Among these building material, stone has rarely been used as building material in Chinese building history. The initial purpose of this regeneration project was to protect buildings containing remnants of this specific style from demolition through reuse and it has successfully turned the area into an energetic distract with commercial centres, galleries and studios, similar to the Soho area of London (See Figure 1).

Figure 1: Left: Shanghai Xintiandi Project and Shikumen architecture (Unknown 2009) Right: Shanghai Xintiandi Project – intervention of a global chain (Zhongjie 2008)

The Xintiandi project has been widely reported as a successful case of urban regeneration, creating a new commercial centre in Shanghai. However, concerns arose regarding whether the transformation might be more critically reviewed if applying principles requiring that the essential core of the historic settlement were maintained, or even better, left 'untouched'. Moreover, concerns have been raised about the sustainability performance of historic buildings (Shuionland, 2012).

1.2 Background

Conservation legislation has played a significant and unparalleled role in the past century, helping to maintain key distinctive and essential features of historic settlements and buildings in the UK (English Heritage, 2008). Although conservation legislation arose from concerns over preserving the heritage buildings, it later expanded to cover the process of protection of entire areas with historic cores. The introduction of the notion of a conservation area in the 1960s, along with the first national investigation to identify such areas, is recognised as a remarkable moment of upgrade to policy. The new policy covered the following: 'Areas of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance' (1967 Act, 1967). It also marked the beginnings of a policy response to theories related to urban form and visual quality, by noticing that the environment of a historic settlement contains more fragile components than simply the heritage buildings within it.

In the current era, a broader definition of urban conservation emerges:

> [U]rban conservation is a long-term political, economic and social commitment to an area with the intention of providing a better quality of life for its users. Conservation encompasses not only the physical urban fabric, but also an understanding of the spatial morphology and a social dimension which makes urban heritage so distance from the more 'object' qualities of the singular built heritage. (Tiesdell, Oc & Heath 1996, p. 318)

In parallel, the maintenance of the historic settlement and small historic districts in urban areas is understood to be weakened in modern society under the threats from economic growth, urban development and globalization.

Modern sustainable development theory creates an agenda that focuses intently on improving the ecological performance of the built environment. (BREEAM 2006) As a response to tighter carbon emission target, this framework has been strengthened several times in the past decade. Having added the remit of enhancing building energy performance, especially reducing the carbon footprint as a fundamental principle of conservation, new conflicts have arisen affecting the design principles guiding current legislation.

In this thesis, the relationship between conservation and the agenda of building environmental sustainability is explored through design.

1.3 Aim and objectives

The overall aim of the research is to achieve conservation aims alongside regeneration and environmental sustainability in historic settlements, by addressing and reconciling conservation principles and performance-based codes for sustainable buildings. Furthermore, while the design will apply the principles inherent in UK conservation legislation within the UK context it is envisaged that the design will also be applicable to projects carried out within a wider geographic area.

The specific aims and objectives are:

- To locate the possible conflicts and overlaps between conservation, enhancement, and sustainable strategies in historic settlements;
- To identify examples of critically acclaimed good designs that have achieved conservation, enhancement, and environmental sustainability aims in Europe and to analyse them;

- To propose a 'model' for creative design which embraces conservation, regeneration, and the enhancement of building performance in a historic settlement;
- To define how buildings, especially domestic buildings, no matter existing or new built, in a historic settlement might be rendered more environmentally sustainable;
    - To establish appraisals against townscape study of a historic settlement;
    - To select and design typical projects;
    - To test the model through design;
    - To critically verify the building performance in various design conditions;
    - To critically appraise all designs;
- To test and to verify all findings through design.

1.4 Methodology

This research studies conservation and regeneration principles and methodology in the hyposensitive context of a historic settlement, particularly targeting new achievements and requirements for environmental sustainability. As a systematic design based study drawing on architectural language, townscape performances, and sustainability parameters, this work is predominantly based on design activities in a studio setting. Beginning with the research questions generated from an initial literature review, case studies and practices, it then formulates a hypothesis proceeding from a review of the literature detailing relevant architecture cases and townscape studies. After which results obtained are verified by conducting critical and repetitive design tasks in the studio and further works concerning the carbon footprint and the wider environmental impact of buildings. Unlike a practical design project, this study strives to contribute to the academic field by moving knowledge forward. It argues 'the studio is a kind of laboratory in which hypotheses, theories and methods may be tested and validated through the act of design' (Forster 2008).

To answer the above aims and research objectives, three main interlinked research methods are applied in the study:

- Literature review: to establish a comprehensive literature background information in creative regeneration in historic settlement, which embraces conservation and environmental sustainability, this study, begins with a profound literature review of conservation legislation, historic settlement, and sustainable development. Through the process of townscape studies, case studies and design works, literature supporting well-known architects and time-tested conservation and regeneration method and theory is applied.
- Case studies: cases are selected under the guidance of the literature reviewed, as established in the first section. There are reviews offered of the differences between current legislation and new conservation and regeneration concepts. The hypothesis in the following is based on a comparison of selected case studies.
- Design studies: offering a model for design strategies to reconcile, test and analyse for environmental sustainable conservation. This is the only method used to test hypotheses conducted in literature studies and case reviews; and differs from standard architectural design. A repetitive design progress, in conjunction with computer calculation, simulation and lab tests can be used to prove how environmental improvements can be achieved through design methods when modifying heritage buildings. SAP is engaged under the context of design works as an tool to simulate energy consumption and building energy performance of the dwelling through all variation. Regarding a briefing of both attributes and limitations of SAP, please refer to 2.4.2 in '*Measurements to assess carbon emission, energy, and environmental performance'*.
-

1.4.1 Research by design

Research by design is the main research method used. Research by design has been used as a research method to test and to verify the hypotheses and theories put forward by practitioners including artists, designers, curators, and musicians. Hauberg (2011), in '*Research by design - a research strategy*' confirmed that 'the most important way in which the architect achieves new cognition is through work with form and space: drawings, models and completed works' (Hauberg 2011, p. 46). He goes on to say that 'research as a broader field includes experience other than that which is gained from science: scientific cognition is not the only way in which we acquire new knowledge and insight' and that 'research in Architecture is a part of all this, acquired physically by imitating or repeating, by making mistakes, and feeling pain or pleasure' (Hauberg, 2011, p. 47). Candy (2006) identified two types of practice related research: *practice-based research* and *practice-led research*, where:

- Practice-based research is an original investigation undertaken in order to gain new knowledge partly by means of practice and the outcomes of that practice.
- Practice-led researches concerned with the nature of practice and leads to new knowledge that has operational significance that practice. (Candy 2006, p. 1)

In this study, a measure of both types of research is employed.

It is also important to distinguish *practice-based research* from *pure practice*, which is also called *practice-as-research* and *practice-as-itself*. Repeated creative practice with the aim of seeking a new technique and the chasing of new concepts should not be recognised as research because these activities aim to reach individual goals. Research should be able to contribute to the store of knowledge in a more general sense. An important distinction between the two is the process and form that the knowledge generation takes. The outcome of *practice-based research* should arise from a structured process guided by university examination regulations for a doctoral degree; the outcome should be able to be shared with the wider community (Candy, 2006). Over and above this are other arguments that differentiate between *practice-based research* and *pure practice*:

> The critical difference is that practice-based research aims to generate culturally novel apprehensions that are not just novel to the creator or individual observers of an artefact; and it is that distinguishes the researcher from the practitioner. (Candy 2006, p. 1)

The 'practice-as-research', being distinguished from 'practice-as-itself', are defined as:

> work under the purpose of expand the knowledge by conducting an original investigation in a through objects and creative processes (Borgdorff 2005, p. 14).

Fallman emphasised that the focus of design-orientated research should be on progression and refection rather than on the design outcome. In '*why research-orientated design isn't design-orientated research*' he states that:

> 'design-oriented research, the knowledge that comes from studying and designed artefact in use or from the process of bringing the product into being should be seen as the main contribution – the 'result' – while the artefact that has been developed findings of the research as they will be developed throughout the study' (Fallman 2005, p. 3a the knowledge that comes from studying).

In the study, research by design is employed to test whether the proposed model based on specific principles may guide creative designs to embrace conservation, enhancement, and environmental sustainability principles in historic settlements. A typical historic settlement is selected as the urban context where both design practices will take place. Two designs of domestic buildings, comprising both retrofit and new design, are proposed as a context in order to allow more variations could be applied and discussed: the variations are addressed on orientations, physical condition of the site, and the degree of sensitivity on street façade; and all conservation principles, and rules regarding building performance in the model are employed and balanced through design. To complete each variation, a following SAP calculation is engaged to calculation the building energy performance. Comparison and discussion of all test variations and carbon emission rate will then lead to an updated and represented model. Here is a sequence of works related to the research by design employed in this study (Figure 2):

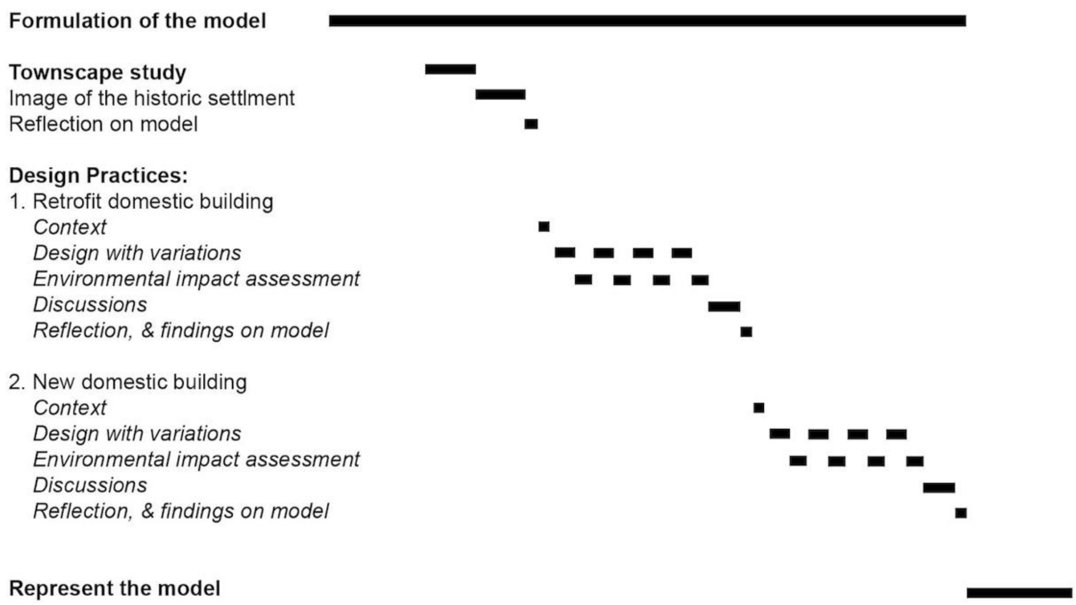


Figure 2: Research by design method employed in this study.

Each design study will then follow a sequence, beginning by a key precedent study, following a learning of context, including preferences on site picking, and identity studies of town and the site, then proposing design practices, assessing environmental impacts and discussing possible variations, at the end of the chapter, the SAP rating and evaluations via point-based model of all variations and the initial design will be displayed in a form of matrix and discussed towards several key findings to bring the study forward. (Figure 3)

The case studies on precedent works, which will be looked at, where possible, will embrace all concerns on conservation, enhancement and environmental sustainability especially on building performance. The context study consists of a list of preferences on site picking, study of the site’s identity related to the design context, and a description of the site and buildings. The design process will be illustrated through diagrams, sketches, drawings, and models. Measures and strategies for energy performance enhancement are considered in parallel with conservation and explored through concept drawings, constructional detail and predicted through software-based simulation. All variations are discussed based on the context of initial design works, following the same sequence of simulation and evaluation. All key data will be displayed together at the end of the chapter for discussion.

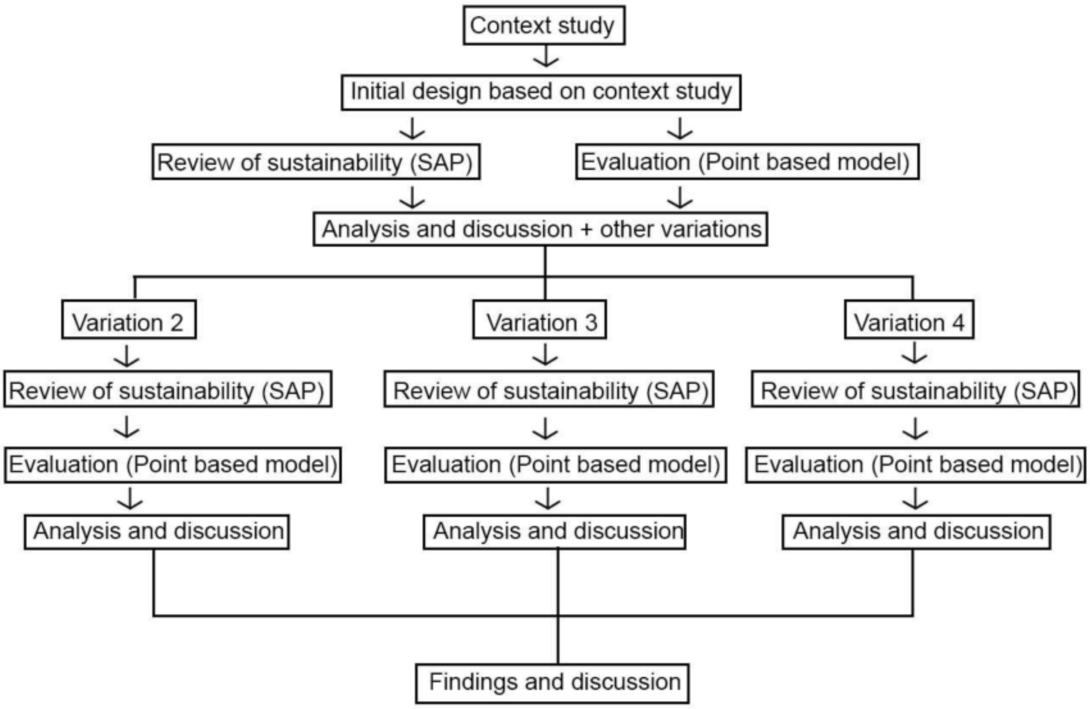


Figure 3: The verification process in each design case study under the context of initial design

The outcomes of each design study will be described sequentially. Each study assesses and verifies the model in a specific section or as a whole; when necessary, the model will be revised and corrected in the middle of a process and tested in the following process.

The conservational enhancement of a historic settlement, especially in environmental sustainable aspect, encompasses complex procedures including both domestic and non-domestic buildings. Improvements on energy performance of domestic buildings may greatly influence carbon emission rate of the entire settlement due to their overwhelming proportions: based on the form of medieval burgage pattern, mostly over

75% of buildings in a medieval or market town are dwellings; plus, there are continuous increase of domestic buildings alongside the population growth (Department for Communities and Local Government, 2017). Non-domestic buildings, especially infrastructures, play significant roles in social and economic aspect of sustainable development: to reinforce a settlement's position in the community, strengthening local identity, and boosting its economic growth.

The study will propose a model (hypothesis) based on a number of principles drawn from literature and case study. The 'model' will then be tested and verified on the bed of a typical historic settlement, using context of both new-build and retrofit domestic buildings. Discussions raised from design practices and SAP ratings, will address on the conflicts and gaps between conservation and performance enhancement strategies in building and settlement scale.

In the study, domestic buildings instead of non-domestic buildings are engaged as design objects and context to test the model due to a few reasons: (1), domestic buildings are the biggest components in a historic settlement, which is established under the form of burgage in most market towns and medieval towns. Plot subdivision to fit growing population would then further increase the total amount of dwellings; (2), the study focuses on the environmental dimension of sustainable development, especially carbon deduction in the settlement scale; and the overall carbon emission rate would be greatly affected by large numbers of domestic buildings; (3), SAP is employed as the assessment tool to simulate the proposed carbon emission rate for all designs of domestic buildings; however, the simulation of DER and DFEE rate of non-domestic buildings would require the involvement of accredited energy assessor. Due to author's knowledge limitation on energy assessment and simulation, non-domestic buildings are excluded from design case studies to test and verify the 'model'.

1.4.2 Formulation of the hypothesis (The design framework)

The hypothesis of the study, the design framework, will be formulated at the end of the literature review and the case study, on the basis of discussions in both conservation and performance dimensions. (4.7) The model should reveal and reflect both overlapped sections and conflicted criteria. (Figure 4)

- Conservation principles will be selected and refined from conservation frameworks and all related publications from English Heritage and Cadw. Place-led conservation method, an architectural strategy to identify the place and to create detailed measures as design guidance, is applied to rephrase policies that are too general to follow in practices. (4.5)
- Guidelines and Strategies to improve building performance are summarised from mandatory rules for sustainable buildings according to Building Regulation Part L and other BREEAM publications. Some of the strategies are also modified and rephrased to fit design languages (4.6).

Principles that are too general to guide design practices will be defined and rephrased to detailed strategies and guidelines. In the study, 'architectural rephrase' will be applied, that is using architectural strategies or design code to identify the place and to create design measures rather than following inadequate or general literatures, for example, abstracting and formulating design languages from key elements of existing townscape. A point-based credit framework is also employed in the assessment scale to establish a tabular evaluation of design practices: hierarchy and weightings of all principles are based on their frequency of appearance and significance in reviewed frameworks and regulations in Chapter Two (the literature study).

The model will theoretically cover possible gaps and overlaps between conservation appraisals and enhancement of building performance. To test and verify the hypothesis, all variations in each design will be evaluated by the point-based credit system, then weightings will be illustrated, analysed, and discussed robotically.

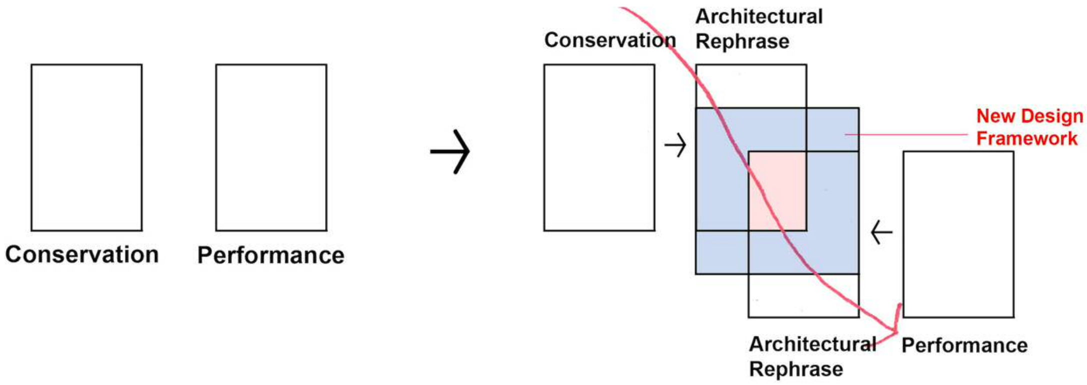


Figure 4: Establishment of the model and possible relationships.

The hypothesis is to create a design model with a point-based assessment framework which combines, rather than separates conservation principles and energy performance criteria, justify and guide intervention or regeneration activities in a historic settlement under increasing sustainable requirements. The hypothesis is tested through a series of hypothetical domestic design cases in a typical historical settlement in the UK to discover how different physical conditions influence building form and performance.

1.5 Scope and limitations

This study of the regeneration of historic settlements, conservation, and new approaches of environmental sustainability will cover both new built and retrofits of domestic buildings. Non-domestic buildings are excluded from this test and verification procedure due to the limitation on energy frame assessment of non-domestic buildings.

The study will propose a model (hypothesis) based on principles drawn from literatures and best practice. The model will then be tested and verified through design practices.

The test bed for the model will take place in a 'typical' historic settlement. It will be comprised of small compact settlements situated around a nuclear historic centre. It will have a highly 'imageable' and distinctive visual character. Llandeilo in Wales has been selected as a typical settlement on which to test the proposed design model. In addition, the definition of a typical historic settlement will be clarified in the following chapter, based on reviews of several forms of settlement.

Although the model will be tested and verified in Wales, it was chosen as a typical case, with the intention that the principles identified would be applicable in other parts of the world, where designs to historic settlements embrace both conservation and sustainability.

Concerns regarding sustainable development focus on the environmental dimension; while sustainable approaches address social and economic dimensions, along with concerns relating to landscapes in the environmental dimension that are not discussed in the study. However, the concerns over all aspects of sustainability and associated approaches can provide a positive guide to the future sustenance of the historic settlement.

Limitations also exist on the amount of framework and legislations reviewed in both dimensions of conservation and performance, from where the model and the point-based elevation system is drawn. Although publications from English Heritage, Cadw, and BREERM may greatly represent the literature background from both aspects.

1.6 Structure

The thesis contains nine chapters, arranged into three sections: first the literature study and case studies (Chapters 1, 2 & 3), hypothesis verification through design activities (Chapters 4, 5, 6 & 7), and a final section drawing conclusions and presenting discussion (Chapters 8 & 9). The literature study, from **chapters one to three** comprehensively reviews background information, offering an initial study of current UK conservation legislation, studying historic towns that are representative of market towns and medieval towns, and introducing sustainable development and code for sustainable homes, offering a profound review of case studies about European historic settlements, covering performance and conservation methods. Based on a literature study and a townscape study, the research hypothesis and methodology in **chapter four** covers two-dimensional concerns from conservation and performance. Based on the intended research methodology, Llandeilo was chosen as the site for design practices to test the hypothesis. **Chapter five** offers a detailed townscape study of Llandeilo from three dimensions: town's image, building performance, and energy level; followed by two design practices targeting specific proposals to test and verify the hypothesis in **chapter six and seven**. The **final two chapters** conclude the research, offering results and findings, and discussing a proposed method to apply in further studies to data pertaining to other historic settlements outside the UK.

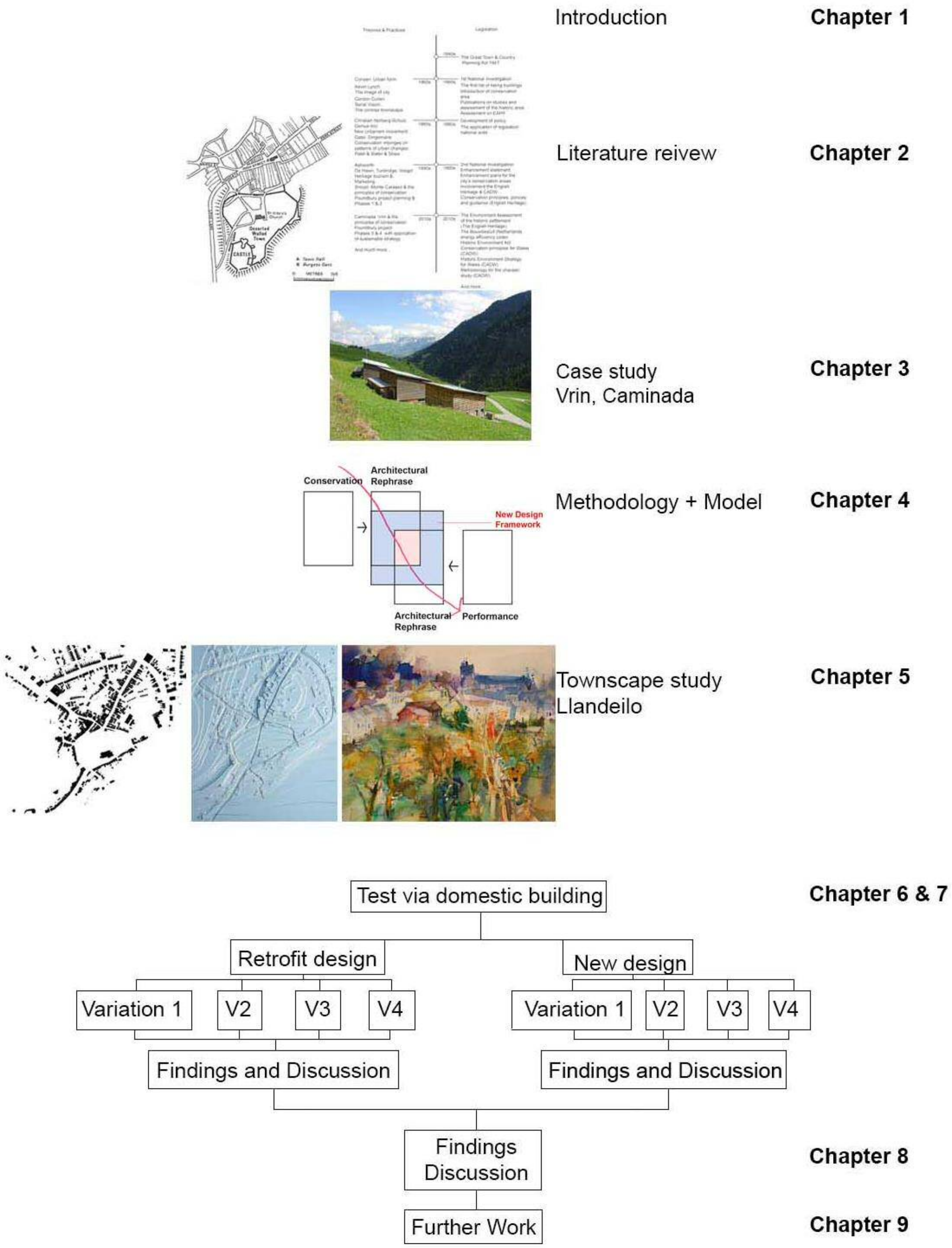


Figure 5: PhD structure diagram

CHAPTER TWO: THE HISTORIC SETTLEMENT

A LITERATURE REVIEW

2.1 Introduction

This chapter reviews the relevant literature in order to:

- Define the historic settlement as discussed in this study, along with its key features (refer to 2.2);
- Analyse the founding principles of the conservation of the historic settlement, along with developments in the field of urban conservation (refer to 2.3);
- Outline components and assessment tools of building performance under UK and EU energy framework and its relevance to this study (refer to 2.4),
- Identify gaps in need of being addressed.

The literature review (see 2.2) commences by explaining the characteristics of the historic settlement; a phrase that can be used to refer to 'medieval towns' or 'the market towns'. It establishes the existence of a number of principles employed to classify a settlement, including its history, layout, population, economy, and services. These features and principles are employed to define and describe the historic settlement in detail.

This is followed by a review of the literature focussing on townscape (in 2.3), and the study of urban form, with implications for the historic settlement. This fulfils the research objective of analysing the principles of the conservation of a historic settlement, along with further developments in the field of urban conservation. Since the 1960s, studies relating to urban form and conservation strategies covered various levels of urbanisation, from the US metropolitan city to the English medieval town. In 2.3, the literature review follows a timeline from M.R.G. Conzen's (1960) study of urban form in the British school, followed by Kevin Lynch's (1960) study of urban images in the USA, and Gordon Cullen's (1961) townscape study of Britain in 1960s, followed by Christian Norberg-Schulz's (1981) study of place in 1980s in Europe, together with the New Urbanism trend arose in the same decade. A summary of the theories covered will be given at the end of this section to justify the importance of the characteristics of the historic settlement, and the importance of maintaining its fragile features.

Section 2.3 also includes a review of the UK conservation legislation established in relation to the initial UK Town & Country Planning Act of 1947. Initiated in 1947, but not fully established until 1967, this legislation was established to: (1) conserve areas of special architectural or historic interest; (2) prevent the sprawl and extension of historic centres, leading to a change in their character; (3) prevent the destruction of historic towns as a result of economic pressures and issues with traffic; and (4) to find new uses for old buildings (Ross, 1991). Development of conservation legislation in the recent decade emphasises values of the historic settlement as a fragile and non-renewable asset, that social, economic and environmental benefits result from sustaining the historic characteristics of a location, and bequeathing it to future generations (CADW, 2011). It is therefore important that a historic settlement alongside most aged buildings establish an effective balance between maintenance and change, in order to fulfil a sustainable commitment to making the most effective use of a non-renewable resource for both current, and future, generations. Finally, this information is placed on a timeline that outlines theory and legislation with implications for historic settlements.

The final section of the literature review (in 2.4) discusses the environmental sustainable approach towards historic settlements and buildings that has been in place since the 1990s. By outlining the measures and assessment tools of building energy performance, a framework is established to test and verify following case studies. UK and EU energy policy and action plan is also reviewed and summarised to explore carbon emission target in 2020 and afterwards.

2.2 The Historic Settlement

2.2.1 Introduction

This section introduces the origins of common town forms, followed by the definitions of a medieval town, and market town, along with the classification principles and features established in the literature. This is followed by a general definition of the historic settlement, using the features and classification principles outlined above to distinguish this settlement from its alternative names (e.g. medieval town and market town). Since the end of the twentieth century, historic settlements have been identified as the most desirable places to live, due to their human-friendly size, unique characteristics, and slow pace of life. It is also noted that these settlements are facing considerable challenges when it comes to conservation, due to their (1) condensed and compact form; (2) small size; and (3) fragile urban performance. It is therefore vital to clarify the scope of the historic settlement, as well as identifying it features, in order to facilitate further study.

2.2.2 Origins

A typical English historic settlement tends to have its origins in a defensive facility, or political centre, either Roman, or earlier (Hindle, 2002). Along with an increasing number of inhabitants, and the consequent growth in the size of the town and its local networks, a settlement is one that has established a fundament role in the provision of services, while also providing a stable centre for social and cultural activities.

The location and site of a town determines its shape, layout, and further development (Conzen, 1960). The most suitable location for a service centre originates from having a geographic advantage, e.g. being located near roads or navigable water. Most prosperous large market towns were built in locations carefully chosen by landowners, including near seaports or water, or at a road junction. These towns have both survived, and strengthened, through attracting additional inhabitants, new cultures, and improving the economy, i.e. over three quarters of the larger towns in England are directly accessible by navigable water (Hindle, 2002).

A number of these towns have developed into regional political and culture centres, as a result of the flow of human beings and information brought by water or road. During the medieval period, the church became the centre of each district, with the power and influence of the abbey, cathedral and church exceeding that previously held by a castle and fortification. As a consequence, the centre of the settlement also became located around the church rather than the castle. During this period, the marketplace played a further important role in providing a communication point for the community other than church. The marketplace is therefore recognised as a symbol of the medieval town (Hindle, 2002).

A rapid increase in small historic towns commenced during the fourteenth century as a result of the Renaissance. The medieval burgage was formed during this period, with additional terraces for domestic and non-domestic purposes constructed within the limited centre of a town. During this period, street networks were also improved and enlarged, while well-connected pavements resulted in the establishment of new quarters outside the town centre. These new quarters attracted upper-class families by their spacious sites and quiet neighbourhoods. The marketplace was also developed during the fourteenth century, with market halls becoming popular, with their guarantee of being able to hold regular events in all weather conditions. These indoor market halls were built in various shapes, one being the octagonal cross, which can be widely observed as a distinctive medieval feature that is still retained in historic market towns (Figure 6). Market halls were primarily built in stone, with the only remaining wooden market hall in the UK being a two story ‘booth’ market hall in the Welsh town of Llanidloes, and which is a source of pride to the local inhabitants (Figure 7).

Figure 6: Octagonal market crosses are widely found historic settlements across the UK
(left: historic image of the octagonal market cross in Cornhill (Cornhill Council, 2002); right: market cross in Malmesbury, built in the 1490s (Westby, 2011))

Figure 7: The well preserved timber framed market hall in Llanidloes in Wales, constructed in the 1610s
(left: contemporary picture; right: historic image (Llanidloes Council, 2006))

In the nineteenth century, as a consequence of rapid economic development and urbanisation, uncontrolled town expansion became the major issue for such historic settlements, with loss of identity being recognised as a particular issues for larger towns (Mayer, 2009).

2.2.3 Town Shape

Conzen (1960) noted that the study of the shape of a historic town is crucial for assessing and estimating its origin, role and growth. The two main influences for shaping a settlement focus on (1) major traffic networks, and (2) geographic location (Conzen, 1960).

The traffic network has historically proved to have the greatest influence on the growth of a settlement, due to the role of traffic in attracting trade and consumers. Historical records exist that establish the town's owners and inhabitants have made regular attempts to construct a new road or a new bridge to provide the town with a bypass to connect it to arterial roads (Hindle, 2002).

The geographical location and natural environment surrounding a town also posed a limit on its growth, thus affecting its shape. Geographically advantageous sites (i.e. in the proximity of a waterfront), were preferred by town owners, leading to a greater likelihood of this being developed into a larger settlement. Norberg-Schulz (1981) concluded that this arose from the instinct of human beings to aim for geographically beneficial sites. Thus, the human settlement is the result of an interaction between the human world and the natural world, resulting in a clear boundary between a settlement and the natural environment (Norberg-Schulz, 1981). An example of the ways both a traffic network and advantageous geography can shape a town is Ruthin, in North Wales. Originating from a castle, the settlement was raised alongside a crossing over the River Clwyd, within the dramatic landscape of the Vale of Clwyd. (Figure 8)

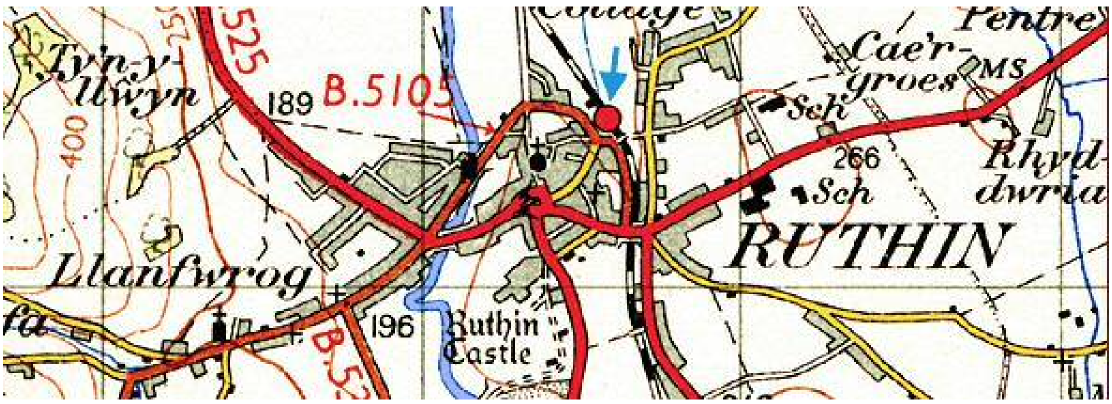


Figure 8: A map of Ruthin shows that the settlement's development is greatly influenced by both of the traffic network and River Clwyd.

A further example is Vrin in Switzerland, which demonstrates the ways a harsh natural environment can shape the layout of a settlement, i.e. dwellings are built in a condensed layout alongside the traffic network, while animal sheds are placed at the edges, facing the meadow, as a barrier to the harsh wind from the Alps. (Figure 9)

Figure 9: A map of Vrin reveals the layout of the village is also influenced by both traffic network and natural environment.

Historic settlements in the UK have a more 'British' layout than the five basic shapes, i.e. linear, nodal, circle, core, and dispersed. In *The Towns of Wales,* Carter (1965) illustrated a number of different layouts of UK towns, while Hindle (2002) also identified the five typical layouts of English with consideration of key features, as follows:

- Town with a central open marketplace: a typical layout in the UK, which includes a number of abbey towns and those developed outside the gates of a castle. The most common shape of the marketplace is triangular, as the original location tended to be at the junction of three roads (Figure 10).
- Linear towns: a town with a main bypass of traffic tends to grow into a linear town, composed of a row of houses and shops on each side of the road, with the marketplace in the central area, i.e. either in the wider section or on the developed divisions of the road. The linear town generally arose following the twelfth century, i.e. at a time when a less defensive structure was required (Figure 10).

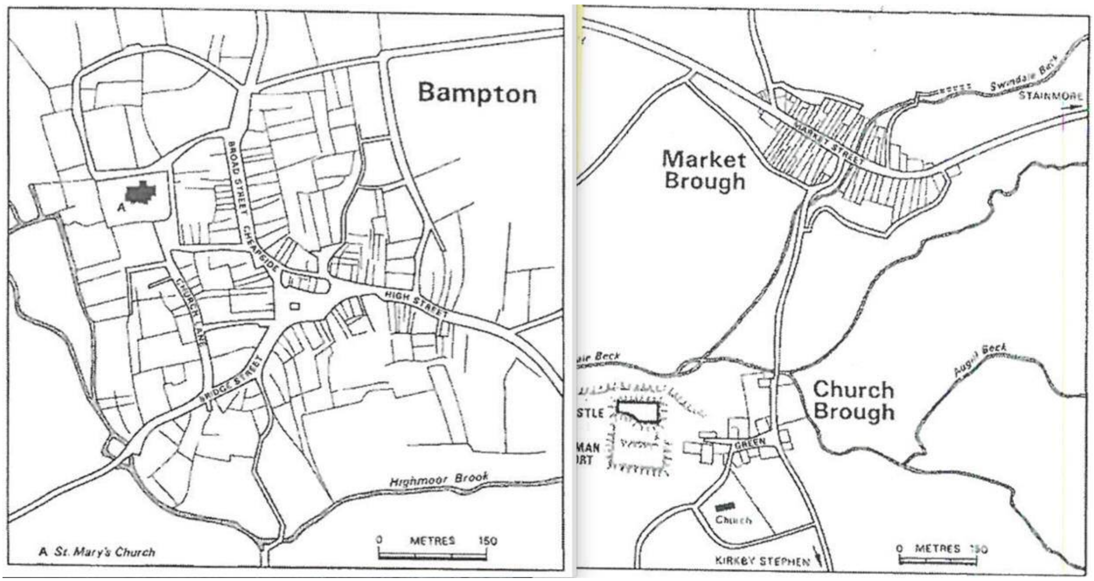


Figure 10: Left: Bampton, Oxfordshire, triangular marketplaces are often found at the junction of three roads (Aston and Bond, 1976). Right: Brough linear market town (Hindle, 2002)

- Castle towns: a town developed outside a castle gate, as populations tended to gather near a castle, both for protection and to provide services. The most common layout is that of a street running out of the castle, with terraced houses on either side. (Figure 11).
- Rectilinear Plans: the majority of new towns created during the Roman and medieval periods in England and Wales feature this layout on a grid plan. Apart from its organic core, the town is divided into several blocks, which are chequered by a number of parallel roads of a similar width. However, the road crossings are normally not at a right angle, due to the geographic limitations and the existence of pre-existing structures. (Figure 11, Figure 12).

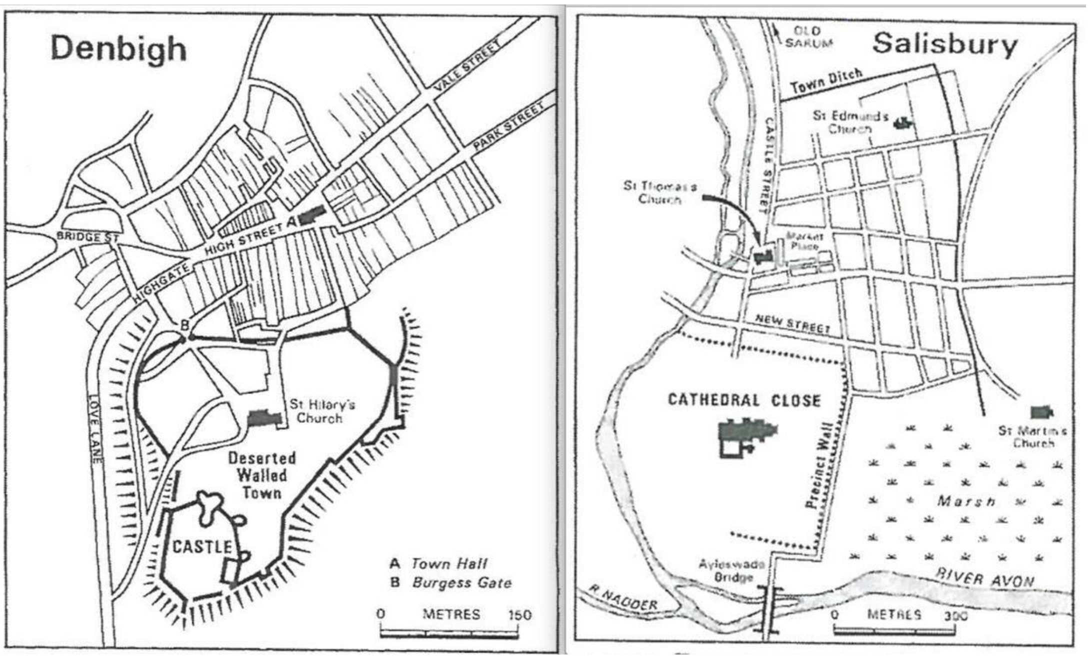


Figure 11: Left: Denbigh, the former walled castle town and new marketplace (Aston and Bond, 1976). Right: Salisbury, a grid-plan town, with large scale formal town planning, founded in 1220s (Aston and Bond, 1976).

- Composite plans. This section focuses on towns whose plans are outside the above four categories. There is no distinctive character to the layout of this kind of town, whose different quarters may have been subject to a number of steps of both planned and unplanned growth. The organic core of most planned towns tend to remain, representing the early stage of growth (Figure 12).

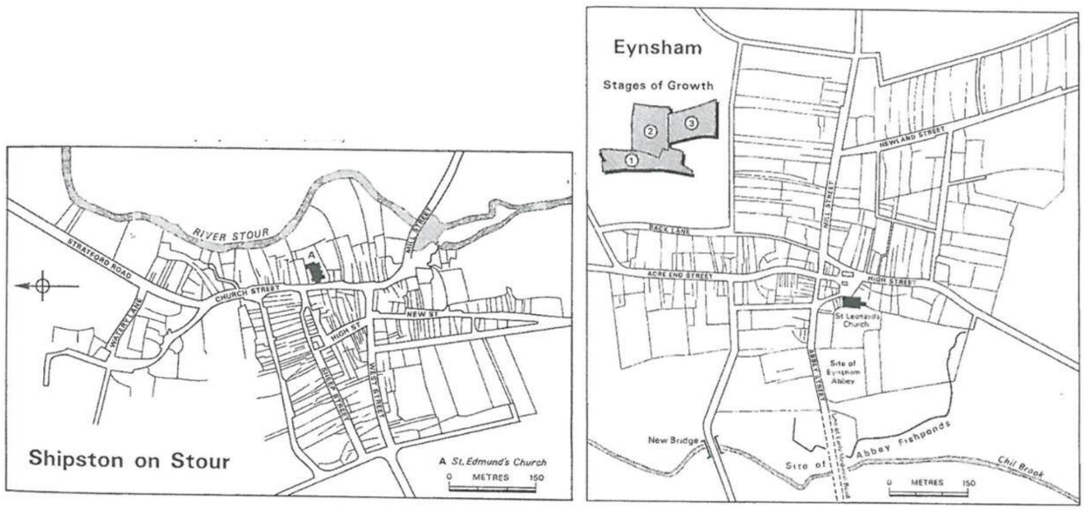


Figure 12: Left: Shipston on Stour, rectilinear plan: a town being enlarged during its various stages (Aston and Bond, 1976). Right: Eynsham, composite layout, with its stages of growth show on the

left top side. Newland Street can be dated precisely to 1215 during the borough extension (Aston and Bond, 1976)

2.2.4 Medieval Town

The medieval town is one in which the settlement has arisen during, or prior to, the medieval era, generally flourishing during the medieval period. The majority of medieval towns certainly retain a number of historic buildings. To be named as a medieval town, Beresford (1988) firstly listed five key features requiring a medieval town must fulfil at least one: (1), A Borough charter; (2), Burgages; (3), Referred to as *burgus* in the assize rolls; (4) Taxed as a borough; (5) Represent a medieval parliament. Hindle (2002) then listed ten 'up-to-date' town features as a renewal of Beresford's (1988) list, stating five key features and ten general features for a medieval town.

The five key features in urban components, separate a medieval town from other historic settlements:

- A medieval street pattern;
- The marketplace;
- A castle and/or other defences;
- A church;
- A medieval burgage, i.e. medieval houses and plot patterns. (Hindle, 2002)

Different from Beresford's list was target on historic political position and social role of a medieval town. Hindle's five key features are focused on physical remaining evidence of the settlement.

The majority medieval towns contain a specific street pattern, shaped by marketplace and medieval burgage. The narrow and winding alleyways, back lanes, pass lanes, and wide openings surrounding the marketplace, are commonly called medieval street pattern as a whole (Hindle, 2002).

Marketplace is also recognised as a key urban elements, who existence determines both the basic function of the medieval town, as well as its essential trading role in the community. Marketplace may appear as various shape, size, and performance: triangular market are typically found, at the junction of three roads from different directions; market places in the linear town can take place where the road widens with a mixture of stalls, shops, and houses (Girouard, 1990); significant medieval town may have large open marketplace for livestock and grain trading.

The third key feature is the castle or other defences appears prior to or during medieval times. Although introduced by the Normans to England, castle and defences such as fortifications are recognised as a symbol of UK. 30% of English towns have been raised alongside a castle, while 85% of Welsh towns were established from a castle (Hindle, 2002). The UK has castles and fortifications of various sizes, popularity, functions and conditions; while almost all of them or ruins (plots) are listed buildings, with a substantial percentage being Grade I (Ross 1996). Castle town is used to name a town developing outside castle walls, regardless the size and population.

From medieval times, the political central of settlements has moved from the castle to the church, leading to a substantial growth in parish churches in medieval towns (Hindle, 2002). However, debates exist on whether a church should be listed as an indispensable element for a medieval town. With the donate of large numbers of parishioners, over 90% of parish churches in the UK remain in good condition, even those that are disused. Unlike castle, most churches, the ancient religious buildings, remain in continuous use nowadays, plus obtaining their social roles for the community.

The final element necessary for a medieval town consists of a pattern of plots and houses forming the medieval burgage. Medieval burgesses had the right to hold property in a town, and (in order to meet the requirement for a frontage on a main street), the plot was divided into a deep rectangular shape, with a narrow width adjacent to the street, and a large depth to the back. It was common for burgesses to build a house at the front of the plot, and to use the remaining backyard space for workshops, gardens, and enclosures.

2.2.5 The Market Town

A market town is one in which a market is held (Thompson, 1995). One in every five English historic towns is named after the function served by the settlement as a market town. In the UK, market towns cover a broad range of size and population, from a hinterland service point (with a population of approximately 1,500) to a sub-regional centre of in excess of 50,000 inhabitants (Wales Rural Observatory, 2007). However, the average population of a market town tends to be between 1,500 and 3,000, and occasionally over 10,000 (Powe, 2007).

The large number of surviving market towns indicates that they were common in the past due to the significance of their functions. In the 1600s, there were approximately 800 market towns in England and Wales (Girouard, 1990), with many more having been in existence in medieval times. The development of modern traffic networks, along with a general increase in transport, has weakened the traditional function of some small hinterland market towns, with a number having turned their marketplaces into car parks.

However, it is important to understand that not all settlements in which a marketplace remains can be called a market town, as a true market town should also provide services and work opportunities for surrounding areas. The broad scope of a market town includes not only medieval towns, but also various small towns in the hinterland holding regular markets, and providing shops and services for the area. Some larger towns now have an established modern retail centre to support the surrounding area. A number of councils have overlooked issues relating to globalisation and a loss of character, considering the modern independent retail centre mode to be a replacement of the farmers' market. However, other literature suggests that the loss of a market (including livestock and farmers' markets), weakens the image of the town, as the market forms a key feature. It is believed that the relationship of the town to agriculture, and the availability of local products, is the natural and fundamental character of a market town.

A town's origins, mode of economy and main source of income, result in corresponding sub-categories of market town, related to the elements of the town's inhabitants, identified by (Powe 2007, pp. 18-19) as: retirement and commuter towns; as employment centres; as service centre or as tourist towns.

- Retirement and commuter towns are related and survive in conjunction with each other. Some small towns are now primarily inhabited by those who have retired, due the overall urban context and culture, which ensure these towns are recognised as a suitable and comfortable place to retire. The cost of living in these towns can also prove considerably higher than others, e.g. Bath. High living costs result in a large percentage of workers being forced to commute from the surrounding areas, due to being unable to afford to live within the town itself. Commuter towns are generally located around a tourist town, retirement town or a large town offering greater employment opportunities.

- There are two different types of tourism towns: (1) a town whose economy is reliant solely on tourism; and (2) a town that also has additional sources of income. A single economic structure tourism town tends to develop from its unique features, i.e. a beautiful landscape or rich culture. It may also have had a core industry, which previously served as its economic foundation, but which has now been discontinued. Blaenau Ffestiniog, in North Wales, for example, has a history of 130 years of quarrying, with the town previously functioning as the service centre and residential gathering place for mineworkers, but has now, with the termination of local slate industry, become a tourist town.

In order to distinguish the market town from other layouts of historic settlement, the Wales Rural Observatory (2007) has categorised each town's position and function into a national economic and social structural model, placing market towns into six models: (1) sub-regional centres: (2) anchor towns; (3) island towns; (4) doughnut towns; (5) satellite towns; and (6) niche towns.

Medieval and market towns are defined through a number of different characteristics and nature: one as a result of their origin, and the other from their function. Although a medieval town is by definition a market town (due to sharing the key feature of having a marketplace), a medieval town also contains a greater number of historic elements and identities in need of preservation. There are therefore many more components to a medieval town than simply containing a marketplace.

2.2.6 The Historic Settlement

Historic refers to being 'famous or important in history' (*Oxford English Dictionary,* 1989). The historic settlement refers to small, compact settlements with a nuclear historic core in shape, containing a highly 'imageable' and distinctive townscape, and playing a central role as a service centre in function. It is a definition that includes the medieval town, the market town, and other smaller settlements containing these key features.

The medieval town and market town are generally defined by their physical components, plus roles and functions under these key features, e.g. medieval street patterns, markets, and service centre. Historic settlements are also defined by a focus on intangible features alongside their physical aspects (Orbasli, 2000). Lynch (1960) described a settlement in terms of 'imageability', i.e. a description of the visual quality of an urban environment: "a highly *imageable* city in this peculiar sense would seem well formed, distinct, and remarkable; it would invite the eye and the ear to greater attention and participation" (Lynch 1960, p. 10). Conzen identified that a historic settlement can provide a sense of place, and retain its fabric and form within a changing environment, as its *genius loci* (Conzen, 1960). There are a number of further descriptions concerning intangible features, including the following: “something we want to appreciate and experience to the fullest extent” (Masser et al 1994, p. 31); “the contemporary uses of the past” (Ashworth 1997, pp. 4-5); “a new cult, whose shrines and icons daily multiply” (Lowenthal 1996, p. 1); “a special sense of belonging and of continuity that is different for each person” (Millar 1995, p. 120); and “a root of contemporary urban, building, culture and social” (Orbasli 2000, p. 2).

The historic settlement is in contrast to the contemporary urban character. Conzen (1961) is of the view that the morphology of a settlement may be broken down into three dimensions, i.e. (1) physical; (2) spatial; and (3) social. Three dimensions not only interrelate, but also need to add the consideration of time as a further dimension. The physical dimension involves various physical components, including historic buildings and building groups; urban patterns and fabrics; streets; public spaces; green areas; and urban vistas. The spatial dimension focuses on internal and external relationships, including traffic, internal circulation, and connections with other towns and surrounding areas. The third dimension, is the social aspect which focuses on the town’s inhabitants and users, as well as its community and population (Conzen, 1960; Orbasli, 2000).

It is important to identify the features of a historic settlement from these three dimensions, i.e. physical, spatial, and social:

Physical Dimension	Spatial Dimension	Social Dimension
Town shape	Market space & large squares	Historic and existing role in the community
Land use	Other public spaces	Construction of the community

Street pattern	Clear boundary of the historic core	Growth and regeneration of inhabitants
Major historic buildings	Circulation and traffic	Population
Other aged buildings and building groups with character		Demands from both the locality and the community
Street performance		
Urban fabric		

In order to preserve all features in the chart, conservation strategies must cover all dimensions, especially those intangible features.

2.3 Conservation of the Historic Settlement

2.3.1 Introduction

This section focuses on the established measures and approaches of urban form study by means of a timeline. The method of identifying human settlements, especially a historic one, commenced in the 1960s, and covered a range of subjects, from Conzen's (1960) study of the urban form in the British school, and Lynch's (1960) study of urban image in USA in 1960s, followed by Cullen's (1961) townscape study in Britain, then Norberg-Schulz's (1981) study of place and new urbanism trend in the 1980s. There is a brief introduction of each theory and its proposer, followed by each study objective and methodology, and the further application of the theory in the conservation of the historic settlement.

This section reviews the UK conservation legislation established as a result of the Town and Country Planning Act of 1947, including its conservation strategies and enhancement schemes for conservation areas. As a reflection of the theories, the conservation legislation commenced with historic buildings and remnants, gradually followed by the introduction of larger settlements. The introduction of conservation areas in the 1960s was closely related to the establishment of theories concerning urban studies related to the urban form, visual impact, and environmental character. During the period of the preservation of fragile historic settlements, the enhancement scheme was introduced on 1990s, being primarily focused on both preventing the sprawl of historic towns and the destruction of the historic centre, as a result of economic pressure (Ross, 1991). Cadw (2009-2015) published appraisals related to urban characteristics that covered a series of historic towns in Wales, emphasising the value of the historic settlement as: “any part of the historic environment providing a distinctive historical association or identity may be considered as an historic asset with four values of evidential value, historic value, aesthetic value, and communal value” (Cadw 2011, p. 11). Cadw (2012) subsequently initiated the historic environment scheme, which specifically stated the importance of interpreting historic character as the core of local distinctiveness and sense of place. On the other hand, the energy policy since 2003 together with followed sustainable design coding made influences on the conservation activities of the historic settlement.

The timeline (see Figure 13) illustrates the establishment of the theories and legislation with implications for historic settlements.

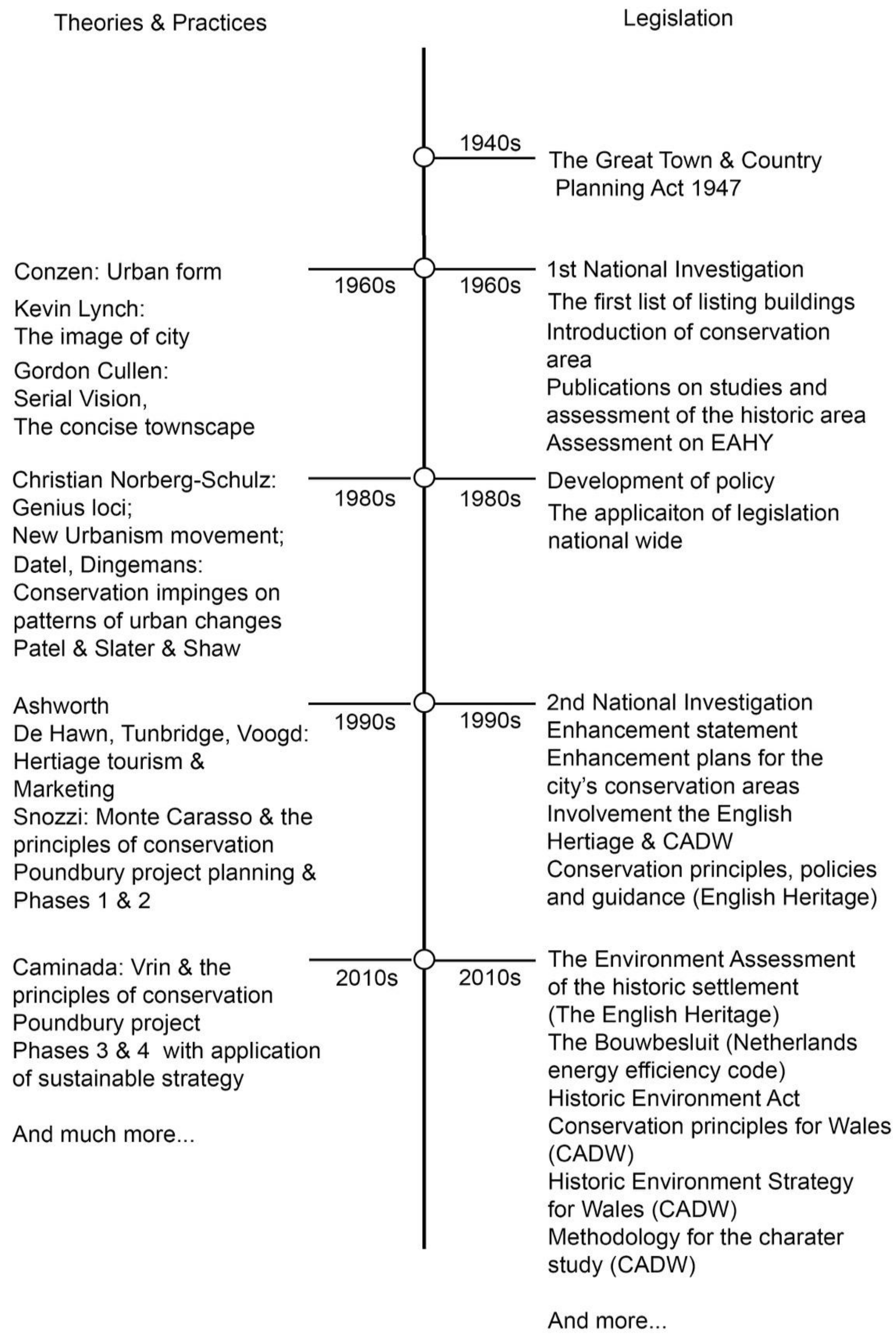


Figure 13: Timeline of theories and legislation with implications for historic settlements

2.3.2 Theories and Practices Since the 1960s

1960s – 1980s

From 1960s, the British school focused on describing, analysing and explaining how urban form is made (Conzen, 1968), concentrating primarily on town planning. Conzen (1968), having a background in geography, viewed the town plan as a vital geographic display of a town's physical layout, containing all the essential characteristics of the urban form. He was of the opinion that three kinds of key documents outlined the urban form, i.e. "the town plan, the distribution plan of urban building types, and the distribution plan of urban land use" (Conzen 1968, pp. 128-145). These three key documents corresponded to three urban analysis methods: "town plan, the building fabric (made of buildings and related open spaces), and the pattern of land and building utilisation (detailed land use)" (Conzen 1978, pp. 113-116). Conzen identified the fundamental unit of a town plan to be the individual plot, described as: "the basic element of the pattern of land subdivision and acts as an organisational grid for the urban form" (Conzen, 1960). Conzen also claimed that the appearance of a townscape is a revolutionary process, resulting from variations in society and culture, i.e. the characteristics of one particular period appear, while others are disseminated and erased by time.

Conzen (1960) employed UK medieval towns to test his studies and verify his theory, selecting a documental study of urban form (i.e. town plans, building types and distribution plans), along with a comparison of historic maps to establish the transformation of the physical urban form. Conzen's (1960) study covers two dimensions: (1) the town plan study of urban form; and (2) a social study related to the origin of a town, along with its transformation and performance.

In the 1960s, Lynch (1960) proposed evaluating visual quality in the USA by studying citizens' mental images of the exterior urban settlement in order to examine the American city. Lynch's study included the observer, the inhabitants of the city, and users of the settlement, encompassing the views of diverse classes and characters to reveal an overall perception of the features common to urban settlements. Rather than analysing the urban form in isolation, Lynch (1960) studied the image of the city through the sensations of human beings, focussing on the exterior of the physical environment. During the progress of establishing urban image, he used the terms *legibility* or *visibility* to evaluate the visual quality of a settlement: “whose districts or landmarks or pathways are easily identified and are easily grouped into an over-all” (Lynch 1960, p. 3). Lynch also gave a definition of the *imageabilty* to the image of the city, to describe a settlement with the ability to create a mental image of identity and structure, in stronger terms than *legibility* or *visibility*:

> That quality in a physical object which gives it a high probability of evoking a strong image in any given observer. It is that shape, colour, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment. (Lynch 1960, p. 9)

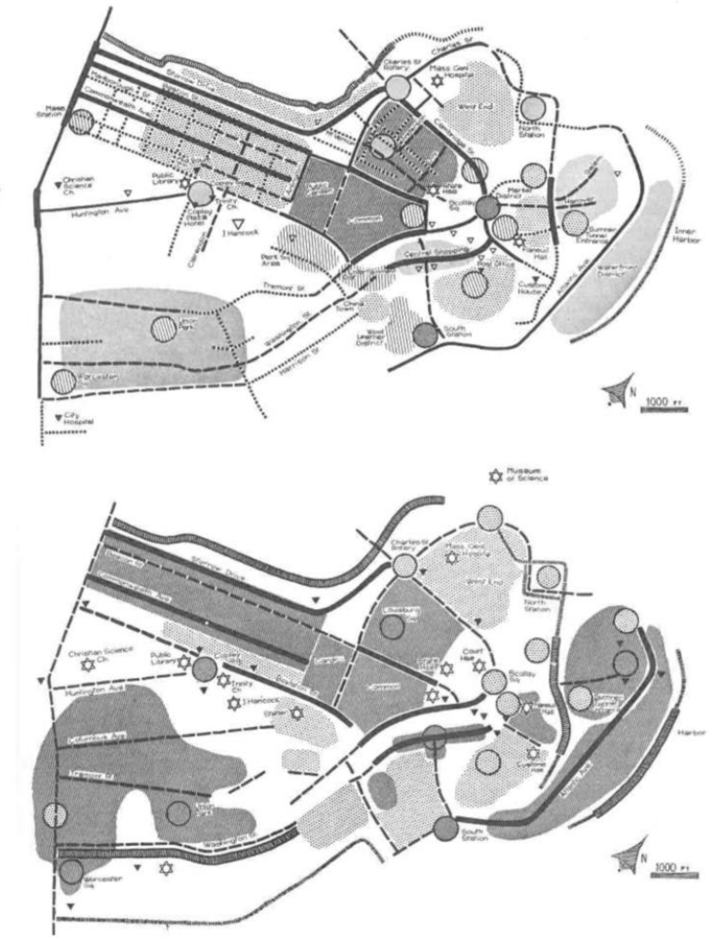


Figure 14: Examples of Lynch's method to 'draw' an image of the city, i.e. Boston, US. upper: the Boston image as derived from verbal interviews; lower: the visual form of Boston as seen in the field (Lynch, 1960)

Lynch used American cities to test and verify his theory, beginning with a first wave of interviews with observers in the office, followed by site inspections and a second wave of interviews at street level, in order to adjust the original urban image sketched during the first wave (Figure 14). Five elements were employed to identify the city image, in order transfer the indescribable mental image of the urban settlement into a physical form, e.g. paths, edges, districts, nodes and landmarks. These five elements, being interlinked rather than standing alone, are considered to be the new symbolic languages that form an integrated aspect of his method, as well as in the reforming of the city image (Sepe, 2013). Lynch's study emphasised the strong element of topological invariance with respect to reality, and the visual quality of a 'place' addressing the issues of structure and identity:

> Above all, if the environmental is visible, organised and sharply identified, then the citizen can inform it with his own meanings and connections. Then it will become a true place, remarkable and unmistakeable. (Lynch 1960, p. 92)

Lynch also considered it highly likely that small settlements are imageable, employing the example of Florence:

> Imageable villages or city sections are legion, but there may be no more than twenty or thirty cities in the world which present a consistently strong image. Even so, no one of these would encompass more than a few square miles of area. (Lynch 1960, p. 93)

Lynch (1960) believed that, in order to preserve and strengthen the structure and identity of a settlement, it is important to create a visual plan for the city, involving both planners and observers, in order to provide "a set of recommendations and controls which would be concentred with a visual form on the urban scale, whose object would be to strengthen the public image". (Lynch 1960, p. 116)

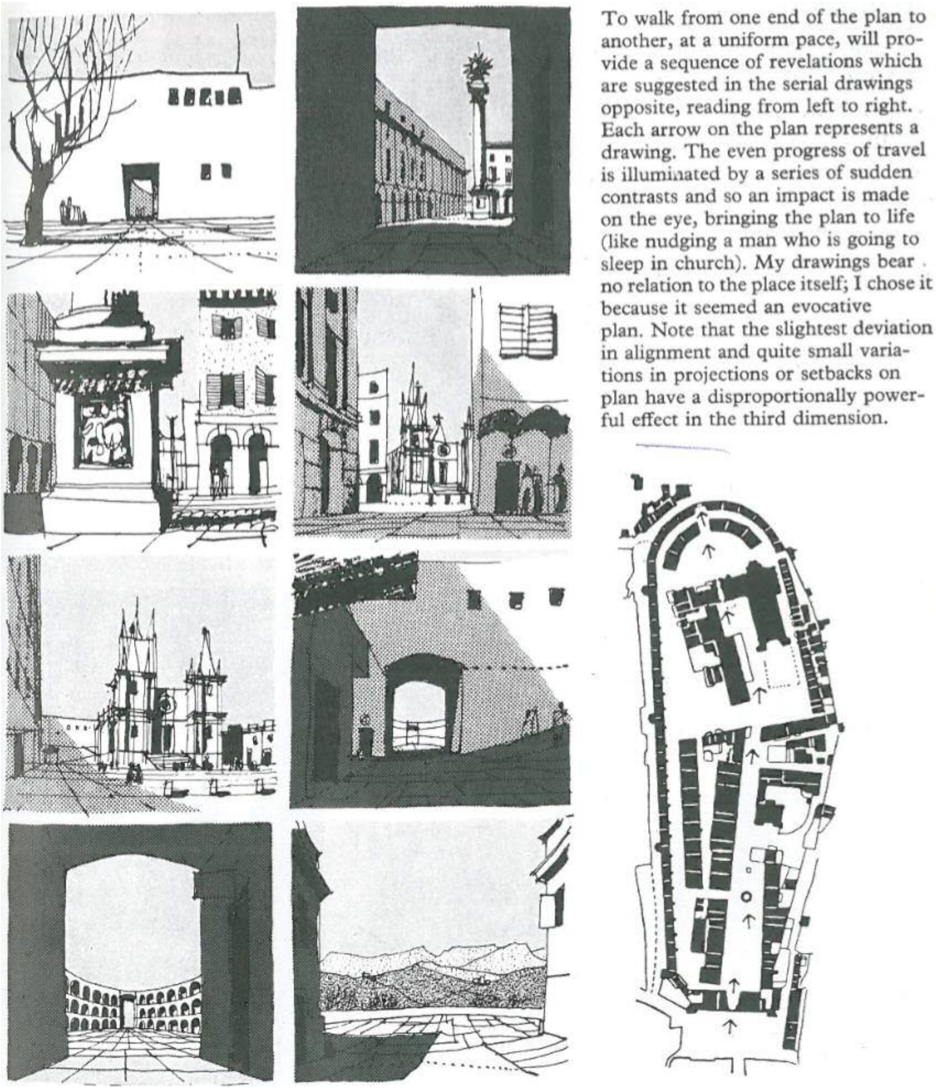


Figure 15: Example of serial vision created by Cullen to study and experience the visual image of a town (Cullen, 1961)

During the 1960s, Cullen (1961) also studied the human vision establishing the theory that emotional reactions to building, space and other elements, could create a response to an entire townscape rather than individual item (Figure 15). Cullen (1961) initialised a serial vision which contrasted records of the visual image of observers through movement at a uniform pace in selected settlements. He established that splitting the human optical viewpoint into the two dimensions of (1) the ‘existing view’ (initial view) and (2) the ‘emerging view’ (imagined from the initial visual impact and other elements), serial vision could be used as a tool to “mould the urban settlement into a coherent drama" by means of an observer's imagination, thus reinforcing its emotional impact and memory (Cullen 1961, p. 9). Cullen thus emphasised that the relationship between buildings and their surrounding elements should be considered an integrated environment created by a townscape.

> In fact there is an art of relationship, just as there is an art of architecture. Its purpose is to take all the elements that go to create the environment: buildings, trees, nature, water, traffic, advertisements and so on, and to weave them together in such a way that a drama is released. For a city is a dramatic event in the environment. (Cullen 1961, p. 8)

Cullen, was thus the first to establish the importance of the emotional impact on observers of the space created by buildings, along with a sense of identity.

Cullen (1961) selected to examine his theory through the historical and traditional English townscape, thus verifying the ways a historic settlement impacted on human beings as a result of its influence on memories. This was considered to take place in three ways: (1) *concerning optics*; (2) *concerning place*; and (3) *concerning content*. (1) *Concerning optics* refers to the emotional impact of the capture of a visual image, either pleasurable or nondescript. He argued that a visual contrast is crucial for the evaluation of whether or not a settlement retains a strong impression, due to the human mind reacting only to a contrast. (2) *Concerning Place* addresses human emotional reactions to the physical environment, corresponding to the theory of the need to recognise a building and its location as a whole. (3) *Concerning content* emphasises the fabric of towns, i.e. their colour; texture; scale; style; character; personality; and uniqueness. Having accepted the fact that the majority of towns have arisen from ancient beginnings, the townscape retains evidence of different periods in architectural style and layout (Cullen, 1961).

Cullen's theory interpreted historic settlements into a three-dimensional complex of plan, building, context, that is both experienced and verified by human motion: "(each) human being is constantly aware of his position in the environment, that he feels the need for a sense of place and that this sense of identity is coupled with an awareness of elsewhere" (Cullen 1961, p. 12).

1980s and onwards

In 1980s, there was an initiation of an investigation into, and illustration of, the ways natural space and man-made space form a factor that is psychological, rather than the practical. Christian Norberg-Schulz's (1981) study of the spirit of place reveals the origins, psychological support, constitutions, and identity of a location. The term 'place' thus refers to a space containing distinct characters in the Genius loci.

> Genius loci is a Roman concept that every 'independent' being has its genius, a guardian spirit, according to ancient Roman belief. The genius loci refers to the spirit of place, being recognised as the concrete reality man has to face and come to terms with in his daily life. Architecture means to visualize the genius loci, and the task of the architect is to create meaningful places, whereby he helps man to dwell. (Norberg-Schulz 1981, p. 18)

Norberg-Schulz also focused on the relationship between human beings and the environment, believing that men and women are the central focus of construction and settlement, in order to satisfy their physical and psychic needs. He argued that earlier studies were too scientifically focused, applying methods adopted from the natural sciences. He therefore introduced the concept of 'existential space' to overcome the lack of the acknowledgement of environmental character in the study of human settlements.

> "Existential space is here divided in the complementary terms 'space' and 'character', in accordance with the basic psychic functions 'orientation' and 'identification'. Space and character are not treated in a purely philosophical way (as has been done by O.F. Bollnow), but are directly related to architecture, following the definition of architecture as a 'concretization of existential space'." (Norberg-Schulz 1981, p. 5)

Norberg-Schulz (1981) verified his study by means of field studies in man-made places around the world, covering settlements from a great variety of cultural backgrounds, along with an analysis of Prague and Rome from the two dimensions of 'spatial structure' and 'character'. Prague and Rome were analysed in the study as examples of established places with a spirit of place, i.e. the *Genius loci* (Goethe and Norberg-Schulz, 1981).

Norberg-Schulz (1981) emphasised that the presence of a settlement is a response to the psychological urge of human beings to build a boundary or threshold from nature through meaningful work. The external spatial morphology of the settlement becomes its general identity, while also forming a significant aspect of the phenomenology of architecture. However, urban space (also referred to as the internal structure of the settlement), respond directly to the general role of the place as a service point or regional centre. i.e. "to fulfil their function, these spaces ought to contain all those things (building, monuments, etc.), the things themselves are the places, and do not only 'belong' to a place" (Norberg-Schulz 1981, p. 176).

Therefore, in order to prevent the loss of the spirit of a place, Norberg-Schulz (1981) drew up a list of elements to be preserved, along with those that should be respected, in order to minimise the impact of unavoidable change on its identity. It is therefore necessary to preserve the location, spatial configuration, and characterising articulation, as these are the objects of human orientation and identification. The list includes primary structural properties, i.e. the type of settlement and building method (including 'massive' and 'skeletal') and characteristic motifs (Norberg-Schulz, 1981). Norberg-Schulz (1981) categorised the unavoidable changes taking place during the process of conservation into three practical dimensions, i.e. (1) social change; (2) cultural change; and (3) the subsequent environmental (physical) implications. The main pressure placed on the *genius loci* relates to new functional demands, resulting in the physical urge for change within the three dimensions.

In early 1980s, new urbanism arose at the opposite position of modernism, metropolitan, and typical post world war II mono-zoning suburban developments, involving discussions on new ways of creating urban form, image and identity. Drawn inspirations from these well-known traditional historic towns in the UK and Europe, new type of urbanity promotes to design a pedestrian-oriented community suitable for living, work, and leisure life. New urbanism also supports the preservation of traditional architectural and urban patterns from urban renewal movement, by which to conserve the unique urban identity and image of traditional stable community (Grant, 2006).

New urbanism advocate that their principles work as a full agenda for policy, planning and design procedure, development practices, that include: (1), the diversity component and usage of neighbourhood; (2), a compact, pedestrian-oriented system in cooperate with vehicle traffic in modern society; (3), reinforcement of public spaces and community institutions in the settlement; (4), the creation of urban place through planning and design, in order to celebrate history, climate, ecology, and building practices (Congress for the New Urbanism, 1999).

New urbanism theory and practices covers a broad scope of projects: in the extent of new interventions, that includes urban conservation, urban restoration, and new development; in the scale and size of the place, that covers a single street, an urban block, a town centre, few suburb areas, and the entire regional neighbourhood (Congress for the New Urbanism, 1999). New urbanism theory encourages and legitimate the growth of the settlement from creating 'small' community with identity through design, while controlling the speed of urban sprawl and planning the shape of the settlement (Grant 2006). The British urban white paper advises the compact, condensed, diversity and mixed-use urban form could be a medicine for uncontrolled suburban sprawl (DETR 2000).

The implication of the new urbanism with sustainable approach appears in all dimensions of sustainability. It has been agreed that the core value of new urbanism, the appeal of compact, mixed use, self-contained, and diverse neighbourhood, is naturally social sustainable (Mayer 2009). In the dimension of economic sustainability, these new communities with more open, liveable, and meaningful urban spaces, are acclaimed to attract various inhabitants and to boost local commercial activities than post-war mono-zoned suburb area (Helbrecht & Dirksmeier 2012). In the environmental aspect, new urbanism theory encourages to create walkable community, using public transport and cycling as a solution to traffic congestion and carbon emission. The principles of encouraging green transport, and locally produced food and materials, are critical methods for achieving environmental sustainability (Congress for the New Urbanism, 1999).

New urbanism theory has been broadly tested by projects through the world, attracting interests from various parties. Poundbury project, initiated by The Prince of Wales, is acclaimed as a successful exemplary of new urbanism new development with environmental sustainable approaches. The masterplan of 400 acres Poundbury was prepared by Krier since 1988 on the outskirts area of Dorchester, a traditional market town. Drawn from historic settlements with a strong sense of place, Krier emphasised the creation of open spaces including squares, enclosures, streets at the planning stage. The total 400 acres are categorised into 250 acres urbanised land for mixed-used buildings and 150 acres of landscaping, play fields, or gardens (The Duchy of Cornwall 2015). As the extension of Dorchester suburban area, Poundbury inherit the urban context and performance of traditional old Dorchester and Dorset architecture.

Proposed to attract approximately 4,500 inhabitants in 40 years by 2025, the entire project is phased into four sections according to the speed of growth of the settlement and market demand (Figure 17). In each phase, an independent small community is created by the designer with a mixture of public buildings, shops, office buildings, houses, and flat. Pummery square, the ‘hub’ of phase 1, is functional as a farmer’s market place, and a community hall, for hosting private and commercial events, occasional theatrical events. Very similar to the layout of small historic settlement, commercials in all sizes, services, and facilities are established alongside the square. (Figure 16) Planning of other infrastructural facilities includes a district centre in phase 2 and a new local primary school in phase 3 and 4.

Figure 16: Pummery Square on a farmer’s market day (The Duchy of Cornwall 2015)

Figure 17: Masterplan of Poundbury project, prepared by Leon Krier in 1988, indicates four phases of the project (The Duchy of Cornwall 2015)

Poundbury Project reflects the increasing environmental concern in its latest development and update, testing and fulfilling stricter building environmental code through design. In order to delivery a low energy consumption and carbon emission community, sustainable design, especially environmental sustainability, is emphasised in phase 3 and 4. A few rules are applied in the priority to cooperate with sustainable strategies: '

- Maintenance of architectural quality without proliferation of 'bolt on technologies';
- An un intrusive system which can be installed to suit master plan layout and building code;
- Compliance with UK and European legislation and incentive are met
- A sustainable rate of build' (The Duchy of Cornwall 2015, p. 10)

As a pilot project, 11 Eco domestic buildings, including 5 houses and 6 apartments are built in phase 3 and 4, rating as excellent by BREEAM EcoHomes rating and 10 by NHER rating. The monitored running costs of these eco homes are 50% lower than equivalent homes built according to 2006 Building regulation standards. Apart from above, in order to introduce renewal energy in the community scale, an anaerobic digestion farm was built in 2012, generating electricity. The biomass boiler, was also employed in service to support hot water for 24 units of houses, apartments, and commercial units. A connection bus between Dorchester town centre and Queen mother square in Poundbury, is powered by electric generated from local anaerobic digestion farm. (The Duchy of Cornwall, 2015)

Also in 1980s, followers of Conzen (1960) (i.e. Slater, (1984); Whitehand, (1987); and Larkham, (1990)) created their own theories on the basis of Conzen's study of town planning. They collaborated to examine the ways in which such knowledge could be applied to the management of historic and contemporary townscapes. Meanwhile, Slater (1988) also focused on the analysis of the town plans of medieval towns, coming to similar conclusions to Conzen (1978).

A timeline for theories with direct implications for the conservation of historic settlements can be found at the end of this section (Figure 13).

2.3.3 Conservation Legislation Since the 1940s

1940s – 1960s

Existing UK conservation policy is founded on the Town & Country Planning Act of 1947, and is made up of two main dimensions of (1) listing buildings and (2) conservation areas. The review follows the time sequence to illustrate the legislation, focusing on its implication for the historic environment. Since the establishment of conservation areas during the 1960s, the value of historic settlements as non-renewable assets has been gradually recognised both by government and the population in relation to the development of the relevant theories.

The listing of heritage buildings containing aesthetic, architectural or cultural significance was initially sanctioned by the Town and Country Planning Act of 1944, which was a development of the earlier 'Ancient Monuments Schedule' scheme. The 1944 Act referred to buildings of special architectural or historic interest constructed prior to 1914, demonstrating respect for recent architecture. Meanwhile, the criteria for selecting listed buildings became increasingly comprehensive and detailed. (Dobby, 1978)

A national investigation into historic buildings and human settlements was undertaken over a period of twenty years, commencing in 1944. The first list was generated in 1968, containing over 200,000 historic buildings. These buildings were categorised into four grades, which were subsequently condensed into a three statutory level system in the 1970s, i.e. Grade I, Grade II* and Grade II. According to the general guidelines, only a very small percentage of buildings qualify to be classified as Grade I (i.e. approximately 9000 buildings, equal to 2% of the total, based on the 1990 records). The majority of these are royal constructions, selected for their historic, rather than architectural, merits. Grade II* is defined as consisting of "particularly important buildings of more than special interest but not in the outstanding class, some second division country houses and churches are in this category" (Ross 1996, p. 71). This grade covers 4% of total listing buildings. The final Grade (Grade II) covers 94% of the total, with the majority of Grade II buildings being of special interest, but not of particular importance (Ross 1996).

The listing scheme focuses on a larger proportion of conservation than regeneration, particularly when it comes to Grade I listing, in which conservation activities must include the maintenance of both the performance, and condition, of the building, including colour, paint and cleanness. The interiors of Grade II and some Grade II* buildings can be altered, under supervision, apart from those buildings with works of arts on the wall. The legislation emphasises that continuous occupancy is vital for the scheme (Ross, 1996), and thus there is a requirement to maintain and enhance the interior of such buildings to increase occupancy levels, by fulfilling new functional requirements, or meeting contemporary standards of comfort. The 2013 survey indicated that listed buildings in Wales had a full occupancy rate of 66.72% (Cadw 2013), as the result of decades of effort under the listing scheme to ensure Britain retains an architectural heritage unique in the Western World (Ross, 1996).

1960s – 1980s

Conservation areas were introduced as part of the 1967 Amenities Act, as an improvement of practice with the addition of areas of special architectural or historic interest, which its character or appearance is desirable to preserve or enhance" (1967 Act 1967). This responded to the establishment of theories following the 1960s related to urban form and visual quality, including noting that the environment of a historic settlement contains additional fragile components aside from listed buildings. In 1976, 3900 statutory conservation areas were identified and recorded, 270 of which were considered outstanding.

It is clear that, when first established in the late 1960s, surveys of the designated conservation areas were entirely based on the discretion of local authorities, or even the standards of individual officers. It is important to review the criteria of East Suffolk County Council, applied when setting a designation area.

> An area selected for conservation should be:
> One where the pattern of streets and enclosed urban spaces, the scale of buildings, their silhouette, the massing of groups of buildings, make a coherent visual unity that has not been spoilt by insensitive development or redevelopment. (East Suffolk County Council 1970, p. 2)

It is notable that the issues of spatial pattern, visual impact and quality raised in Lynch (1960) and Cullen's (1961) study have been firstly referenced in the above criteria. The setting of criteria introduced an element of consistency for future designations and reviews (The Royal Town Planning Institute, 1994).

Between 1960 and 1970, each district council created their own publications focussing on the historic environment, alongside procedures and criteria for establishing designated areas. These publications consisted of comprehensive descriptions of each historic settlement (including its character) within the designated area. The description of a townscape included: "(the) topography of the area, the historical development, construction materials, and the quality and interrelationships of its buildings and of its trees and open spaces". (Ross 1996, p.111) The principles also stated that "certain aspects will almost always form the basis for assessing special character" (Ross 1996, p.111). An example of such a publication is *Vivat Ware: Strategies to Enhance a Historic Centre*, by Townsend and Cullen (1974) for East Hertfordshire District Council, and which formed the pioneer study for the assessment of the historic environment, and was subsequently referenced, including in appraisals in 2010.

An early assessment of British conservation schemes and practice was generated in 1975, during the European Architectural Heritage Year, reflecting their success. In EAHY, Reynolds (1975) reviewed several districts, and conservation areas, concluding "it is perhaps outside the designated conservation areas that the greatest safeguards have to be established" (Reynolds 1975, p. 355). The key issue concerning conservation areas was also argued in EAHY as being "the variable standard in direct proportion to the personalities of planning officers and their staff" (Worskett 1975, pp. 9-18). The financial pressures of conservation schemes were also highlighted during the recession of the 1970s.

1980s – 2000s

During the 1980s, following its nationwide application, the establishment of conservation areas was recognised as a successful approach towards conservation strategy, in ensuring the retention of heritage (Civic Trust, 1988). It was also noted that the conservation zone scheme achieved positive results in preventing the destruction of historic centres under economic pressure from the recession (Ross, 1991). The updating of the conservation measures during the 1980s primarily referred to the increase of control within designated conservation areas, as a result of the reduction of the power of local authorities. It also required that any grant-aided conservation work must make "a significant contribution towards preserving or enhancing the character or appearance of that area" (Civic Trust, 1980, p. 4), while there was a lack of definition concerning the 'significant contribution' (Civic Trust, 1980).

The enhancement scheme proposed in the 1990 Act included preparation for the enhancement of each conservation area. It emphasised that enhancement activity should focus on preserving and reinforcing existing character or appearance of any conservation areas, rather than intervening a new or a false appearance. (1990 Act, 1990) The design guidance published under the enhancement scheme provided clear indications about urban and architectural design elements that contributed to the key characteristics of the townscape in the area (1990 Act, 1990). The guidance indicted that any unsympathetic changes to urban elements (e.g. shopfronts and house extensions) could result in a significant impact on a street scene, while piecemeal changes made by households over the long term could potentially transform the character of entire residential area (Chapman and Larkham, 1992). However, a number of arguments were made that some good and bad practices in proposals were too ‘utopian’ and had little regards to the participation on economic dimension to achieve this success (The Royal Town Planning Institute, 1994).

It is significant that in the 1990s (apart from the continuous practice of the enhancement scheme), policies reinforced the concerns in relation to those areas, including residential areas, which has high quality urban character although without containing any particular architectural or historic remains. It is acclaimed that the setting, layout, open spaces and vegetation may contribute to the special character of the area, together with building heritage. (The Royal Town Planning Institute 1994)

2000s – 2010s

Since the 2000s, there has been a remarkable improvement in the involvement of English Heritage in England, and Cadw in Wales, as the government’s statutory advisors, thus ensuring the implementation of the policies and systems for managing and protecting the historic environment. It has also established the positive relationship between the preservation of the historic environment and economic benefit: “Historic buildings, parks and open spaces make a great contribution to the character, diversity and sense of identity of urban areas. Small-scale improvement to the historic fabric of an area can generate a market-led return to urban living, supporting existing communities and adding to the economic base” (DETR 2000, p. 72). Cadw (2011) further emphasised the value of historic settlements as a renewable human asset: “any part of the historic environment providing a distinctive historical association or identity may be considered as an historic asset with four values of evidential value, historic value, aesthetic value, and communal value”. (Cadw 2011, pp. 10- 14). In the meantime, theories on town form and place-making which have been developing since the 1960s have also contributed to the development of conservation strategies with the aim of identifying the distinctive character of the historic environment and preserve its uniqueness.

English Heritage defines conservation as 'the process of managing change to a significant place in its setting in ways that will best sustain its heritage values, while recognising opportunities to reveal or reinforce those values for present and future generations' (English Heritage 2008, p. 7). It suggests that changes to historic assets are inevitable, such as the erosion or fading of building fabric through natural forces or regular use over time. It is necessary to repair and restore those changes in fabric or other dimensions that can affect the aesthetic values. It is the role of conservationists to monitor and assess changes to ensure the future of the historic asset, ensuring their significance is not diminished as a consequence (Cadw, 2011). English Heritage also confirms that the spatial and social dimension of conservation is as important as the physical dimension of conservation (English Heritage, 2008).

In *Conservation Principles, Policies and Guidance* (2008), English Heritage proposes six conservation principles which provide a comprehensive framework for the sustainable management of the historic environment. These are:

> Principle 1: The historic environment is a shared resource.
> Principle 2: Everyone should be able to participate in sustaining the historic environment.
> Principle 3: Understanding the significance of places is vital.
> Principle 4: Significant places should be managed to sustain their values.
> Principle 5: Decisions about change must be reasonable, transparent and consistent.
> Principle 6: Documenting and learning from decisions is essential.
> (English Heritage 2008, p. 7)

Cadw has also proposed six conservation principles, based on the abovementioned principles, which were tailored and adapted for use in Wales in 2011. Cadw emphasise that the protection and management of the historic environment should be holistic and encompass community engagement, learning, access and the passing on of traditional skills to current and future generations (Cadw, 2011).

Apart from English Heritage and Cadw's efforts on historic environment, in 2003, UK government launched a Sustainable Communities Plan for England, which is a long-term plan to create sustainable communities in urban and rural area, especially under increasing demand on new houses. Since 2004, the nation-wide programme is announced to using 'design coding' to quickly and efficiently produce attractive, well planned environment (ODPM 2003). A design code is an 'operating system', formed by sets of illustrated design rules and requirements, to provide possible instructions and advices on the physical development of a site or an area (Communities and Local Government 2006). Being build upon principles already established in higher layers of policy and guidance, the aim of design coding is to add layers of prescription, setting site-specific design rules from three-dimension. A wide rage of interested parties is involved in the design coding including local planning authority, architects, developers, landowners, and other key agencies. A successful design coding should identify and cover five common objectives to deliver the right design vision: distinctive places, continuity and coordination, public realm quality, creative interpretation, and sustainable design (Communities and Local Government 2006). Also, there are four scales of elements covered in the design code, namely settlement pattern, urban form, urban space, and built form, which could be presented in the combination of drawings, diagrams, and tables.

Been tested through 7 initial pilot studies between 2004-2006 and practiced in more than hundreds of programmes afterwards, the design coding, if used correctly, is acclaimed as a valuable tool to positively identify and control essential elements in urbanism, whilst still allowing for creative design and enhanced market value (Communities and Local Government 2006, Urban Design Group, 2012). Some positive examples include Greenwich Millennium Village, Hulme and Newhall in the UK, Borneo Eiland and Borneo Sporenburg in Amsterdam, Netherlands, and in Germany. Studies on design cases also reveal the codes appears more valuable when encounter: large sites developed as a domestic zone, sites in multiple ownership, and sites that are likely to be designed or developed by different design teams and developers (Carmona 2009). However, some evidence suggests that a design coding created in the form of non-site-specific development or created based on an unclear masterplan is less likely to deliver better urban design (Carmona 2009). Moreover, some surveys reveal architects (Imrie and Street 2006) and developers (Heriot- Watt University 2007) are increasingly concerned about the design coding may stifle their creative design and profitable solutions due to excessively detailed regulations covering all elements.

The design code as a tool, need to be well designed and appropriately used as a solution. It could be style neutral, equally delivering innovative contemporary or interpretative traditional design results. Although good creative designs do not need to be constrained by design codes, however, the code could encourage the delivery of a place with stronger sense, leave less uncertainties on the planning process and push the speed of development. The design code also focusses on two aspects: new urbanism principles targeted on delivering places with better identity and character, and building performance issues aiming to increase energy efficiency which is the concern of this study.

2010s and onwards

The serial appraisals published by Cadw since 2009 to 2015, known as *Understanding Urban Character*, assessed the distinctiveness of the historic environment through characterisation, i.e. identifying how places could be shaped over time and the reason behind their distinctiveness (Cadw, 2009). It was argued that, in addition to building traditions, the character found in the patterns of spaces and connections are ingredients of a unique identity of place. It is important to study and maintain these key ingredients, in order to ensure the special character of a place is retained despite changing conditions (Cadw, 2009). The appraisals covered a series of towns across Wales, each with their own distinctive characteristics. The aim of the study was to establish definitions of the characteristics of a historic settlement, as a solid foundation for planning, design, in order to sustain local distinctiveness (Cadw, 2009). Cadw also indicates that the purpose of assessments is, on a larger scale, to understand the value of historic towns and landscape apart from historic buildings. This is a vital starting point to manage change and sustain the value of the historic settlement as an asset (CADW, 2009).

English Heritage provided similar guidance for assessing the value of the historic environment and its characterisation in *Understanding Place: Principles and Practice* (2011 revised in 2012):

> Historic characterisation is the term given to area-based ways of identifying and interpreting the historic dimension of present day townscape and landscape. It looks beyond individual heritage assets to the understanding of the overall character of a whole neighbourhood or area that is central to securing good quality, well designed and sustainable places. (English Heritage 2012, p. 3)

Assessment of the historic area is a vital and efficient method to understand the 'heritage interest of a small area or neighbourhood, such as a small town, a suburb or a village' (English Heritage 2010, p. 5). The scope of the assessment is also defined as follows: 'on the historic built environment, encompassing both buildings themselves and the elements of the landscape – street and road patterns, boundaries, open spaces – that provide their setting, but it should also have regard to existing knowledge of buried or upstanding archaeological remains in the locality, especially where these have a bearing on the historic evolution of a place' (English Heritage 2012, p. 4).

Since 2010s, the term of sustainable development is frequently mentioned in publications and guidelines of English Heritage and Cadw. The launch of the *Historic Environment Strategy Plan* for Wales by Cadw in 2010, specifically stated the importance of understanding historic character as the heart of local distinctiveness and a sense of place, leading to working with partners from the Historic Environment Group to develop a climate change action plan for the historic environment of Wales (Cadw, 2013). The plan also targeted the conservation, modification, and enhancement of historic buildings at risk, alongside approaches focussing on environmental sustainability. The plan also noted the long-term sustainable strategy to achieve conservation as including an encouragement of conservation, and the development of traditional building skills within the community.

English Heritage launched the *Strategic Environmental Assessment, Sustainability Appraisal and the Historic Environment* initiative in 2013. This is a complex mixture of guidance and assessment measures, targeting the maintenance of the historic environment in England, alongside the achievement of sustainable objectives. English Heritage (2013, p. 2) stated that: "assessment plays a vital part in achieving the target on ensuring that the historic environment we enjoy today is continuously enjoyed by future generations".

Strategic Environmental Assessment, Sustainability Appraisal and the Historic Environment (English Heritage, 2013) provided guidance for the process of environmental assessment when heritage assets are encountered. The historic environment was broadly defined in this report as covering: "a wider range of heritage assets, including area, buildings, features and landscapes with statutory protection" (English Heritage 2013, p. 3). The guidance states that the environmental/sustainability appraisal report resulting from the assessment, should clearly and robustly demonstrate the following issues:

- The significance of heritage assets.
- The impact of proposed sustainability objectives on the significance of the heritage assets and the wider historic environment.
- The impact of proposed policies and plan alternatives to the significance of the heritage assets.
- Any act to avoid (or minimise) any adverse impact on the significance of heritage assets.
- Any act to optimise benefits to the significance of heritage assets. (English Heritage, 2013)

This is the first official guidance for sustainability appraisal reports related to the historic environment (i.e. heritage assets). The decision-making criteria listed in the guidance illustrates principles from the three dimensions of environmental, social, and economic (English Heritage, 2013). However, the detailed criteria (Figure 18) reveals that the guidance fails to mention either the reduction of carbon emissions, or any improvement in the environmental quality of buildings. The guidance emphasises the significance of the historic environment as an asset, but has a lack of detailed illustrations concerning the components of a historic settlement.

APPENDIX 3: DECISION-MAKING CRITERIA

Environmental Criteria

Will it:

- Conserve and/or enhance heritage assets and the historic environment?
- Contribute to the better management of heritage assets?
- Improve the quality of the historic environment?
- Lead to the repair and adaptive reuse of a heritage asset?
- Respect, maintain and strengthen local character and distinctiveness?
- Promote high quality design?
- Provide for increased access to and enjoyment of the historic environment?
- Integrate climate change mitigation and adaptation measures into the historic environment sensitively?
- Alter the hydrological conditions of water-dependent heritage assets, including paleo-environmental deposits?

Social Objectives

Will it:

- Increase the social benefit (e.g. education, participation, citizenship, health and well-being) derived from the historic environment?
- Improve the satisfaction of people with their neighbourhoods as places to live?
- Engage communities in identifying culturally important features and areas?
- Provide for increased understanding and interpretation of the historic environment?
- Provide new leisure, recreational, or cultural activities?
- Support and widen community uses through shared facilities?

Economic Objectives

Will it:

- Increase the economic benefit derived from the historic environment?
- Promote heritage-led regeneration?
- Lead to the repair and adaptive reuse of a heritage asset?
- Make the best use of existing buildings and physical infrastructure?
- Promote heritage based sustainable tourism?
- Ensure that repair and maintenance is sympathetic to local character?
- Secure a supply of local building and roofing materials?
- Help to reduce the number of vacant buildings through adaptive re-use?

Figure 18: The decision-making criteria of the Strategic Environmental Assessment (English Heritage, 2013)

Understanding Urban Character, the series of appraisals concerning historic towns in Wales, published by CADW since 2009 until 2015, form examples of defining the distinctive urban character and verifying the full value of heritage as an asset. CADW stated that the study:

> Serves as a tool for the sustainable management of the historic environment by supporting positive conservation and regeneration programmes. Sustaining the historic character of places is an asset in regeneration, bringing social, economic and environmental benefits. (CADW 2011, p. 3)

This appraisal illustrated the image of a place, covering the local history, urban typography, and performance of area of outstanding character, as well as buildings with character. The study is a successful, and vivid, statement of the significance of the proposed historic town. In *Historic Environment Strategy for Wales* (CADW, 2013) CADW's further focusses on the promotion of conservation and traditional building skills, with the appraisals being beneficial for sustaining such valuable and distinctive assets. However, such appraisals (along with other publications by CADW) fail to mention sustainable development for the historic settlement, and, in particular, the reduction of their carbon footprint.

The following section reviews the inclusion of environment sustainability in relation to building industry and communities in the settlement scale.

2.3.4 Timeline

The timeline of theories and legislation with implications for the conservation of the historic settlements. (Figure 19)

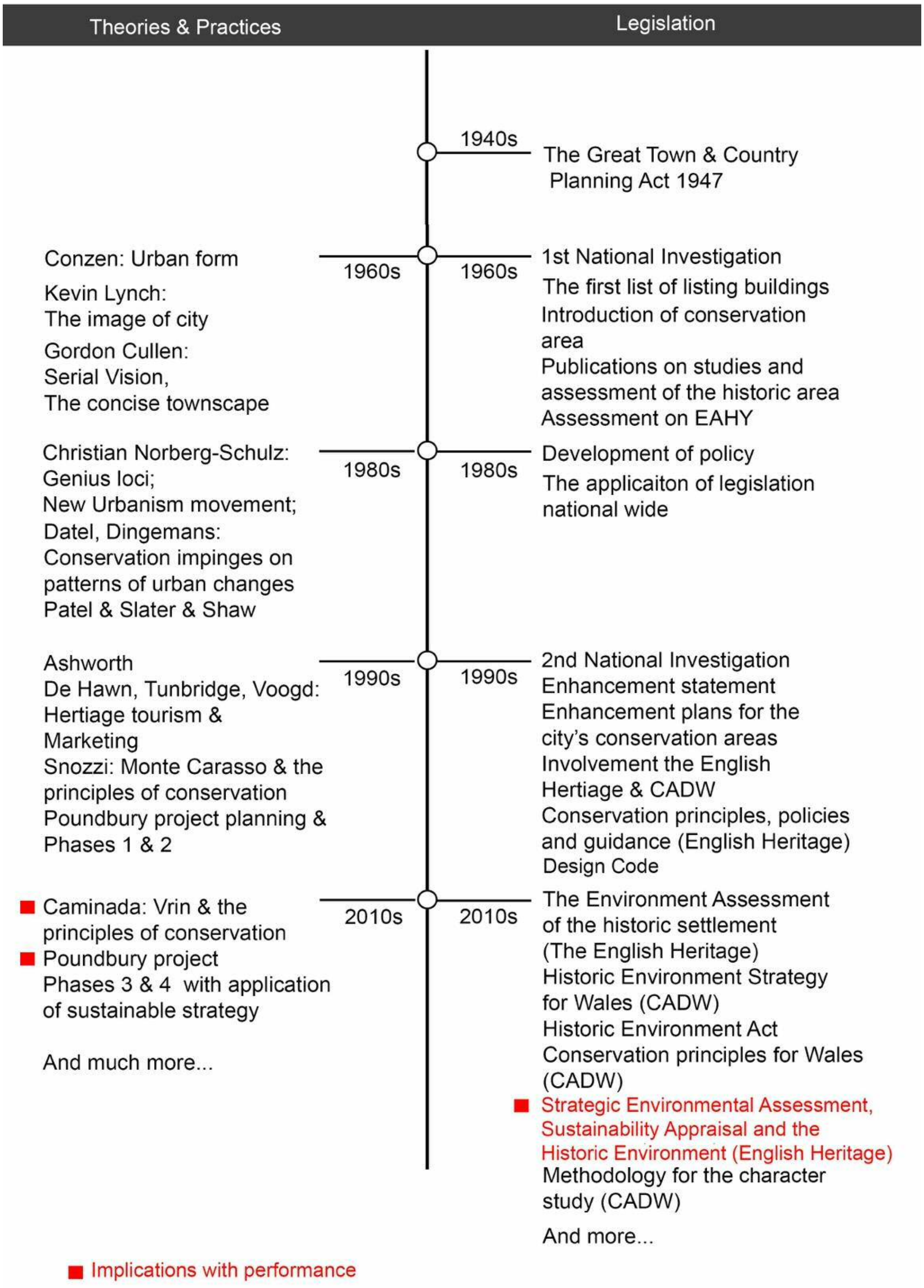


Figure 19: Timeline of theories and legislation with implications for historic settlements

2.4 Performance

2.4.1 Introduction

This section introduces the implications of environmental sustainability in relation to building performance and historic settlements. Section 2.4.2 reviews the literature focussing on the measures and approaches towards environmental sustainability within the building industry. In Section 2.4.3, the review covers a summary of UK and Europe energy policy together with proposed action plans to fulfil carbon emission reduction target in 2020 and afterwards.

The issue of sustainable development had been raised in the later part of the twentieth century, as a result of: (1) climate change; (2) the global increase in pollution; (3) the non-sustainable use of non-renewable resources; and (4) both economic and cultural globalisation. The Brundtland Commission's (1987) definition of sustainable development is a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (WCED 1987, p. 8) However, the generally accepted definition of sustainability is the revised definition, published following the 1992 Rio Earth Summit: "development which fulfils current needs without compromising the capacity of future generations to fulfil theirs". (UNCED 1992, pp. 12-18)

From its initial focus on issues of environmental risk, sustainable development is now interlinked with human development in the three dimensions of economy, society, and environment, as demonstrated by the 'three pillar' model (Keiner, 2005). The 1996 Kyoto summit resulted in a number of additional concrete measures concerning the amount of carbon reduction required to achieve environmental sustainability. The summit also highlighted the importance of an environmental sustaidnable approach on the part of the building industry, as a result of its high carbon consumption and level of emissions from demolition and construction, etc. (Gauzin-Muller, 2002).

2.4.2 Sustainable architecture and sustainable design

Approaches for sustainable architecture can be applied in two stages: (1) during the construction process; and (2) through the lifecycle of a building (Figure 20). There are three different construction methods: (1) a completely new building; (2) the demolition of an existing building followed by a reconstruction; and (3) a retrofit of an existing building. It has been calculated that in all European cities building demolition is responsible for 40% of total energy consumption, and over 24% of human-generated waste across all industries (ODPM 2003). In addition, it has been established that, of the three types of construction methods outlined above, the reuse of old buildings consumes the least amount of energy (ODPM 2003). This leads to the potential for sustainability in the construction industry to be established through a reduction in demolition, and an increase in the reuse, and retrofit, of existing buildings. In addition, it is important to take account of a building's lifecycle when designing a new construction, or a retrofit, in order to save the maintenance and operational expenses during occupancy (Friedman, 2012).

Since the late twentieth century, architects, planners and environmental engineers in the UK and Europe have established effective methods of reducing energy consumption throughout the lifecycle of a building, resulting in low environmental impact and energy efficient buildings. During this process, designers also aim to create a comfortable and healthy building environment, with the minimum impact from the climate. The field of sustainable architecture has developed the following sub-categories: (1) sustainable design; (2) sustainable materials; and (3) sustainable construction (Edwards, 2005).

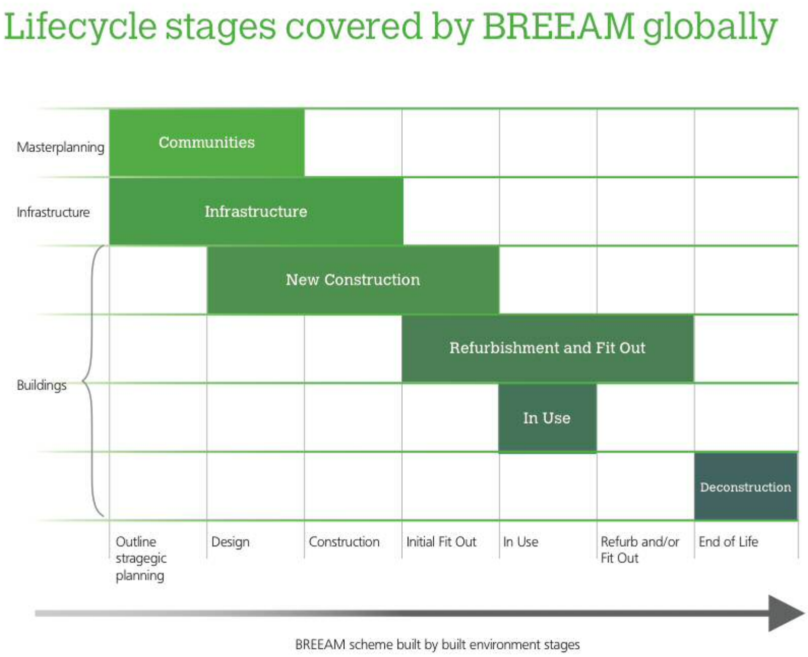


Figure 20: illustration of the stages of the built environment (BRE Trust, 2015)

In 2006 in response to the UK's carbon emission reduction commitment in the Energy White Paper (i.e. a 60% reduction by 2050), the government amended the Building Regulation Part L. The amended part L addressed four key issues:

- The environment;
- Reliability of energy supply;
- Affordable energy for the poorest in the community; and
- Competitive energy markets for business. (BRE, 2006)

Building Regulation Part L also includes measures to limit building heat loss and to control excessive solar gains, enhance energy efficiency, and introduce alternative energy systems (BRE Trust, 2006). BREEAM, as a leading UK institute in environmental assessment, has made a considerable contribution to the establishment of building environmental assessment tools during the design stages of both dwellings and non-domestic buildings to achieve higher levels of energy efficiency. Part L has been updated several times as a reflect to carbon cutting progress, with a 6% increase in the performance standard for domestic buildings in 2014, along with a 9% increase for non-domestic buildings in comparison to the previous version.

According to part L, sustainable design can be achieved through design strategies relating to:

(1) building energy performance;

(2) energy efficiency;

(3) a reduction in carbon emissions;

(4) the use of alternative energy; and

(5) assessment of occupant’s comfort level.

Building energy performance

Passive design is a combination of a number of design strategies employing solar energy to maintain the interior environment of a building within a comfortable temperature range. This is achieved through collecting, storing, and distributing solar heat from openings and thermal mass in winter, while reflecting solar heat, and encouraging ventilation (i.e. the movement of air) in summer (Edwards, 2005). The key aspect of passive design is to ensure the layout of a building, including its openings, take advantage of the local climate and geographic conditions. This emphasises the importance of establishing an accurate site analysis at the initial design stage, including orientation, wind and air pressure during different seasons, along with the existing vegetation. In the northern hemisphere, where less (or no) sunlight reaches the north façade of a building, it is less effective to obtain solar gain from openings on the north elevation, leading to a recommendation to minimise openings on the north in order to prevent heat loss in winter. At the same time, it is recommended that large openings are placed on the southern aspect, in order to maximise sunlight for both heating and natural lighting (Friedman, 2012). It is also recommended that rooms designed for daytime activities should be arranged on the southern section of the layout, in order to benefit from passive design (Figure 21).

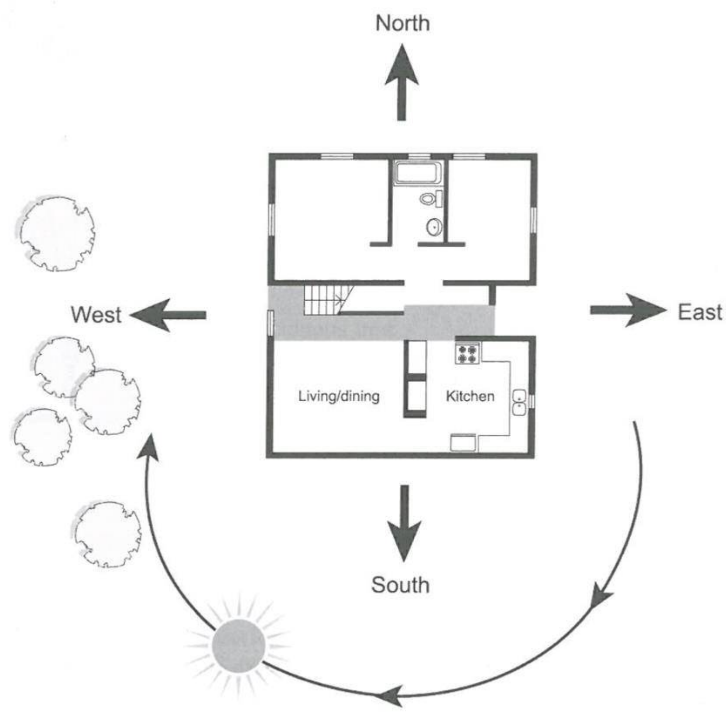


Figure 21: Building layout can be responsive to the site. Rooms used at night, or with lower levels of daytime activities can be arranged along the northern façade, to create an additional insulating buffer. (Friedman, 2012)

Apart from layout, the effectiveness of passive design can be influenced by elements including: the size of openings; construction materials; insulation; thermal mass; shading; and ventilation. Insulation and thermal mass are essential to the thermal comfort of the inhabitants. Firstly, insulation is used to reduce unwanted heat loss or heat gain. Secondly, thermal mass (as part of the body of a building) is used to store heat, thus providing 'inertia' against fluctuations in temperature. Shading and ventilation are also used to ensure the quality of indoor air, and, in the northern hemisphere, to prevent over-heating in summer.

Energy efficiency

Energy efficiency is increased when energy loss through the building fabric and building operations is minimised. A clear understanding of energy efficiency measures ensures that energy is used more wisely. The energy efficiency assessment also monitors the way a building is used in terms of its occupancy and the occupants' activities and lifestyles (BREEAM, 2014).

Carbon emission

The reduction of carbon emissions refers to a deduction in greenhouse gas emissions which affect climate change. There are numerous strategies aimed at minimising energy usage and carbon emissions in the building industry: by encouraging retrofit and reusing existing buildings; through passive design; through the application of low carbon technologies; by producing energy efficient equipment; introducing alternative energy and localising building materials to reduce transport (BREEAM, 2015). For existing buildings in use, carbon emission is monitored as heat loss. The use of double (or triple) glazing, and a fully and highly insulated wall, floor, and roof, are recommended to achieve a high energy performance envelope. Cold draughts can be prevented, or treated, both during, and following, the design stage, in order to prevent inward or outward air leakages. (Figure 22)

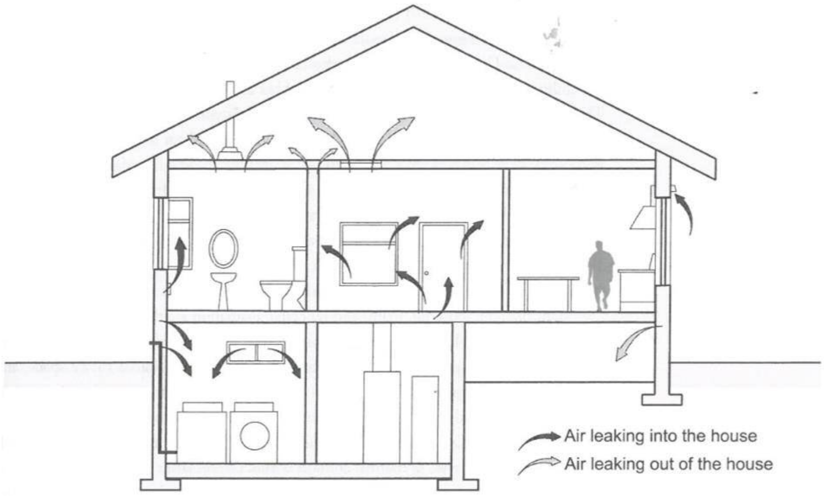


Figure 22: Common air leakage points into, and out of, a building (Friedman, 2012)

The use of alternative energy

An effective measure to meet the tighter carbon emission standard in sustainable design, is to use alternative energy to partially (or fully) replace traditional fossil-based energy. The Office of the Deputy Prime Minister (ODPM, 2006) recommended eight low and zero carbon technologies, as follows:

- Absorption cooling;
- Biomass heating;
- Micro-CHP (combined heat and power);
- Ground cooling;
- Ground source heat pumps (for heating and cooling);
- Solar electricity (Photovoltaic panel and tiles);
- Solar water heating; and
- Wind turbine generators. (BRE, 2006) (Figure 23)

Micro-CHPs, photovoltaic panels, and wind turbines are generally permanently connected to the power grid to ‘upload’ and store excessive energy. All the electricity generated is assumed to displace electricity from the main grid. Biomass heating and ground source heat pumps are, by comparison, more cost effective and more easily accepted in most domestic cases (BRE, 2006). By estimating the levels both of cost and carbon saving, designers are able to estimate the outcomes following installation. It is also important that a designer understands the full scope of each product, in order to create a suitable installation plan for each case.

Compared to other principles, the installation of some renewable energy system may greatly lay impact on the visual image of the building, even the townscape, i.e. photovoltaic panel on a street frontage, or wind turbine in landscape.

Figure 23: Alternative renewable energy systems

Assessment of occupant's comfort level

The occupants' comfort level, related as it is to human health and wellbeing, needs to be taken into consideration at the design stage to create a high value asset. BREEAM lists five aspects of the indoor environment, which are linked to the occupants' comfort level: indoor pollutants, temperature, ventilation, daylight, and sound insulation (BRE Trust, 2015). There are corresponding design strategies for each component of the indoor environment to achieve a high quality indoor environment. The occupants' feedback and post-construction monitors are also important.

The following chart (Figure 24) indicates how BREEAM assesses the indoor environment according to two aspects, which relate to the life cycle of the building: the physical performance and building operation. Regulations which clearly define the comfort levels in buildings are still limited.

	BREEAM In-Use	
	Part I: Asset Performance	**Part II/III: Building/Occupier Management**
Indoor environment (Health and Wellbeing)	– Daylighting – Glare Control – Thermal comfort (occupant control) – Ventilation (occupant control) – Microbial contamination – Light levels – Lighting (occupant control) – Ventilation (provision of fresh air)	– Ventilation / fresh air rates – Operating temperature – Monitoring air quality – Monitoring noise – VOCs – Acoustic conditions – Deep cleaning – Legionella management

Figure 24: How BREEAM addresses health and wellbeing across different life cycle stages of the built environment (part of table for indoor environment (BRE Trust, 2015)).

Measurements to assess carbon emission, energy, and environmental performance

The requirement of assessing the environmental impact of all buildings (including dwellings and non-domestic buildings) at the design stage was established in the building regulation Part L. (BRE, 2006) The energy calculation tools (e.g. the SAP, Standard Assessment Procedure), under the propose of simulating energy consumption during the design progress, for dwellings and other buildings were also introduced by the regulation. Developed by BRE based on BRE Domestic Energy Model (BREDEM), SAP is now used as an official calculation tool to assess energy performance of all domestic buildings not exceeding 450m2. Apart from SAP, SBEM (Simplified Building Energy Model) is the default tool for calculation carbon emission for buildings containing floor area greater than 450m2 (BRE, 2006). SAP rating is based on energy consumption associated with space heating, water heating, ventilation, and lighting, then deducing energy generated from new technologies. Calculated based on Energy Cost Factor (ECF) in the form of a worksheet, SAP takes into account a range of factors including construction materials, thermal insulation, ventilation characteristic, heating system, openings, solar gain, water heating, lighting, and renewable energy installation (BRE, 2006). SAP rating is not affected by the geographical location of the building in the UK. SBEM calculates BER (Building Emission Rate) and carbon dioxide emission based on a description of the building geometry, construction, use, airtightness, HVAC (heating, ventilation, air conditioning), and lighting equipment. SBEM calculates a carbon emission value of a ‘notional building’ of the performance and geographic location as the proposed building; then target carbon emission value is defined on the base of this ‘notional building’ with the application of the Regulations. Requirement of providing EPBD (Energy Performance of Building Directive), also known as energy performance certification for both new and existing buildings, is now enforced by UK building regulation. (BRE, 2006).

A SAP calculation is based on the four main aspects of elements of structure, heating and hot water system, internal lighting and small appliance, and renewable technologies. Although the rate normally ranges from 1 to 100+ for the annual energy cost, negative SAP rating is possible in the case of very inefficient homes, such as a solid stone wall terrace with a pre-year 1979 boiler. For retrofitting of these properties, some small cumulative measures, such as insulating the boiler, upgrading heating controls, or loft insulation, will make no or very limited impact on the SAP rating. It is because of the method of Calibration of CO2: 'improvements on energy efficiency' could sometimes be different to 'reducing environmental impact and carbon emission' For example, switching from bottled gas to mains gas could possible be an improvement in the SAP score, but the environmental impact would remain the same with the same amount of CO2 emitted every year. The estimated energy saving from solar hot water and PV also seems very conservative compared to BRE guidance in domestic building retrofitting cases. (Banks 2008)

Apart from simulations on carbon emission, BREEAM creates a large range of assessment tools and standards to assess buildings in various categories, such as new buildings, building in-use, refurbished buildings, etc. Most assessment tools are point-based framework, equipped with corresponding manual and standard. BRE tools may cover a series situation from construction to occupancy.

It is significant to note that measures for sustainable design may impact on existing buildings in relation to the establishment of an 'improved' building envelope, while at the same time retaining its historic character. Review of UK and some European energy policies in section 2.4.3 reveals exemptions or special instructions for historic architecture or buildings improving energy performance are now listed in the recent amendments of the code. Should any conflicts occur, detailed and practical measures or guidance may preserve the unique building character from being replaced or destroyed.

2.4.3 UK and European Energy Policy

As a response to greenhouse gas reduction target, strict standards and frameworks are established and legitimated to maximum energy performance efficiency for demotic and non-domestic buildings, also known as code for sustainable homes/ buildings. This review and comparison of building regulation for energy performance efficiency in UK and some European countries covers few crucial aspects: (1), the coverage and enforcement of the regulation at the current stage; (2), plan or strategies to achieve nearly zero-energy target 2020; (3), any recent amendments of the code related to historic buildings or existing buildings with historic interests.

U.K.

The building regulation conservation of fuel and power: approved document L (Part L) in England and Wales is a building performance based code, setting prescriptive energy efficiency criteria for all new and existing buildings in national wide. From its introduction on 2005, the code and building regulations have been strengthened several times in order to achieve national nearly zero carbon emission target in 2020. Documents L1A and L1B is targeted on fuel and power consumption in new and existing dwellings; and Documents L2A and L2B are applied on all other new and existing non-domestic buildings. Strict requirements are now listed in Part L including: Design Emission Rate (DER) should not exceed the Target Emission Rate (TER), plus, the calculated Dwelling Fabric Energy Efficiency rate (DFEE) must not greater than the Target Fabric Energy Efficient rate (TEFF) (HM Government 2013). The code addresses on building thermal envelop, building air tightness, main energy consumption system, and the installation of renewable energy. Apart from baseline on DER and DFEE, it provides the basic U-value standard for building fabric of all domestic and non-domestic buildings, and regulates the mandatory computer modelling and simulation at design stage before construction commencing, such as using SAP for domestic buildings. The post-construction assessment by an accredited energy assessor is once again enforced to verify that the DER and DFEE rate has been met when work is complete. Airtightness test, inspections and certifications of all appliances, such as boilers, HVAC systems, all lightings, are enforced. The installation of any low-carbon or renewable energy technology for offsetting carbon consumption is recommended. The code also covers the energy efficient operation and user's behaviour at use: the owner of the building should be provided with sufficient information about the building and the operation manual, to achieve the expected level of building energy efficiency in building's life cycle (HM Government 2015). The regulation covers a full list of building functions that is related to carbon consumption and emission (CO^2 in kg):

- Position and orientation
- Passive design
- U-value of building envelope
- Heating and cooling
- Airtightness and dehumidification
- Thermal bridging
- Ventilation
- Boiler and hot water
- All other mechanical parts in the building (pumps etc.)
- Lighting
- Solar gain and solar protection.
- Daylighting
- HVAC systems
- All other appliances
- Renewable Energy (solar, PV, others)

The UK building regulation encompasses almost all energy efficiency techniques, building performances, and renewable energy that is related to building industry. By announcing the legally binding target for carbon reduction in 2008, UK has been a model and pioneer in energy policy, and certification scheme. However, there is lack of a determined plan for carbon reducing processes before 2020 and detailed penalties for non-compliance of the code.

The 2015 amendment of the code indicates historic and traditional buildings, including dwellings and non-domestic buildings, may have an exempt from the energy efficiency requirements: '

- listed in accordance with section 1 of the Planning (Listed Buildings and Conservation Areas) Act 1990;
- in a conservation area designated in accordance with section 69 of that Act; or
- included in the schedule of monuments maintained under section 1 of the Ancient Monuments and Archaeological Areas Act 1979'; (HM Government 2015, p. 7).

For these listed historic and traditional buildings, the exemption only applies to an extent that the energy efficiency regeneration would alter the significant building character or appearance.

Ireland

Ireland's Building Regulation Part L (released in 2002, with latest Amendment in 2017) is also a performance-based code that requires energy frame calculation from design stage and mandatory inspections on and after the construction phase to control the carbon mission. The code is formed by two sections, one for dwellings and another for buildings other than dwellings, all equipped with detailed standards and baselines. Penalties for non-compliance of the code are fines and refusal of permission to occupy. Ireland's Part L encompasses many progressive and dynamic aspects that includes:

- Position and orientation
- Passive design
- U-value of building envelope
- Heating (space heating and water heating) and cooling
- Heat recovery
- Airtightness and dehumidification
- Thermal bridging
- Ventilation
- Hot water
- All other mechanical parts in the building (pumps etc.)
- Lighting
- Solar gain and solar protection.
- Daylighting
- Renewable Energy (solar, PV, others)

The 2011 update of Part L highlights the application of the environmental assessment to buildings of architectural or historical interest. Measures for a sustainable retrofit are advised to undertake further assessment of their "material and visual impact on the structure". (Environment, Community and Local Government 2011, p. 10). In addition, historic elements (i.e. windows and doors) are required to be repaired rather than replaced. Should any conflicts occur, retrofit practice should follow the guidance and measures of the Department of the Environment, Heritage and Local Government's *Planning Guidelines No 9: Architectural Heritage Protection - Guidelines for Planning Authorities* and *Energy Efficiency in Traditional Buildings* (Environment, Community and Local Government, 2011).

In 2017 amendment, a clear definition on 'nearly zero-energy building' is provided as:

> " 'nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I to Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast) (O.J. No. L 153, 18.6.2010, page 13). The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;". (Statutory Office, 2017. P. 2)

Germany

The EnEV (Energy Conservation Regulation) in Germany is a national level performance-based code that enforces the energy frame calculation to establish an estimated primary energy consumption of domestic and non-domestic buildings, firstly introduced and implemented on 2002. The regulation addresses on building thermal envelope, energy consumption and renewable energy producing systems in the simulation, that includes, hot water, lighting (for non-domestic buildings only), HVAC, bio-climatic design and renewable energy. EnEV supervises and encompasses a wild scope of strict inspections, starting from detailed design progress, to construction stage, then to post completion (prior to occupation) inspection. And the enforcement of the code is mandatory, applying to all construction and occupation application.

The building energy usage and functions covered by the code are:

- Position and orientation

- Passive design
- U-value of building envelope
- Heating and cooling
- Airtightness and dehumidification
- Thermal bridging
- Ventilation
- Hot water
- Lighting
- Renewable Energy (solar, PV, others): require 15%-50% of heating energy are supplied based on renewable source, depending on building function.

The 2014 amendments and supporting policies encompasses many solid and progressive rules, plus a national target for carbon free buildings by 2020. According to the code, all new buildings will have to be built to the lowest energy building standard according to European regulations after 2021. Detailed activities include lowering maximum u-values, enforcing computer simulation, requesting air-tightness test, boiler and HVAC testing. Penalties for non-compliance of the code includes refusal and suspension of building and occupancy permit. In social aspects, 2014 amendments emphasise the establishment of low energy education schemes and incentive schemes. The 2016 amendments once again tighten the code; however existing building renovation projects of existing buildings are exempted from updated 2016 energy standard.

The Netherland

The Netherland code Bouwbesluit 2012 is a national level performance-based code that requires maximum allowed EPN (Energy performance coefficient) for both domestic and non-domestic buildings. The code enforces an energy frame calculation for all proposed building projects, addressing on building envelope and energy-consumption systems such as, HVAC, hot water, lighting, bioclimatic design and renewable energy. Bouwbesluit 2012 defines ‘nearly zero-energy building’ as a building with an extreme high energy performance level, consuming very low amount of energy or with majority reimbursement from renewable energy sources produced on site or nearby. The Netherland code sets year 2020 as the target for achieving zero energy for all building projects, and there is a determined plan in place:

> 'As of 31/12/2018 new governmental buildings will have to built with an EPC near 0. All other new buildings will have to be build with an EPC near 0 as of 31/12/2020.' (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, Bouwbesluit 2013)

Bouwbesluit 2012 covers a wide scope of energy uses and functions that includes:

- Position and orientation
- Passive design
- U-value of building envelope
- Heating and cooling
- Airtightness and dehumidification
- Thermal bridging
- Ventilation
- Hot water
- Other Building parts (lifts, pumps etc)
- Lighting
- Solar gain and solar protection.
- Daylighting
- Renewable Energy (solar, PV, others) (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, Bouwbesluit 2013)

Bouwbesluit 2012 sets strict and mandatory requirements for all new buildings, especially in terms of passive design, thermal insulation and airtightness. In renewable energy aspect, the code emphasises the development of heat pump, in combination of renewable electricity. In all domestic building projects across rebuilt or renovation, a determined environmental performance calculation must be included in the permit application. Unlike UK, there are around 70,000 new dwellings built every year under new energy efficiency standard in Netherland. In the interest of conversation, the code also exempts monuments and historic buildings from complete or partial renovation or alteration in order to increase energy performance.

2.4.4 Timeline

The timeline lists the establishment of sustainable design theories and energy policies through UK and some European area. (Figure 25)

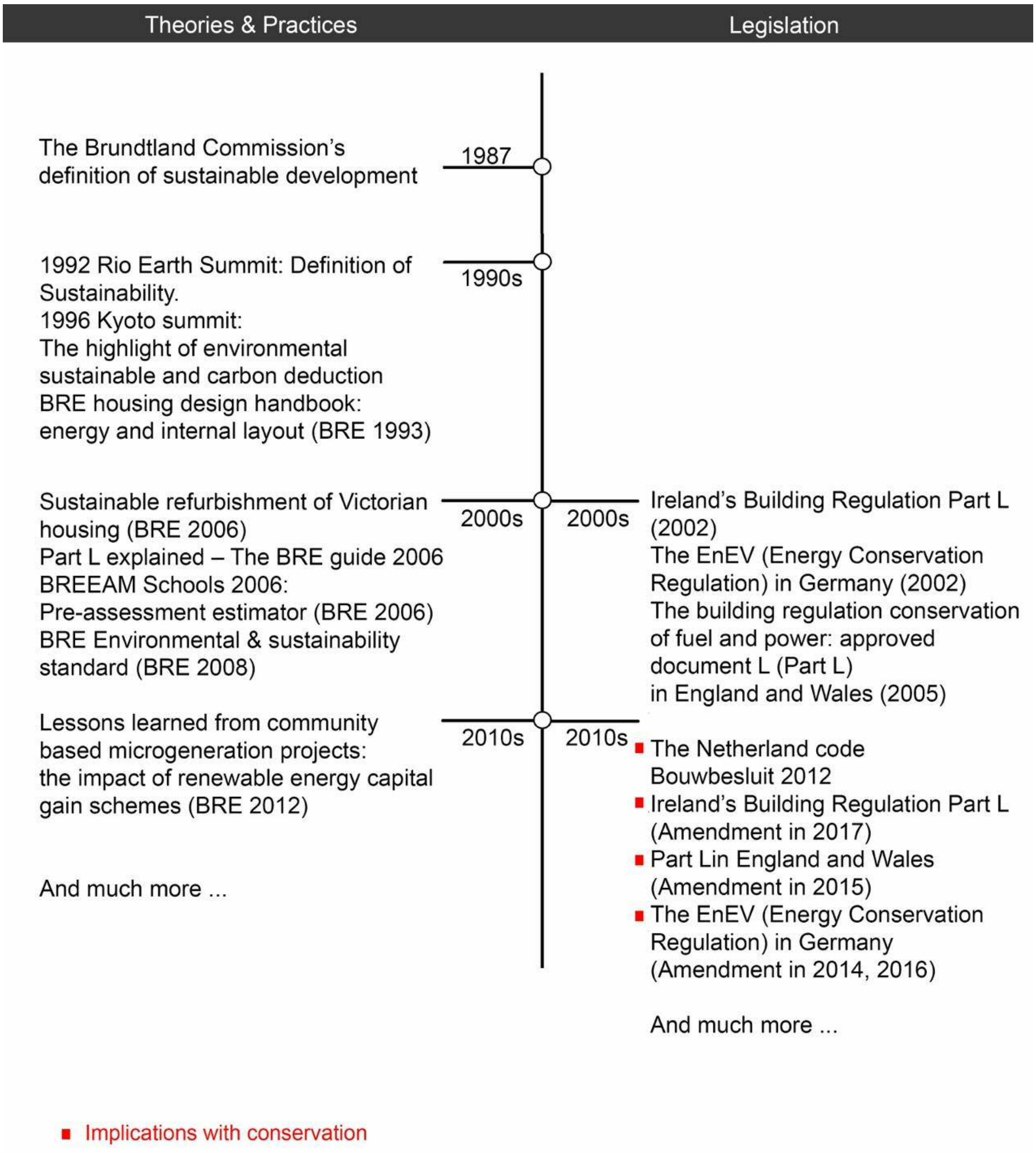


Figure 25: Timeline of design theories and energy policies through UK and some European area.

2.5 Findings

A number of key findings in relation to the current study have emerged in this chapter, commencing with the definition of the historic settlement:

- There has been a considerable development since the 1960s in theories related to identifying, describing, analysing and explaining urban form, urban image and key elements. Some theories have made a considerable contribution to the understanding of the distinctiveness of the historic settlement. This emphasises the importance of the historic settlement and its morphology in the creation of place and identity.
- Since the 1940s, UK conservation legislation has developed into a comprehensive scheme, covering a wider range of heritage assets, including area, buildings, features and landscapes with statutory protection.
- In order to identify the character of a historic settlement or a place, there are differences between the traditional conservation-led character assessment (as the assessment method applied in the 1st and 2nd national survey) and place-led assessment (as in Lynch's and Cullen's theory).
- *The Conservation Principles, Policies and Guidance* (2008) and *The Conservation Principles in Wales* (2011) both advise the importance of guiding and justifying inevitable interventions alongside conservation. However, little information is provided to illustrate how this can be effectively achieved.
- In order to design in the historic settlement, designers themselves need to identify the place and employ practical measures as guidance of design; plus, there are conflicts between preservation and enhancement in detailed approaches.
- A design code may guide design activities and developments in the settlement scale under detailed controls on townscape and building elements. A well designed and appropriate applied code should not restrain creative design and flexibility of interpretation, however, a large amount of design code is designed and applicable to development of a new domestic area or new communities instead of regenerating existing historic settlement.

- Poundary is a trial and exemplar settlement scale project, creating a new small community on the foundation of new urbanism, design code, and performance-based environmental sustainable design strategies. Poundary project tests low-environmental impact place-making in the small settlement scale, however, through 'new-build' instead of regenerating existing historic settlement. There would be foreseeable further limitations on building energy performance refurbishment within a historic settlement.
- CADW's appraisals of historic towns in Wales, *Understanding Urban Character (2009-2015)*, successfully upgraded the traditional conservation-led character assessment. The appraisals described the distinctive urban character and the value of heritage as an asset in the conservationists' way. However, it is still different from character assessments based on 'place-identify'.
- CADW's appraisals also failed to address the issue of future environmental sustainability.
- Apart from CADW's appraisals, current official guidance, appraisals and frameworks related to urban and building conservation contain limited information concerning the environmental sustainable development measures when encountering historic settlements, particularly when it comes to reducing carbon footprint and improving environmental performance at building level.
- The launch of *Strategic environment assessment, sustainability appraisal and the historic environment* by English Heritage in 2013 created guidance and assessment measures targeting the maintenance of the historic environment, alongside the achievement of sustainable objectives. However, it failed to note the issue of carbon footprint in relation to environmental sustainability.
- Sophisticated measures and assessment tools are in place and proved to achieve building environmental sustainability, particularly in the reduction of carbon footprint and improving energy performance, know as 'Nearly Zero-Energy Building'. Initially applied and verified on 'new-build' instead of existing buildings, however, these measures and approaches to achieve passive design

and the introduction of renewable energy may still have visual impact when encounter the historic building and settlement.

- In the international scale, rather than only in the UK, code for environmental sustainable building (mostly performance-based code) are established and are intensified as a response to environment concerns. Although majority of the codes apply full or partial exemptions to listed or monuments buildings with historic interest, the codes pay less or minimum concerns on aged buildings with unique urban characteristics, or a historic settlement as the whole piece.
- The achievement of Nearly Zero-Energy building target in 2020, Nearly Zero lifecycle in 2030, then Zero carbon in 2050, would greatly relay on both 'new build' and 'historic building regeneration', especially a considerable amount of aged domestic building in the historic settlement. These aged dwellings contribute on unique characters, streetscape, and visual image of a settlement, even they are not exempt from the code. These buildings may become the gap between conservation of characterises and performance enhancement. Apart from above, the introduction of renewable energy in settlement scale could possibly alter the streetscape and urban image.
- Few literature attempted to join theories from four dimensions together, namely, identifying the character of the historic settlement, preserving the identity of a place, enhancing the whole settlement, and especially embracing the low carbon trend. Therefore, there is a lack of practical guidance and evaluations for designing in the historic settlement. Designer needs to create the guidance from observations of different places by themselves; and conflicts arise between conservation and enhancement.
- SAP rating will be used to in following case studies to assess the energy consumption of all domestic design works.

CHAPTER THREE: FIELD STUDY IN VRIN, SWITZERLAND

3.1 Introduction

This chapter includes an exemplar of a critically acclaimed approach to design in the village of Vrin, Switzerland by Swiss architect Gion Caminada. The village was visited by the author and studied in the context of the previous Chapter. Vrin was awarded the Wakker Prize in 1998 for the preservation of its architectural heritage. St. Maria Church in Vrin is listed as a national heritage site of significance in Switzerland. The village underwent a population decrease during the 20^{th} century; and the Cantonal historic preservation department targeted ETH Zurich to strengthen the village's economic infrastructure and to encourage population growth. Gion Caminada is dedicated to inheriting and transmitting the soul of traditional Swiss architecture and craftsmanship into contemporary design (Caminada 2008). The projects in Vrin collectively had several complex design aims as follows:

- Strengthen the peripheral region through careful design of the cultural landscape;
- Conserving the identity of the settlement;
- Maintaining the traditional local agricultural economy;
- Preserving and developing the prototype of local traditional architecture;
- Localisation of building materials; and
- Ensure environmental sustainability.

Figure 26: Central Vrin in the Alps in summer

3.2 Location and origin

Vrin (Figure 26), a traditional historic village in Alps mountain area (Figure 27), is located at the end of the Lumnezia alley in the Graubünden area. The village is in a mountainous Alpine area, and there is only one road along the valley to it. Vrin is the last village in the valley, at the end of this pass.

Vrin has experienced slow but steady growth in previous decades, like other small historic settlements in the remote area. The Graubünden area has a very fertile subsoil base composed of eroded slate. Together with the irrigation provided by the valley, the region is well suited to agriculture. The main economy and income in the village has traditionally been based on agriculture, and about half of the 280 inhabitants still make their living from it. Living and surviving in the rugged mountain environment requires a detailed observation of nature. The villagers follow a traditional lifestyle, respecting nature and understanding the Alpine continental climate. This respect for nature is represented though the village's layout and traditional architecture.

Figure 27: The relationship between nature and the village (Source: Image taken from the valley by the author)

3.3 Village shape and layout

The village is a small compact human settlement with a central nucleus and four outlying settlements. Its expansion is constrained by geographic barriers, and so it has established itself in a compact linear shape clustered close to the road (Figure 9, Figure 28). Compared with other layouts, a compact layout has both ecology and economy advantage from providing a built environment for concentrated activities of residence (Asquith & Vellinga 2006). The compact layout with agriculture facilities on the periphery is also to resist the harsh wind from Alps in winter. Meanwhile, a compact human settlement uses less arable land, which is a non-reusable resource, especially in a settlement reliant on agriculture.

In the Graubünden area, the local climatic and geological conditions combine to create a special compact village form. The special features of this form mean the centre of the village is composed of public buildings, surrounded by residential buildings, and then on the periphery there are outlying facility buildings for agriculture, facing down to the agricultural sites along the open valley.

Figure 28: Vrin’s layout

3.4 Traditional architecture and the identification of the village

The dominant building materials available in this region are timber and stone. The majority of the old buildings in the village are built of stone and timber with slate tiles created by local craftsmen. Stone is used for the building’s foundations and as a base to isolate humidity; and timber is used for the main structure, framework and walls; Roof tiles are made from local slate. In Vrin, the majority of the buildings, including domestic and non-domestic ones, share a unique building style, developed from local materials and with awareness of the climate.

This traditional construction style is called Strickbau; literally meaning of ‘knitted construction’, and it has been widely applied in the region for constructing all building types, including houses, farm sheds, barns and other agriculture buildings. The most basic cell in this style is a rectangular layout composed of two rooms; the short partition wall between the two rooms is established to reinforce the corner joints. The size of the cell is determined by the length of the beam. The long, straight trunks of local fir trees are the ideal construction material, and the specialist aspect of this building typology is that it is an easily extended system. To build an extension, a new cell is placed adjacent to the original cell with a corridor between the two; a new cell can be added in both horizontal and vertical ordering, depending on the shape or geographic condition of the site (Figure 29).

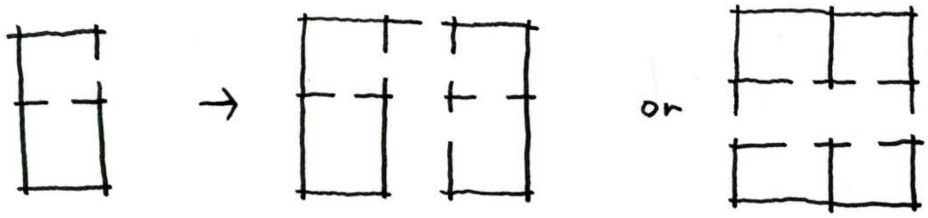


Figure 29: The basic cell of the traditional building form in the region and its extension form.

The entire system is very similar to the contemporary cladding system in which:

- Round logs are laid and woven over each other to form the framework of the wall, the section of logs woven together comes out the building corner (Figure 30); and
- The exterior or internal wall is boarded with sidings.

Today, domestic buildings and animal sheds are typically based on wooden frames rather than round logs, to maintain the tightness of the building envelope (Figure 31). Rough round logs are still used in the upper levels of animal sheds and agricultural facilities. The combination of round log and adjustable siding boards provides controllable ventilation for drying and storing, when threshing is taking place.

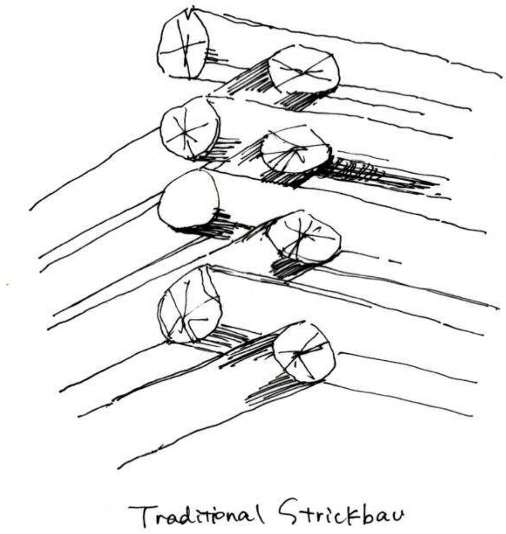


Figure 30: Sketch showing the traditional construction method – Strickbau. Round logs weave with each other to form the building corner.

The benefits of this building typology are that it means the minimal amount of arable land is covered and extension or restoration is easy. In Vrin, buildings are inherited from generation to generation; they are well maintained and their damaged or decayed sections are restored as necessary (Figure 31).

Figure 31: Domestic buildings in Vrin. Left: aged Strickbau building in use; right: aged Strickbau building with a new extension / restoration

There are four types of building performances in Vrin according to the investigation:

- Domestic Strickbau buildings (Figure 32)
- Non-domestic Strickbau buildings (Figure 32);
- Contemporary buildings (Figure 33); and
- Contemporary architectures designed applying the concept of Strickbau buildings (Figure 33).

Figure 32: Buildings in Vrin. Left: domestic Strickbau building; right: non-domestic Strickbau building

Figure 33: Buildings in Vrin. Left: building with contemporary materials; right: designed contemporary architecture with Strickbau concept

3.5 Gion Caminada's principles

Gion Caminada is highly concerned with the typology of the site and in his publication "Meaningful Architecture in a Globalised World", he defines typology as: 'the typology, which takes up information from all sorts of life habits, construction methods, geometries etc. is open to change. It is easy to identify which are the core elements that cannot be changed. (Caminada 2007, pp. 82-94) He believes typology is the most important element for a settlement; because the varied repetition of basic typological patterns contributes to a charming historical city. In contrast, without a basic typology, contemporary cities are frequently disordered due to their visual diversity and disorder. Although typology has changed over time, its singular and the most basic pattern exists under the image of every historic settlement.

Gion Caminada also explains that Carlo Scarpa's attitude to design in a historic settlement is to create diversity newe things from the tradition instead of picturesque and superficial reproduction (Schultz 2007). When Gion Caminada began working in Vrin, he expended great effort learning about the essential features of a Graubünden cowshed, its origins, and the transformative process behind its performance. He wanted to reconcile the conflicts between the basic pattern of typology in Vrin, and the intervention of contemporary architectural form in the townscape.

To fulfil his design aims, nine theses guided his practices in Vrin:

1. Peripheral regions as a catalyst:

   '*Mountain regions are characterized by a specific yet varied landscape, history and culture.*' Reinforce the '*strong identity in spatial and in social terms*'. (Caminada 2008, p. 134)

2. Differences between peripheral regions and regional centres:

‘*Identity is a question of inner structures and difference. The differences and hence also the borders between urban and peripheral regions must be more clearly emphasised*’. (Caminada 2008, p. 134)

3. Urban planning must promote the independence of peripheral regions:

   ‘Regional urban planning must counter the effects of urban sprawl without hampering economic growth’. (Caminada 2008, p. 134)

4. Regulation of agricultural enterprise and attractive landscapes:

   ‘*Alpine regions’ cultural landscape is the greatest economic capital*’ and should be well conserved. (Caminada 2008, p. 135)

5. Authentic and holistic agricultural economies in mountain regions:

   Local premium agricultural products ‘*should be acknowledged and accepted by all sectors of society*’. (Caminada 2008, p. 135)

6. The guest is king – and so is the native inhabitant.
7. Constant features of a location as a basis for new architecture:

   ‘The authenticity of farmers’ architecture derives from other constant features, the climate, topography, history and so forth.’ (Caminada 2008, p. 136)

8. Economic growth = a lot of work combined with minimal material costs - building with local materials.
9. Aesthetic aspects of technical usage:

   ‘*Protect a landscape to maintain its distinguishable feature*’ instead of to design according to technical usage. (Caminada 2008, p. 136)

3.6 Gion Caminada's design practices

3.6.1 Introduction

From the 1990s onwards, under a programme proposed by the Cantonal historic preservation department and ETH Zurich, Gion Caminada was invited to present a series of design cases, especially infrastructures. The programme's aim was to strengthen the village's economy and infrastructure, and to develop the peripheral regions to prevent further population loss. The nine theses Caminada listed were employed as design principles, to guide his practices in Vrin.

Four designs for infrastructure of Vrin are reviewed in the study: the telephone box, a group of cowsheds, a mortuary for Vrin, and an extension of the sports hall for the local primary school.

3.6.2 Telephone Box (1997)

The phone booth is the first contemporary intervention Caminada applied in Vrin in 1997 to test his 'language' of contemporary Strickbau and his design principles (Figure 34):

- The telephone box fulfils a local requirement to provide a public landline;
- It is located at the edge of the residential houses, along the bypass near the assembly point for public services, like local buses;
- The overall form of the booth is a simple box standing on a concrete foundation, with a canopied waiting area outside;
- Local timbers are used as the main material;
- Precisely trimmed timber frames are used to form the corner joint of the Strickbau; and
- There are detail designs to meet functional needs, such as mounted aluminium drainage.

Figure 34: The telephone box in Vrin as found. Upper left: exterior; upper right: image of tower of St. Maria Church from the telephone box; lower left: corner joint of Strickbau using local timber; lower right: design detail

3.6.3 Group of Cowsheds (1998)

One year after the telephone box was constructed, Caminada designed a group of cowsheds in response to a request from the local community. It is also fulfilled his own principle (number 5) to encourage '*authentic and holistic agricultural economies in mountain regions*'. The group of buildings includes two cowsheds and one slaughterhouse to fit the required size and function (Figure 35, Figure 39, Figure 40). There are a several points to highlight in relation to this design:

- The site has been carefully chosen to ensure the layout of the village does not become sprawling. The conflicts between economic growth and urban sprawl are highlighted in this design. Caminada stated that urban sprawl could change the appearance of the valley and the village;
- The site is located on the outskirts of Vrin, next to several other farmhouses, and at a slightly lower terrain to ensure established paths can be used;
- The group of cowsheds is composed by positioning three free-standing sheds together to form a farm unit. The volume of each cowshed is very similar to that of other traditional cowsheds in the village.
- Three units have been designed with the same volume and form: comprising a simple rectangular timber box with a single pitched aluminium roof.
- Caminada reinforced the difference in functions by creating a different building envelope.
- A concrete interior wall is applied within the slaughter house to ensure a hygienic environment can be easily maintained, which is an essential requirement;
- Local timbers and stone are used as the main materials;
- Precisely trimmed timber frames are used: these frames are fully capable of bearing loads, either as walls or floors; and this functionally lightens the work load of local farmers; and
- There are design details reflecting functional needs, such as vents.

The chart compares the traditional farmhouse with Caminada's cowshed; illustrating that they both involve interactions between structure and skin (Table 1)(Figure 36, Figure 37, Figure 38).

Table 1: Comparison of the traditional farmhouse and Caminada's cowshed

Traditional farmhouse	**Caminada's innovated cowshed**
Functional division: lower level – animals; upper level – threshing	*Functional division: lower level – animals; upper level – threshing*
Martials: rough round logs	*Martials: wooden frames (local fir) instead of rough-hewn logs*
Structure logic: layering and weave over each other	*Structure logic: wooden frames are mounted over each other on site, with the long sides horizontally parallel*
Envelope: exterior boarded with siding	*Envelope: interior cladding – practical board, concrete board; exterior cladding – wooden board*
Special treatment of structure: the interwoven corner connections remain free	*Special treatment of structure: the exterior corner is no longer of interwoven planks, instead it comprises interwoven frames, designed for aesthetic purposes, the design of small vents in the upper level of the cowshed for threshing*
	Additional special treatment: the interior core has a smooth finish of concrete to meet modern hygiene standards, the installation of other contemporary facilities such as a sprinkler system

Figure 35: Group of cowsheds. Left: site of cowsheds and their location relative to the rest of the village; right: cowsheds as viewed from the village.

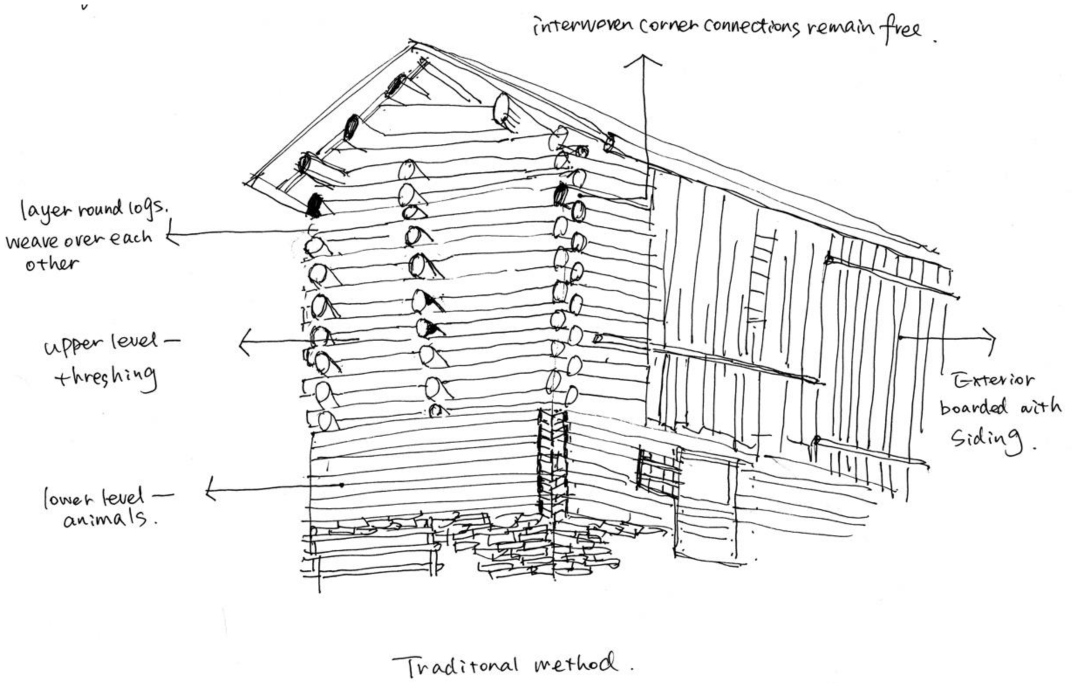


Figure 36: Structure detailing a traditional farmhouse

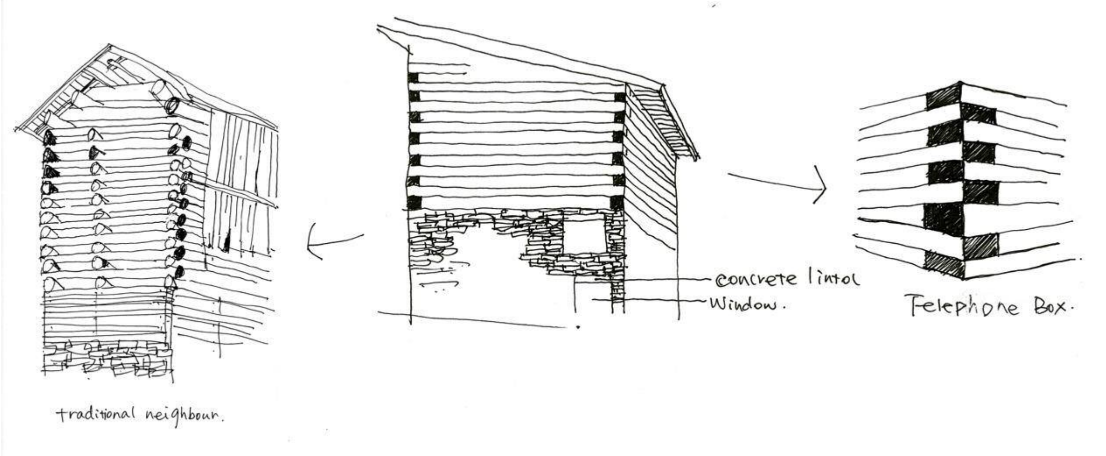


Figure 37: The traditional farmhouse, the renovated cowshed, and detail of the timber joint Strickbau.

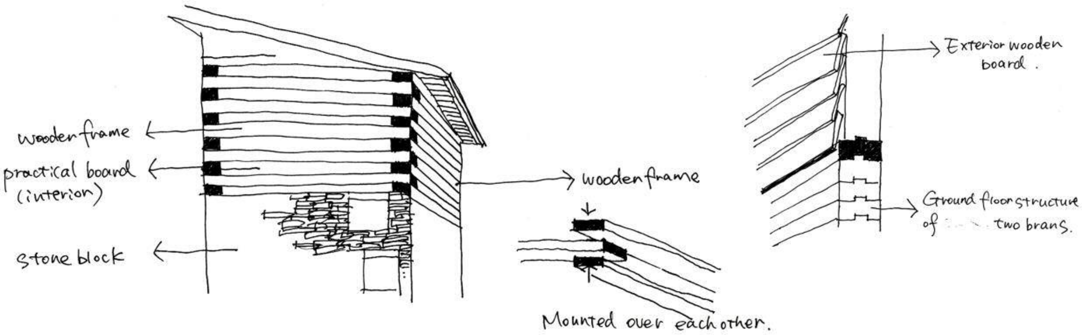


Figure 38: Caminada's innovative cowsheds

Figure 39: Details: Concrete interior of the slaughterhouse

Figure 40: Design details. Upper left: adjustable vents in the upper floor of the cowsheds; upper right: vents from exterior; lower left: joint of timber; lower right: ventilation openings.

3.6.4 Mortuary for Vrin (2002)

Four years after the group of cowsheds were finished, Caminada completed a third project in Vrin; this time for a new mortuary on church grounds. In a small settlement such as Vrin, the church is normally located in the centre of the settlement, surrounded by cemeteries. The church forms the focal point of the community: the villagers hold baptisms and funerals in this church, and are buried in the churchyard. It is a place upon which ritual is centred in Vrin (Figure 41, Figure 42, Figure 43). There were, thus, several points to be highlighted in the mortuary design:

- A new mortuary emphasises the role of the church in the community. The mortuary is a public space for all villagers that can be used for several functions in addition to its designated function of 'mourning', such as, as a tea room;

- A site below the churchyard is preferred to emphasise its independence from the church and to avoid blocking the view from the cemetery.
- Highly modulated Strickbau helps to create a heavy and solid building envelope and gloomy interior lighting, conveys the function of the building as 'mourning';
- Two entries are provided: one from the cemetery, and another from the village, suggestive of the boundary of the village and nature. Caminada believes everyone should have the right to choose which way to enter the building, as they decide how to mourn the death of their loved one (Caminada 2007, pp. 82-94);
- Local timbers are used and painted white to resemble the church; and
- Detailed designs: slate tiles are applied to the top of the aluminium roof cladding, in consideration of the views of the cemetery as seen from a higher level site.

Figure 41: Mortuary for Vrin. Upper left: view of mortuary together with the church from the valley (Caminada 2008); Upper right: the mortuary; lower left: mortuary and cemetery; lower right: view of cemetery, mortuary, and valley from the church.

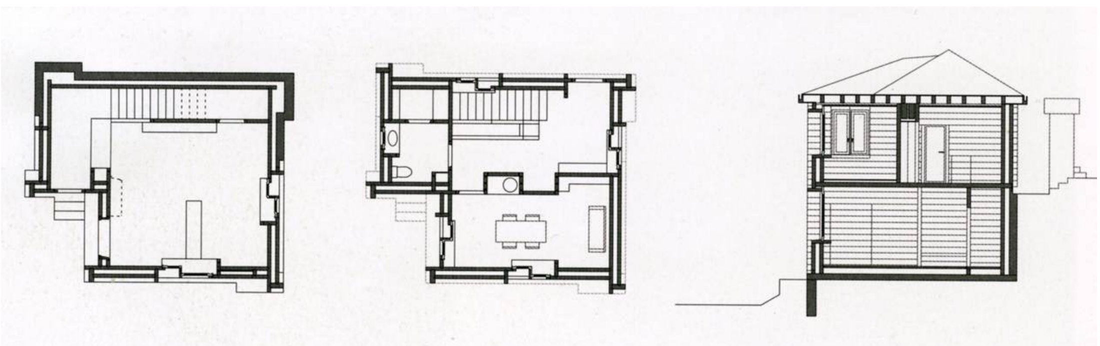


Figure 42: Layouts and sections

Figure 43: Detail designs. Upper: aluminium roof & slate tiles; lower: joint of timber and concrete

3.6.5 Refurbishment and extension of the sports hall (2003)

Located at the edge of the village, Vrin's primary school is a contemporary building built in the early 1990s (Figure 44). The building was constructed with concrete, stone, glass brick, and a timber framed window. It was previously extended, and Caminada was asked to design another extension to the main sports hall for the entire community (Figure 45).

- The site located at the end of the village is a large site (for Vrin), facing the valley;
- The overall form of the sports hall is a timber rectangle box with a pitched roof and a simple façade;
- Strickbau and wooden board cladding is employed to create the new building envelope;
- Local timbers are used as the main materials;

- The design of the ‘picture frame’ ribbon windows ensures they capture the picturesque valley view;
- Detailed designs: structure and timber beams; and
- Passive design and sustainable design.

Figure 44: Vrin primary school - main building as found

Figure 45: Sports hall. Upper left: exterior elevation; upper right: building interior; lower left: comparison with the old hall; lower right: window details

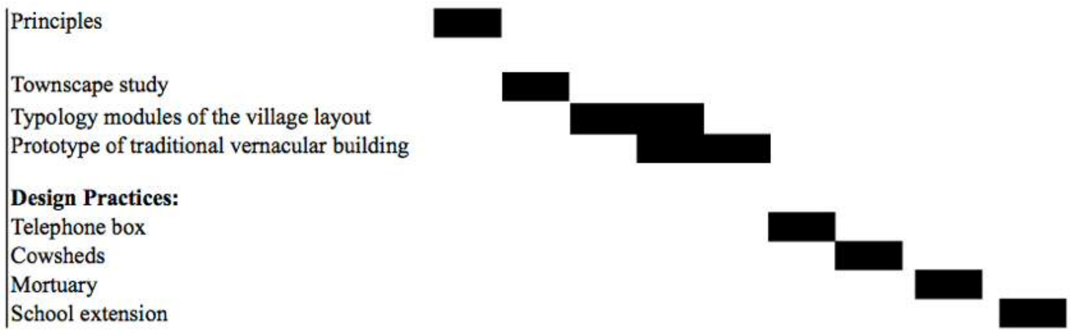
3.7 Review of Caminada's design methodology

The aims of the programme in Vrin are to strengthen the village's economy and infrastructure, and to develop its peripheral regions to prevent further population loss. A further aim is to strengthen the area's peripheral regions by carefully designing the cultural landscape to embrace both conservation and development. As discussed above, Caminada established nine themes to explain how the peripheral regions could be conserved and developed sustainably. These themes covered several dimensions, such as the identity of the peripheral regions, the difference between the regional centre and the peripheral regions, the landscape, the economy, and the community. Each design theme can be traced as key principles guiding specific design strategies and approaches. For example, Caminada encourages use of local timbers in all his designs, in line with his eighth principle '*economic growth = a lot of work combined with minimal material costs*'. Table 2 combines the extent to which each of the four designs he created in Vrin correlates with his principles in a single chart.

Table 2: Application of Caminada's principles to the designs completed in Vrin

Principles	Telephone box	Cowsheds	Mortuary	Sports hall
1. Peripheral regions as a catalyst	√	√	√	√
2. Differences between peripheral regions and regional centres		√	√	
3. Urban planning must promote the independence of the peripheral regions		√	√	√
4. Regulation of agricultural enterprise and attractive landscapes		√		√
5. Authentic and holistic agricultural economies in mountain regions		√		
6. The guest is king – and so is the native inhabitant	√	√	√	√
7. Constant features of a location as a basis for new architecture	√	√	√	√
8. Economic growth = a lot of work combined with minimal material costs	√	√	√	√
9. Aesthetic aspects of technical usage	√	√	√	√

To adhere to these key principles, Caminada's design work began with a study of the townscape. He then established a building typology, describing the village layout and providing a prototype for traditional vernacular building types based on his observations. The four designs were created following a sequence of local requests, promoting the inevitable development of the entire settlement.



To progress the four designs, nine themes based on Caminada's principles were tested, reviewed and amended; the designer's prototype of a traditional building in Alpine region was further applied, tested and upgraded.

Drawing strongly from the traditional Strickbau structure, Caminada believes that a modified prototype Strickbau is suitable to facilitate contemporary construction methods, and can be repeatedly applied in practice in the peripheral regions in the mountainous Alpine area:

> *First of all I made the corridors a little wider. Then I started to place room cells in position and surrounded them with walls…. Ultimately this made me realise that the construction can be very highly modulated when using this method, and it is not necessary to think exclusively in horizontals and verticals. So I cut more and more out of the body of the building, hollowed it out, as it were. This generated new, exciting spatial experiences… No other timber construction has such a dense mass as Strickbau.* (Caminada 2007, pp. 82-94)

3.8 Findings from the case study

The key findings that can be applied to take the study forward are given below:

- The designs in Vrin have been critically acclaimed as good examples. The author found the identity of Vrin, including the form and the image of the settlement to be well preserved.
- Caminada has proven that it is possible to strengthen peripheral regions through design, while embracing both conservation and development.
- Caminada's nine theses are based on the peripheral region in the Alpine region, which has a different history, landscape, townscape, economy, and community from the other historic settlements studied in the UK.
- Vrin is a tiny historic settlement compared with most of the historic settlements studied in the UK.
- Some principles are repeatedly applied to each design and are directly reflected in design approaches: principle 7. The constant features of a location as a basis for new architecture; principle 8. Economic growth = a lot of work combined with minimal material costs; principle 9. Aesthetic aspects of technical usage.
- Design is highly responsive to the site as found and building group as found.
- Caminada tried to design simply, only emphasising typology, form, and materials.
- Caminada tried to learn from vernacular buildings in forms, materials, and building techniques, then transform and employ the 'tradition' in the 'new' using contemporary design techniques.
- Sustainable development is considered in the design phase; such as using locally sourced building materials to reduce transport. Caminada noted that the major reason for using local timber is to meet the concern to support economic growth (principles 8)
- Environmentally sustainable design (passive design) is only explicitly applied in the design of the sports hall, which reflects considerations of both ventilation and daylighting. However, all buildings are constructed in accordance with the

already demanding environmentally sustainable Swiss design standards; in that case the buildings are all well insulated with high standard energy performance.

Caminada's nine themes are formulated based on architecture, townscape, and landscape in the peripheral region of Alps area. In these themes, there are four key principles, namely, *interpretation of the place*, *siting key infrastructures within the core*, *drawing the typology*, and *interpretation of traditional construction to performing contemporary but sourced locally*, that are more universal than the others.

Interpretation of the place refers to understand the historic, geographic, functional, and economic reasons behind patterns and characteristics of existing settlement, which is a significant value when encounter place with strong identity. *Siting key infrastructures within the core of the settlemen*t addresses on infrastructures rather than domestic buildings because infrastructures support local economy and the role the settlement serves; in the meanwhile, siting key infrastructures in the centre instead of the outskirt area helps to reinforce the core and resist sprawl. In Vrin, Caminada was focused on the recreation of infrastructures due to the original purpose of this regeneration project, by strengthening village's economic infrastructure. However, by looking at Caminada's other design cases in Alpine area, large amount of new domestic buildings are designed based on his model, and his contemporary rephrase of traditional. *Drawing the typology* indicates architects should define a local typology to apply in the design instead of duplicate the tradition. *Interpretation of traditional construction to performing contemporary but sourced locally* refers the use of local materials to create a new 'vernacular' and for being economic wise; in Vrin, this is also to trace the soul and typology from traditional Swiss Alpine architecture to rephrase it in contemporary language.

Caminada also proved that the method of verifying and testing the themes through a methodical process of designs is practical. Caminada expresses his respectation and sympathy to the historic settlement, committing to preserve but also enhance it through design. Caminada's principles and design methods will be employed, in order to rephrase conservation principals in architect's languages, to formulate the model in Chapter four. His method of verifying the principles through robotic designs has also been employed in the study.

CHAPTER FOUR: HYPOTHESIS AND A MODEL FOR THE DESIGN OF THE HISTORIC SETTLMENT

4.1 Introduction

Based on the literature review and field study, this chapter covers the following:

- A research hypothesis (4.2)
- The creative design 'model', which comprises conservation principles and code for environmental sustainable building for achieving conservation, enhancement, and environmental sustainability in the historic settlement (4.3-4.6).

4.2 Hypothesis

The hypothesis is to create a design model with a point-based assessment framework which combines, rather than separates conservation principles and energy performance criteria, justify and guide intervention or regeneration activities in a historic settlement under increasing sustainable requirements. The hypothesis is tested through a series of hypothetical domestic design cases in a typical historical settlement in the UK to discover how different physical conditions influence building form and performance.

4.3 Formulation of the model

The model, which is actually the design process itself, will be formulated on the basis of two dimensions together with architect's rephrase: the conservation principles, and strategies to improve building performance (Figure 46). In the model:

- Conservation frameworks and all related publications from English Heritage and Cadw reviewed in Chapter 2 are engaged to establish conservation principles. Noted the vital differences between conservation-led and place-led character assessment, certain principles will be rephrased according to selected place-led conservation theories from architects such as Lynch, Cullen, Caminada, and etc. (4.4).

- Strategies to improve building performance are summarised from mandatory rules for sustainable buildings according to Building Regulation Part L and other BREEAM publications. Some of the strategies are also modified and rephrased to fit design languages (4.5).

Apart from main principles in two dimension, some sub-attributes are framed based on two terms: (1), detailed definition to clarify the main principle; (2), strategies or approaches to reach the main criteria. All principles and their sub-attributes are granted with points to ensure this assessment tool (the model) could be efficiently and preciously applied in design tests. A determination of credits in the model is according to the performances of all principles on existing reference.

The findings presented in Chapter Two (the literature study) reveals that gaps exist between conservation appraisals and enhancement of building performance, particularly when alterations happen on street-facing elevations with high visual sensitivities, in historic settlements. On the other hand, overlaps exist between certain dimensions in conservation and performance, when rephrased by architects. The possible new design framework might be a combination of selected rephrased principles, recreated in a form with Hierarchy (Figure 46).

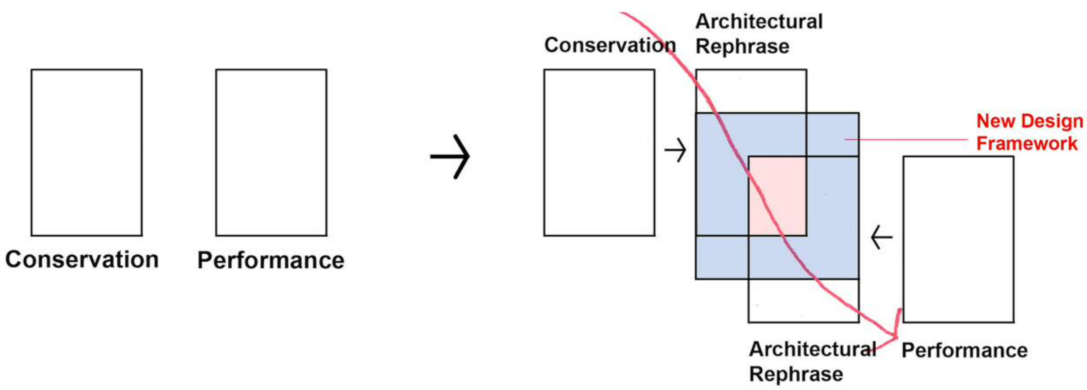


Figure 46: Establishment of the model and possible relationships.

4.4 Conservation principles and architect's rephrase

UK conservation legislation with supplementary regulation and framework from English Heritage and Cadw encompasses conservation strategies to historic buildings and historic environment with distinctive characters. With the aim of identifying the distinctiveness of the place and preserving unique historic assets from loss, the *Conservation Principles, Policies and Guidance* (2008) proposes six conservation principles which provide a comprehensive framework for the sustainable management of the historic environment. These are:

> Principle 1: The historic environment is a shared resource.
> Principle 2: Everyone should be able to participate in sustaining the historic environment.
> Principle 3: Understanding the significance of places is vital.
> Principle 4: Significant places should be managed to sustain their values.
> Principle 5: Decisions about change must be reasonable, transparent and consistent.
> Principle 6: Documenting and learning from decisions is essential.
>
> (English Heritage 2008, p. 7)

Cadw has also proposed six conservation principles, based on the abovementioned principles, which were tailored and adapted for use in Wales in 2011. Cadw emphasise that the protection and management of the historic environment should be holistic and encompass community engagement, learning, access and the passing on of traditional skills to current and future generations (Cadw, 2011).

Compared with place-led conservation theories, conservation principles proposed by English Heritage and Cadw are too general to guide detailed practices. In order to design in the historic settlement, designers themselves need to identify the place and employ practical and detailed measures as guidance of design; plus, there are conflicts between preservation and enhancement in detailed approaches. Apart from above, the decision-making criteria, published by English Heritage as an add-on to the conservation principles, covers not only environmental criteria, but also social and economic objective (Figure 47). In order to propose the hypothesis 'model' (4.7), conservation principles must be rephrased and enriched with the coordination of architectural theories and design strategies.

APPENDIX 3: DECISION-MAKING CRITERIA

Environmental Criteria

Will it:

- Conserve and/or enhance heritage assets and the historic environment?
- Contribute to the better management of heritage assets?
- Improve the quality of the historic environment?
- Lead to the repair and adaptive reuse of a heritage asset?
- Respect, maintain and strengthen local character and distinctiveness?
- Promote high quality design?
- Provide for increased access to and enjoyment of the historic environment?
- Integrate climate change mitigation and adaptation measures into the historic environment sensitively?
- Alter the hydrological conditions of water-dependent heritage assets, including paleo-environmental deposits?

Social Objectives

Will it:

- Increase the social benefit (e.g. education, participation, citizenship, health and well-being) derived from the historic environment?
- Improve the satisfaction of people with their neighbourhoods as places to live?
- Engage communities in identifying culturally important features and areas?
- Provide for increased understanding and interpretation of the historic environment?
- Provide new leisure, recreational, or cultural activities?
- Support and widen community uses through shared facilities?

Economic Objectives

Will it:

- Increase the economic benefit derived from the historic environment?
- Promote heritage-led regeneration?
- Lead to the repair and adaptive reuse of a heritage asset?
- Make the best use of existing buildings and physical infrastructure?
- Promote heritage based sustainable tourism?
- Ensure that repair and maintenance is sympathetic to local character?
- Secure a supply of local building and roofing materials?
- Help to reduce the number of vacant buildings through adaptive re-use?

Figure 47: The decision-making criteria of the Strategic Environmental Assessment (English Heritage, 2013)

Based on the relevant literature and case studies, the rephrased principles with split sub-points which relate to conservation rules are:

1. Define character and understand the significant of the place - through place-led identifying method including townscape study and mapping;
2. Treat the historic environment and buildings as non-renewable assets - through strict conservation to elements with high sensitivity;
3. Clarify and reinforce the boundaries the settlement - through multiple conservation strategies including maintaining the unique character of the conservation area, creating consistent streetscape, repeating building character and pattern, and establishing a few key buildings at the boundary;
4. Guide and justify inevitable interventions - all interventions activities within the conservation area must be assessed;
5. Design with flexibility - all design interventions could be revised or retracted, and ability of fitting other junctions;

6. Assess all interventions after construction - to guarantee all conservation principals are observed from design to construction;
7. Sustain all resource in the historic settlement - covering materiality, building pattern, building details, craftsmanship, landscape, and vegetation;
8. Protect and reinforce the position of the historic settlement in the community - via enhancement of key infrastructures, attraction of new populations, boost economy; and
9. Strengthen the historic core – including preserve and enhance public space, infrastructure, variations, reduce areas with blur image.

Attached is a tabular summary of key conservation principles and sub-attributes. Extracted from conservation framework and publications, reshaped with added sub-elements from reviewed architectural theories and case studies, these criteria are combinations of primary rules and approaches in conservation of a heritage place. 4.4.1-4.4.9 explains and reveals the basis and definition of these criteria and references that have been extracted. Being derived from literatures, frameworks, and case studies, rewarded points under each criteria are equivalent to the frequency of the corresponding point in reviewed literatures, as shown in Figure 48.

No.	Key Principles	Sub-elements	References	Points
1	Define characters and significant of the place	*Townscape study*	*Cadw, English Heritage*	*7*
		Mapping	*Cullen, Lynch, Cadw, English Heritage*	*5*
2	Non-renewable assets: Conservation to elements with high sensitivity		*English Hertiage, Cadw, Lynch*	*9*
3	Reinforce the boundaries of the settlement	*Maintain the unique character of the conservation area*	*Lynch, English Heritage, Caminada, Snozzi*	*3*
		Create consistent streetscape	*English Hertiage, Cadw*	*2*
		Repeat building character and pattern	*English Hertiage, Cadw*	*2*
		Establish a few key buildings at the boundary	*Caminada, Snozzi, Cullen*	*3*
4	Guide and justify inevitable interventions		*Cadw, English Heritage*	*5*
5	Design with flexibility	*Design could be revised or retracted*	*Cadw, English Heritage*	*2*
		Ability of fitting other functions	*Cadw, English Heritage*	*2*
6	Assess all interventions after construction	*to guarantee all conservation principals are observed from design to construction;*	*Cadw, English Heritage*	*5*
7	Sustain all resources in the historic settlement	*Materiality*	*Caminada*	*1*
		Building pattern	*Cadw, English Heritage*	*2*
		Building details	*Caminada*	*1*
		Craftsmanship	*Caminada*	*1*
		Landscape	*Lynch*	*1*
		Vegetation	*Conzen*	*1*
8	Reinforce the position in the community	*Infrastructures*	*Caminada, Snozzi, Cadw, English Heritage*	*4*
		Attraction of new populations	*Caminada, Snozzi,*	*2*
		Economic boost	*Caminada, Snozzi,*	*2*
9	Strengthen the historic core	*Public spaces*	*Caminada, Snozzi,Cullen, English Heritage, Cadw*	*4*
		Infrastructures	*Caminada, English Heritage, Cadw*	*2*
		Varieties	*English Heritage, Cullen*	*2*
		Reduce areas with blur image	*Lynch, Cadw*	*2*

Figure 48: Summary of conservation principles, sub-elements, and references.

4.4.1 Define character and understand the significant of the place

Historic character is established in the process of town development, based on culture, knowledge, beliefs, skills, and available natural resources, shaped through time and transformation from one generation to another (take Bath as an example shown in Figure 50). Historic character lies at the heart of local distinctiveness and sense of place, representing how places have been shaped over time and what makes them unique (Cadw, 2010). Norberg-Schulz defines character as ‘the most general ‘atmosphere’ which is the most comprehensive property of any place’ (Norberg-Schulz 1981, p. 5). Cullen categories character as a component of the contents of a town, alongside colour, texture, scale, style; character is a key ingredient to obtain the uniqueness of the place (Cullen, 1961).

Lynch and Cullen tried to define character through visual image, that is, through the urban image captured by an observer and the abstract emotional impact on them experienced during a walk through the settlement (Figure 49). They both argue that a valuable historic settlement creates a clear image in the memory of the observer. While Lynch focused on illustrating whether the structure or components of the image are clear enough, Cullen felt that the unexpected contrast between images delivers the message that 'this is a place with strong character' to the observer (Cullen, 1961; Lynch, 1960).

English Heritage and Cadw tried to identify character through picturing (mainly photographing) buildings, details, streets and space patterns (Cadw, 2009). The appraisals Cadw published since 2009, entitled *Understanding Urban Character*, give full descriptions of the topography, space, building characters and character areas to piece together a full image of a town's character. These do not employ the techniques used by Cullen, Lynch and others to capture character and atmosphere in the way that Norberg-Schulz defines it.

Known from literature in chapter two, there are weaknesses on English heritage's or Cadw's conservation principles: the conservation-led character defining is different from 'place-identify' assessment, as in Lynch's and Cullen's theory, therefore, the established conservation principles are now lack of methods to identifying and preserving the place. In the townscape study in Chapter five, 'place-led' identifying method will be employed to define character of a historic settlement, as a basis for further study.

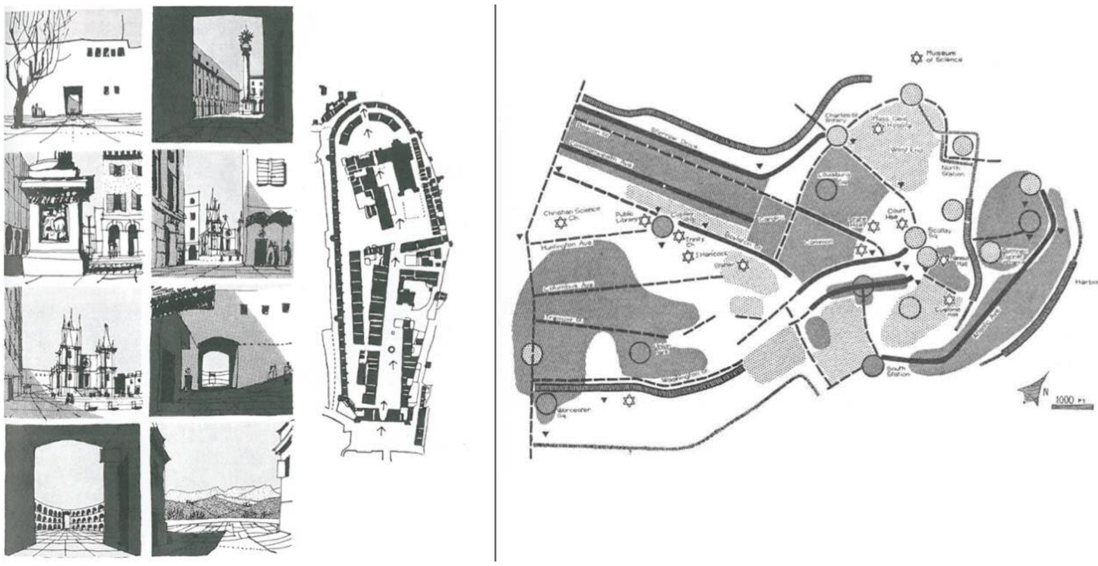


Figure 49: Defining character with place-led idneitfying method. Left: Cullen using visual image as serial vision to illustrate town character; Lynch's illustration of structure and components of a settlement (Cullen 1961, Lynch 1960)

Both place-led method of townscape study and mapping are efficient approaches to define characters and significant of the place. This criterion is now marked as a baseline of conservation in any historic settlement: a comprehensive understanding of the place before planning and detailed activities. According to its performance in Cadw and English heritage publications, a total 13 points is granted with 7 in townscape study and 5 in mapping.

Figure 50: Defining character with place-led identifying method. Narrow lanes between buildings intensify the sense of enclosure and is a characteristic of the historic core of Bath (based on the analytic drawings by the author)

4.4.2 Treat the historic environment and buildings as non-renewable assets

English Heritage and Cadw emphasise the fact that all parts of the historic environment should be treated as non-renewable assets, considering that all components and features may contribute to the distinctive historical identity of the settlement (English Heritage, 2008; Cadw, 2011). English Heritage has established several steps to identify the significance of a place over and above the national assessment guidelines, as indicated below:

> Firstly, to understand the fabric, how and why it has changed over time;
> Secondly, to consider:
> - Who values the place, and why they do so
> - How those values relate to its fabric
> - Their relative importance
> - Whether associated objects contribute to them

- The contribution made by the setting and context of the place
- How the place compares with others sharing similar values

(English Heritage 2008, p. 21)

Cadw (2011) argues that the four values of the historic settlement, that is, evidential value, historic value, aesthetic value, and communal value, are interlinked with the economic, social, and environmental dimensions. To be sustainable, investment in the conservation of the historic environment should bring social and economic benefit. On the other hand, investment in social and economic programmes should also bring environmental benefits (Cadw, 2011) (Figure 51).

Lynch (1961) explains the significance of viewing a place as an asset through an analysis of the three-dimensional relationship between the settlement and humans. He argues that a pleasing environmental image has three components: identity, structure, and meaning. Identity is what distinguishes the settlement from any other in the observer's eyes. Structure concerns the spatial or pattern relationship between the object and the observer and with other objects. Meaning refers to the strong connection forged with the observer, in both practical and emotional terms. These three components of a historic settlement are therefore strongly connected to humans and the values inherent within it are vital and irreplaceable (Lynch, 1961).

In practice, identifying and conserving elements with high sensitivity in a historic settlement would be the efficient approach to treat the whole settlement as a place and the non-renewable assets. Elements with high sensitivity may cover various components with different values, which requires the accompany of conservation principle 1 to establish a baseline to compare with. Been emphasised by both English Heritage and Cadw in several publications, this principle will have 9 credits in the rating system.

Figure 51: Treating the historic settlement and buildings as non-renewable assets

4.4.3 Clarify and reinforce the boundaries the settlement

Boundaries, including natural boundaries and man-made physical boundaries, play a vital role in preventing sprawl and in reinforcing a sense of identity for the space within the boundary. Natural boundaries, such as hills, rivers, and woods, would have existed from the outset of the settlement. Man-made boundaries are established during the history of the settlement. They can include walls, defences, bridges, and railways. Apart from the major benefit of controlling sprawl, boundaries offer additional benefits, some of which are listed below:

- Boundaries contribute to the identity of the historic environment encompassing its own natural value, aesthetic value, historic value, and social value.
- A clear boundary can have a strong impact on the inhabitants and visitor, creating a sense of being 'inside' and 'outside' the enclosure. Lynch argues the importance of edges in forming a mental image of the structure of the environment (Lynch, 1960).
- Defining and establishing the boundaries of the historic core is important in the conservation process in order to ensure the efficient distribution of limited resources.
- Establishing a clear boundary for the designated area may also guarantee the quality of a survey and ensure the cost effectiveness of the historic area assessment. However, this boundary should be treated as permeable when considering significant events or interventions outside the area, because the pattern of urban development may not have been contained by the boundary (English Heritage, 2012). It is important to treat the entire settlement as an integral whole when discussing any enchantment scheme.

It is seen as important to reinforce the border of the historic settlement to control the sprawl of the settlement. Snozzi and Caminada both verified this principle through design and showed that a clear boundary can efficiently maintain the condensed size of a historic settlement. (Caminada 2008; Disch, 2005) Uncontrolled urban sprawl was referred to as a barbaric phenomenon by Snozzi (Disch, 2005) Snozzi maintained that a solid construction at the boundary is useful to put a clear, precise limit on urban expansion (Disch, 2005). A clear boundary may also centralise most of the infrastructure and public facilities within the historic core, which is useful for the community in the long-term.

In addition, settlements with clear boundaries may establish a clear image to observers, and may more effectively preserve the spatial character within. Lynch claimed that a boundary, a kind of edge, is one of the five key elements which identify the image of the settlement. The boundary can be either transparent or in a continuous solid form with breaks, such as shores, walls, edges of developments, and railroad cuts (Lynch, 1961). The border helps the observer to form an image of the identity of a place by contributing to a sense of closure (Cullen, 1961).

Figure 52: Clarify and reinforce the boundaries of the settlement, including the continuity of street frontage and main junctions to enter the historic core.

Abstracted from conservation publications, architectural theories and well-reputed architectural practices, four sub-attributes are listed as multiple conservation strategies to clarify, maintain, and reinforce the boundaries of the historic settlement: (1), maintain the unique character of the conservation area; (2), create consistent streetscape; (3), repeat building character and pattern; (4), Establish a few key buildings at the boundary. In the rating system, corresponding points are granted to each features: the unique character and key buildings obtains more scores than the other two because they are repeatedly raised in publications and practices.

4.4.4 Guide and justify inevitable interventions

Changes to historic settlements are inevitable: changes may be due to the decay of buildings caused by environmental conditions or wear brought about by use or they could be due to enhancement activities responding to social, economic, or technological requirements (Cadw, 2011). Over and above these changes, contemporary interventions are inevitable in order to fulfil contemporary demands made by inhabitants and to meet the challenges of globalisation (Knox & Mayer, 2009). A historic settlement can be considered an organism with a constantly changing and self-renewing character. Its maintenance should follow the pace of self-renewal of the settlement to fulfil reasonable and inevitable demands. It is important to treat conservation as a process of managing changes, guiding all inevitable interventions. Interventions must be justified by careful review through the assessment on proposal and on site. (Cadw 2011, English Heritage 2008)

> 'Decisions about change must be reasonable, transparent and consistent. Sufficient assessment and public engagement is vital to justify the decision.' (Cadw 2011, p. 13)

As an emphasised and listed conservation principle in both Cadw and English Heritage frameworks, guide and justify inevitable interventions is granted with 5 points in the rating system. However, complying the principle may require fulfilment from other criteria and sub-attributes, such as detailed assessment guideline for all intervention activities within the conservation area.

4.4.5 Design with flexibility

In conservational interventions on historic settlements, architects are responsible for gifting new functions to historic buildings and establishing new buildings with specific functions. Design with flexibility is both economical and environmentally friendly: by adapting a building to serve multiple functions, the building as a limited resource may better serve the settlement and enable it to be more sustainable.

Designers should consider possible further or alternative functions buildings could serve in their design. Added contemporary elements to any existing building should be able to retracted without harming the original structure. New building should reflect the needs and demands of the locals in both function and comfort. Maximising the function of a building so it can be used by the whole community makes economic sense and renders the building more sustainable.

Two sub-features are listed as the supplement of the principle, representing two dimensions of the definition: (1), all design interventions could be revised or retracted to respect the original; (2), the ability of fitting multiple functions in one, especially for public buildings. Each features obtain 2 points for being stated by both conservation framework and architectural practices.

4.4.6 Assess all interventions after construction

In order to taking account of any changes between design and construction, mandatory post-construction assessment could be an effective method to guarantee minimum impact of contemporary interventions on the historic settlement. Designers must express empathy with the townscape and landscape where the intervention is to be placed, abolishing unnecessary decorations, revealing the logic of the structure and the character of materials (local materials if applicable), and creating a sense of timelessness. All construction activities must strictly follow the proposed design in the permit-applying version. The essential and unreplaceable surrounding environment of the construction site, including vegetation and landscape, must be protected and observed during construction. Penalties should be applied for any alterations beyond the proposed design. This is a key principle (worth 5 points) mentioned in both Cadw and English heritage publications to guarantee all conservation principles listed are observed from blue print to actual building.

4.4.7 Sustain all resource in the historic settlement

The historic settlement is a mix of physical remains, history, culture and the recording of human ambitions, memories, activities, and craftsman skills (Figure 53, Figure 54).

Settlement records reflect the culture, knowledge, aesthetic understanding, beliefs, and traditions of current and past communities. Design is a continuous process which ensures the distinctiveness, meaning, identity and quality of the place we live (Cadw, 2013). Although the townscape, which is the result of a revolutionary processing of society and culture over time, only reflects one particular period at a time, the different cultures and societies which contributed to it have not vanished but may be traced from hidden, fragile objects (Conzen, 1960). It is the responsibility of each generation to shape and sustain the historic environment to enable people to enjoy and benefit from it without compromising the ability of future generations to do the same (Cadw, 2013).

To itemising this principle, sub-features are listed in the model including materiality, building pattern, craftsmanship, landscape, and vegetation. Building pattern is complicated than the rest features, covering style, appearance, and colour scheme, therefore obtaining 2 scores.

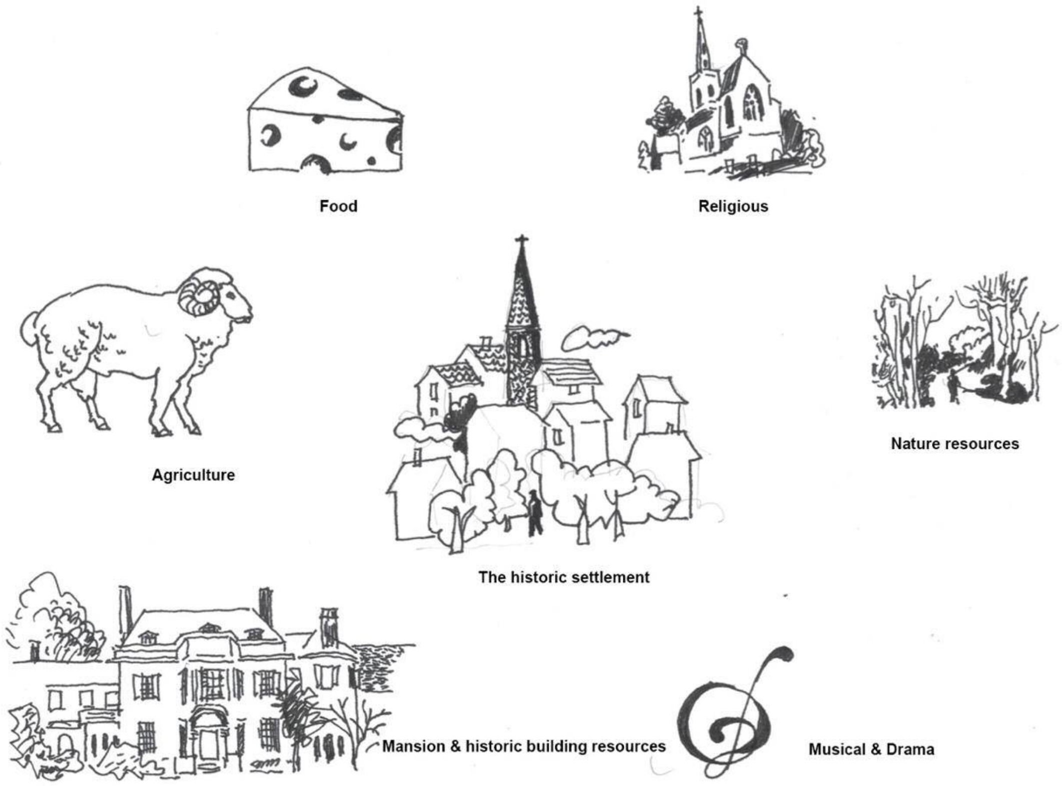


Figure 53: All resources in a historic settlement.

It is vital to value all resources in the conservation process, including material, vegetation, landscape, and craftsmanship, rather than buildings, that compose a historic settlement. For design of new buildings, the consistency of resources such as material and craftsmanship may help to establish a continuous visual image in the settlement. A character study as listed in principle one is crucial for achieving this principal.

Figure 54: Well preserved Cardiff Castle in central Cardiff, a complex mix of physical remains, history, and culture and a record of human ambitions, memories, activities, and skills.

4.4.8 Protect and reinforce the position of the historic settlement in the community

The conservation and enhancement proposal should be assessed from the point of view of the settlement in the community: it should not harm the role of the regional centre or rural service centre that the settlement serves. The proposal should take into consideration the quality and quantity of public buildings, the infrastructure, the local economy, and the population. In a long term development, the 'role of the service centre' is interlinked with the social aspect of the town, its economy, and the distinctiveness of the town's character.

The growth of an independent local economy was mentioned several times in Caminada's principles. The definition of the historic settlement at the end of Chapter

2.2 also highlights its role in the settlement as a service center. In the case of Vrin, Caminada argued that, compared to the construction of infrastructure, the grants made for the construction of a second holiday home are of little long-term benefit to Vrin's local economies (Caminada 2008).

Three sub-attributes are listed on the foundation of both conservation frameworks and successful cases: (1), enhancement of key infrastructure, (2), attraction of new populations, (3), boost local economy. They are recognised as key strategies to reinforce the position of a historic settlement in the community, therefore preserve its unique distinctiveness and social character in the long-term scheme.

Due to the methodological limitations on carbon emission calculation and energy assessment on non-domestic buildings, this principle addressing on infrastructures could not be tested in the following through design. However, this principle is emphasised in both English Heritage's and Cadw's principles; Caminada also highlights the significance of infrastructures from several design criteria. It is one of the key principle in conservation rules and must be listed in the model.

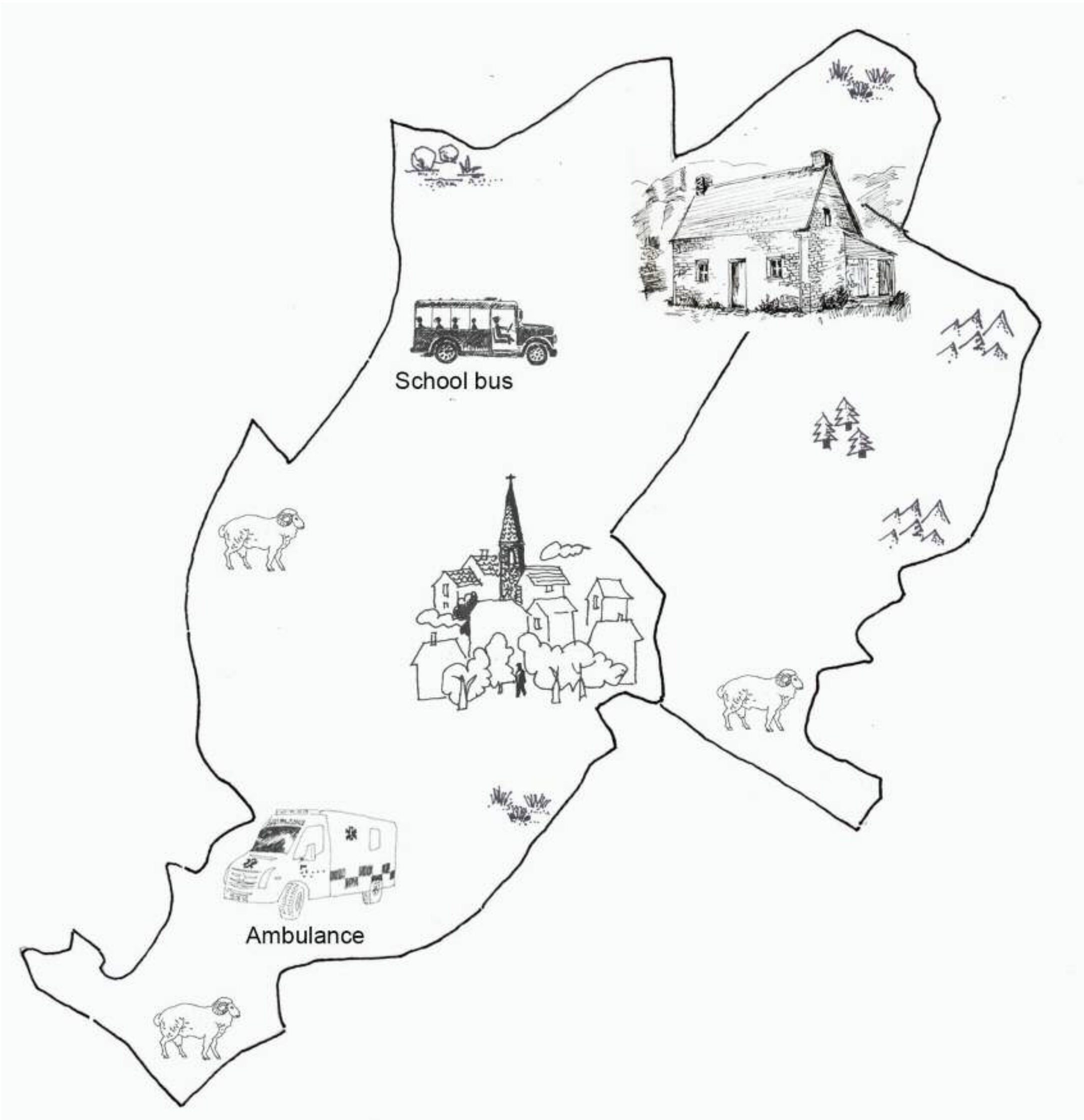


Figure 55: Protect and reinforce the position of the historic settlement in the community

4.4.9 Strengthen the historic core

The historic core refers to the central section of a historic settlement within the conservation area: a high density, mixed used area containing public building groups and spaces. In *The Concise Townscape*, Cullen (1961) claimed that 'this complex contributes to the sense of place and the sense of identity; but it is hard to duplicate and vulnerable from preservation' (Cullen, 1961). The identity of the historic core goes beyond the character of the individual heritage assets. 'Open spaces also devoted to public gatherings have formed an integral part of the urban and cultural heritage of many societies and towns throughout history and played a critical role in the genesis of commerce, the emergence of democracy and the vitality of civic life' (Friedman, 2014). The historic 'meeting places' should be preserved or enhanced to conserve the human scale and sense of the historic settlement (Gehl, 2010).

In the case of Monte Carasso, Snozzi started from the restoration of the core by retrofitting the monastery to once again become the central point of the village (a public space) along with several other facilities in the centre. He verified that an enhanced historic core may benefit the entire settlement by keeping current inhabitants living within its boundaries and attracting people from outside (Disch, 2005).

In the Vrin case, Caminada's design of the mortuary also contributes to the enhancement of core: 'the catafalque is not a fixed permanent feature; the building is intended to serve other purposes than taking leave of the deceased', such as a chamber concert, a reading, or simply afternoon coffee and cake. Caminada tried to create a place which acted as a parlour for the village, serving all the abovementioned functions, as well as a mourning place (Caminada 2008).

The emphasis of the historic core lies on four aspects, that is public areas, infrastructures, varieties, and reduce area with blur image. The complex four components contribute to the sense of place and identity. Public areas, including both public buildings and open spaces such as squares, are recognised with more weight than the others.

Once again, this principle will not be tested through design due to methodological limitations in measurement. Emphasis of historic core and public spaces in different conservation theorise arose since 1960s, and has been tested through practices in Monte Carasso, Vrin, Poundbury, etc. Therefore, it would be a complement to current conservation rules by listing the principles in the model.

Figure 56: Strengthen the historic core

4.5 Performance: Low energy consumption, low environmental impact building, and passive design

The other dimension of the proposed model, performance, refers to low energy consumption, low environmental impact building, and passive design. In order to maintain the environmental sustainability, particularly by carbon cutting, of historic settlements, the energy consumption and carbon emissions of all the buildings within the settlement have to be reviewed. However, it is noted that the majority passive design strategies are fulfilled through improving building envelop, altering the layout, and adding renewable technologies; while these are fundamental elements of a building's physical appearance. By changing the appearance of a single building, the overall character of a whole settlement could be then altered. For example, a simple window upgrade from traditional sash to plastic window could change the historic significance of a place. These areas are also the main conflicts between conservation and performance enhancement.

Therefore, enhancement of performance could greatly alter the character of the settlement and the sense of place, when applying passive design strategies in a historic settlement. The impact on new and existing building envelopes is critical in terms of wall thickness, appearance and detail; and the impact of renewable energy technologies is also a major consideration when balancing issues of conservation, enhancement and sustainability.

Part L of the Building Regulations (2006) was drawn up in response to the government's White Paper on Energy which commits to raise the energy performance of buildings, including both new and retrofit buildings. It includes measures to limit building heat loss and to control excessive solar gains, enhance energy efficiency, and introduce alternative energy systems (BRE Trust, 2006). Building energy performance, energy efficiency, and carbon emissions are three interlinked aspects of sustainable design (BREEAM, 2006): once building energy performance is enhanced, or energy efficiency is increased, then the carbon emissions level is reduced. Computer based testing and simulation can be employed to simulate the proposed carbon emissions, providing a reliable picture for the designers at the design stage which could lead to possible improvements in building energy performance or energy efficiency. For example, SAP is engaged in the study as a robust energy assessment tool to simulate energy consumption and carbon emission during the design progress through all variations; the comparison of SAP ratings and simulated carbon emission results contributes to the analysis and discussion of the model.

To meet the tighter carbon emissions standards in sustainable design, alternative energy is now frequently employed to partly or fully replace traditional fossil fuel based energy in both retrofit and new designs.

BREEAM also points out that the occupants' comfort levels should also be taken into account: the occupants' comfort level is determined by the complex mix of sound, lighting, temperature, and hygiene within a building's indoor environment, which can be controlled by measures to remove indoor pollutants, control temperatures, ensure ventilation and daylight, and sound insulation (BRE Trust, 2015).

The 2013 amendment of Part L arises the quality of construction and commissioning, referring observation and assessment of consistent building performance after construction as its calculated carbon emission rate (HM Government, 2016).

The following list presents criteria and key considerations in performance enhancement with split sub-attributes, as drawn from the relevant literature:

1. Building energy performance – covering building position and orientation, building layout, passive design, U-value of building envelope, natural lighting, ventilation, solar gain, and solar protection;
2. Energy efficiency – including heating and cooling system, boilers and hot water, all other appliances, HVAC systems, user's behaviour, and lighting;
3. Carbon emission – airtightness, carbon emission during construction period, and user's behaviour;
4. Alternative renewable energy – including solar hot water, alternative heating, and electric generation;
5. Occupants' comfort – indoor pollutants, comfortable temperature, ventilation, daylight, and full insulation without drought; and
6. Construction quality and post-construction assessment – covering insulation, heating and cooling system, boilers, all other appliances, airtightness, and treatment of droughts.

Attached is a tabular summary of key performance principles and sub-attributes. Extracted from updated building regulation for energy performance efficiency, reshaped with added sub-elements from reviewed BRE case studies and publications, these criteria are the combination of primary rules and efficient strategies for enhancing building energy performance plus controlling the proposed carbon emission. 4.5.1-4.5.6 explains and reveals the basis and definition of these criteria and references that have been extracted. Being derived from literatures, frameworks, and case studies, rewarded points under each criteria are equivalent to the frequency of the corresponding point in reviewed literatures, as shown in Figure 57.

No.	Key Principles	Sub-elements	References	Points
1	Building energy performance	*Building position and orientation*	*BRE Trust*	*1*
		Building layout	*HM Government, BRE Trust, EnEv, Bouwbesluit*	*2*
		Passive design	*HM Government, BRE Trust, EnEv, Bouwbesluit*	*3*
		U-value of building envelope	*HM Government, BRE Trust, EnEv, Bouwbesluit*	*3*
		Natural lighting	*BRE Trust*	*1*
		Ventilation	*BRE Trust*	*1*
		Solar gain	*BRE Trust*	*1*
		Solar protection	*BRE Trust*	*1*
2	Energy efficiency	*Heating and cooling system*	*HM Government, BRE Trust*	*3*
		Boilers and hot water	*HM Government, BRE Trust*	*2*
		All other appliances	*HM Government, BRE Trust*	*2*
		HVAC systems	*HM Government*	*1*
		User's behaviour	*BRE Trust*	*1*
		Lighting	*BRE Trust*	*1*
3	Carbon emission	*Airtightness*	*BRE Trust*	*1*
		Carbon emission during construction period (example: demolition, material delivery)	*HM Government, BRE Trust*	*2*
		User's behaviour	*BRE Trust*	*1*
4	Alternative renewable energy	*Solar hot water*	*BRE Trust*	*1*
		Alternative heating (example: ground source heat pump)	*HM Government, BRE Trust*	*2*
		Electric generation (example: photovoltaic)	*HM Government, BRE Trust*	*2*
5	Occupants' comfort	*Indoor pollutants*	*BRE Trust*	*1*
		Comfortable temperature (around 25oC)	*BRE Trust*	*1*
		Ventilation	*BRE Trust*	*1*
		Daylight	*BRE Trust*	*1*
		Full insulation without drought	*BRE Trust*	*1*
6	Construction quality and post-construction assessment	*Insulation*	*HM Government*	*1*
		Heating and cooling system	*HM Government*	*1*
		Boilers	*HM Government*	*1*
		All other appliances	*HM Government*	*1*
		Airtightness	*HM Government*	*1*
		Treatment of droughts	*HM Government*	*1*

Figure 57: Summary of performance principles, sub-elements, and references

4.5.1 Building energy performance

Enhancing building performance means increasing the ability of the building to resist climate change in order to create a comfortable and stable indoor physical environment for the user while minimising energy consumption, particularly carbon energy (BRE,

2006) (Figure 58) The majority of energy consumed by a building is consumed during their life cycle rather than during construction or demolition. Existing buildings, therefore, have more potential for enhancing building performance than new-builds, which is an additional reason for applying environmentally sustainable measures to historic settlements.

The enhancement of building performance is normally achieved through passive design and the improvement of a building's air tightness (BRE Trust, 2006). In the UK, the improvement of building tightness was recognised as a main concern in the past. BRE argues that it is also important to consider the risk of buildings overheating within the context of a global temperature increase (BRE Trust, 2015).

The establishment of the *code for sustainable homes*, an environmental assessment method, gave rise to minimum standards of environmental performance for new domestic buildings (DCLG and BRE Trust, 2010). For existing buildings, reaching current energy performance standards is a huge challenge, especially if there are further demands on building façades, elevations, site, and other elements. A large proportion of existing buildings in historic settlements will face the same difficulties in becoming more sustainable in order to survive in the new trend.

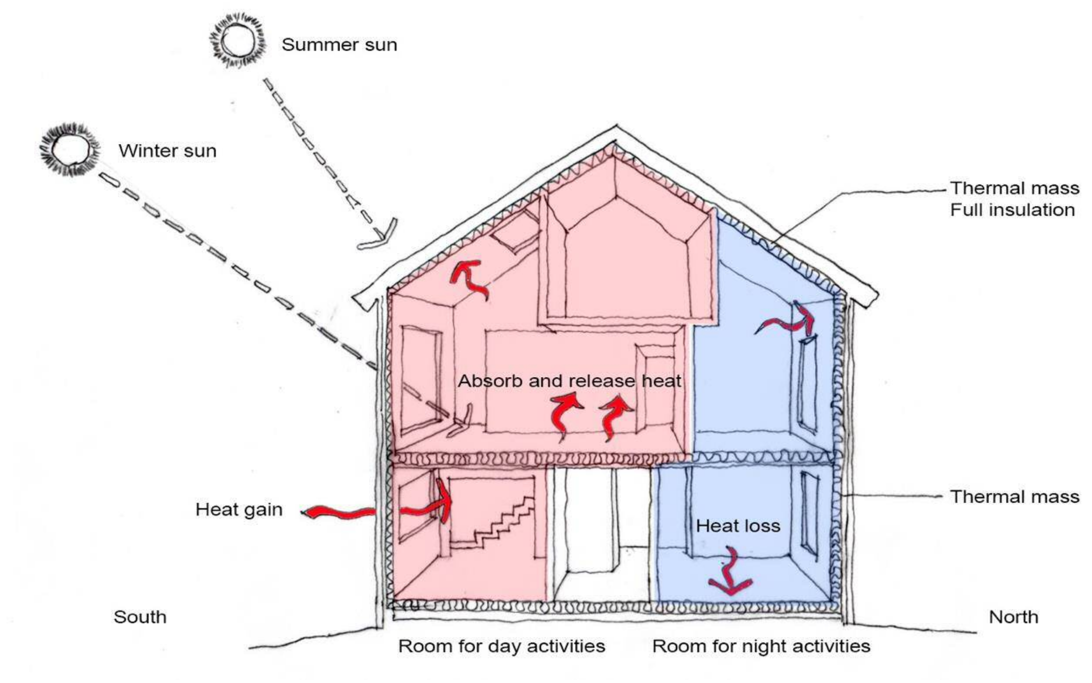


Figure 58: Measures and principles for passive design.

In sum, building energy performance embraces all physical components of building, including position and orientation, building layout, passive design, U-value of building envelope, natural lighting, ventilation, solar gain, and solar protection. In all sub elements, building layout, passive design, and building envelop are emphasised in multiple frameworks and assessment tools, which may directly make efforts on the final carbon emission rate.

4.5.2 Energy efficiency

Energy efficiency is determined by both the physical condition of buildings and occupant's behaviour and lifestyle. A tight building envelope, high energy rating heating and cooling system, boilers and hot water, lighting, all other appliances, and HVAC system are all greatly contribute to the energy efficiency level. 'Provision for energy-efficient operation' is also listed as a key criterion in Part L, to guarantee the owner of the building could operate it in a reasonable and proposed circumstances after sufficient training (HM Government, 2016)

4.5.3 Carbon emission

Carbon emission on building level could be monitored and controlled through airtightness test, control of carbon emission during the demolition and construction period, and educations on user's sustainable knowledge and behaviour. In the settlement scale, emissions from traffic, industries, etc. need to be considered on the basis of emissions from domestic buildings.

4.5.4 Alternative renewable energy

Renewable energy are powerful tools in low carbon design to fit a building into a tight emission band, but it need to be verified from two aspects in the design: firstly, it may impact the building appearance from introducing new elements to an elevation, such as photovoltaic; secondly, most renewable energy source are expensive systems compared to general ones, cost-wise need to the considered in practice. In the study, all renewable energy sources are categories into three aspects of hot water (solar panel), alternative heating and cooling, and electric generation system.

4.5.5 Occupants' comfort

BREEAM's list of five aspects in the indoor environment is employed in the following framework to test this principle, that is indoor pollutants, comfortable temperature, ventilation, daylight, and full insulation without drought.

4.5.6 Construction quality and post-construction assessment

Post-construction assessment in the performance aspect refers to inspection and check of all key physical elements related to the final carbon emission rate, that is including insulation, heating and cooling system, boilers, airtightness, treatment of droughts, etc. This principle ensures the simulated carbon emission at design stage may be reached in practice. Part L highlights several tests and inspections during this stage: thermal bridge, drought, airtightness, pressure test, and inspections of heating and hot water system (HM Government, 2016). For example, lack of treatment of any joints between pitched roof and horizontal wall, or discontinuous insulation at the joints area could be result as server drought and thermal bridge, leading to excessive carbon emission than the original design.

4.6 Proposal of a new model

The discussion on the various approaches to designing in a historic settlement from points of two aspects highlights some parallel areas and overlapping concerns and defined the aims and objectives of such an undertaking. However, the discussion also revealed areas that were either omitted or had the potential to cause operational difficulties and professional tension.

The following are the overlaps and links that were identified:

- *Post-construction assessment*: this principle is highlighted in both aspects of conservation and performance, but with slight different emphasises. In conservation aspect, the assessment should focus on strictly observing the proposed design and design concept, preserving essential and unreplaceable environment during construction process, including buildings, landscape, and vegetation. In performance aspect, the assessor should pay attentions on physical components of the building envelop and all other applicants, testing the actual carbon emission rate with comparison to the proposed design rate.

- *Sustain all resources including materials* (Conservation) vs *Energy performance* (Performance): Materiality is taken into account in both aspects of conservation and performance. 'traditional' materials are always preferred and supported in conservation strategies and guidance when dealing designs or regenerations in the historic settlement; with architects' rephrase, apart from listed buildings, designers should focus on visual consistent in materiality for most design cases in the conservation rather than mimicking the 'old'. It is now also important to review the U-value and joints of all employed materials from performance aspect during design stage.

Apart from overlaps, some areas that may give rise to conflict:

- *Preservation* (Conservation) vs *Enhancement* (Performance): The target of conservation procedure is to preserve the place from changing, by playing a role of revealing and sustaining the historic environment and buildings, particularly the significant ones, during the development of the historic settlement. However, changing happens from all sorts of reason which has been reviewed from the literature. On the other aspect, performance enchantment is the new trend and will be greatly involved in this procedure under the requirements of environmental sustainability, especially carbon deduction. The carbon emission rate of the entire settlement need to be considered as a whole piece, reflecting on changes of building envelope even street images. During this process, architects play a role of balancing enhancement and maintenance of historic buildings and places through design, bridging most gaps and conflicts during this procedure.
- *Conservation* (Conservation) vs *Alternative energy* (Performance): same as above, this is a conflict between preservation and added new elements. Concerns on preserving building façade, details from the elevation, and other components are always highlighted in conservation guidance; because change

of them may harm the value and significance of the building heritage and urban heritage. While in order to offset overall carbon emission, the introduction of alternative energy is one of the most effective solution in aspect of performance. It has been approved with examples that these added elements without careful verification could severely alter image of streetscape and visual impact of the historic settlement. (Figure 59, Figure 60)

Figure 59: The historic Edinburgh: a mixture of old and new buildings along Princess Street, as a result of inappropriate conservation decision. (Source of image: Miller 2015 in Daily Mail 13/02/2015)

Figure 60: Installation of photovoltaic above the roof of train station changes the cityscape of the historic Edinburgh. (Source of image: Miller 2015 in Daily Mail 13/02/2015)

Apart from above overlaps and conflicts, there are some more key points to clarify:

- In the next chapter, a more 'place-led' assessment approach (on the basis of theories from Cullen, Lynch, and Norberg-Schulz) will be employed rather than the 'conservation-led' (such as Cadw's appraisal), when identify and assess the significance of an exemplar historic settlement. As discussed earlier, this is a key difference between both ways of observing a place: 'conservation-led' analysis mainly describe and image a settlement through texts and photographs to reveal the characters; while 'place-led' methods, such as Cullen's and Lynch's, employ techniques of analytical sketching together with photographs, to capture the image and rephrase the characteristic. Place-led assessment method would benefit character definition and illustration of the significate of a place.
- The spatial characteristics of the settlement will be emphasised in the townscape study including boundaries and centres, that follows Snozzi's key principles.
- Caminada's principle and approach of 'learning from tradition, but innovated to contemporary' is important in reinforcing character in new domestic building design in the historic settlement.
- Although the conservational principle of 'design with flexibility' is not overlapped with performance enhancement, it is socially and environmentally sustainable by serving a limited building resource with multiple functions.
- There are two conservation principles, '*protect and reinforce the position of the historic settlement in the community*' and '*straighten the historic core*', greatly rely on the recreation or renewal of infrastructures and public spaces. The development of infrastructures also brings long-term benefits such as maintaining the function and position of the settlement, boosting local economies, maintaining valuable public resources, and resisting the sprawl of the settlement. In this study, both principles will not be fully tested through design practices and energy assessment due to the methodological limitation on energy rating for non-domestic buildings. On the other hand, existing domestic

buildings, holding a large proportion in a settlement, are the major objects contributing to the enhancement of overall performance of a historic settlement. While introduction of new contemporary standard domestic buildings also attracts new inhabitants into the historic settlement, benefiting local economic, and changing the blur image of some Backlane site as a character of burgage plot.

By illustrating the principles and design strategies from both aspects of conservation and performance, then rephrased and reshaped under place-led assessment theories, a new model containing a point based form is then proposed in the following. The model will then be employed to rate all design approaches, as diagrammed in 4.7. This is a unpolished initial attempt to provide a hierarchical distinction between different criteria. By testing the model in a number of theoretical design case studies in the next few chapters, the model with its assessment tool will be future refined.

In the model, the sub-principles under each criterion are formulated according to literatures reviews and analysis above, explained as the strategies and design solutions of each criterion. Available credits marked for each principle presents the weightings of each criterion or sub-principle according to their performances in the reviewed literature. The overall credit in the conservation aspect is more than 1/3 higher than the performance, due to their different weightings and influences to design approaches in the context of the historic settlement. For example, in the conservation aspect, it is reviewed principle 1 *Define characters and significant of the place*, should be essential with the highest credits as the core and foundation of following design approaches. It would be difficult to create suitable and sustainable design strategies without correctly understanding a place. Conservation principle 2, 3, 8, 9 are all established on the townscape rather than building scape, containing higher credit than principle 4, 5, 6, and 7. In the performance aspects, principles 1 and 2 targeting on building envelop and energy performance contains higher total credits than the others according to their determined position in building carbon emission and their extended relationship with conservation.

The study is established on the foundation of existing conservation legislation, framework, and recent publications, then exploring new building regulations on energy efficiency plus their possible efforts to conservation activities in both settlement and building scale. Under the context of a historic settlement, especially within the conservation zone, identifying and preserving the distinctive urban context, townscape, streetscape and building appearance would be the priority than achieving performance-based sustainability. In the meanwhile, the summarised conservation principles could guide all interventions from planning stage to post-construction stage, while performance principles are target on single building or a small community with a building group. Take all above aspects into consider, the conservation principles are granted with higher weightings than performance criteria in overall. However, it is undeniable the tightening low carbon emission target may put efforts on retrofitting and new built cases in the historic settlement, especially for the large proportion of domestic building. Therefore, two essential criteria in the performance aspect, building energy performance and energy efficiency, are highly valued in the rating system to verify the design result. By addressing and reconciling conservation principles and performance-based criteria, the assessment tool could provide a guideline for creative design embracing conservation, regeneration, and performance in a historic settlement, especially for the large amount of domestic buildings as tested in the study.

Table 3: A proposed point-based framework to assess all design approaches

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7		
Mapping	5		
2 Non-renewable assets: Conservation to elements with high sensitivity	9		
3 Reinforce the boundaries of the settlement			

Maintain the unique character of the conservation area	3		
Create consistent streetscape	2		
Repeat building character and pattern	2		
Establish a few key buildings at the boundary	3		
4 Guide and justify inevitable interventions	5		
5 Design with flexibility			
Design could be revised or retracted	2		
Ability of fitting other functions	2		
6 Assess all interventions after construction	5		
7 Sustain all resources in the historic settlement			
Materiality	1		
Building pattern	2		
Building details	1		
Craftsmanship	1		
Landscape	1		
Vegetation	1		
8 Reinforce the position in the community			
Infrastructures	4		
Attraction of new populations	2		
Economic boost	2		
9 Strengthen the historic core			
Public spaces	4		
Infrastructures	2		
Varieties	2		
Reduce areas with blur image	2		
Performance:			
1 Building energy performance			
Building position and orientation	1		
Building layout	2		
Passive design	3		
U-value of building envelope	3		
Natural lighting	1		
Ventilation	1		
Solar gain	1		
Solar protection	1		
2 Energy efficiency			
Heating and cooling system	3		
Boilers and hot water	2		
All other appliances	2		
HVAC systems	1		

User's behaviour	1		
Lighting	1		
3 Carbon emission			
Airtightness	1		
Carbon emission during construction period (example: demolition, material delivery)	2		
User's behaviour	1		
4 Alternative renewable energy			
Solar hot water	1		
Alternative heating (example: ground source heat pump)	2		
Electric generation (example: photovoltaic)	2		
5 Occupants' comfort			
Indoor pollutants	1		
Comfortable temperature (around 25˚C)	1		
Ventilation	1		
Daylight	1		
Full insulation without drought	1		
6 Construction quality and post-construction assessment			
Insulation	1		
Heating and cooling system	1		
Boilers	1		
All other appliances	1		
Airtightness	1		
Treatment of droughts	1		
Total	113		

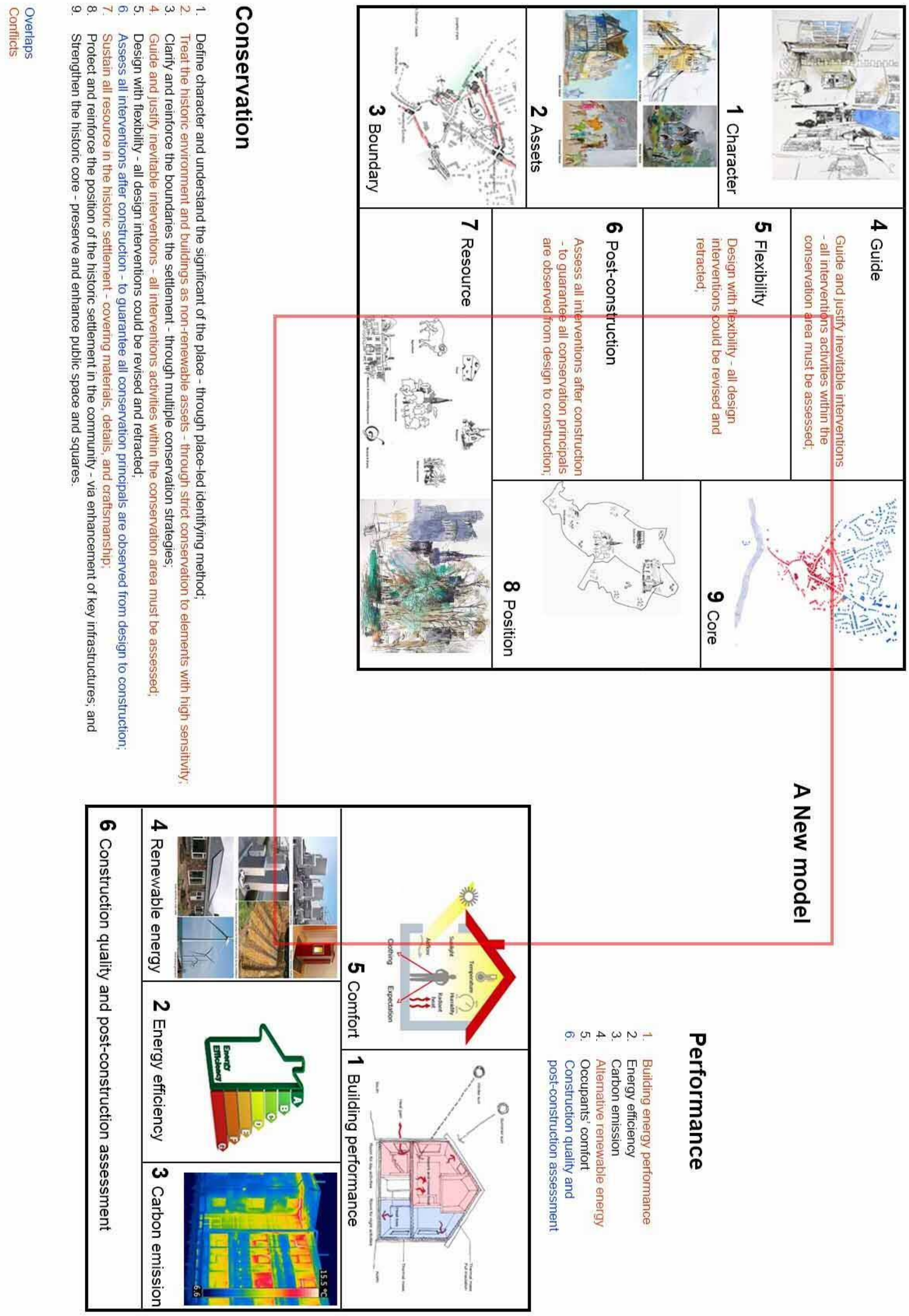


Figure 61: Proposed model

4.7 Test of the model

The model is then tested through:

- townscape study (chapter 5),
- design case one – domestic building retrofit in four variations (chapter 6), and
- design case two – domestic new built in four variations (chapter 7).

In the townscape study, place-led identifying and assessment methods are employed to picture conservation context and characters in Llandeilo for design cases. Outcomes from mapping are then assessed and discussed against the model in both aspects of conservation and performance (see 5.4).

Two proposed design cases in Llandeilo are drawn from outcome of townscape study and mapping (conservation principle 1): (1) design one is a domestic building retrofit, the outcomes and discussion could be a pioneer study for the large amount of aged domestic buildings in Llandeilo, targeting on meeting tight carbon emission rate while still maintaining the image of the settlement. Over 75% of existing domestic buildings in Llandeilo are now facing the upgrading of energy performance due to their physical condition; while retrofitting might jeopardise the visual image and character, becoming a challenge for conservation. (2), design two is a new built domestic building project, providing new contemporary standard dwelling within the historic center to attract new inhabitants. The site of the project could located in an area with blur image, or at either the boundary or the historic core of the conservation area. Well guided design in either location may benefit the preservation and improvement of the place from the conservation aspect. A well established and continuous boundary or a compact historic core would be critical for identifying the place.

Four hypothesised variations will be displayed, simulated by SAP, tested and evaluated against the model, then discussed in each design case, coded as V1 to V4. Under the same research method, variation 1 is the initial design work, proposed based on actual context, geographic, and physical condition of the building and site. This design under more onerous conservation requirements will be the foundation and context of following variations, and variation 2, 3, and 4 would inherit the same building layout from the initial design (V1). Variation 2 is also under onerous conservation requirements with univariate on geographic condition: the whole site is hypothetically twisted 180 degrees. Variation 3 and 4 are proposed under less conservation requirement, which may leads modifications on street façade and roofscape when necessary. Variation 3 has the same geographic background with the initial design, while the site for variation 4 is hypothetically twisted 180 degrees as variation 2. It is important only one variant is applied in each test, and all tests in the same design share the identical building layout. Figure 62 is a diagram showing the relationship within four variations in each design case.

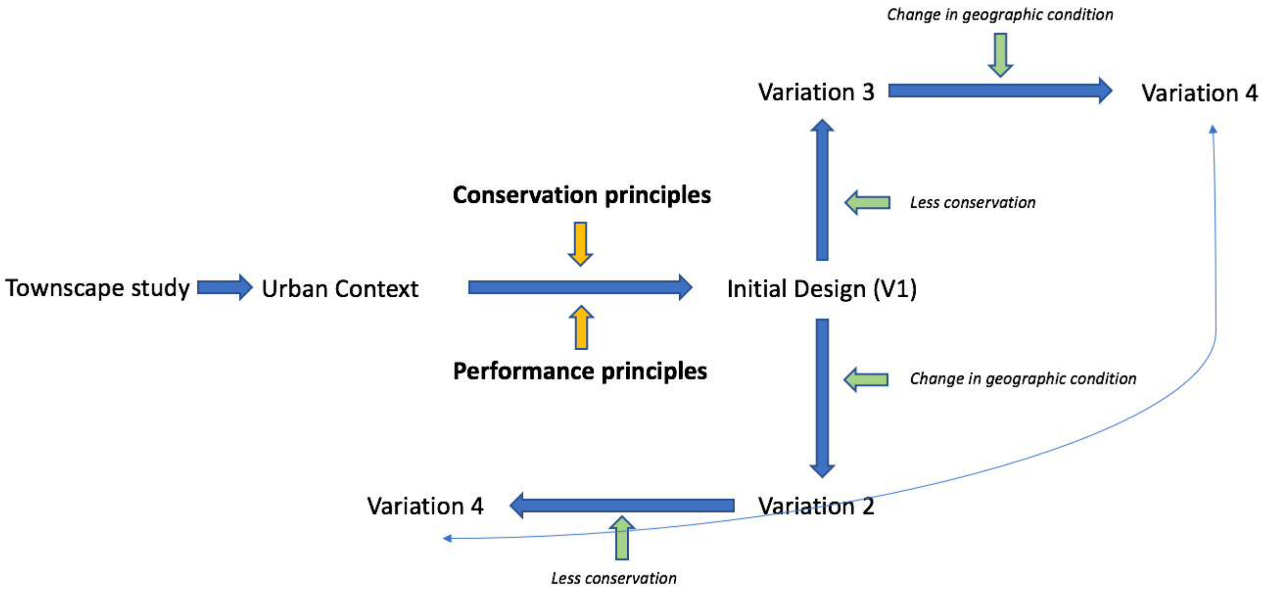


Figure 62: Diagram showing the relationship within four variations in each design case.

Figure 63 reveals how conservation principles and sub-elements are tested in all variations of each design. Several principles, especially sub-elements guiding infrastructures and non-domestic buildings, are not tested in the study, such as '*establishment of key buildings at the boundary*'. Due to the limitation on timeframe and simulation of building energy consumption, non-domestic buildings are not discussed in the study. Some sub-principles on emphasising gaps between new and old, for example, '*design could be revised or retraced*', are only applicable to the retrofitting case. All variations in each design are evaluated against the model through the credit system; in the study, points are awarded by the author according to the fulfilment of the corresponding principle. Although any credit loss may trace to explanations on the notes column, there might be limitations or biases because of author's knowledge background. On further studies, a council scale vote using point-based questionnaires could be employed under the same research method.

No.	Key Principles	Sub-elements	Design 1	V1	V2	V3	V4	Design 2	V1	V2	V3	V4
Conservation												
1	Define characters and significant of the place	*Townscape study*		√	√	√	√		√	√	√	√
		Mapping		√	√	√	√		√	√	√	√
2	Non-renewable assets: Conservation to elements with high sensitivity			√	√	√	√		√	√	√	√
3	Reinforce the boundaries of the settlement	*Maintain the unique character of the conservation area*		√	√	√	√		√	√	√	√
		Create consistent streetscape		√	√	√	√		√	√	√	√
		Repeat building character and pattern		√	√	√	√		√	√	√	√
		Establish a few key buildings at the boundary	*For public builidngs*	*X*	*X*	*X*	*X*	*For public builidngs*	*X*	*X*	*X*	*X*
4	Guide and justify inevitable interventions			√	√	√	√		√	√	√	√
5	Design with flexibility	*Design could be revised or retracted*		√	√	√	√	*not applicable for new built*	*X*	*X*	*X*	*X*
		Ability of fitting other functions	*not applicable*	*X*	*X*	*X*	*X*	*not applicable*	*X*	*X*	*X*	*X*
6	Assess all interventions after construction	*to guarantee all conservation principals are observed from design to construction;*		√	√	√	√		√	√	√	√
7	Sustain all resources in the historic settlement	*Materiality*		√	√	√	√		√	√	√	√
		Building pattern		√	√	√	√		√	√	√	√
		Building details		√	√	√	√		√	√	√	√
		Craftsmanship		√	√	√	√		√	√	√	√
		Landscape		√	√	√	√		√	√	√	√
		Vegetation		√	√	√	√		√	√	√	√
8	Reinforce the position in the community	*Infrastructures*	*For public builidngs*	*X*	*X*	*X*	*X*	*For public builidngs*	*X*	*X*	*X*	*X*
		Attraction of new populations		√	√	√	√		√	√	√	√
		Economic boost		√	√	√	√		√	√	√	√
9	Strengthen the historic core	*Public spaces*	*For public builidngs*	*X*	*X*	*X*	*X*		√	√	√	√
		Infrastructures	*For public builidngs*	*X*	*X*	*X*	*X*	*For public builidngs*	*X*	*X*	*X*	*X*
		Varieties	*For public builidngs*	*X*	*X*	*X*	*X*	*For public builidngs*	*X*	*X*	*X*	*X*
		Reduce areas with blur image	*Location*	*X*	*X*	*X*	*X*		√	√	√	√

Figure 63: List of conservation principles and sub-elements that are tested in all variations of each design.

As shown in Figure 64, the majority of performance principles and sub-attributes are tested through two cases; with a few of them are only overviewed in some variations, such as alternative heating and energy generation.

No.	Key Principles	Sub-elements	Design 1	V1	V2	V3	V4	Design 2	V1	V2	V3	V4
Performance												
1	Building energy performance	*Building position and orientation*	*Two variations have limitations on orientation*	√	***X***	√	***X***	*Two variations have limitations on orientation*	√	***X***	√	***X***
		Building layout		√	√	√	√		√	√	√	√
		Passive design		√	√	√	√		√	√	√	√
		U-value of building envelope		√	√	√	√		√	√	√	√
		Natural lighting		√	√	√	√		√	√	√	√
		Ventilation		√	√	√	√		√	√	√	√
		Solar gain		√	√	√	√		√	√	√	√
		Solar protection		√	√	√	√		√	√	√	√
2	Energy efficiency	*Heating and cooling system*		√	√	√	√		√	√	√	√
		Boilers and hot water		√	√	√	√		√	√	√	√
		All other appliances		√	√	√	√		√	√	√	√
		HVAC systems		√	√	√	√		√	√	√	√
		User's behaviour		√	√	√	√		√	√	√	√
		Lighting		√	√	√	√		√	√	√	√
3	Carbon emission	*Airtightness*		√	√	√	√		√	√	√	√
		Carbon emission during construction period (example: demolition, material delivery)		√	√	√	√		√	√	√	√
		User's behaviour										
4	Alternative renewable energy	*Solar hot water*	*Only installed in two variations*	√	***X***	√	***X***	*Only installed in two variations*	√	***X***	√	***X***
		Alternative heating (example: ground source heat pump)	*Only installed in two variations*	***X***	√	***X***	√	*Only installed in two variations*	***X***	√	***X***	√
		Electric generation (example: photovoltaic)	*Only installed in one variations*	***X***	***X***	***X***	√		√	√	√	√
5	Occupants' comfort	*Indoor pollutants*		√	√	√	√		√	√	√	√
		Comfortable temperature (around 25oC)		√	√	√	√		√	√	√	√
		Ventilation		√	√	√	√		√	√	√	√
		Daylight		√	√	√	√		√	√	√	√
		Full insulation without drought		√	√	√	√		√	√	√	√
6	Construction quality and post-construction assessment	*Insulation*		√	√	√	√		√	√	√	√
		Heating and cooling system		√	√	√	√		√	√	√	√
		Boilers		√	√	√	√		√	√	√	√
		All other appliances		√	√	√	√		√	√	√	√
		Airtightness		√	√	√	√		√	√	√	√
		Treatment of droughts		√	√	√	√		√	√	√	√

Figure 64: List of performance principles and sub-attributes that are tested in all variations of each design.

CHAPTER FIVE: TOWNSCAPE STUDY: LLANDEILO

5.1 Introduction

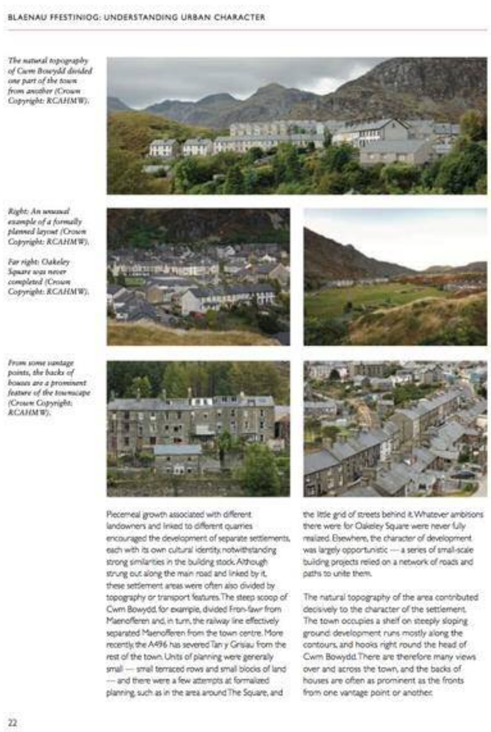
This chapter presents the townscape study undertaken in order to define the character and identify the significance of the settlement chosen to serve as the basis for sustainable design within a historic environment.

Llandeilo, a compact, historic town in Carmarthenshire, Wales, was selected to test the model through design. With its origins dating back to Roman times, the settlement is proud of its history, its picturesque town image, and its Welsh cultural background. The town also serves the surrounding rural district of eastern Carmarthenshire as the administrative centre.

The aims of townscape study are:

- To record the geographical conditions, origins, layout, and characteristics of the settlement, and to establish a visual image of the place through mapping (5.2).
- To reveal the strengths, weaknesses, and opportunities for development of the settlement (5.3).
- To implement the model for conservational regeneration in the historic settlement as proposed in Chapter 4 (5.4).
- To serve the designs presented in Chapter 6 and 7 (5.5).

In order to critically assess the historic settlement in terms of its geographic conditions, origins, layout, sense of place, and character, a combination of two types of methods is employed: the historical and photographic survey (based on the Cadw characterisation studies) and a more architectural and townscape approach (based on the spatial characterisation of Gordon Cullen) (See Figure 65). In the appraisals for Welsh towns *Understanding Urban Character* (Cadw, 2009) the town characteristics are expressed mainly through photography and description, including topography, space, character areas, and building characteristics. Cullen (1961), seeing and illustrating the settlement from an architect's point of view, used a mixture of drawings, photographs, serial vision and analytical sketches to reveal the town's image and its spatial characteristics.


BLAENAU FFESTINIOG: UNDERSTANDING URBAN CHARACTER

The natural topography of Cwm Bowydd divided one part of the town from another (Crown Copyright: RCAHMW).

Right: An unusual example of a formally planned layout (Crown Copyright: RCAHMW).

Far right: Oakeley Square was never completed (Crown Copyright: RCAHMW).

From some vantage points, the backs of houses are a prominent feature of the townscape (Crown Copyright: RCAHMW).

Piecemeal growth associated with different landowners and linked to different quarries encouraged the development of separate settlements, each with its own cultural identity, notwithstanding strong similarities in the building stock. Although strung out along the main road and linked by it, these settlement areas were often also divided by topography or transport features. The steep scoop of Cwm Bowydd, for example, divided Fron-fawr from Maenofferen and, in turn, the railway line effectively separated Maenofferen from the town centre. More recently, the A496 has severed Tan y Grisiau from the rest of the town. Units of planning were generally small — small terraced rows and small blocks of land — and there were a few attempts at formalized planning, such as in the area around The Square, and the little grid of streets behind it. Whatever ambitions there were for Oakeley Square were never fully realized. Elsewhere, the character of development was largely opportunistic — a series of small-scale building projects relied on a network of roads and paths to unite them.

The natural topography of the area contributed decisively to the character of the settlement. The town occupies a shelf on steeply sloping ground: development runs mostly along the contours, and hooks right round the head of Cwm Bowydd. There are therefore many views over and across the town, and the backs of houses are often as prominent as the fronts from one vantage point or another.

22

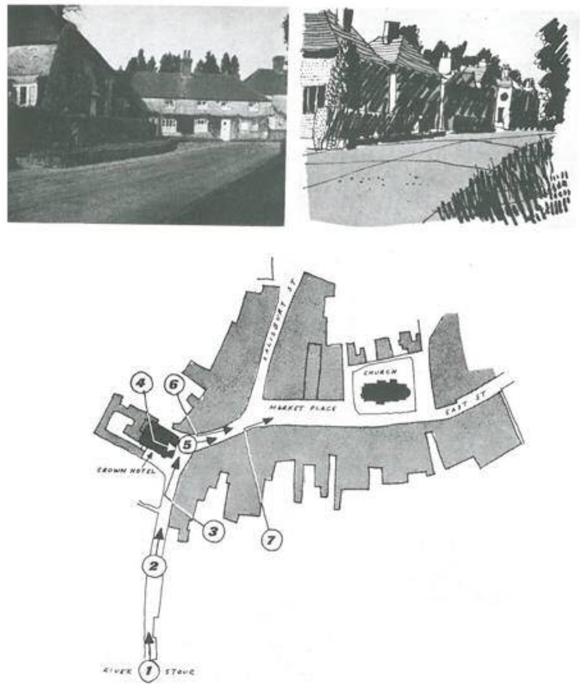


Figure 65: Example of methods used in a townscape study. Left: a page from Cadw's *Understanding Urban Character*, using photographs and descriptions to picture urban characteristics (2009, p.22). Right: a page from Cullen's (1961) *The Concise Townscape* using photography and analytical sketches to illustrate an enclosure (p. 107).

The mapping process will comprise several aspects:

- **Landscape**: underlying landform, waterways, terrain, green areas. These elements may help clarify the origins of the settlement and identify restrictions to development.
- **Shape and layout**: historical and current layout, shapes, routes, paths, squares, public spaces.
- **Morphology**: scale and enclosures, land use, materials.
- **Land use and listed buildings**: identifying the ratio of domestic and non-domestic buildings in existing land use and pinpointing listed buildings on the map.

- **Characteristic areas**: analytical sketches together with photographs to reveal areas and places of character. These areas are assets to the settlement and are what make it distinctive.
- **Others**: a mixture of drawings and figures are about the proximity of the settlement to the natural surroundings, in order to reveal spirit of place.

5.2 Mapping process

Llandeilo is a compact, historic settlement and a market town located above the north bank of the Afon (river) Tywi, in Carmarthenshire, Wales. The A483 passes right through its historic centre, crossing the A40 in the north of Llandeilo. The settlement fulfills a significant role in the district as the administrative centre for Carmarthenshire. The town has experienced some expansion since the 20th Century; the built up area has expanded beyond the boundary of the traditional Llandeilo community which spans from the bridge in the south to New Road in the north. Nowadays, the south built up area encompasses Ffairfach on the south of the river, and the north built up area reaches up to the A40. The population of Llandeilo has also increased sharply since the 1980s: in 2001, the population of Llandeilo reached 2540, which is a 9.1% increase on the population figure of 1991 (Wales Rural Observatory, 2007, p. 86).

Llandeilo is proud of its historical, cultural, social, and economic background. The settlement originated from Dinefwr Castle, which dates back to Roman times. The earliest evidence of its existence can be found in 13th Century records, which confirm Dinefwr's position as the principal court of the Kingdom of Deheubarth. The construction of Dinefwr Castle pre-dates the 12th Century. Records dating back to the 6th Century also indicate that Llandeilo was a well-known Christian centre. The tower of St. Teilo church is of medieval origin and the site, including the churchyard, have a profound place in Welsh culture. The present St. Teilo church was reconstructed in 1850. The church was named after St. Teilo, who chose Llandeilo as his base (Avent, Hughes, James, and Kenyon 2006, pp. 247-255). In the 19th Century, because of its location en route from mid-Wales to London, central Llandeilo became a local banking and commercial centre also hosting a number of public facilities. The Shire Hall was built to serve as the headquarters of the Carmarthenshire Constabulary in 1802 (Wales Rural Observatory, 2007). Rhosmaen Street (A483), which is the main route passing through the centre and the churchyard, is recognised as the main street of Llandeilo, and hosts most of the commercial and public facilities, such as the post office, the job centre, and the banks. The local economy is independent and because of the existence of the banks and two markets, has been relatively stable and prosperous throughout the centuries.

The booming economy brought about several issues, one of the main ones, according to the *Llandeilo Conservation Report* (Carmarthenshire County Planning Department, 1972), being excessive traffic, including heavy trucks, passing through the narrow historic street of Llandeilo's central area. The speed with which Llandeilo's sprawl grew, with the establishment of Ffairfach in the south, is another concern. The report also mentioned the possible effects of modern development and globalisation on the town's identity (Carmarthenshire County Planning Department, 1972).

5.2.1 Landscape

Figure 66: **Geographic location**. This drawing reveals the location of Llandeilo in Carmarthenshire, Wales, together with its geographic relationship with Dinefwr Castle and Ffairfach. The Llandeilo settlement originated from Dinefwr Castle and was the second town established in the county. Ffairfach is a built up area developed in the south of Llandeilo across the river. Llandeilo is encircled by farmland.

Figure 67: **Topography.**

Figure 68: **Vegetation and landscape**. The drawing reveals that Llandeilo is surrounded by dramatic landscapes comprising trees and farmlands.

Figure 69: **Hierarchy of ways**. This drawing reveals the hierarchy of routes in old Llandeilo and surrounding built up areas. Both the main road (A483 Rhosmaen Street) and Carmarthen Street (connecting to A 40) are narrow at the historic core, and return to a standard width away from the centre. The pedestrian paths can easily be spotted leading from the historic community to the peripheral landscape. North Llandeilo (outside the conservation area) has a clear pattern of roads in residential areas.

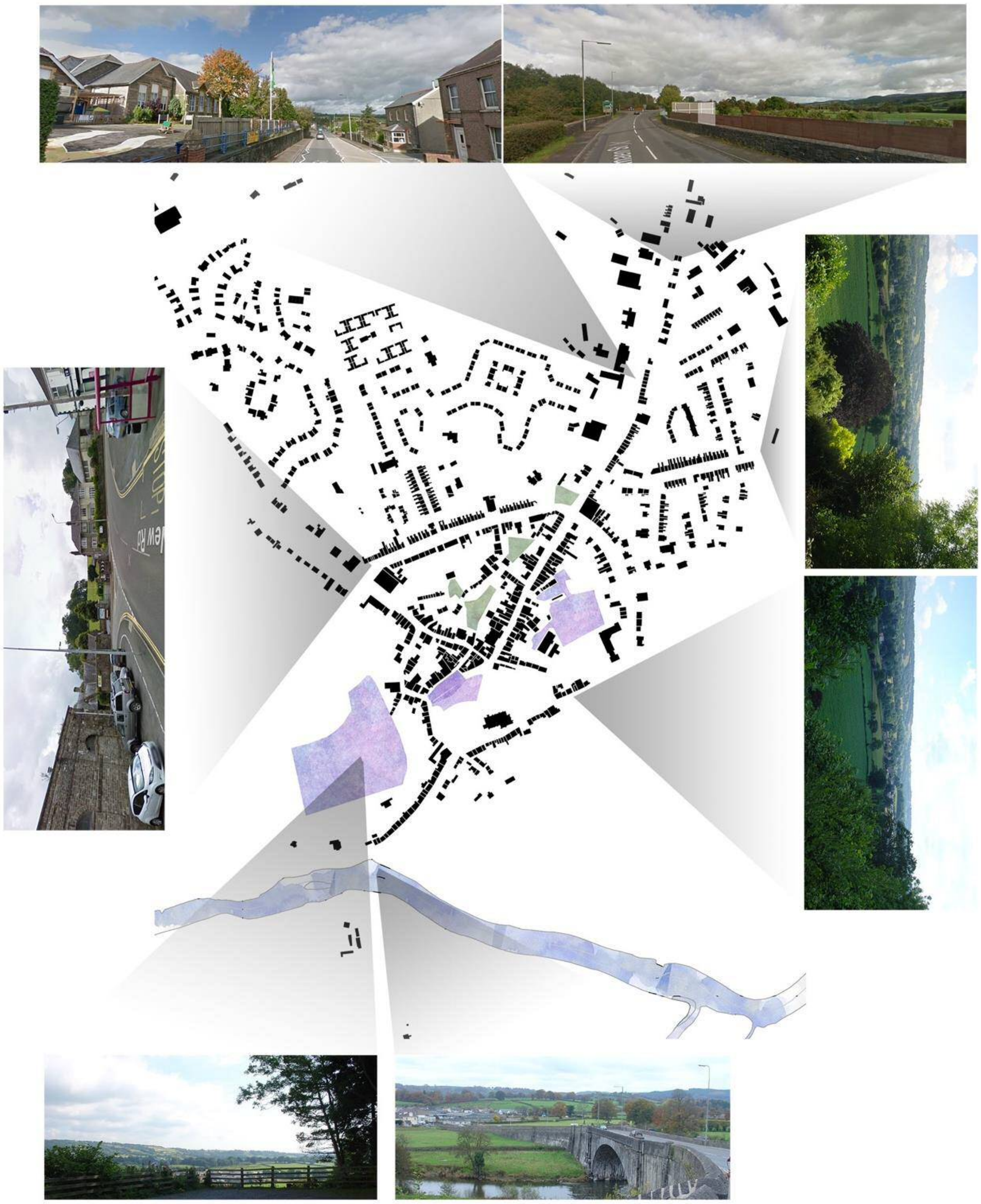


Figure 70: **View from the settlement.** This drawing reveals there are dramatic unobstructed view from the east and south edges of Llandeilo. The terrain emphasises these views.

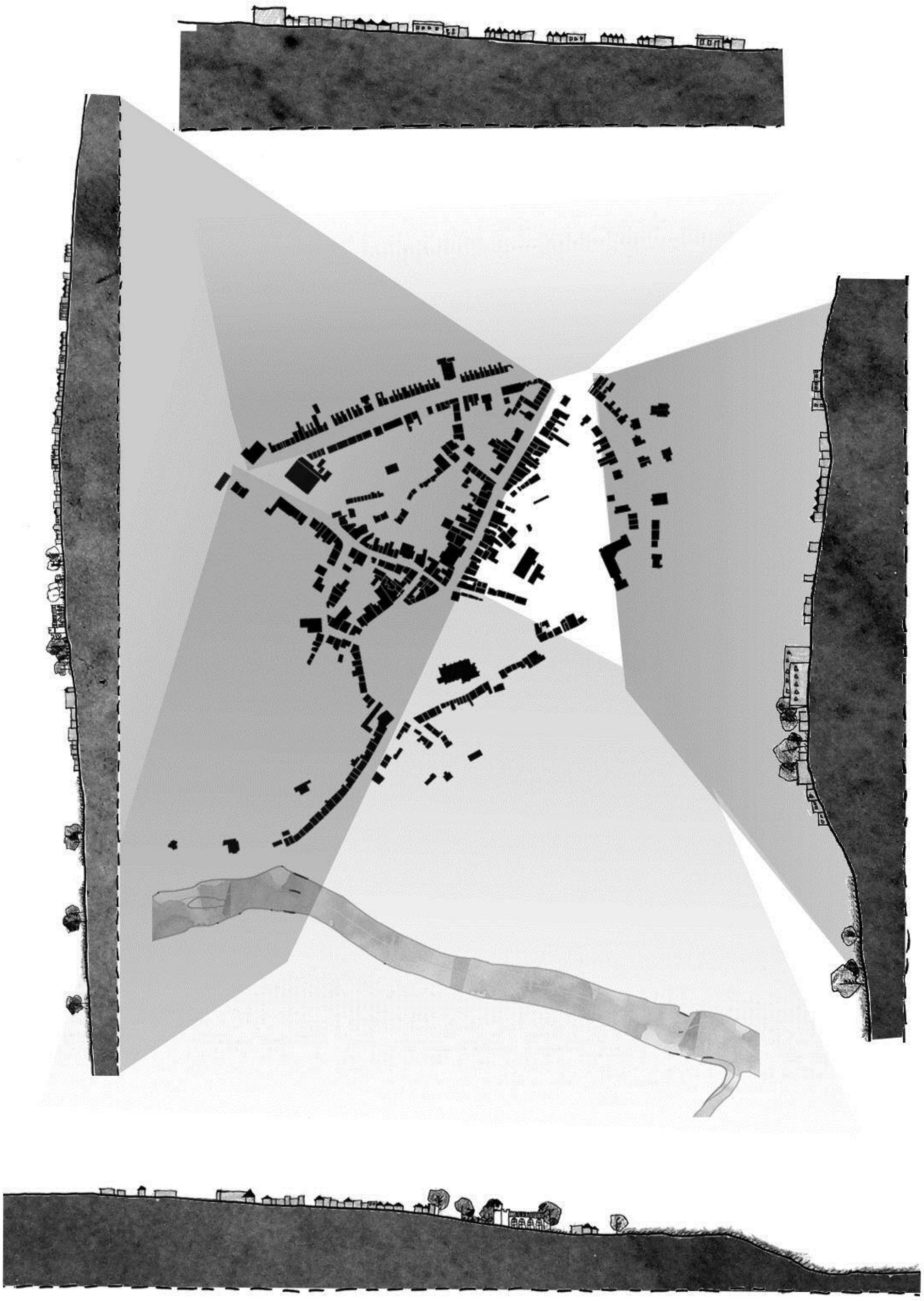


Figure 71: **Sections through the town centre.** This drawing illustrates the typography of Llandeilo, together with the volume of buildings.

5.2.2 Shape and layout

Figure 72: **History.** This image reveals the changes in the town's shape throughout history: Llandeilo has sprawled significantly to both the south and the north of the historic centre.

Figure 73: **Town shape**. Llandeilo's town shape has been strongly affected by both traffic and its geographic condition (refer to Chapter 2 Point 2.2). The town developed along two main roads (A483 Rhosmaen Street and Carmarthen Street), forming the 'Y" shape it has retained until now. The steeply dropped terrain presents a limitation to development in the east. Compared to the east, the north-west Llandeilo is better developed, comprising mainly domestic buildings.

Figure 74: **Public squares and other private car parks**.

5.2.3 Morphology

Figure 75: Spaces and yards.

Figure 76: Rhosmaen Street elevation. This drawing reveals changes in street elevation from the north (at the boundary of the conservation area) to the south (near the historic core). As one gets closer to the centre, the boring building façades strong contrasts in terms of style, character and size. Cullen (1961) believes that this rhythm is established through change and the organic development unique to the historic settlement.

Figure 77: Carmarthen Street elevation. It can be noted that the street becomes more curved, narrow and steep as it goes from west to east, especially after passing George Street. The terrain decreases from 68.3m at George Street junction to 59.5m at the east end. The curves and terrain add interest to the streetscape: observers are not able to form an image of the town from one glimpse; the visual image changes as one moves along.

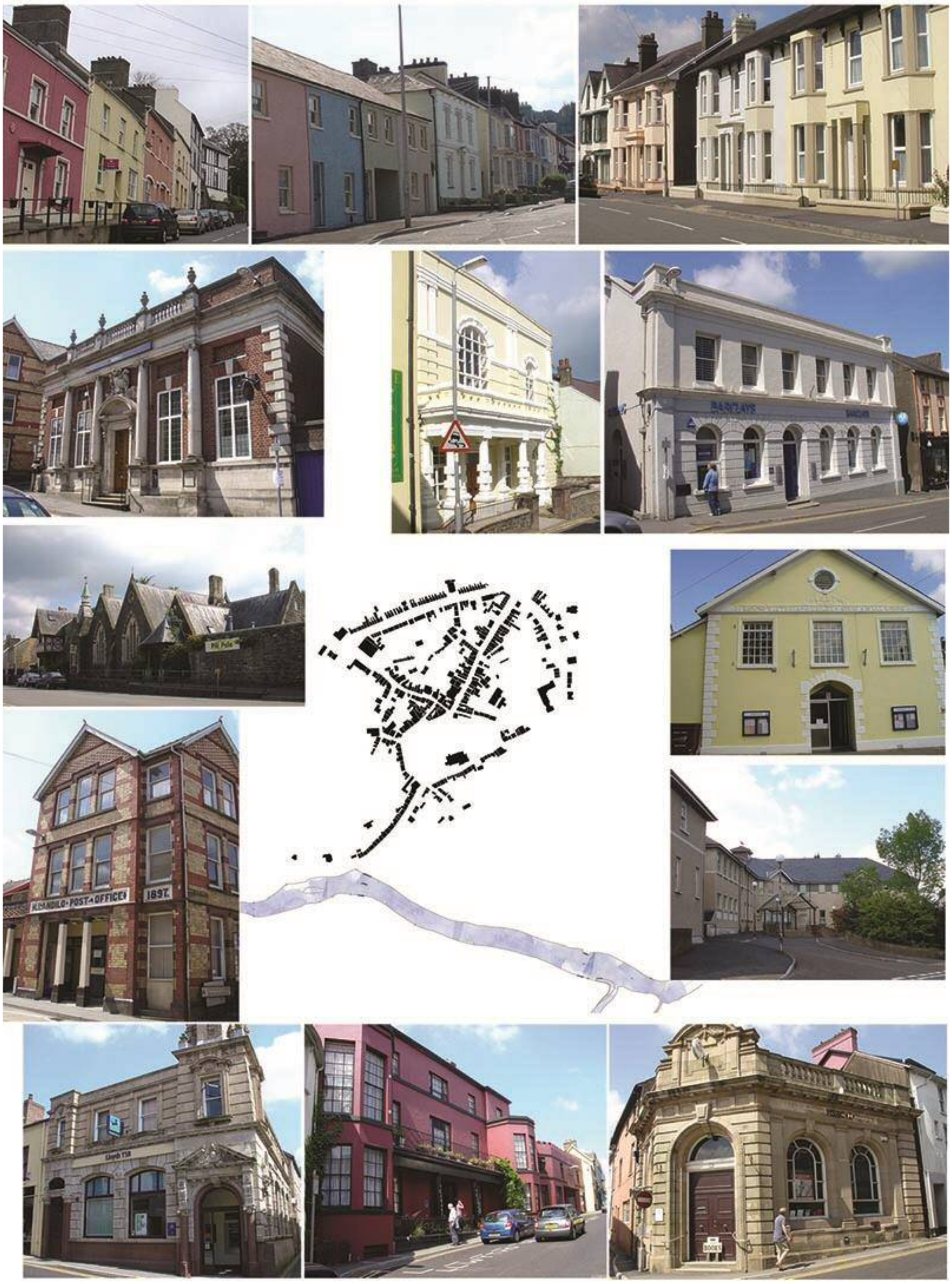


Figure 78: **Materiality in Llandeilo.** This image reveals the commonly found building materials in Llandeilo, helping to understanding the components of the character. Colour washed façade is the most popular in both domestic and non-domestic buildings. Besides, stones, and some bricks may be easily found in both types of buildings.

5.2.4 Land use and listed buildings

Figure 79: **Land use**. This drawing reveals the large proportion of domestic buildings in Llandeilo. With over 75% of buildings in Llandeilo are domestic buildings. Most of the commercial and non-domestic buildings (such as banks) are located in the densely populated historic centre. In the conservation area, the first and second floors of most traditional commercial buildings are for domestic use.

Figure 80: Llandeilo conservation area. The drawing shows the boundary of the Llandeilo conservation area (based on the Llandeilo Conservation Report, 1972) and the buildings included in the area. It is noted that the east boundary of the conservation zone extends to the edge of Dinefwr Castle including Dinefwr Park. This is more evident in the larger site map shown in Figure 82.

Figure 81: Map of listed buildings 1. The majority of listed buildings are located in the historic centre. A full list of listed buildings is given in Appendix 1.

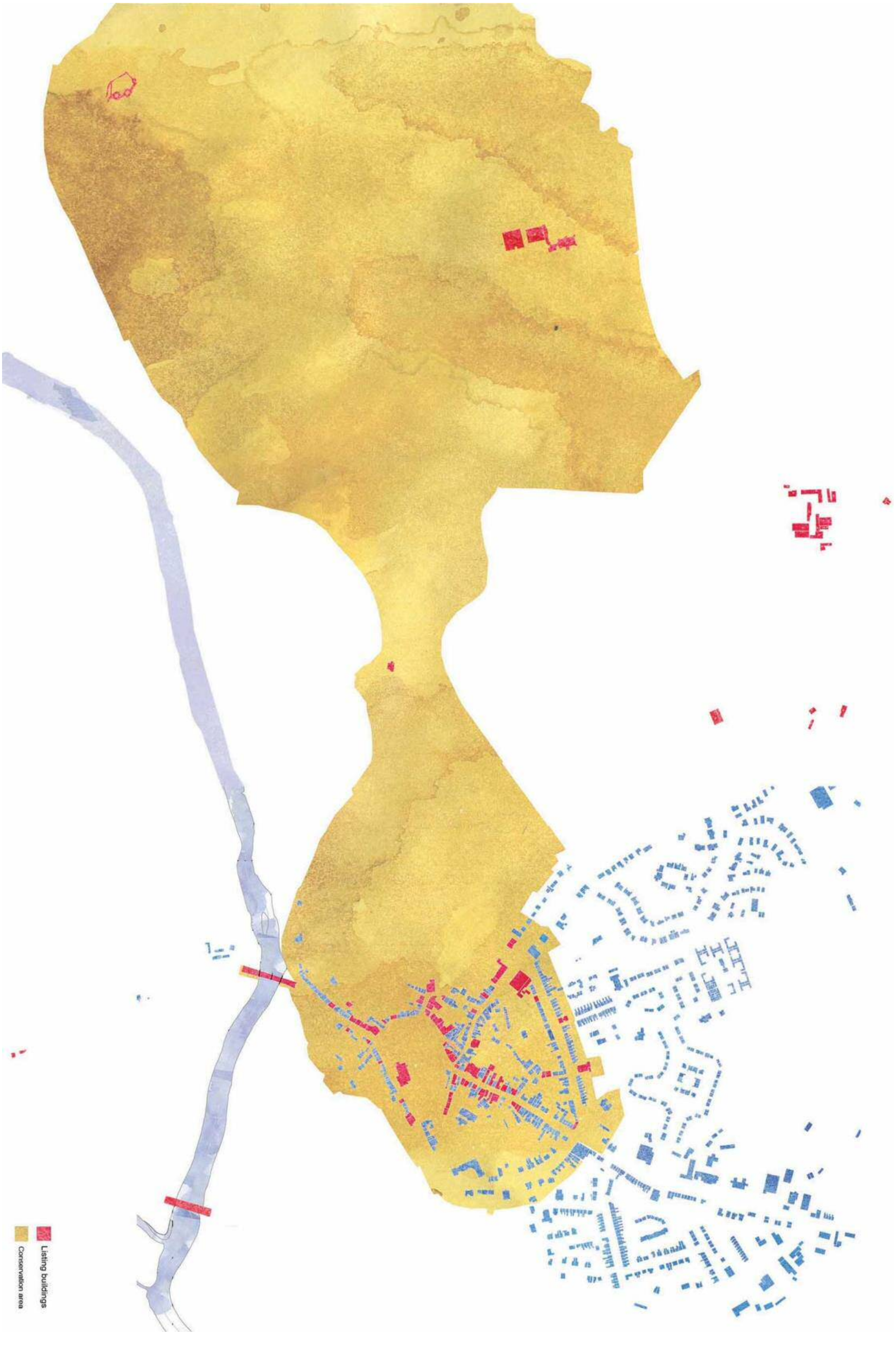
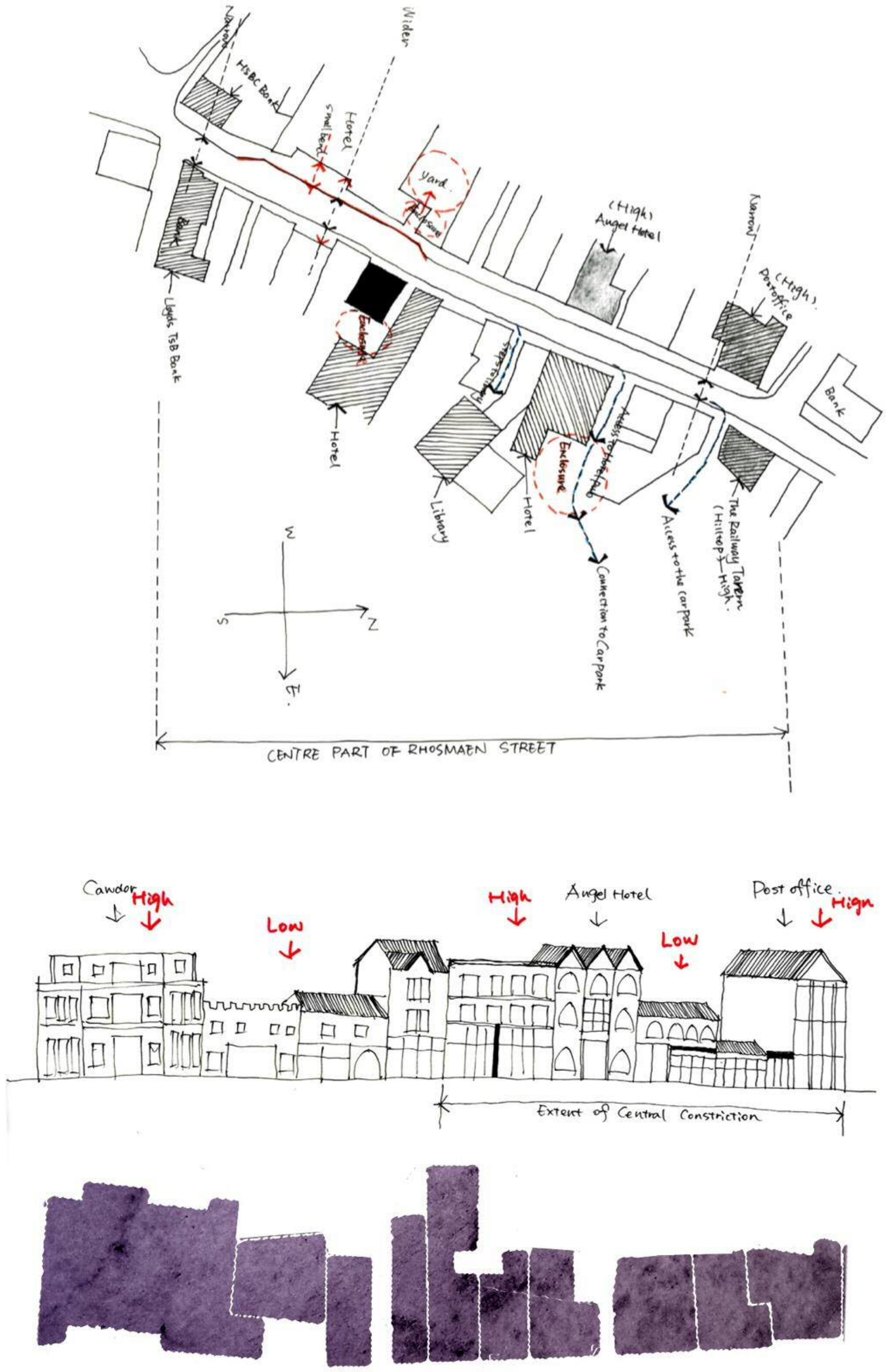


Figure 82: Map of listed buildings 2 and conservation area.

5.2.5 Areas of character



(south) -- Central section of Rhosmaen Street -- (north)

Figure 83: Central section of Rhosmaen Street. The south end of Rhosmaen Street has a unique identity and has several interesting points to explore. This drawing illustrates the narrow lanes, paths with openings onto the street, small yards, sub-spaces and enclosures.

Figure 84: This drawing illustrates the different visual images from different points of view and different observer positions. It is interesting to test this theory in central Llandeilo. A particular building disappeared from view because it is positioned back from the street frontage. The different angle leaves a different visual impact on the observer, the street seem more open even though the street width remained the same.

Figure 85: Sub-spaces is the unique patterns of the medieval burgages commonly found in Llandeilo.

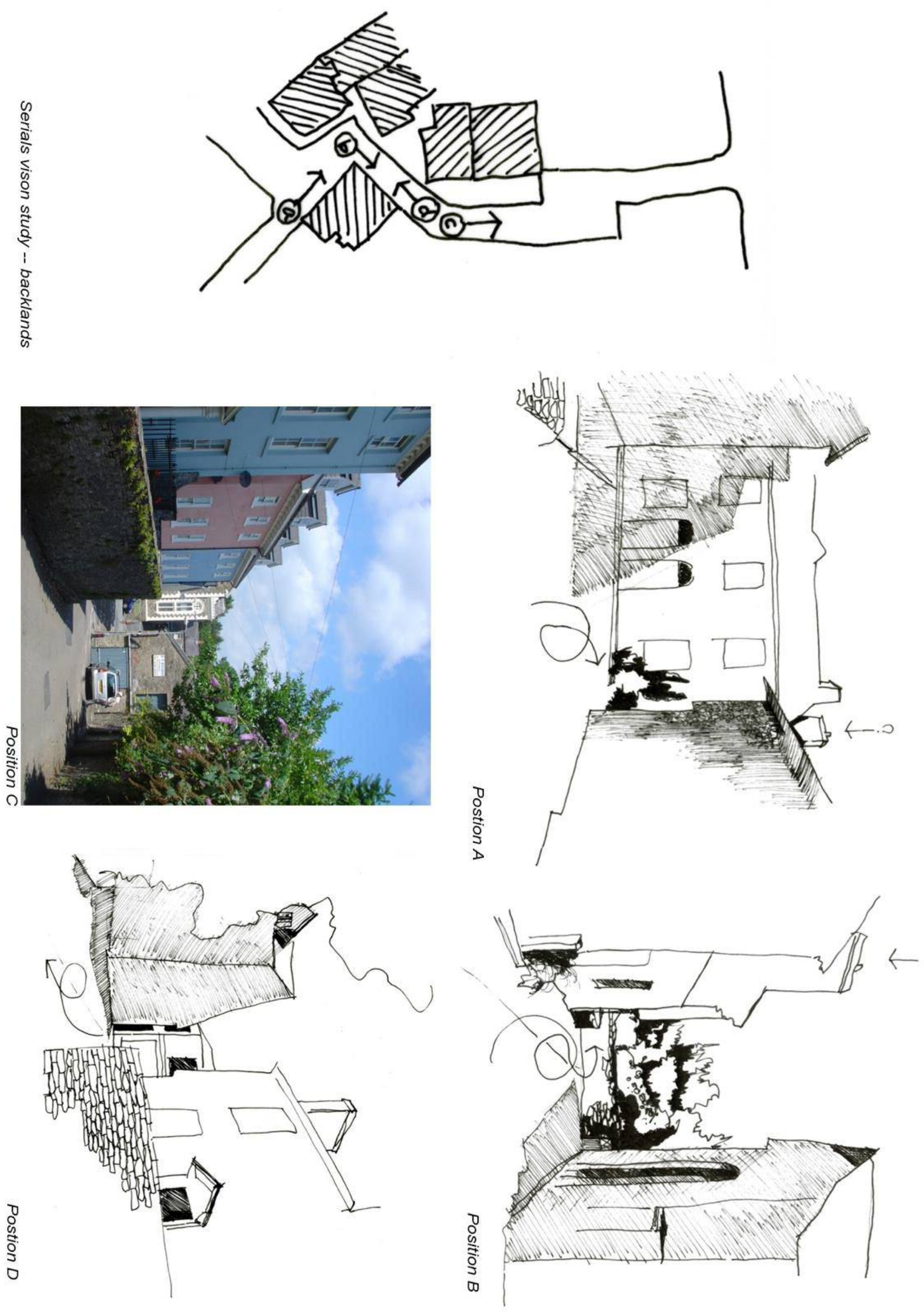


Figure 86: Backlands through Bank Buildings via serial vision. There is a strong sense of enclosure in this area, reinforced by the narrow lane and the shadows thrown by the high buildings.

Figure 87: King Street and Market Street square. This triangular square was originally the old market. The buildings are full of character; and the street elevation is traced here. In the Market Street section, the built up narrow lanes intensify a sense of enclosure. It is interesting to notice that one of the buildings has a front yard onto the narrow lane.

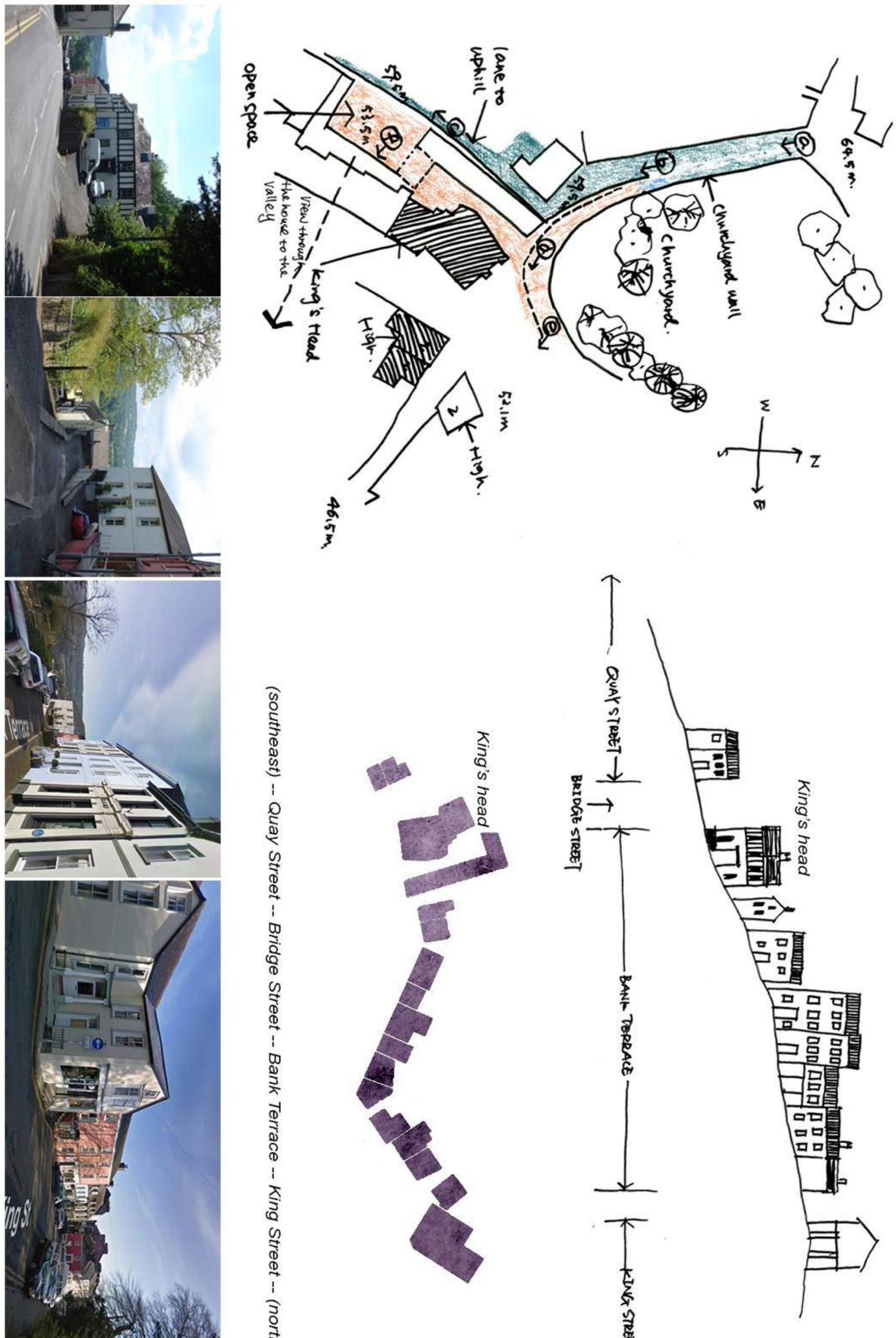


Figure 88: Bank Terrace. The origins of Llandeilo as a centre of economy. There is a huge drop of the terrain from the Market Square (King Street) across Bridge Street, to Quay Street.

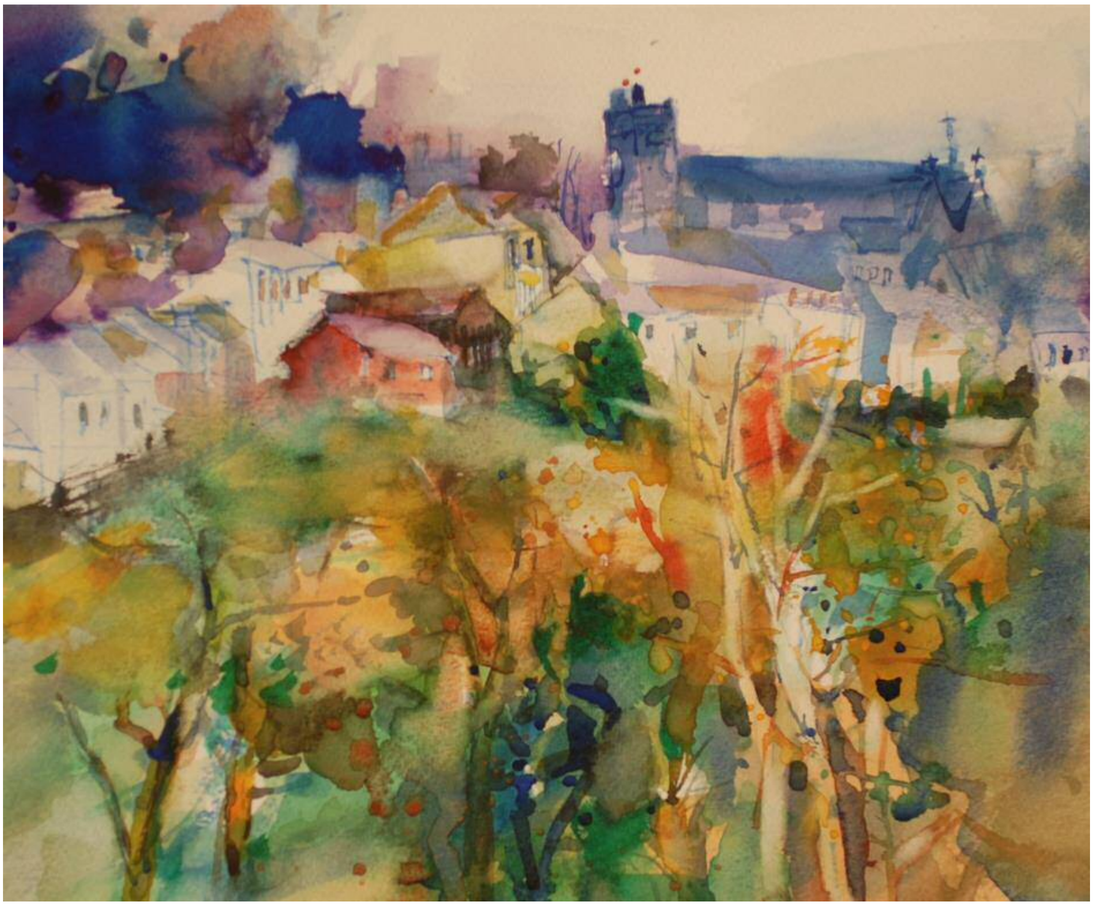


Figure 89: Llandeilo from the bridge. This drawing is based on the author's first impression of Llandeilo. Photographs taken from the same angle and position are commonly used in posters and websites to publicise the settlement. The image reveals several characteristics of Llandeilo: colourwashed terraced houses wind along the steep hill (Bridge Street), emerging into a cluster of buildings and trees. The purple slated roofs of these terraces, light toned building frontages and inclining rooflines are man-made components in this image, while the beech clumps on the top of rooflines and trees in the front in a variety of colours are natural elements. This is a vivid image of Llandeilo.

Figure 90: Llandeilo in snow

Figure 91: St. Teilo's church. This drawing reveals author's feeling for the church: the stone façade reflects the mass and gravity of the church while the surrounding vegetation brightens the image. Limestone and sandstone are commonly used in non-domestic buildings in Llandeilo, and St. Teilo's church is one of the biggest of such buildings.

Figure 92: St. Teilo's church and churchyard. This drawing reveals the well maintained vegetation and the sense of peace and quiet in the churchyard. The colourwashed façades and pitched roofs of the terraced houses can be seen from the middle of the yard, together with the landscape along the river.

5.2.6 Others

Some of the following drawings and figures are about the proximity of the settlement to the natural surroundings, in order to reveal spirit of place.

Figure 93: Model. A physical site model of the conservation area within Llandeilo helps clarify the terrain, landscape, buildings, and squares.

Figure 94: Two trees in Dinefwr Park. This drawing of two trees in Dinefwr Park was created during a site visit to Llandeilo in 2009. Genius Loci - the impression of an open unobstructed view which is typically found in and near Llandeilo.

Figure 95: **A farm cottage near Llandeilo.** An image revealing the peaceful landscape at the periphery of Llandeilo. This drawing was made when the author explored the town and got lost.

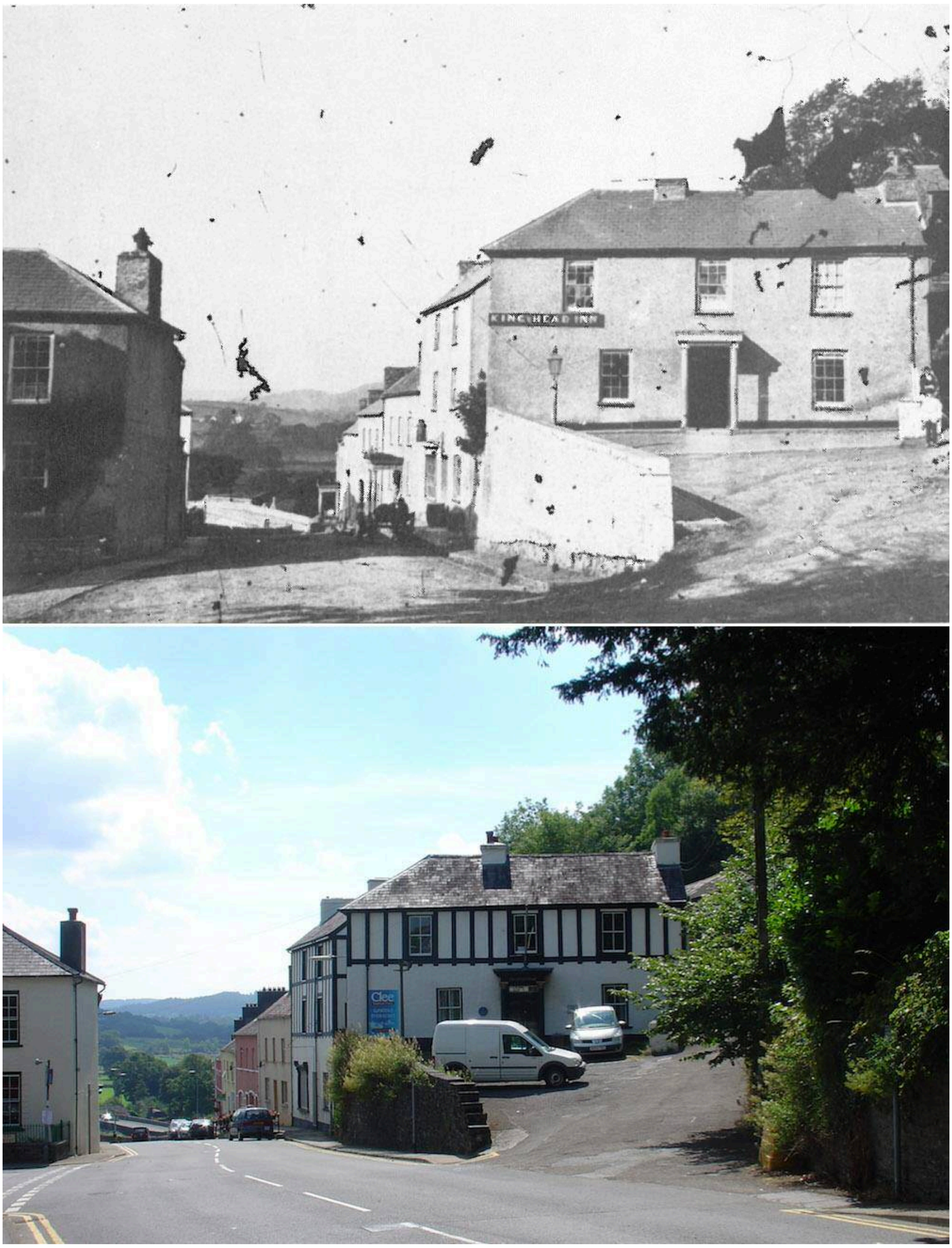


Figure 96: Old images of Llandeilo. King’s head in 1900 and nowadays (source of old photography: DCSD (1991))

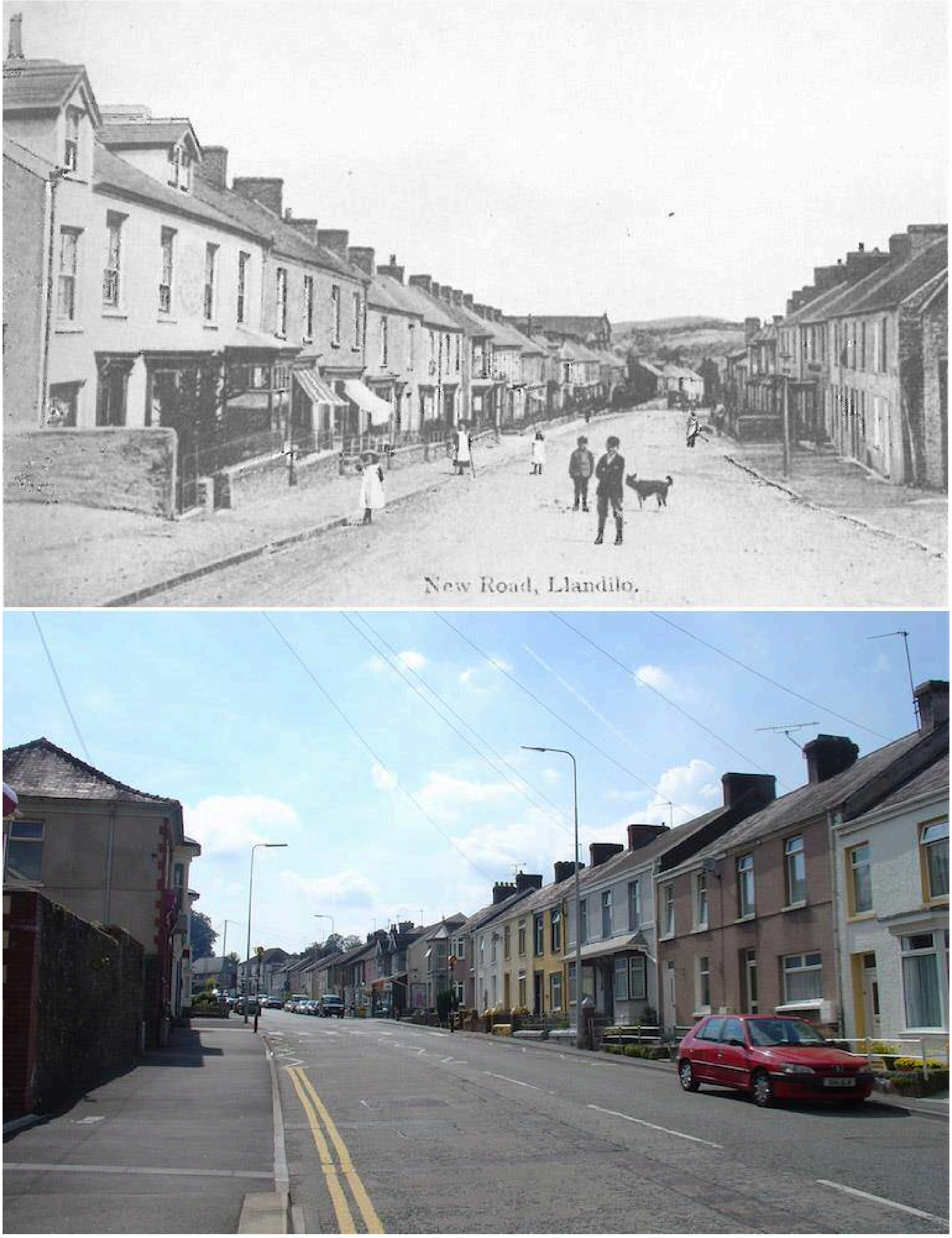


Figure 97: Old images of Llandeilo. New Road in 1900 and nowadays (source of old photography: DCSD (1991))

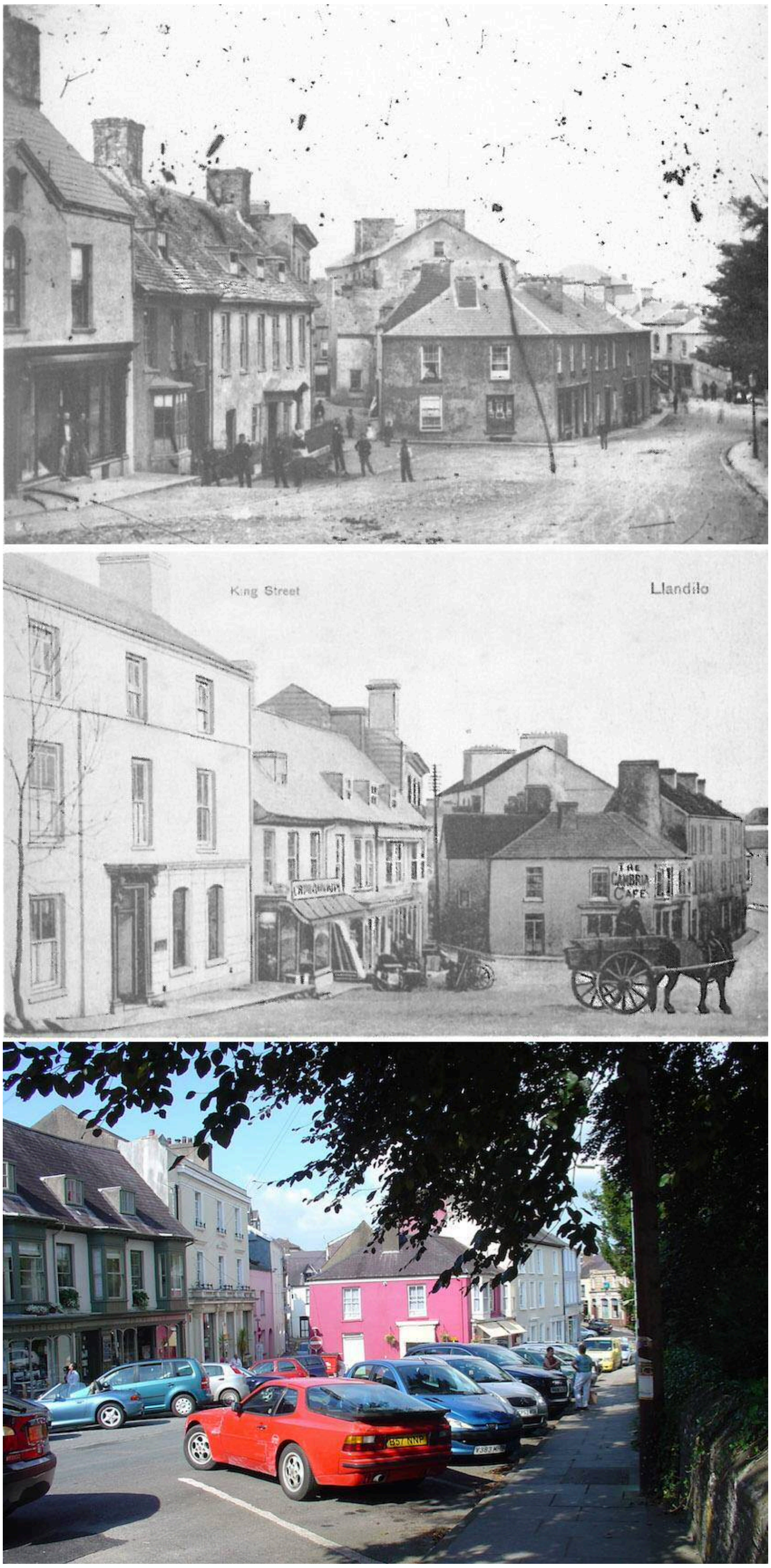


Figure 98: Old images of Llandeilo. Triangle square along King Street in 1800, 1900, and nowadays (source of old photography: DCSD (1991))

5.3 Mapping outcomes

The outcomes of the mapping exercise can be categorised under two dimensions, i.e. ***strengths*** and ***weaknesses***:

Strengths:

- Llandeilo's landscape is visually coherent – colourful and the fabric well managed and maintained.
- The historic layout of the settlement has been generally maintained, except for the expansion of domestic buildings to the north and south from the 1950s onwards. These areas are not densely built up.
- The number of car parks and street parking spaces in central Llandeilo meet parking requirements at this stage, though there might be additional demand for parking lots in the future considering the development of the settlement. Secondary parking near the north boundary of the conservation area would be helpful.
- Historic roads, spaces and enclosures within the conservation area are conserved in good shape; some enclosures or sub-spaces are nowadays functioning commercially; for example they are being used as a secondary open yard for a hotel restaurant.
- The listed historic buildings in Llandeilo are mostly well preserved and continuously occupied; the unlisted buildings located in the main street of the historic core are undergoing careful repair and maintenance.
- The overall character and the identity of Llandeilo is reflected in several areas of character in Llandeilo.

Weaknesses:

- The traffic passing through the centre of the settlement via narrow Rhosmaen Street is still affecting the life of the inhabitants since the problem first arose in 1972. Detour or rerouting the main traffic from mid Wales to London, to avoid the historic centre of Llandeilo would require the coordination of several departments and their financial support; the issue is beyond the abilities of conservationists and architects. However, conservationists may still raise the issue.
- The settlement is short of large indoor public spaces. Meanwhile, a couple of listed buildings lie empty, such as the Llandeilo market hall which has been disused since 2004. Most non-domestic buildings with communal functions have reached their limit in terms of space and are looking for extension possibilities.
- There are several areas within the conservation area, such as the *backlands,* which do not meet the overall building performance standards and characteristics. These areas mostly comprise a mix of social housing and garages.
- Stone and brick are the major building materials in Llandeilo, together with some single glazing sash windows. The energy performance and carbon emissions of most buildings are far from environmentally sustainable. The entire settlement should be looking at prompt retrofitting to fit in with the tight agenda for carbon cutting.
- The speed of further sprawl of the settlement to both south and north needs to be controlled.

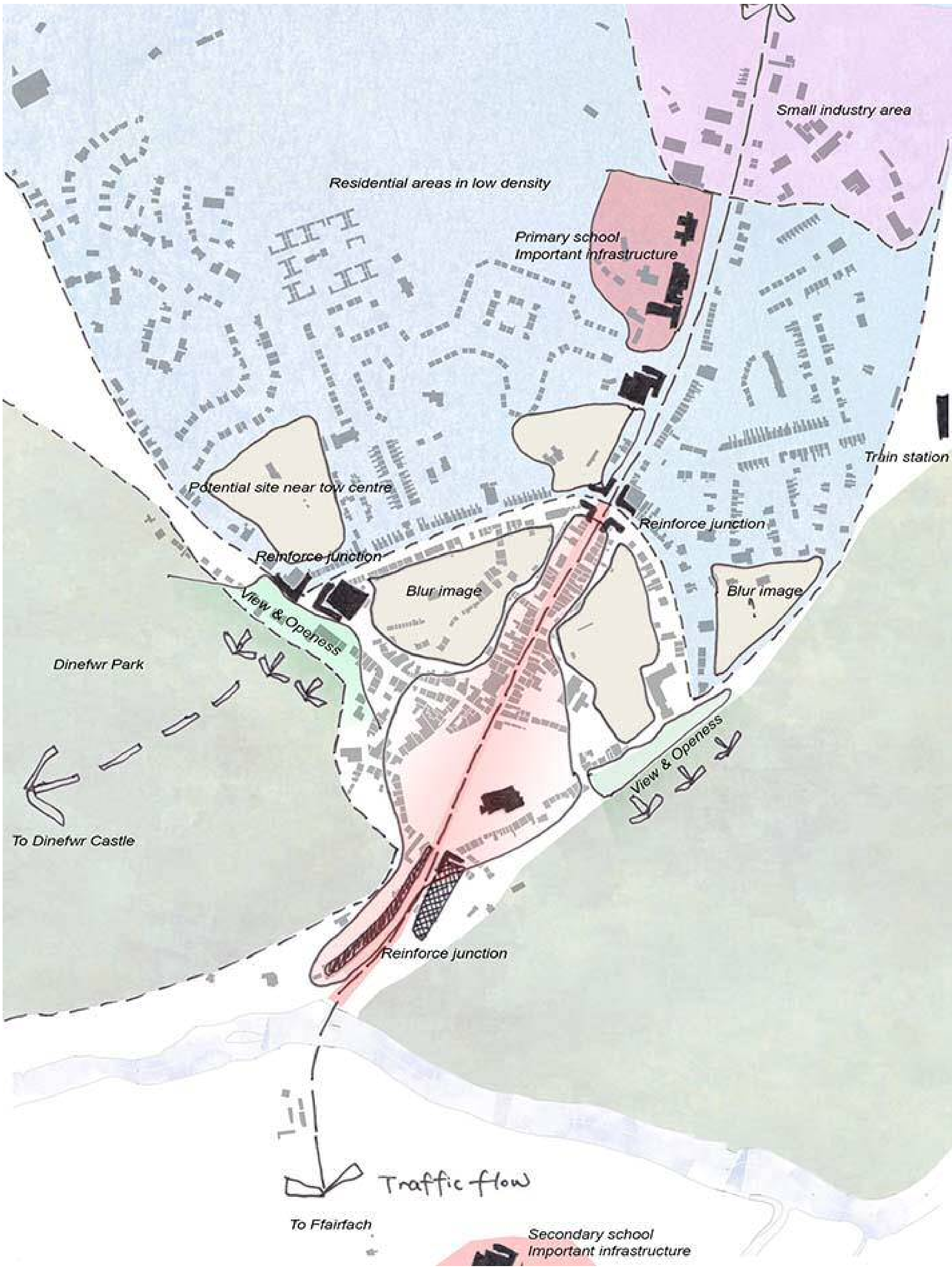


Figure 99: This drawing illustrates the mapping result. Llandeilo has some strengths and some weaknesses.

5.4 Reflections from the model

The mapping of Llandeilo has helped identify certain strengths which require continuous preservation and weaknesses which need to be promptly addressed. It is important to review all the weaknesses which were identified against the model (Figure 61) put forward in Chapter Four, to ensure that all potential enhancement proposals fall within the design model and will not harm the distinctiveness of the settlement.

A chart is used to illustrate concerns according to the principels in both dimensions (C = conservation, P = performance). The same abbreviations will be used in the following chapters:

<table>
<tr><th>Weaknesses</th><th></th><th>Concerns according to the model</th></tr>
<tr><td>Traffic loads</td><td colspan="2">Not discussed in this study due to knowledge limitations.</td></tr>
<tr><td rowspan="2">Provide larger indoor public places, extensions or rebuilding of other proposed non-domestic buildings with communal functions</td><td>C</td><td>The enhancement must:
• be located within the conservation area if possible (according to principle 9)
• follow characteristics of Llandeilo townscape and streetscape (according to principle 1)
• carefully treat and deal with the original building when retrofitting a historic building (according to principles 2 and 4)
• prioritise non-domestic with unduplicated communal functions over repeated infrastructure (according to principle 5)
• prioritise the use of local material (according to principle 7)
• design for flexibility and site for extension possibilities when conditions allow (according to principle 5)
• be assessed after construction (according to principle 6)</td></tr>
<tr><td>P</td><td>The enhancement must:
• reduce carbon emissions and fit in with the agenda of carbon cutting through improved energy efficiency and well-insulated</td></tr>
</table>

		building envelopes with advanced air tightness (according to principle 1,2,3) • attempt the introduction of renewable energy for further carbon offsetting (according to principle 4) • create a building interior with a contemporary standard level of comfort (according to principle 5) • be assessed in construction quality and energy performance (according to principles 6)
Improve 'shabby' and unpleasant areas with a blurred image	C	The enhancement must: • follow the character of the Llandeilo townscape and streetscape (according to principle 1) • verify the facts carefully when a hyposensitive street frontage is involved (according to principle 2, 4 and 7) • benefit the whole settlement in the long-term (according to principle 9) • attract new inhabitants if possible (according to principle 9) • draw from the typology and form of the settlement (according to principle 6) • be assessed after construction (according to principle 6)
	P	The enhancement must: • reduce carbon emissions and fit in with the agenda of carbon cutting through improved energy efficiency and well-insulated building envelopes with advanced air tightness (according to principle 1,2,3) • attempt the introduction of renewable energy for further carbon offsetting (according to principle 4) • create a building interior with a contemporary standard level of comfort (according to principle 5)

		• be assessed in construction quality and energy performance (according to principles 6)
Ensure that the settlement conforms with the carbon mission target in the near future	C	The enhancement must: • no harm is done to the distinctiveness of the townscape and streetscape (according to principles 1,2,4,7) • no change is made to the identity of buildings with character (according to principles 1,2,4,7) • nothing is done to endanger the significance of listed buildings (according to principles 1,2,4,7) • preserve these hyposensitive and fragile components of both buildings and open areas, which are key elements in establishing the current image of settlement • use materials fitting the image and character of the settlement and which offer a high energy performance (according to principle 7) • be assessed after construction (according to principle 6)
	P	The enhancement must: • reduce carbon emissions and conform to the agenda of carbon cutting through improved energy efficiency and well-insulated building envelopes with advanced air tightness (according to principles 1,2,3) • attempt to introduce renewable energy to further offset carbon emissions (according to principle 4) • create a comfortable building interior according to contemporary standards (according to principle 5) • be assessed in construction quality and energy performance (according to principles 6)

Control the sprawl of the settlement	A	The enhancement must: • provide new dwellings within the historic centre (according to principles 3,8) • control the siting of key infrastructural buildings to ensure that they do not relocate to the outskirt of the settlement (according to principles 8,9) • justify new design proposals at the outskirts of the settlement, and increase the density of existing residential areas (according to principle 3,9)
	E	• No concerns

Figure 100: The model proposed at the end of chapter four.

5.5 Findings that take the study forward

Based on the mapping outcomes compared with the model, a map is drawn to reveal areas and buildings with opportunities for enhancement while taking into consideration the concerns of the three groups of specialists. This map will serve the designs put forward in Chapters 6 and 7.

Figure 101: This drawing reveals the opportunities for Llandeilo's enhancement. There are several buildings can be improved to reinforce and further support the overall image of the settlement. The continuity of some street frontage could be improved to strengthen the boundary of the settlement. Main junctions accessing to the historic core could be reinforced from improved buildings. Some areas obtaining blur image within the historic core could be restored. Areas or paths with advantages in views could be highlighted and better used.

Figure 102: This drawing reveals the location of two proposed designs in Llandeilo with duties on conserving the settlement and enhancing energy performance. Design 1: domestic building retrofit will benefit all aged domestic buildings in Llandeilo to meet tight carbon emission rate while still maintaining the image of the settlement. The discussion on this design covers major conditions on the rest 75% existing domestic buildings in Llandeilo, upgrading the energy performance of the entire town while not jeopardise the visual image and characters. Design 2: New domestic project will provide new contemporary standard dwelling within the historic centre to attract new inhabitants; it will also improve the continuity of New Road where near the north boundary of the settlement. The introduction of new dwelling also helps to change the blur image of The Backlane and other blur areas.

CHAPTER SIX: DESIGNS: DOMESTIC BUILDING RETROFIT

6.1 Introduction

In this and the following chapters, two case studies relating to domestic building design practices are employed to test the model with one retrofit and one new design. There are three specific objectives:

- To test the model proposed in chapter four through design;
- To critically review and report all design variations (precise, robust, clear); and
- To refine and modify the model in response to the findings from each design.

6.2 Precedent study

Project: ***Low Carbon Retrofit: Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s Urban Semi-detached House***

Research Group*: Design Research Unit of the Welsh School of Architecture (DRUw)*

The retrofit of a typical terraced house is prefaced by a precedent study, based upon which some highlights and reviews for the design can be established. The project aimed to refit an existing low-rise semi-detached social house, to meet UK government's target to reduce carbon emissions and enhance the building's energy performance. The building described in the design is a 1980s urban semi-detached (end of the terrace) two-bedroom social house, intended for three persons. The project aimed to identify 'optimal, reliable, practical and replicable' low carbon solutions for this building and similar buildings. (Forster and Heal 2009, p. 2)

Whilst the building post-dates much of the housing stock in Llandeilo, the scheme is appropriate for review here, as it employs a 'cutting edge' approach to low carbon retrofits.

Concept

Responding to the initial survey and assessing the environmental impact of the building on its physical environment, the design proposes improvements to the building's internal space to overcome the lack of usable space in the property, refurbishing the external envelope and supplying innovative technologies that the tenants can operate. Four aspects are considered in the project: *form & space*, *building fabric, appliances, and systems*. Each aspect has been analysed in terms of *carbon savings*, *costs*, *buildability*, and *comfort and conditions* (Forster and Heal 2009) (Figure 103).

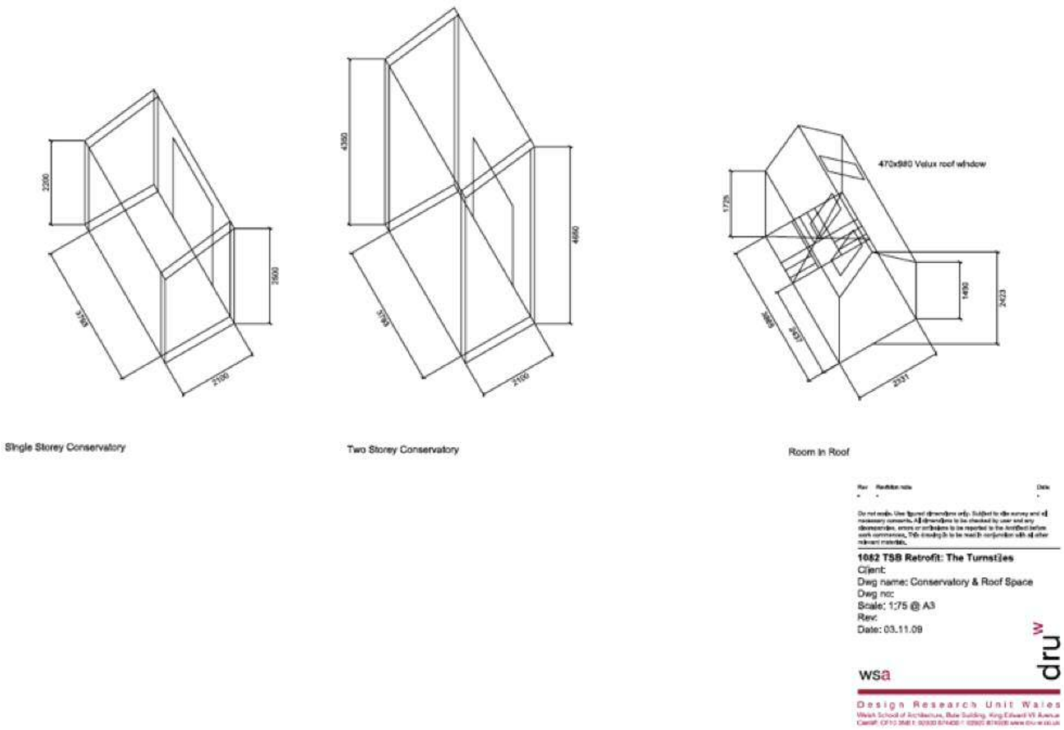


Figure 103: Early analytical drawings exploring potential improvements to the space (Source: Forster and Heal, 2009)

Environmental issues

Several measures intended to support energy saving and energy production are integrated into the design (Figure 104). The improvement of building energy performance is achieved through dry lining and insulation added to the internal walls, triple glazed windows, and doors with improved air-tightness. A ground source heating pump is installed at the rear of the property, and 2KWhp Photovoltaic panels are also installed to introduce renewable energy sources to the building. The overall ventilation of the building is improved and controlled through trickle vents into the loft area. The ultimate design result is assessed through post-refurbishing monitoring of the building's physical environment, carbon emissions, and an evaluation of the tenant's energy bills. Data collected after the study indicates that the changes to the building's performance are positive and that the property can be readily heated up quickly to a comfortable level. In terms of cost saving and the reduction of carbon emissions, the monitor data advises that the ground source heat pump provides the highest overall savings (Forster and Heal, 2009).

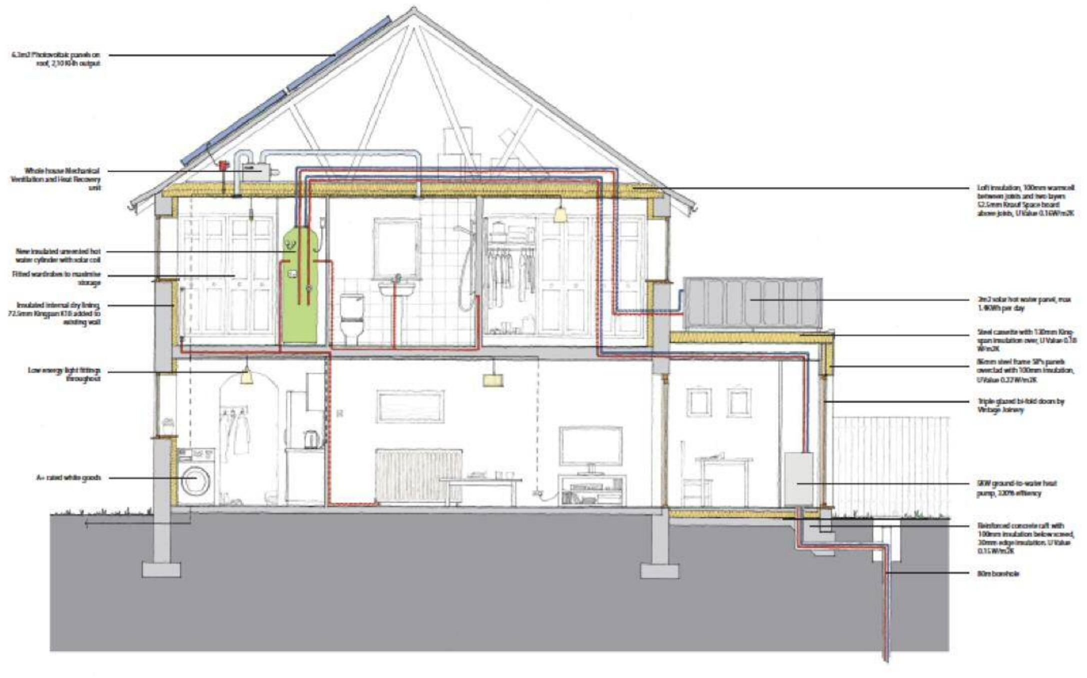


Figure 104: Schematic showing integration of all energy saving and energy producing measures (Forster and Heal, 2009)

Review

The design of the property achieved the research objectives in terms of carbon savings, costings, buildability, comfort and conditions; especially with regard to the priority commitment to reduce the carbon footprint. In terms of the architectural dimensions, the interior space was improved by both an increase in the overall floor area and the addition of a roof light to maximise daylighting. The construction of the conservatory provides additional living space for the user. It is also necessary to note that the retrofit was completed while the tenants were living in the house, which is also appropriate for a terraced house in Llandeilo. Due to the use of dry liner internal insulation, the building exterior walls, including the windows were barely touched. The photovoltaic panels added to the south facing roof to benefit from solar gain and fulfil the local council's primary objective of significant carbon reduction by providing highly efficient and reliable alternative energy. In this case, the south facing roof is street facing; and the appearance of photovoltaic panels is commanding from the street view, therefore changing the visual perception of the observer (Figure 105). However, considering the building's location in a fast developing suburb in Newport, near an industry zone, the preservation of the street's visual image is recognised as a secondary concern, and is deemed less of a priority than cutting the carbon footprint.

Figure 105: The front elevation of the house before (left) and after (right) retrofit (Forster and Heal, 2009)

6.3 Context study

6.3.1 Programme

On employing an existing domestic building in Llandeilo as the context to undertake the design practice and test the model, there are a few preferences of site, plot, and density on picking the building:

- An aged terrace house with a typical layout that may represent the majority of existing domestic buildings in Llandeilo, probably originally constructed between 1800s to 1900s when central Llandeilo was established;
- Within the conservation area, near the historic core or at the boundary if possible;
- A typical low to mid density area with burgage pattern, that is a terrace with narrow street frontage; medieval burgage plot are normally long and slim, smaller than plots divided after 1950s;
- A typical street façade may represent Llandeilo's tradition;
- On a street with strong and distinctive Llandeilo streetscape; and
- An aged building interior if possible.

The design standard is to create a contemporary, comfort, low energy consumption building interior whilst preserving the significant building and urban elements.

6.3.2 The town's identity

The visual impact of Llandeilo on the observer (Figure 106):

- Compact town centre with a well preserved landscape on the periphery of the town (as seen from a glimpse in the street);
- Human scale streets and architecture;
- The winding undulating streetscape and buildings informs the topography;
- Continuity of the street façade, high density, mixed used terraces;
- Silhouetted roofscape, formed by pitched roofs and chimneys;

- Terraces with plain and simple façades, mostly colour washed;
- Small openings, well preserved sash windows, some with detailed decorations; and
- Characteristics of Georgian and late Victorian buildings.

Figure 106: Streetscape (view from middle Carmarthen Street to central Llandeilo of Market Street)

Llandeilo's domestic buildings as found:

The majority of the domestic buildings in the Llandeilo conservation area are stone buildings with colour washed façades. In addition to these, a small number of buildings have stone or brick façades. The majority of the buildings are important to their occupiers, and are therefore carefully maintained. The buildings' street facing elevations are regularly repainted to preserve the colour and condition of the façades. Timber framed sash windows are commonly found in Llandeilo, along with the original narrow openings.

Colour-washed elevation

Bridge Street New Road Crescent Road

Figure 107: Continuous colour-washed elevation

Stone

New Road Market Street Market Street George Street

Figure 108: Stone used in building façades in Llandeilo domestic buildings

Red bricks

New Road George Street George Street

Figure 109: Bricks used in building façades in Llandeilo's domestic buildings

Sash window

Bank Buildings New Road George Street Rhosmaen Street

Figure 110: Sash windows preserved in Llandeilo's domestic buildings

Key elements in the majority of Llandeilo's domestic buildings

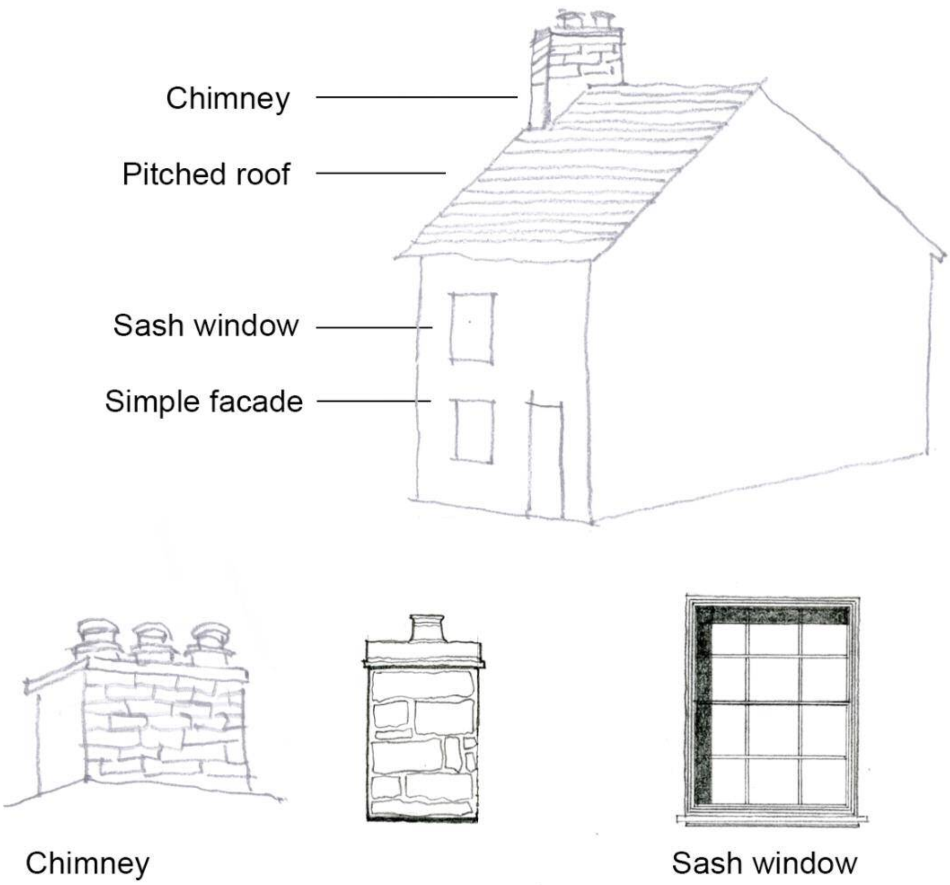


Figure 111: Key elements in the majority of Llandeilo's domestic buildings

6.3.3 Site and building as found

The building selected for this study is located in a row of terraces in Church Street. Located next to the churchyard, Church street is one of several earliest domestic sites in Llandeilo, which may trace back to 1750s with a fully establishment on early 1800s. (Carmarthenshire council planning department 1972) (Figure 113). The appearance of Church Street is narrow, windy, but with continuous, simple, tidy, and well maintained façade. Although just next to Rhosmaens Street (A483) in parallel, Church Street is surprisingly quite with limited passing vehicle and pedestrians except local residences. From the geographic aspect, located at the eastern boundary of Llandeilo, most of the terraces in Church Street have the benefit of elevated and unobstructed river and meadow views.

The building is a two-bedroom house in south-north direction, with a narrow street front elevation, and a small back yard. There is only one bathroom at the back of the building, which is probably from extension on 1900s in original. Compared to its neighbours in Church Street, this building still holds a more typical layout, façade, and extension from its built date, although the building is also expected under several renovations in history (Carmarthenshire council planning department 1972). Some other houses in Church Street with wider street frontage could be possibly built from merged frontage of two terraces. The building interior is also well preserved with low interior height, small openings on both elevations, and fire place (unused now). It is noted No. 7 Church Street fits all preferences listed in 6.3.1 for undertaking the case study of domestic building retrofit.

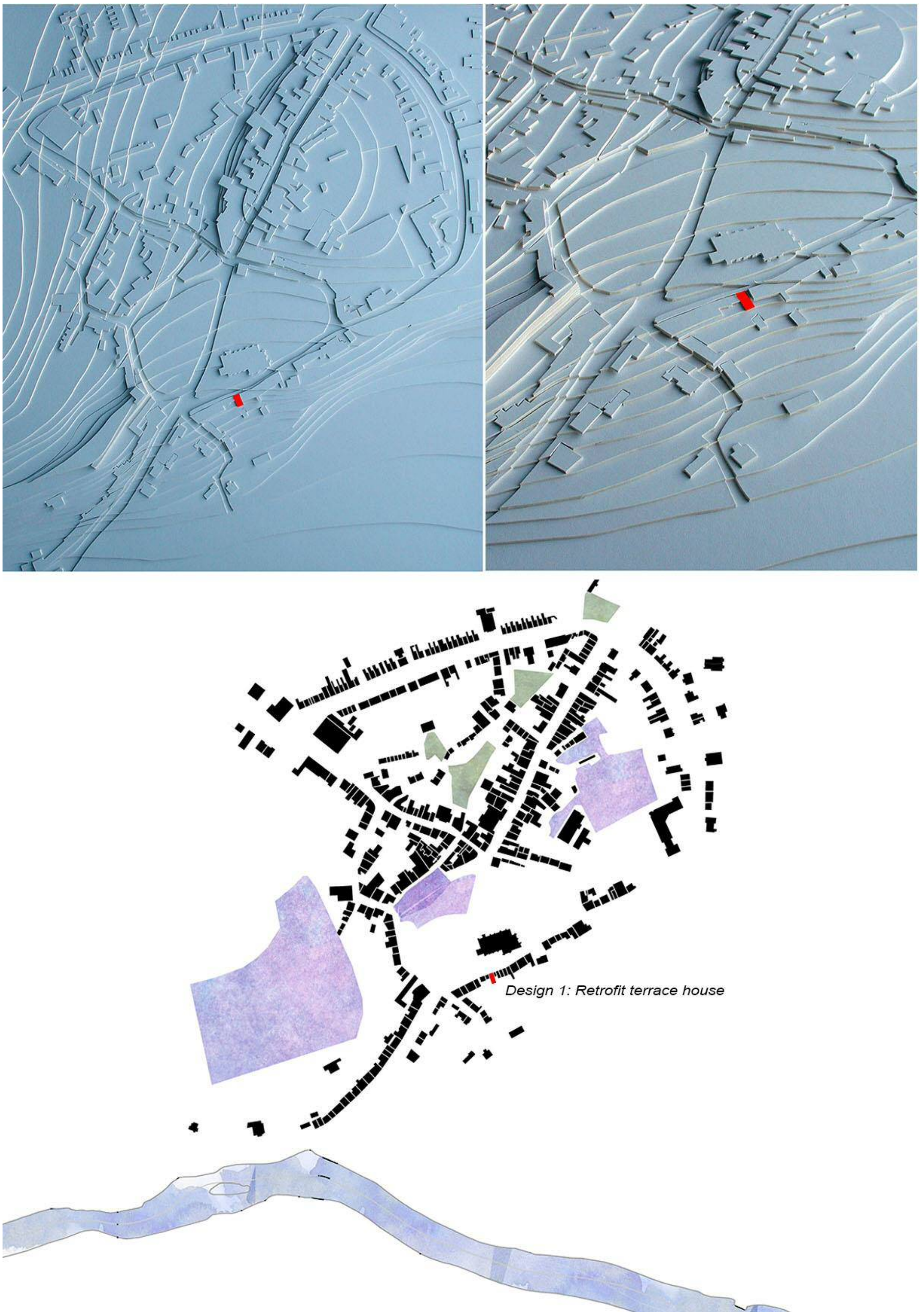


Figure 112: Site in Llandeilo

Church Street as found:

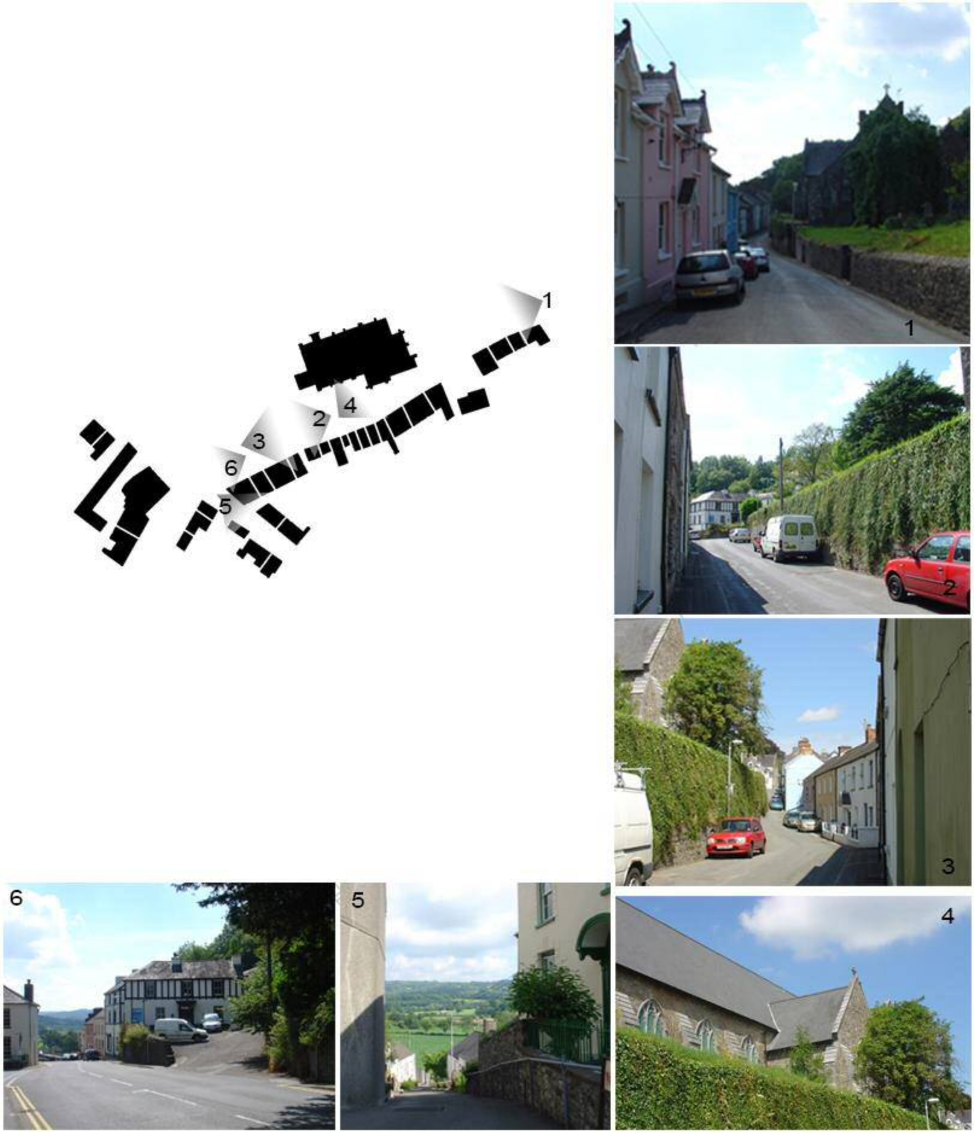


Figure 113: Church street as found (street images)

Church Street enclosure (Figure 113):

Along the eastern boundary of churchyard, Church Street is the longest terrace in this section. The southern street is situated below and opposite the church appearing humble in scale by comparison. The long horizontal rooflines contrast with the vertical emphasis of the church tower, and the narrowness of the road and high churchyard wall (up to fifteen feet) contribute to a sense of enclosure. In general, the houses are very attractive, rendered and colour-washed in a variety of pastel shades, and contrasting pleasantly with the austerity of the stone wall. Only one house has a coarser stone wall, which detracts from the uniformity of the street as a whole, by adding an additional texture into the street scene. In South Street, the sense of enclosure created by the church boundary is further emphasised by the King's Head Inn.

The site is oriented in a roughly north-south direction, with north facing adjacent to the street. The building has a church view across the street to the north. The terrain falls rapidly at the south boundary of Llandeilo, with the result that most of the terraces in Church Street have unobstructed meadow views to the south. In Llandeilo, the cold wind comes from the north in winter; while predominantly a variable cool/warm breeze comes from a south-southwest direction in other seasons. A lower sun angle is expected from the south in the wintertime in the UK. (Figure 114)

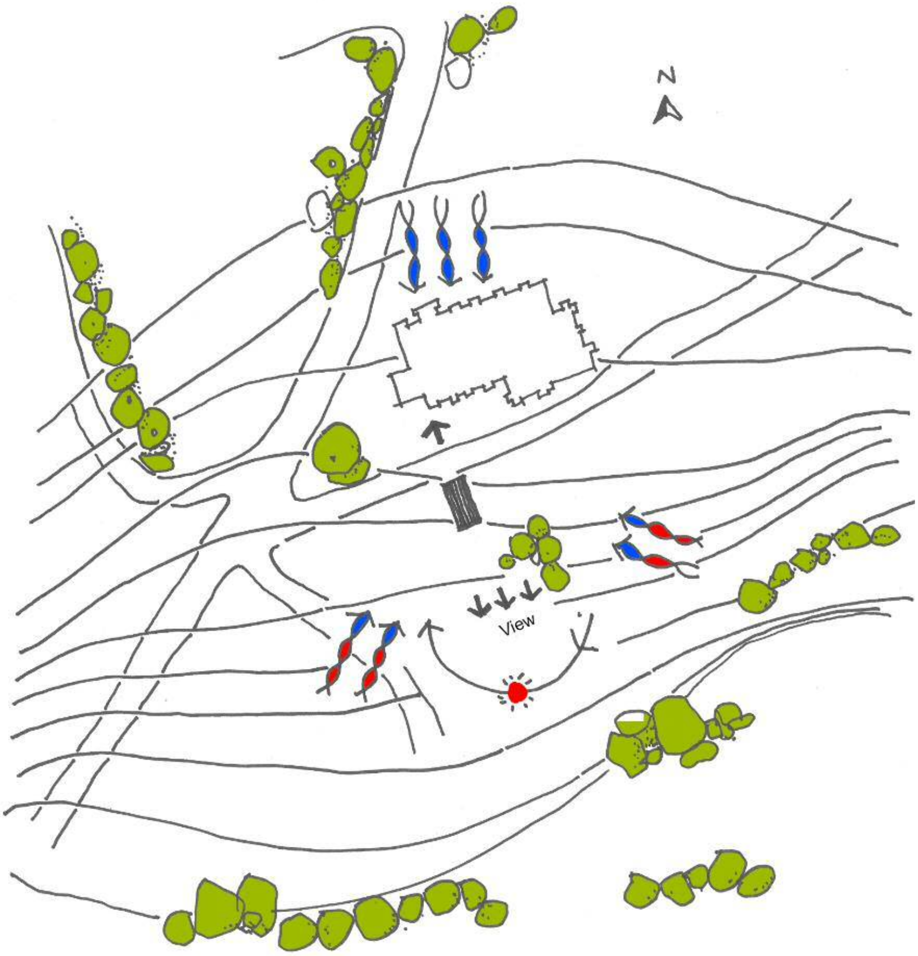


Figure 114: Site analysis (location, view, & geographic condition)

Existing layout, elevation and section as surveyed:

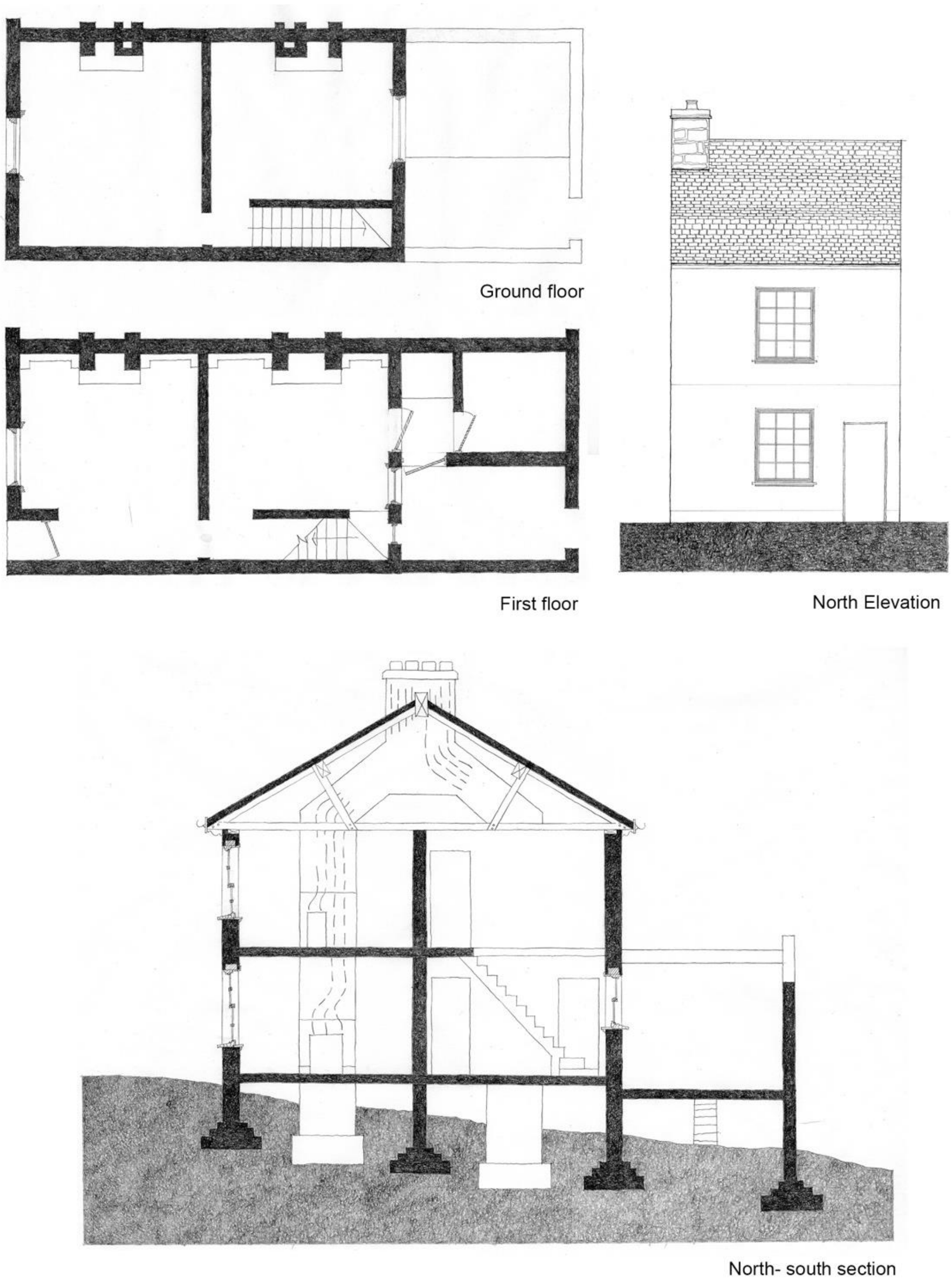


Figure 115: Floor plan and street facing elevation of No.7 Church Street

- **Ground Floor**: Lounge and living area, a small corridor to the kitchen and dining area. A small buffer area to the bathroom from kitchen then to the garden.
- **First Floor**: One double bedroom, one single bedroom.

Room distribution and views

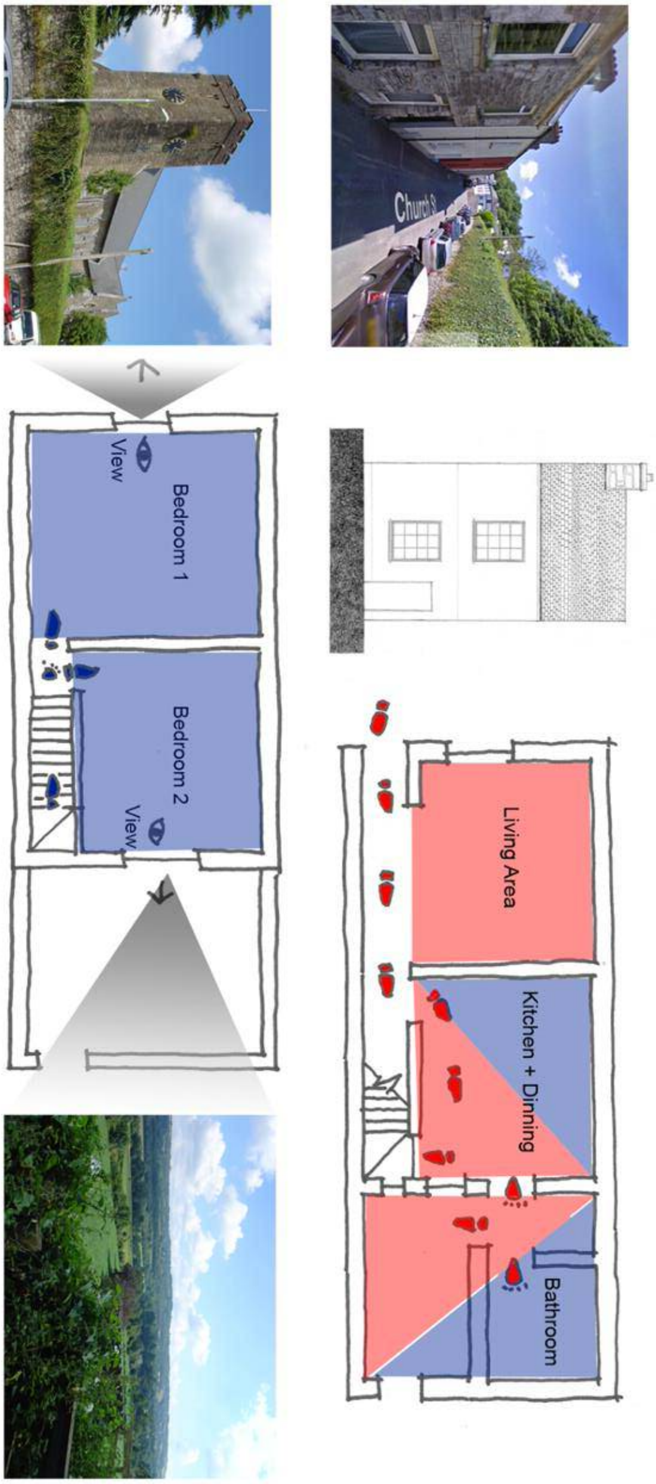


Figure 116: Building as found: the distribution of rooms with functions, views, streets image

Description of the existing building from three dimensions: conservation, architectural, and performance:

- Conservation: this building and its neighbours in Church Street contribute greatly to establishing the town's image and character within the Llandeilo conservation area. The colour washed façades, stone terraces with sash windows, and narrow openings along the street are signature characteristics of Llandeilo. Similar street elevations are found in other character areas in Llandeilo; such as Bridge Street, King Street, and Carmarthen Street.
- Architectural: the domestic building has a typical medieval burgage, with a narrow street front and deep layout. According with tradition, the building is a rendered, colour washed stone building, with a double pitched roof with a chimney. The building contains two principal floors and a loft area. The traditional design concept of 'active zone and quiet zone must be split' also applies to the distribution of rooms: the ground floor is defined as an active zone, and is where the living room, kitchen, dining and bathroom are located, while the first floor has private bedrooms (Figure 116). The loft area is used to store a water tank. To use the space economically, the stairwell is located at the back end of the house, which is characteristic of long narrow domestic buildings of that period. The stair runs from the back corner of the ground floor, heading to the middle of the first floor, where the partition wall to create two bedrooms with entrances is located. This layout means users must pass through the entire first floor to go upstairs. As with most of the traditional terraces in the historic settlement, the building has undergone several refurbishments and extensions through its life. A flat roof bathroom at the back of the building was constructed as an extension. There is no record of when the extension was added; and it is highly likely that since its original addition, the extension has been reconstructed (Carmarthenshire council planning department 1972).
- Performance: similar to most of the traditional stonewall terraces in Llandeilo, the building is with a low energy efficiency, and it is not always possible to establish a stable and comfortable interior environment for the user. The building's envelope is constructed of poor thermal materials, and it is not very airtight, which exacerbates heat loss in winter. U-value, or thermal transmittance, is used to rate

the heat conductivity of materials. Lower U-value denote a buildings strong ability to resist heat loss. The main wall material for the terrace is limestone; and the heat conductivity (U-value) for limestone is approximately 1.26-1.33W/(mK). A wall thickness of 650mm does not help with the reduction of U-value. Single glazing is commonly used for traditional sash windows; and the U-value for single glazing is around 3.20W/(mK). Cold draughts are expected in all the sections adjacent to openings and junctions between materials. In addition, draughts also come from the fireplace and chimney when not in use. The primary negative point arising from the building's poor energy performance is the heavy load on the aged heating system, which leads to high energy bills, and reduces users' comfort levels.

6.4 Initial design (variation 1)

6.4.1 Design strategies and approaches

Design target and concept

Responding to the analysis above, the retrofit addresses the enhancement of the building's interior space, refurbishing the building envelope to improve performance, and providing an efficient and economic heating system, designed to consume alternative energy. During the entire process, the principal conservational concern is to minimise the visual impact of the retrofit to the building's north (street facing) façade. For this retrofit case study, the accomplishment of above design target would require design approaches on three main aspects: *function, space, and performance*.

Function

Clarifying the boundary between private and public spaces and identifying rooms with different functions is important to improve the quality of life. The interior space may also be enlarged through the reconstruction of partition walls and make use of loft space. Even in a tight layout, a corridor is important to ensure the 'privacy' of rooms, by ensuring they are not used as a pathway through the house (Figure 117).

The construction of a conservatory by clearing the tiny backyard space is an option, to contribute additional interior space to the tight layout. A two-storey conservatory also creates an indoor terrace on the first floor, maintaining a comfortable and stable environment, together with unblocked views to the meadows beyond, through enlarged full glazing. Plus, the conservatory space might be used as a buffer section to improve the building's environmental aspect.

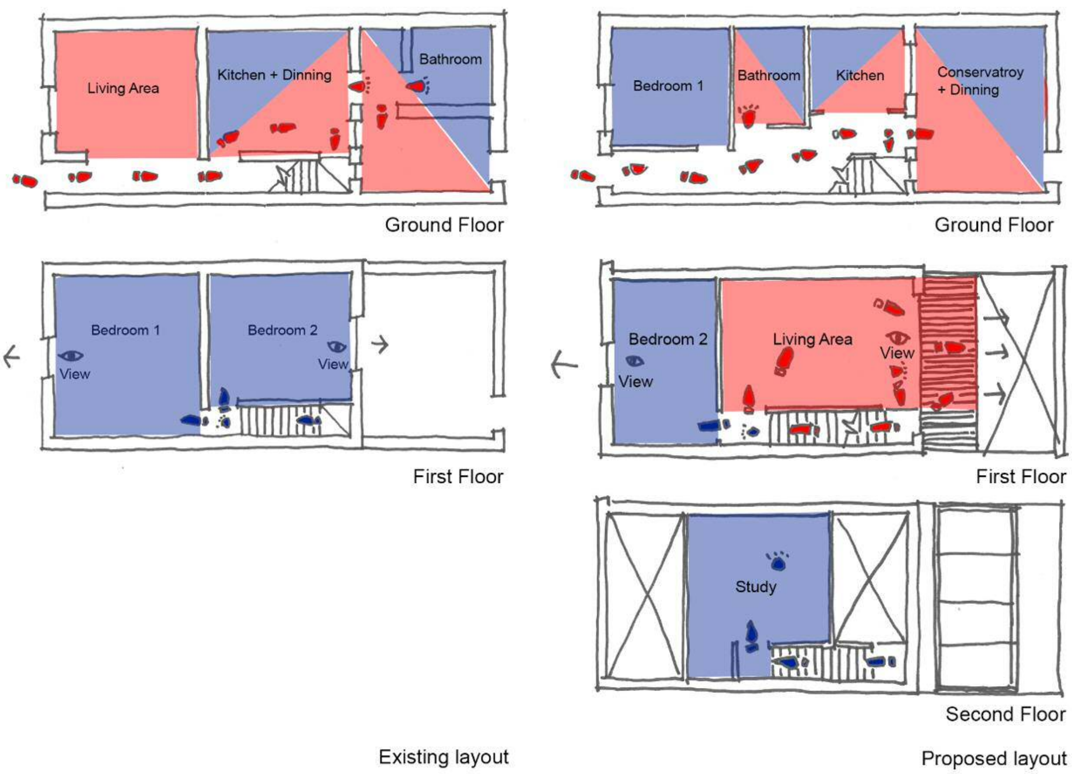


Figure 117: Proposed new distribution of rooms with different functions

Space

The enhancement of building interior space is achieved through three interlinked innovations:

Enlarged living area with views of meadow (Figure 118)

Compared to the original layout, the living area in the proposed plan occupies the largest space in the building (Figure 117). In a snug layout, the living area is the main place in the dwelling that people spend their family time, both day and night, in contemporary life. It is important to position the living area within the dwelling, so that it has the best view and faces the sun, to gain sufficient solar energy during the daytime. In this design, the first floor offers a south facing space with a meadow view, which is deemed an ideal good space for a living area.

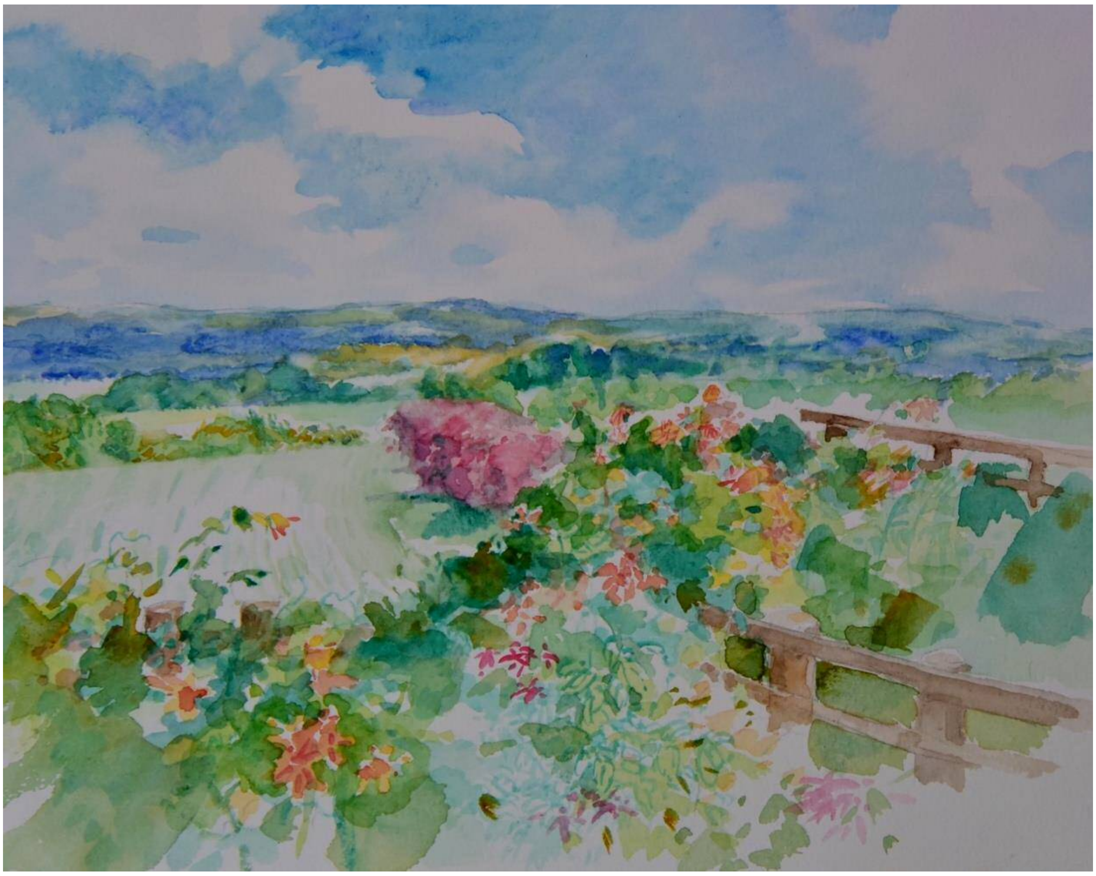


Figure 118: Unobstructed meadow view from the house to the south, with the potential of useful solar gain

Separate study area in the loft

By converting the unused and cold traditional storage space, in the loft area, it is possible to create a separate study space. Additional skylights can be added to the south facing pitched roof to ensure sufficient daylight, and to ease the pressure created by the height of the room. Full and continuous pitched roof insulation plus double glazing skylights guarantee the energy performance in this area.

Conservatory

A conservatory provides additional indoor space that benefits from a seasonally flexible use as a dining area, and family room with storage. The connection between the roof of the conservatory and the roof of the house helps to create a 4.5-meter height space with full glazing and a meadow view (see Figure 118) to contribute valuable living space as well as providing an environmental buffer that employs the principles of passive solar design.

Performance

Extremely high carbon emission rate and high energy bill is the main concern of this 1800s terrace house and many similar domestic buildings in Llandeilo. Almost all strategies are employed in the study to improve building energy performance; some strategies are treated or converted to either follow conservational principles or reach a balance point.

Passive design

To take advantage of the passive design, rooms that are most frequently used during the daytime are placed at the south where they benefit from direct solar heating; while bedrooms used mostly at night are to the north (Figure 119). Openings on the south elevation have also been altered to maximise solar gain. To maintain the north façade, the original sash windows are retained, but renewed with double glazed units. The sizes of the openings are unaltered. Additional insulation through the building envelope and the ground floor is added to prevent energy loss. A successful accomplishment of passive design reply on architects' design approaches on layout and interior space.

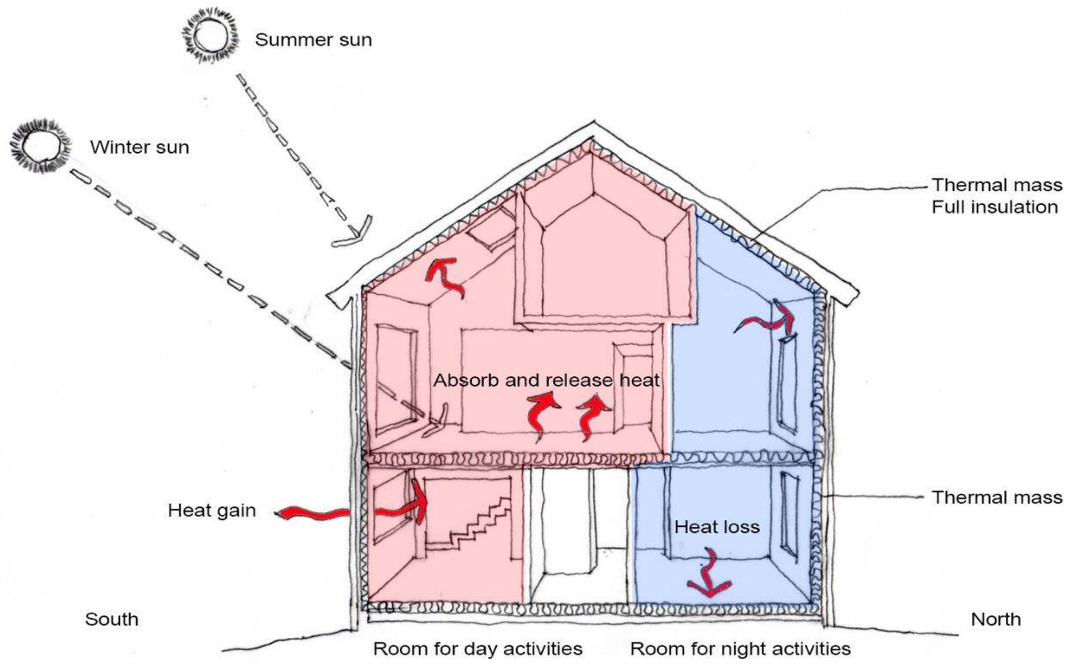


Figure 119: The solar gain of No.7 Church Street

Building envelope and fabric

To establish a building envelope with high environmental performance and air tightness, full insulation is required throughout the house, including the floor, wall, and full roof (Figure 120). Dry liner internal insulation is employed because the maintenance of the building exterior façade, especially north elevation, is a priority concern in this design. For all the openings to the south elevation and the conservatory, triple glazing is used. To avoid altering the appearance of windows on the north façade, secondary windows with triple glazing are employed from the interior to guarantee the U-value initially. In practice, limitations of seconding glazing are revealed: firstly, it is hard to access the original window in daily uses; secondly, special detailed treatment are important at the joints of secondary glazing to prevent cold droughts; finally, it slightly reduces the daylight and visual pleasure. In further studies, it is advised there are conservational standard wooden frame double glazed sash windows in the market now. The product has been widely applied in building regeneration cases with highly rewarded reputation for its conservational appearance and low U-value. Treatments on all joints, such as the secondary glazing, roof and foundation, skylights and the chimney, are important to create a continuous building envelope without thermal bridge (Figure 120).

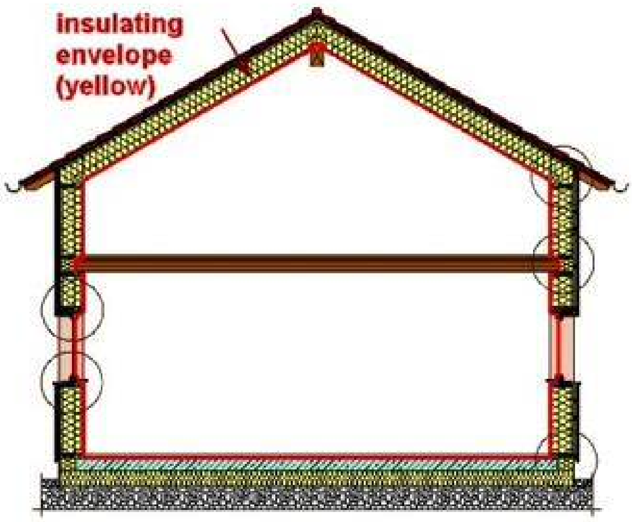


Figure 120: Example of very good full thermal insulation with roof insulation. Circle areas are sections with the possibility of a thermal bridge; designers are required to pay extra attention to these areas.

Natural lighting and solar gain

The daylight factor is considered an environmental concern, because suitable daylighting factor guarantees users can carry out their duties without artificial lighting in normal weather conditions (CIE overcast sky). The proposed south section of each house can be naturally lighted easily, with a fully glazed conservatory and additional skylights on the roof. To reduce overheating in summer, variable angle internal shading can be used to accompany the skylights. There might not be adequate day light in the bedrooms in the north section and the bathroom because of the preservation of the opening size. The reason for arranging bedrooms along the north wall is to deduce the influence of poor lighting level on the residents' daily lives.

Ventilation

Effect ventilation is achieved through window trickle vents (Figure 121), included with all the newly installed openings. The image shows window vents can be combined with framing materials in several variable shapes.

Figure 121: Window trickle vents made from plastic and timber

In the design, the whole ventilation system composed of the chimney, skylight, and existing openings could enhance the building's comfort level in the summer (Figure 122). Variable angle shadings combined with skylights might directly obstruct sunlight between 12am and 3pm. The proposed ventilation through the chimneys, using differences in air pressure might form an effective airflow to blow off heated air during the night time to cool down the building.

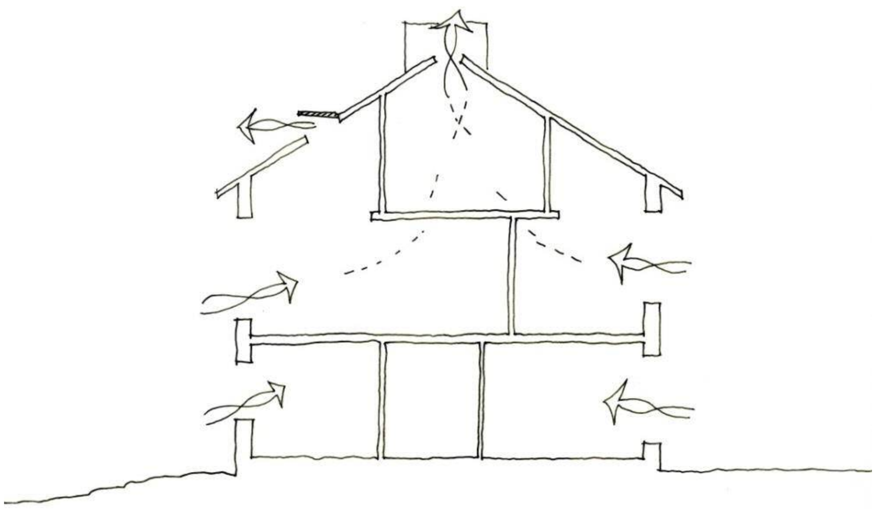


Figure 122: The main ventilation flow through the chimney

Besides the natural ventilation system, a mechanic ventilation system is also employed in addition to the natural ventilation system in the design. This is deemed the most effective way to blow off over-heated air and to activate airflow in the summer when the natural wind pressure is not sufficient (Figure 123). In winter and other seasons, the participation of electric fans ensures excessive humidity does not gather in the interior. The activities of showering, bathing and cooking often increase humidity; and condensation on the cool walls of the building are the main reasons for mould.

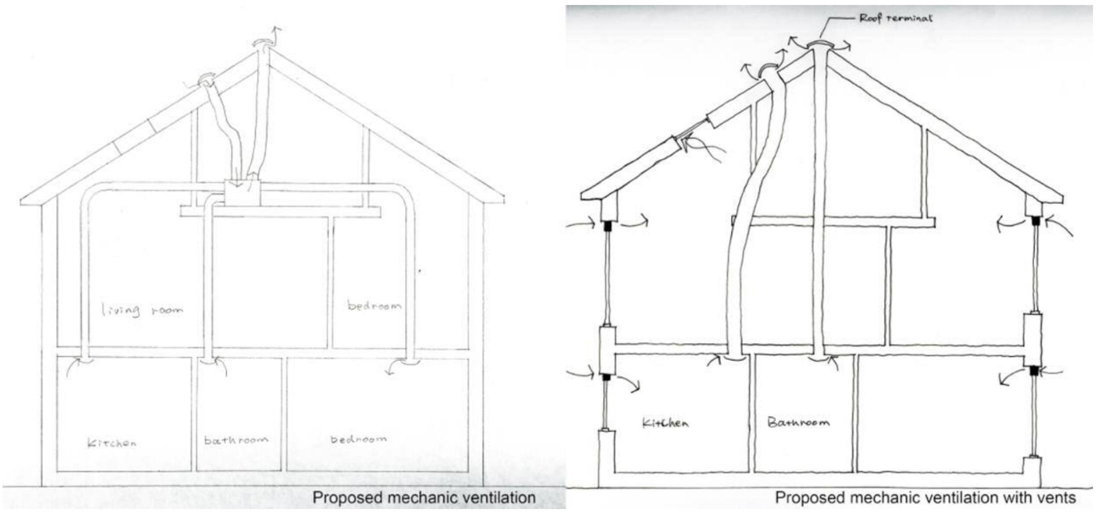


Figure 123: Proposed mechanic ventilation and window vents helps effective ventilation in cold and hot weather.

Systems

The energy production is achieved through the installation of a solar water heating system. In domestic uses, total energy saving ranges from 12% to 20% with the correct installation of a solar thermal collector on a pitched south-facing roof (Martin 2001). Photovoltaic panels are not used initially due to the space limitation on the roof and the costs.

In order to achieve further energy cutting, a biomass boiler consuming wood chips or a ground heating source pump can provide additional winter heating rather than traditional hydronic heating (combi boiler). Further analysis is required in this case, however, as there is a space requirement for both systems.

6.4.2 Design works

Figure 124: :'Church Street' street image (upper: before retrofit; lower: after retrofit)

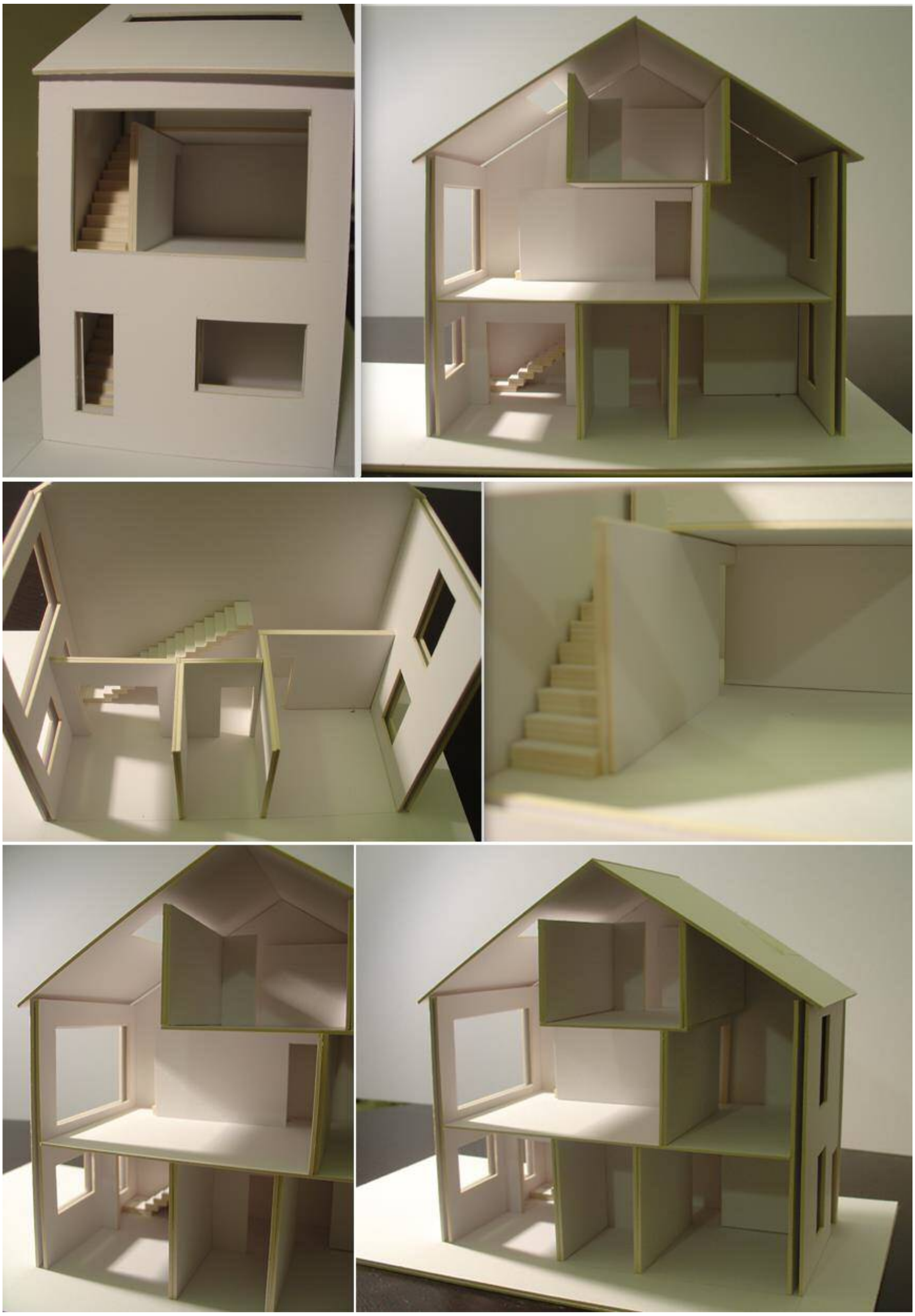


Figure 125: Model for proposed design (upper left: south elevation; upper right: section; middle left: first floor; middle right: living area and stair detail; lower left: detail; lower right: full house)

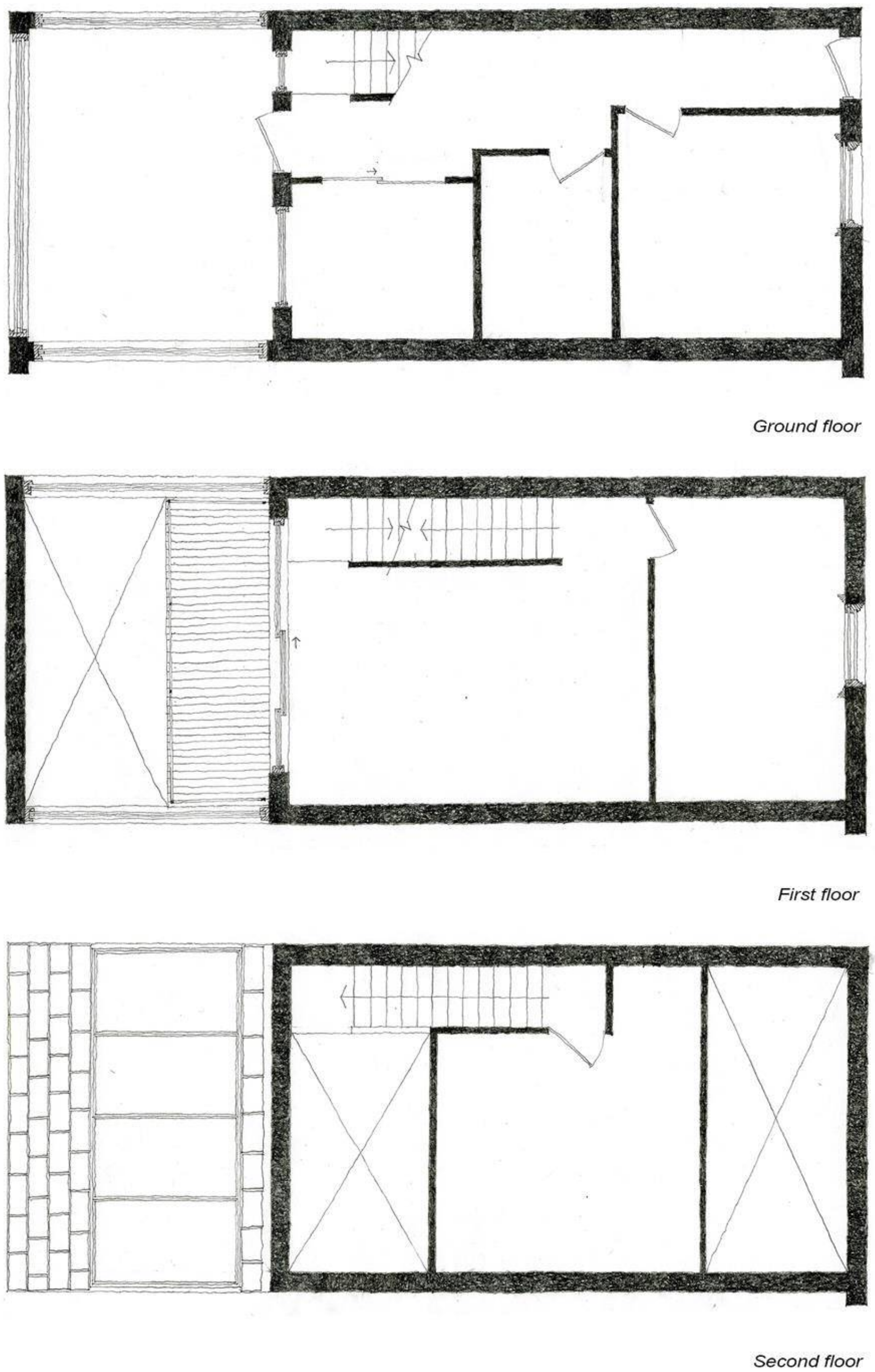


Figure 126: Proposed floor layout (upper: ground floor; middle: first floor; lower: loft)

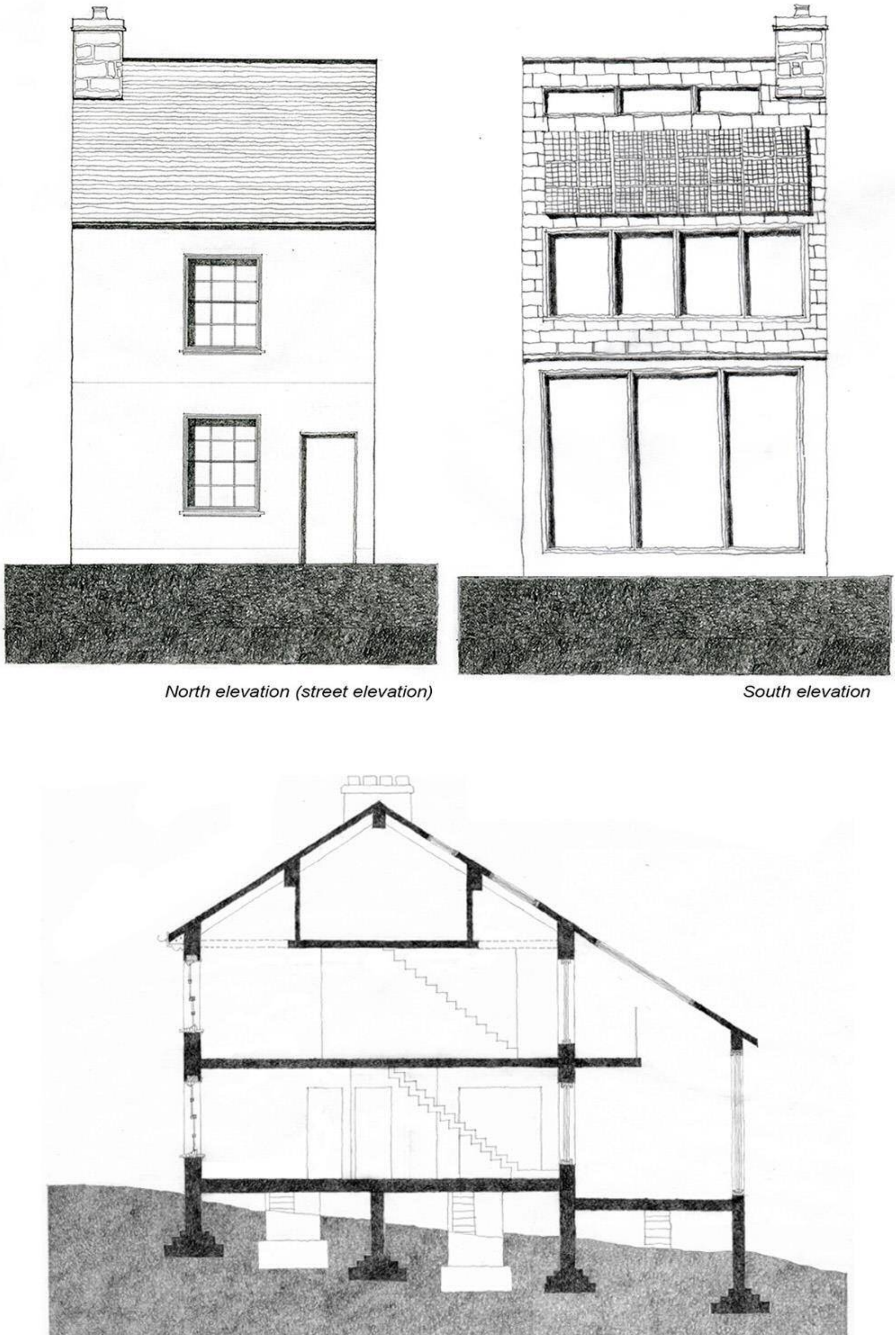


Figure 127: Proposed elevations and section, south elevation (back elevation from Church Street),

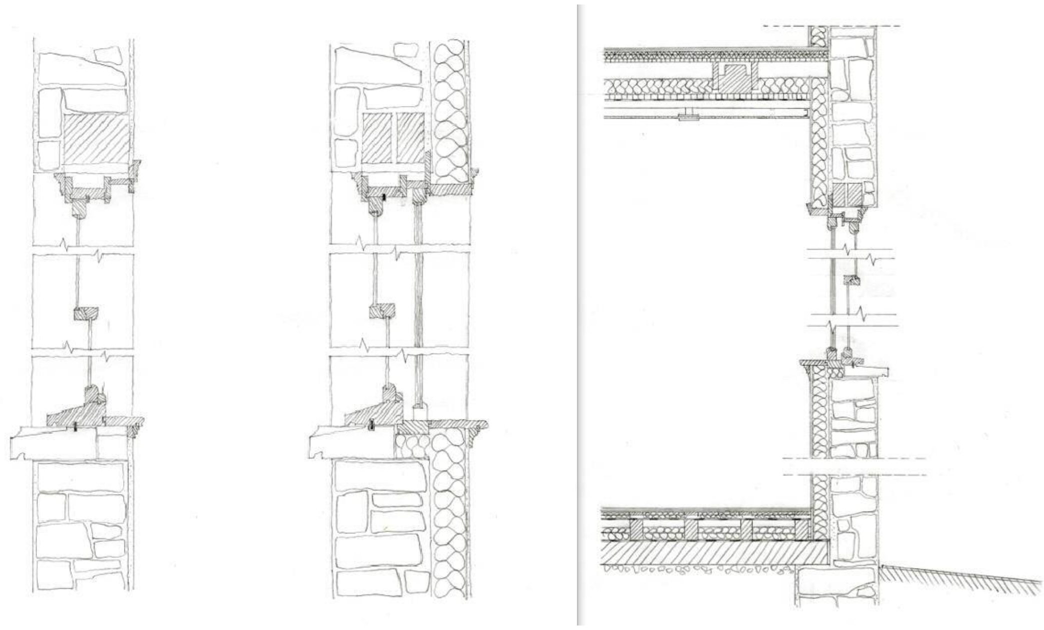


Figure 128: Detailed sketch for secondary glazing, wall insulation and ground insulation

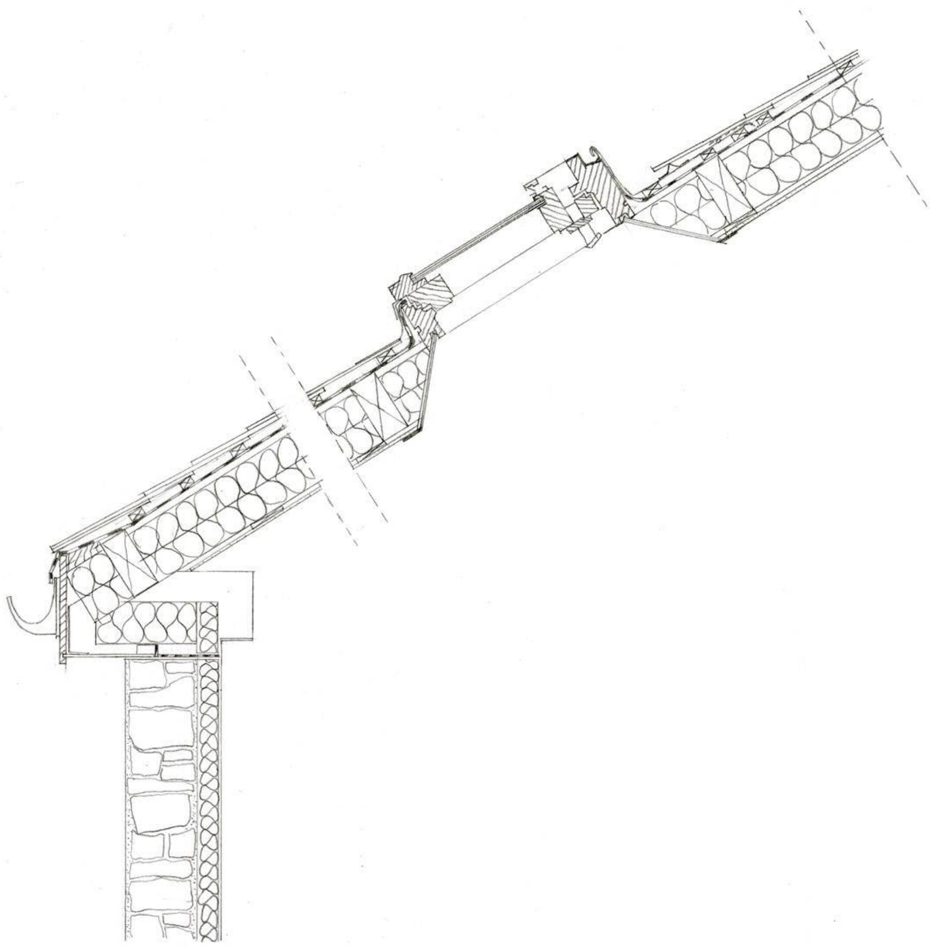


Figure 129: Detailed sketch of roof insulation

6.4.3 Review of sustainability

The design result is predicted by using the BRE certified energy calculation tool at design stage: standard assessment procedure (SAP). SAP 2012 calculator is employed in both case studies; and the calculation is based on the physical conditions including the location, orientation, building's performances, all main systems, overheating, etc., assessing the carbon emission rate.

There are three tests targeting the different proposed conditions; and the results are compared and evaluated.

Table 4: A conclusion of energy simulation result through SAP: test 1

Round	Building Condition	Total energy required KWh/year	SAP rating	SAP band
1-1	Original terrace	41,660	55.04	D
1-2	Variation 1 (with solar hot water)	13,117	81.04	B
1-3	Variation 1 (with solar hot water + PV)	2,427	94.96	A

For a complete copy of the SAP testing result, please see Appendix II.

Test 1-1 is a simulation for the existing terrace. The other two tests are based on the proposed retrofit. The differences between tests 1-2 and 1-3 relate to the installation of a package of 4KWp photovoltaic panels. The test result illustrates that there is massive reduction in energy consumption after retrofitting the building layout and envelope and installing solar hot water system. The introduction of a new energy source (photovoltaic) brings further deduction on energy requirement in test 1-3. In the practice, to further deduce energy bills and carbon emission, in consideration of the cost, users may choose to install air source heat pump or biomass boiler for heating; extra pack of photovoltaic panel could be an options as well. With a better building envelope, offering internal insulation, the house can be heated up more quickly to comfort level.

6.4.4 Evaluation of the design against the model

It is useful to evaluate the design against the point-based framework proposed at the end of chapter 4 (Table 5); a bar chart is used to illustrate the completion rate of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model (Figure 130). The evaluation result of all design attempts will then be discussed together at the end of this chapter:

Table 5: Evaluation of design attempt 1 (initial design) against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	As completed in Chapter 5
Mapping	5	5	As completed in Chapter 5
2 Non-renewable assets: Conservation to elements with high sensitivity	9	9	Well preservation of key components such as chimney, sash windows, etc.
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	3	
Create consistent streetscape	2	2	
Repeat building character and pattern	2	2	
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	5	
5 Design with flexibility			
Design could be revised or retracted	2	1	Some alterations could be retracted such as sealed chimney
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	5	
7 Sustain all resources in the historic settlement			
Materiality	1	1	
Building pattern	2	2	
Building details	1	1	

Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	1	New populations could be attracted by contemporary standard houses.
Economic boost	2	1	House renovation project and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	0	Not related
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	0	Not related
Performance:			
1 Building energy performance			
Building position and orientation	1	1	
Building layout	2	2	
Passive design	3	3	
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	1	Normal combi boiler rather than new system is employed in the test.
Boilers and hot water	2	2	Solar hot water
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	LED lights
3 Carbon emission			
Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	

User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	1	
Alternative heating (example: ground source heat pump)	2	0	Could be applied as an option.
Electric generation (example: photovoltaic)	2	0	Could be applied as an option.
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25°C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	0	New system less energy consumption could be applied as an option.
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	84	

Evaluation result reveals the terrace retrofit design attempt 1 is proposed under 74% completion of total 113 credits in both conservation and performance aspects. In nine conservation principles, '*define characters and significant of the place*' (principle 1) and *post-construction assessment*' (principle 6) could not be assessed at the design stage: principle 1 is completed by place-led townscape study and mapping in Chapter 5; although principle 6 is presumed as fulfilled in the evaluation, a full post-construction assessment should be completed by an accredit assessor in the real project. Some conservation principles are less applicable to domestic retrofit instead of town planning and siting, such as '*reinforce the boundaries', 'reinforce the position in the community',* and *'straighten the historic core'*. The design quality and degree of conservation may not be determined through point losses in above principles. The design is also highly presented in performance: fully completed ‘*energy performance*’ and ‘*occupancy comfort*’ are achieved through re-established building layout, constant full insulation, passive design, and natural ventilation. ‘*Post-construction assessment*’ (principle 6) in performance is also credited according to design proposal in the study, a full post-construction assessment should be completed by an accredit assessor in real project. Most point loss happens on new energy source, especially for heating. Solar hot water is employed in the second round of simulation; then added photovoltaic panels brings more carbon offset in test 1-3. It is proposed some new energy source for heating could be applied in other tests if needed.

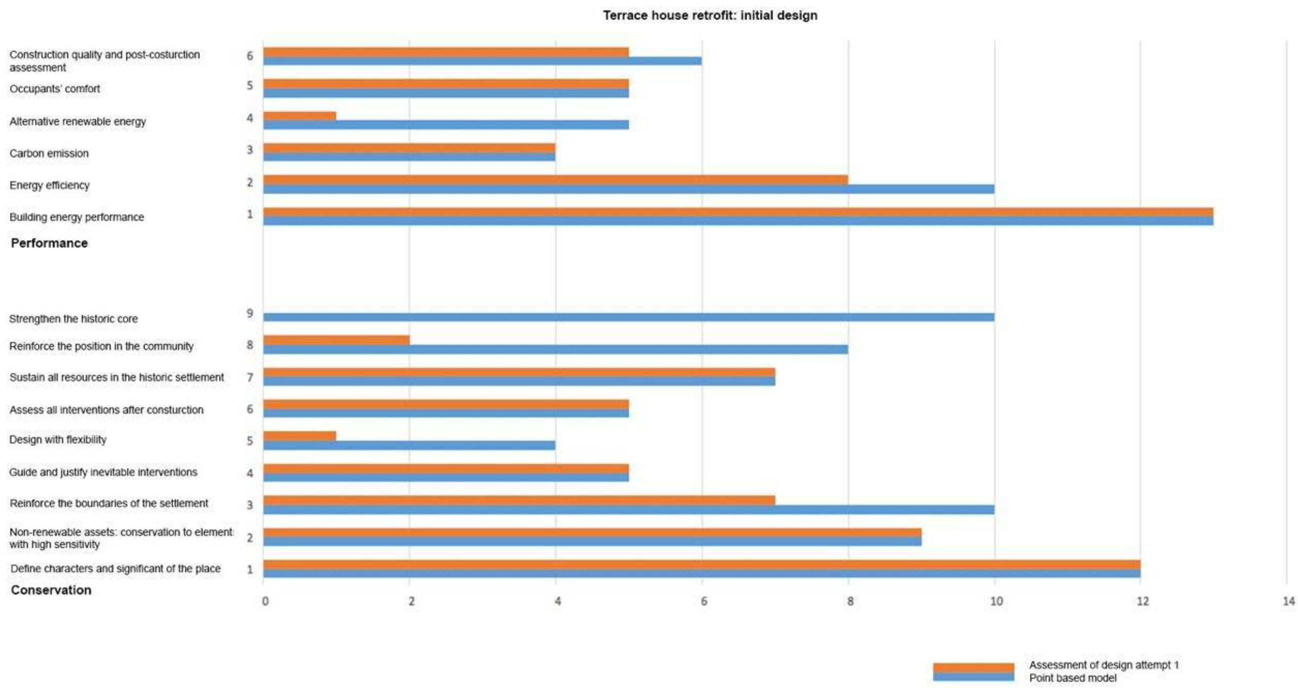


Figure 130: Bar chart revealing the completing status of each principle against the model in design attempt 1.

This chart shows principle 1, 2, 4, 6, and 7 in the conservation aspects and principle 1, 3, and 5 in the performance aspects are fully achieved. In details, there are four principles in the conservation aspect, principles 3, 5, 8, and 9, are not fully achieved, because these principles are less related to domestic buildings. The point loss principles in the performance aspect are principle 2, 4, and 6 for unemployment of new energy source for heating.

6.4.5 Analysis and discussion

Several reflections and recommended strategies were made after the design, energy assessment and evaluation:

- Renewal on energy performance of majority aged domestic buildings in a historic settlement is an indispensable and effective approach in achieving nearly zero carbon. Carbon emission of the original terrace is far beyond the target emission rate, and the total energy consumption is reduced more than 28,000 KWh/year after the retrofit of the building layout and envelope and installing solar hot water, successfully fitting the dwelling into SAP band B.
- On the basis of compact and full insulation, systems using new energy source, sensibly verified according to some conservation principles, could be applied to further offset the total carbon emission, for example, one package of 4KWp photovoltaic panels employed in the simulation 1-3 successfully reduce almost 10,000 KWh/year energy consumption on the basis of test 1-2.
- The introduction of renewable energy, such as photovoltaic panels in this design, may lay the visual impact on the roofscape, therefore affect the image on the streetscape. It is intolerant from conservation principles if these impacts are observed from street and change the visual image of the place.
- The existing building of No. 7 Chruch Street is the terrace with a north facing street façade, which provides benefits for the initial design attempt. By taking most alterations in the back elevation also the south facing elevation, such as enlargement of openings, and adding skylights, etc., the basic passive design criteria are fulfilled without harming the street façade with high sensitivities. However, a terraced house with a south facing street elevation and north facing back yard will require further assessment and verifications on design approaches; and it might take more challenges to create the passive design under conservation restrictions. On the basis of the initial design works, three

variations are reviewed, assessed, and then discussed together at the end of this chapter. Variation 2 is still under more onerous conservation requirements, with a south facing street façade. Design variation 3 and 4 are under less onerous conservation requirements, one with a north facing street façade and the other with a south facing street façade.

6.5 Design variation 2

6.5.1 Changes and challenges

On the context of the initial design works, three variations are then reviewed, assessed, and then discussed together at the end of this chapter. Very similar to the initial design, variation 2 is under more onerous conservation requirements; however, the whole site is twisted 180 degrees with a hypothetical south facing street façade. In order to control editable elements in the test, all physical parts of the building, including the layout of the terrace, size and position of openings, skylights, building materials and insulations employed remain exactly the same as the initial design. There might be systems with renewable energy source, such as air source heat pump and photovoltaic, employed to fit the building in a tight carbon emission band. Alterations on the orientation of the site is under the hypothesis, only affecting building solar gain: imaging the current street facing façade becomes a south facing; and the backyard with meadow view shifts to north-oriented.

It is estimated the main challenges may address the appearance of building energy performance under a north-oriented condition. The passive design strategies applied on building layout is established based on the original orientation; with a 180 degree twisting, day-activity spaces, including living and kitchen, are now north-oriented, which will lead to noticeable differences on building solar gain. Nevertheless, justified from aspects of interior natural lighting (gain from enlarged openings), privacy, and views, it would still be a suitable option to place day-activity spaces near the backyard instead of street front. As stated in the initial design, the preservation of street-facing façade is under extremely high level of sensitivity, which may affect opening sizes, type of windows, any added new elements on the roof such as skylights, solar panel, and photovoltaics.

6.5.2 Review of sustainability

Two rounds of SAP simulation are summarised in the following, with detailed results included in appendixes II.

Table 6: A conclusion of energy simulation result through SAP: test 2

Round	Building Condition	Total energy required KWh/year	SAP rating	SAP band
2-1	Variation 2	18,536	74.59	C
2-2	Variation 2 (with air source heat pump supplying heating and hot water)	10,257	84.08	B

The simulated energy consumption in test 2-1 is dramatically increased compared to test 1-2, although the total energy performances are greatly improved with fully insulated envelop compared to the original terrace. Changes on the orientation, passive design, and solar hot water system may possible lead to this increase. With high visual exposure of solar panels on the street facing roof, solar hot water is excluded in test 2-1 under conservation concerns. In simulation 2-2, there is a massive drop in total energy requirement and corresponding increase in SAP rating after applying air source heat pump (24 KW output) as the main heating and hot water source. In the situation of sites with strict restrictions on exposed elements, air source heat pump may be used as an alterative option, supplying both heating and hot water. Installation cost and space for heat pump should be considered in practice.

6.5.3 Evaluation of the design against the model

By employing the same evaluation method through the test, the proposed variation 2 is now scored based on the point-based framework (Table 7); a bar chart is also used to illustrate the completion status of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model (Figure 131).

Table 7: Evaluation of design variation 2 against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	
Mapping	5	5	
2 Non-renewable assets: Conservation to elements with high sensitivity	9	9	
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	3	
Create consistent streetscape	2	2	
Repeat building character and pattern	2	2	
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	5	
5 Design with flexibility			
Design could be revised or retracted	2	1	Some alterations could be retracted such as chimney
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	5	
7 Sustain all resources in the historic settlement			
Materiality	1	1	
Building pattern	2	2	
Building details	1	1	
Craftsmanship	1	1	
Landscape	1	1	

Vegetation	1	1	
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	1	New populations could be attracted by contemporary standard houses.
Economic boost	2	1	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	0	Not related
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	0	Not related
Performance:			
1 Building energy performance			
Building position and orientation	1	0	The day-activity spaces are now north-faced under conservation requirements.
Building layout	2	1	North-facing day-activity spaces.
Passive design	3	1	North-facing day-activity spaces.
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	0	South facing elevation with small openings may reduce the efficiency of solar gain.
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	2	Air source heat pump.
Boilers and hot water	2	1	Air source heat pump.
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	
3 Carbon emission			
Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	

4 Alternative renewable energy			
Solar hot water	1	0	South-facing roof is now under strict conservational control from adding any new elements. Air source heat pump is now used.
Alternative heating (example: ground source heat pump)	2	2	Air source heat pump
Electric generation (example: photovoltaic)	2	0	Could be applied as an option.
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25˚C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	1	Air source heat pump
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	81	

A total evaluation result of variation 2 is 81 out of 113 (72%) which is a slightly drop from the initial design. The completion rate in the conservation aspect (48 out of 70) remains the same as the initial design, and principles 3, 5, 8, and 9, are not fully achieved due to their less relationship to domestic buildings. By fitting the original design to a hypothetical site with different orientations, there are some clear point loss in the performance aspect, especially in principle 1 '*energy performance*'. Although the building envelope is fully insulted, credit on solar gain, layout, passive design may still be affected by geographic changes. Some point switch happens between solar hot water and new energy source of air source heat pump. It is possible to fit the tight carbon emission rate without breaking conservation principles if a suitable renewable energy system were selected.

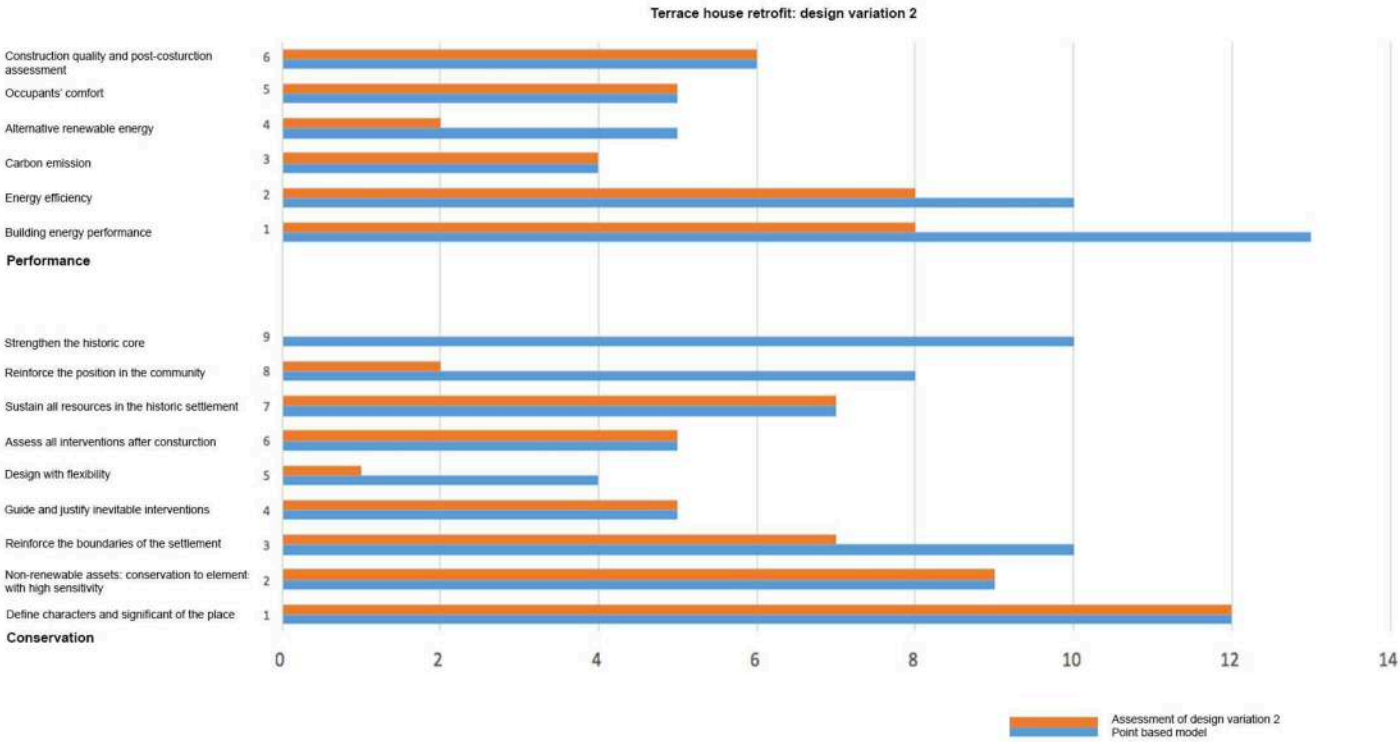


Figure 131: Bar chart revealing the completing status of each principle against the model in design variation 2.

Changes on this bar chart mainly addresses in the performance aspects in principle 1, 4, and 6. Principle 1 *building energy performance* is less than 2/3 (8 out of 13) achieved: it is less 'passive' by arranging day-activity spaces north oriented with large openings; on the other hand, the ability of solar gain is limited by small historic sash windows on the south elevation. Also under the requirements of conservation to *elements with high sensitivity* (conservation principle 2), any added new elements on the roof, including solar panel for hot water and photovoltaics, are prohibited. Under such circumstances, selection of a *renewable energy system* (principle 4) should always under careful verifications on its possible visual impact, plus balancing running efficiency of the system and preservation of street façade. In this test, air source heat is applied in simulation 2-2, supplying both heating and hot water rather than solar water and photovoltaics. Otherwise, solar panels installed horizontally on the backyard or other side of the roof could be another solution; however, shades need to be considered in small sites.

6.5.4 Analysis and discussion

Several reflections and recommended strategies were made after the design, energy assessment and evaluation:

- Building orientations, passive design, building layout could possibly make impacts on building's total energy consumption, under the condition of full insulated building envelop. However, systems consuming new energy source might be the critical term for reaching the tight target carbon emission rate, such as air source heat pump employed in test 2-2.
- In terrace retrofit, most unfollowed performance principles, caused by unalterable geographic conditions, are likely to be improved through design strategies; and the target carbon emission rate may also be met through design.

6.6 Design variation 3

6.6.1 Changes and challenges

The changes of variation 3 and 4 address 'level of conservation', especially on elements with high sensitivities (conservation principle 2): variation 3 is under less onerous conservation requirements, with a north-facing street frontage; while variation 4 has a hypothetical south-oriented street façade under the same ground of less onerous conservation requirements. With higher tolerances on breaking conservation criteria, it is possible to enlarge openings with extra 30% on the street elevation and add skylights on the front roof. Double-glazed timber frame sash windows must be employed rather than contemporary style ones under conservation concerns. Both alterations may largely increase the daylight factors in bedrooms near the front; in variation 4's circumstances, above modifications may also increase room temperature caused by insufficient solar gain. However, enlarged openings, even in sash style, may still stand out from its neighbours, changing the constant street elevation. Further amenities could happen in variation 4 to fit the design into the tight carbon emission band: new elements of photovoltaic panels may be used to further reduce building energy consumption.

It is estimated main challenge exists on gaps between conservation and performance. Architects, who is responsible to design practices, should refine some principles with detailed design strategies. There might be correspondingly point loss in the conservation aspect for variation 3 and 4, especially if photovoltaic panels were installed on the street frontage façade.

Drawings of building's street frontage elevation could be used to illustrate visual differences and impacts from three degrees of renovation:

Figure 132: Changes of building's street frontage façade: from left to right, under strict conservation, less conservation, the elevation possibly jeopardise streetscape.

6.6.2 Review of sustainability

SAP simulation result is summarised below, with detailed results included in appendixes II.

Table 8: A conclusion of energy simulation result through SAP: test 3

Round	Building Condition	Total energy required KWh/year	SAP rating	SAP band
3-1	Variation 3 (with solar hot water)	13,361	80.99	B

With the same orientation and 12m^2 of solar panel supporting hot water, this SAP simulation is very similar to the result of test 1-2. Although openings on the north elevation (also the street front elevation) are enlarged, the total heat loss is barely affected because sash style triple-glazed windows with U-value of 0.9W/m^{2}K is used to guarantee a high performance building envelope.

From aspects of occupants' experience, the daylight factor might be significantly improved with bigger street-facing openings, especially in the front section of the terrace. Long slim layout with a dark zone in the middle of the house is very typical for terraces constructed before 1900s; in the initial design, over 70% of the backyard elevation are alerted to transparent elements in consideration of natural lighting and occupant's comfort. There should be a great upgrading for the dark corridor in the middle of the house after enlargement of street facing openings.

6.6.3 Evaluation of the design against the model

The point-based framework is once again employed to evaluate the design variation 3 (Table 9); a bar chart is also used to illustrate the completion rate of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model (Figure 133).

Table 9: Evaluation of design variation 3 against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			

Townscape study	7	7	
Mapping	5	5	
2 Non-renewable assets: Conservation to elements with high sensitivity	9	7	Slightly enlarge the size of openings on the street facing façade.
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	2	Losing point on enlarged openings.
Create consistent streetscape	2	2	
Repeat building character and pattern	2	1	Small openings are a character of 1800s terraces.
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	4	The style of sash window will still be employed.
5 Design with flexibility			
Design could be revised or retracted	2	1	All the street facing renewals could be retracted.
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	5	
7 Sustain all resources in the historic settlement			
Materiality	1	1	
Building pattern	2	1	Size of openings
Building details	1	1	
Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	1	New populations could be attracted by contemporary standard houses.
Economic boost	2	1	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	0	Not related
Infrastructures	2	0	Not related

Varieties	2	0	Not related
Reduce areas with blur image	2	0	Not related
Performance:			
1 Building energy performance			
Building position and orientation	1	1	
Building layout	2	2	
Passive design	3	3	
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	1	Normal combi boiler rather than new system is employed in the test.
Boilers and hot water	2	2	Solar hot water
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	
3 Carbon emission			
Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	1	
Alternative heating (example: ground source heat pump)	2	0	Could be applied as an option.
Electric generation (example: photovoltaic)	2	0	Could be applied as an option.
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25˚C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	

6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	0	New system less energy consumption could be applied as an option.
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	78	

In this table, total score (78 out of 113) and the conservation credits (42 out of 70) are both dropped from evaluation results on variation 1 and 2. Conservation principle 2 '*elements with high sensitivity*', principle 3 '*reinforce the boundaries*', and principle 7 '*sustain all resources*' are disturbed by enlarged openings. Small openings with solid façade is a unique character of UK terrace houses in 1850s to 1900s. This variation has a same total performance credit (36 out of 43) as variation 1, because they share the same building layout, insulated envelope, and geographic conditions. The point loss principles in the performance aspect are principle 2, 4, and 6, under the reason of heating system; general combi boiler is applied instead of new system with renewal source. Air source heat pump employed in test 2 could be an additional option for heating and hot water supplement to further offset carbon emission and to add points in the performance aspect.

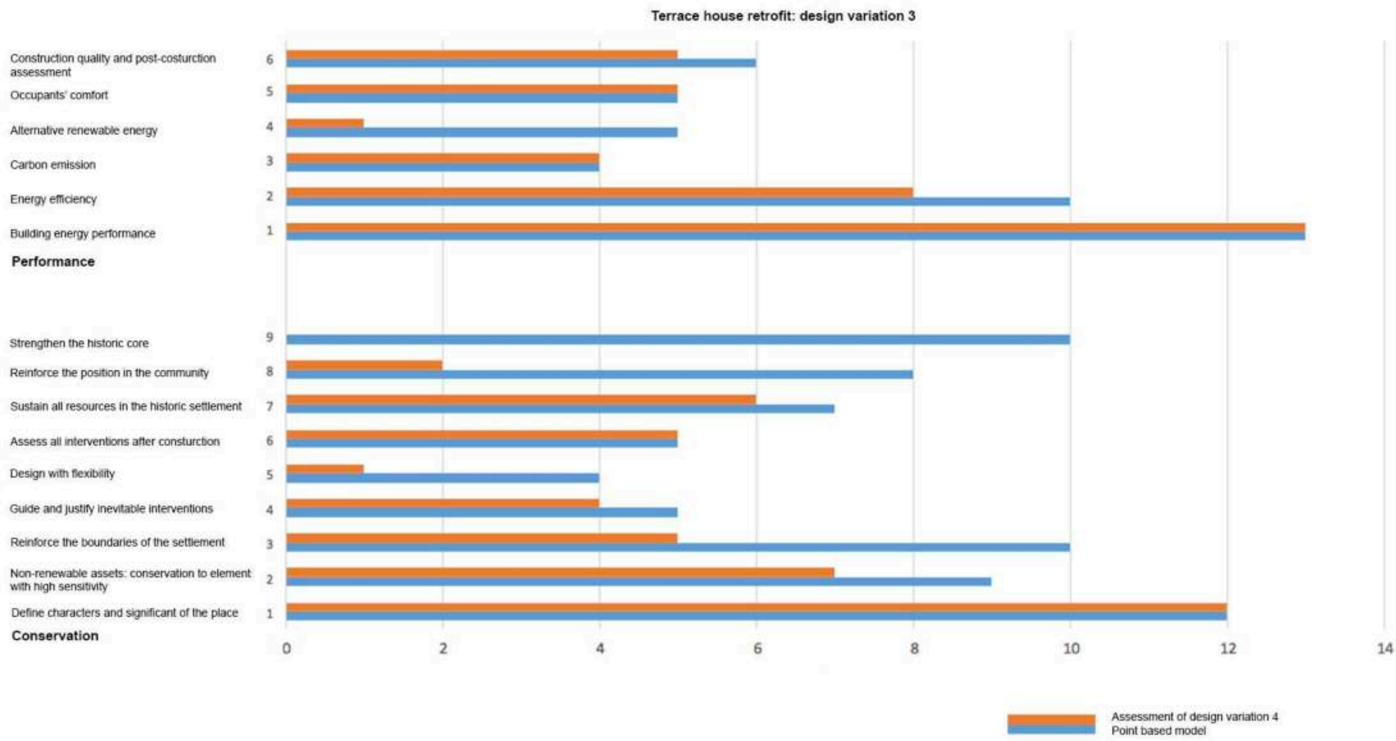


Figure 133: Bar chart revealing the completing status of each principle against the model in design variation 3.

This chart shows this variation is failed to complete almost all conservation principles, except principle 1 and principle 6. low credits in conservation especially in principle 2 and 3 are caused by enlarged street front openings, which may affect the visual constant in streetscape. Both principle 1 and 6 are not assessed at the design stage: principle 1 is completed by place-led townscape studies and mapping in Chapter 5; although principle 6 is presumed as fulfilled in the study, a full post-construction assessment should be completed by an accredit assessor in real project. In the performance aspect, point loss happens in principle 2 and 4 because general combi boiler is used to provide both heating and hot water instead of renewable energy source.

6.6.4 Analysis and discussion

Several reflections and recommended strategies were made after the design, energy assessment and evaluation:

- Alterations on the street facing elevation do not bring noticeable improvement on SAP in this test, the simulation result is very similar to test 1. Under the same ground of well-insulated building envelope, the simulation might be affected by geographic condition, main energy consuming systems such as heating, cooling, and hot water, and installation of renewable energies such as photovoltaic and air source heat pump.
- The enlarged street facing openings and added skylights on the front roof do not bring obvious improvement on the evaluations of performance and the SAP; however the overall enhancement on user's comfort, building interior space, and the daylight factor is certain and it could be verified. From architects' aspect, it is important to justify from both aspects: the necessary in regeneration and carbon deduction, and degree of impacts to conservation.
- In terrace retrofit, most unfollowed conservation principles, caused by enhancement of building performance, are less likely to be improved or fixed through design strategies.

6.7 Design variation 4

6.7.1 Changes and challenges

Same as last test, variation 4 is under less onerous conservation requirement, but a hypothetical south-oriented street façade. With higher tolerances on breaking conservation criteria, apart from enlarging street front openings and adding skylights, further amenities such as installing photovoltaic panel could be an option to fit the design into a tight carbon emission band, as displayed in Figure 132. The simulation for variation 2 shows it is important to employ heating systems with renewable energy to offset heat loss from large openings in the north elevation and insufficient solar gain in the south. In this test, the modification of window sizes in the street elevation could slightly increase solar gain.

The purpose of testing this variation, especially under the propose of installing photovoltaic on street facing pitched roof, is to justify conflicts between conservation and performance in all possible circumstances. It is estimated the conservation credits might be much lower than other variations; but with photovoltaics plus air source heat pump, this test may achieve a high score in the aspect of performance, especially on energy efficiency and renewable energy.

6.7.2 Review of sustainability

SAP simulation result is summarised in the following, with detailed results included in appendixes II.

Table 10: A conclusion of energy simulation result through SAP: test 4

Round	Building Condition	Total energy required KWh/year	SAP rating	SAP band
4-1	Variation 4 (with air source heat pump + PV)	2,054	97.20	A

Benefited from the installation of both air source heat pump (24KW output) and photovoltaic (a package of 4KWp panel), terrace in variation 4 could be operated with the lowest energy consumption in this case study. As proposed in this variation, air source heat pump supplies both heating and hot water in the house; photovoltaic panel are installed on the south-facing roof with 45 degrees, connecting to the main power grid. The employment of multiple renewable energy sources greatly offset any disadvantages from the geographic condition and heat loss from north-facing conservatory.

6.7.3 Evaluation of the design against the model

The evaluation of variation 4 follows the same methods as above: the point-based framework (Table 11) and a corresponding bar chart (Figure 134) is used to illustrate the completion status of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model.

Table 11: Evaluation of design variation 4 against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	
Mapping	5	5	
2 Non-renewable assets: Conservation to elements with high sensitivity	9	4	Enlarge the size of openings on the street facing façade. Skylights on street-facing pitched roof. Installation of PV on street-facing pitched roof
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	1	Enlarged openings, skylights, and Photovoltaic.
Create consistent streetscape	2	1	Stand out elevation with new elements.
Repeat building character and pattern	2	1	Small openings are a character of 1800s terraces.
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	2	Pattern of sash window will still be employed.
5 Design with flexibility			
Design could be revised or retracted	2	1	Some alterations could be retracted such as chimney
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	5	
7 Sustain all resources in the historic settlement			

Materiality	1	1	
Building pattern	2	1	Size of openings
Building details	1	1	
Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	1	New populations could be attracted by contemporary standard houses.
Economic boost	2	1	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	0	Not related
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	0	Not related
Performance:			
1 Building energy performance			
Building position and orientation	1	0	The day-activity spaces are now north-faced under conservation requirements.
Building layout	2	1	North-facing day-activity spaces.
Passive design	3	1	North-facing day-activity spaces.
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	Enlarged openings and added skylights guarantees solar gain from south-facing elevation.
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	3	Air source heat pump.
Boilers and hot water	2	2	Air source heat pump.
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	

3 Carbon emission			
Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	0	Hot water is supplied by air source heat pump system.
Alternative heating (example: air source heat pump)	2	2	Air source heat pump.
Electric generation (example: photovoltaic)	2	2	Photovoltaic could be installed under less conservation requirements.
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25˚C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	1	Air source heat pump
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	73	

According to the evaluation, there are significant total point losses in total (73 out of 113) and in the the conservation aspects (35 out of 70), addressing on conservation principle 2, 3, and 4 related to the level of intervention and preservation of elements with high sensitivity. Figure 132 displays a changing progress of the terrace's street façade, from strict conservation of non-renewable elements, to moderate degree of change on key elements, then to additional new elements. Learn from place-led townscape study, the plain and simple colour washed façade, with small timber framed sash windows, is one of the unique characters of Llandeilo's domestic buildings, forming the repeated and constant streetscape of most streets in the conservation area. The street frontage elevation proposed in variation 4 makes impacts on some key elements including window size (the transparency of the elevation) and skylights on the roof (the constant roofscape). Apart from above, it also adds a new element of photovoltaic, a glazing panel not containing any historic characters, to the street frontage. Although solar panels are employed in variation 1 and 3, the different orientation of the site causes the glazing panels are installed on the roof facing backyard with non-direct street views.

On the other hand, an extremely high score (38 out of 43) is reached in the performance aspect, especially on principle 2 and 4. With less concerns and regulations from conservation, new systems with renewable energies may easily applied neglecting the position of the site. Principle 1 '*energy performance*' is still not fully achieved due to the geographic condition.

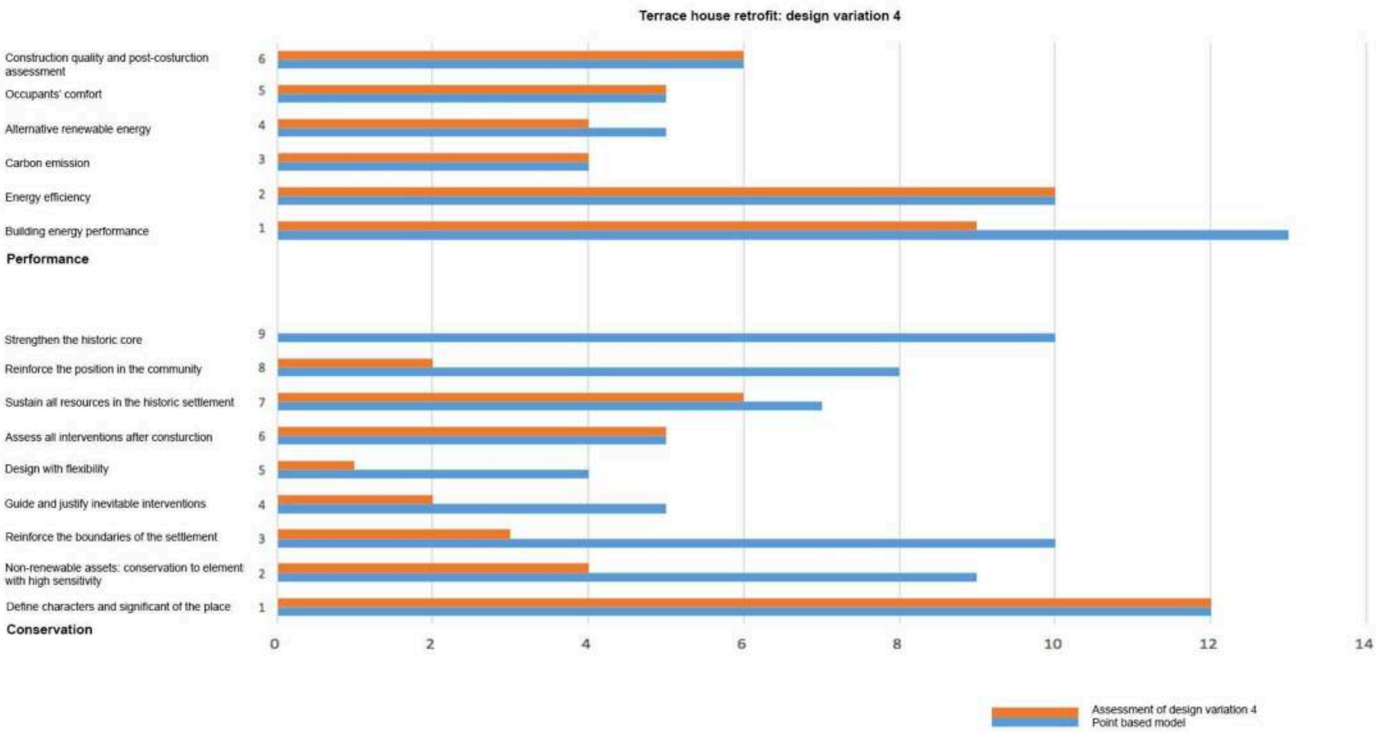


Figure 134: Bar chart revealing the completing status of each principle against the model in design variation 4.

This chart shows an unbalanced points distribution for this variation: in the conservation aspect, almost all principles are unfollowed, except principle 1 and principle 6 are not assessed at design stage; while majority of performance principles are completed. The credit loss in performance principle 1 is caused from building's orientation and north facing conservatory, however, point gain in other performance aspects especially in principle 2 and 4 may offset the loss.

6.7.4 Analysis and discussion

Several reflections were made after the design, energy assessment and evaluation:

- It is easier to achieve a better performance with less controls on elements with high sensitivity in conservation. Otherwise, a careful review and verification would be required for installing new systems in a tight site containing a historic south-facing street frontage. Instead of harming elements with high sensitivities, there are several strategies may be used to adapt design in any orientation: (1), modify the design especially passive design if possible; (2), seek alternative system fitting geographic condition of the site and building; centralised renewable energy supplement could also be an option for tight sites or high density area; (3), use design strategies to alter the building fabric if necessary.
- With the fitting of air source heat pump and 4KWp photovoltaic, variation 4 has the lowest carbon emission through all tests under this case study based on SAP. Nevertheless, the overall design proposal may significantly harm the unique characters of a historic settlement if the low carbon design were achieved through breaking main conservation criteria.
- In terrace retrofit, most unfollowed conservation principles, caused by enhancement of building performance, are less likely to be improved or fixed through design strategies.

- In this test, to bridging gaps between conservation and performance, architects may suggest: (1), use sash window and check the final window size from street view; (2), do not add skylights unless necessary; and (3), never install solar panel on the street frontage elevation, in search of alternative solutions.

6.8 Findings and discussion

To assist discussion and achieve findings, two tables (Table 12, Table 13) are employed: one for displaying evaluation credits of all tests against the model; another for demonstrating SAP results of all design variations. The trend of simulated energy consumptions through all design variations are drawn in Figure 135. Bar charts (

Figure 136, Figure 137) are used to illustrate the completion rate in each principle and categorised total credits of all variations.

Table 12: Matrix of scores covering all tests

Principles	Available credits	Test 1	Test 2	Test 3	Test 4
Conservation					
Principle 1: Characters & significant	12	12	12	12	12
Principle 2: Elements with high sensitivity	9	9	9	7	4
Principle 3: boundary	10	7	7	5	3
Principle 4: Guide interventions	5	5	5	4	2
Principle 5: Flexibility	4	1	1	1	1
Principle 6: Post-construction Assessment	5	5	5	5	5
Principle 7: Sustain all resources	7	7	7	6	6
Principle 8: Position in community	8	2	2	2	2
Principle 9: Historic core	10	0	0	0	0
Sum (conservation)	70	48	48	42	35
Performance					
Principle 1: Energy performance	13	13	8	13	9
Principle 2: Energy efficiency	10	8	8	8	10
Principle 3: Carbon emission	4	4	4	4	4

Principle 4: Renewable energy	5	1	2	1	4
Principle 5: Occupant's comfort	5	5	5	5	5
Principle 6: Post-construction Assessment	6	5	6	5	6
Sum (performance)	43	36	33	36	38
Total	113	84	81	78	73

Illustrated by Table 12, test 1 of the initial design achieves the highest scores in both aspects and in total; while test 4 has the lowest. Both test 2 and test 3 reaches a similar score in total, and test 2 is in a slight higher benchmark. With a higher rating in the conservation aspect, test 2 loses several points in the performance aspect on the reason of geographic condition. Standing on an opposition position, test 3 is stronger in the performance, but achieve low credits in conservation. In details, principles 5, 8, and 9 in the conservation aspect are the points losing principles for all tests; same as principle 2 and 4 in the performance aspect.

Overall, all tests are completed over a rate of 50% for this framework containing all principles: variation 4 with the worse appearance has a 65% achievement; and the variation 1 reaches 74% which is the highest in all. Learn from discussions of each variation, variation 1 also obtains the better balance between conservation and performance, especially without crucial shortage in any related principle.

Table 13: A conclusion of energy simulation result through SAP

Round	Building Condition	Total energy required KWh/year	SAP rating	SAP band
1-1	Original terrace	41,660	55.04	D
1-2	Variation 1 (North Church Street Facing, with solar hot water)	13,117	81.04	B
1-3	Variation 1 (North Church Street Facing , with solar hot water, and PV)	2,427	94.96	A
2-1	Variation 2 (South Church Street Facing)	18,536	74.59	C

2-2	Variation 2 (South Church Street Facing, with air source heat pump supplying heating and hot water)	10,257	84.08	B
3-1	Variation 3 (North Church Street Facing , with solar hot water)	13,361	80.99	B
4-1	Variation 4 (South Church Street Facing, with air source heat pump, and PV)	2,054	97.20	A

This table summarises SAP results of all simulations in each variation. Apart from simulation for the original terrace before retrofit, the first test of variation 2 has a highest carbon consumption, while variation 4 consumes the lowest. By sharing the same orientation plus same heating and hot water system, second test of variation 1 and variation 3 are similar in total energy requirement and SAP rating; and small increases in energy consumption is cause by heat loss from enlarged north openings. By twisting the site 180^{o}, removal of solar panel and heat loss from the north-facing conservatory may affect the SAP, as shown in test 2-1. The energy consumption of variation 2 test 1 jumps to the highest, the rate is then dropped significantly after adding air source heat pump to supply heating and hot water. Further dramatic reduction happens in variation 4 with the combination of air source heat pump and PV.

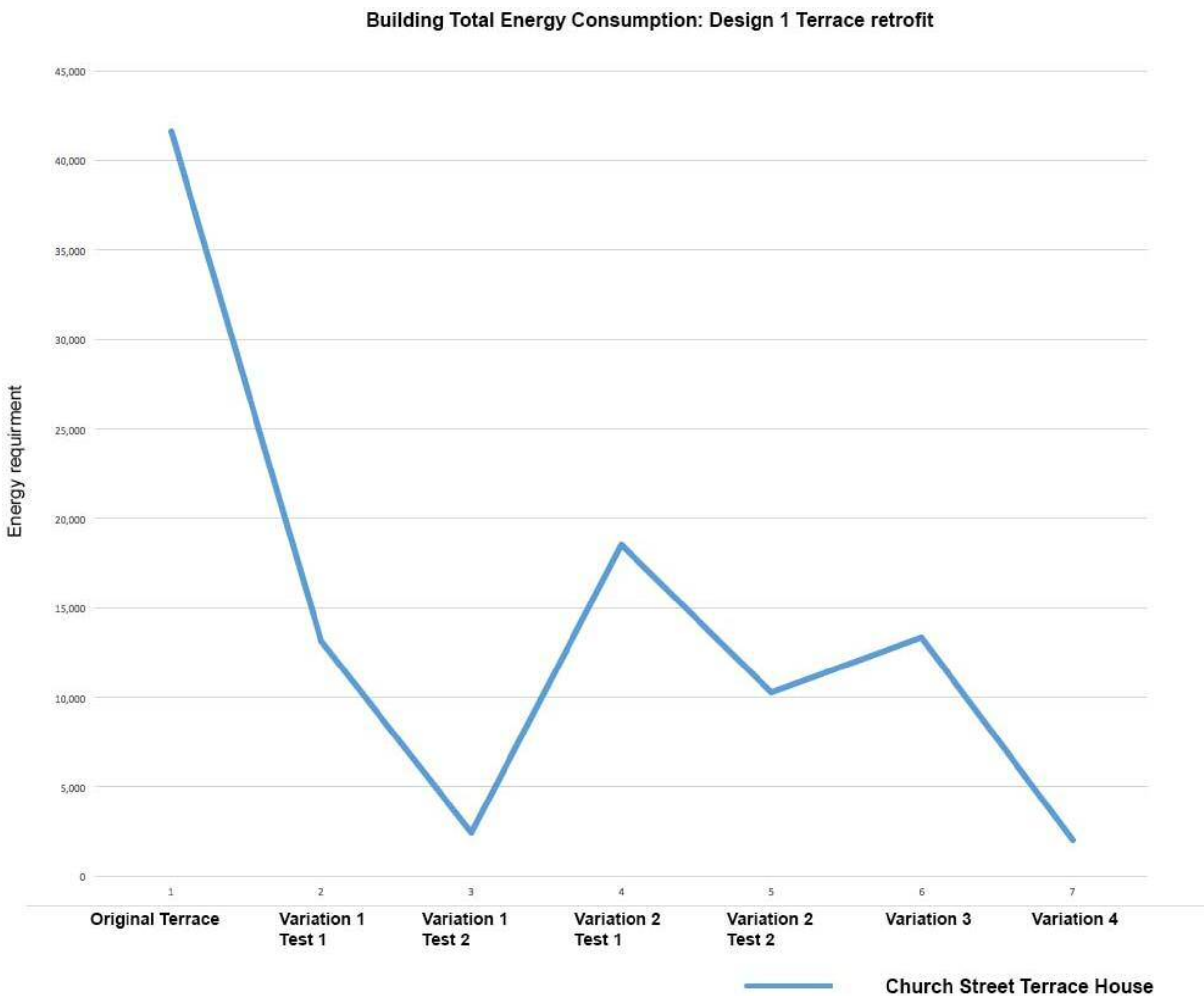


Figure 135: Building total energy consumption through all design variations (containing the energy consumption of the original terrace)

This figure reveals a trend of building's total energy consumption through all tests. It is obvious there are dramatic deduction on the annual-based energy requirement after the retrofit. Both variation 1 test 1 and variation 2 test 2 under onerous conservation requirements has a similar energy consumption, although they have opposite geographic conditions. With a twisted orientations and heavy conservation restrictions, the energy consumption of test 2-1 jumps to the peak on the basis of test 1-1. By taking air source heat pump to supply heating and hot water, the result drops significantly without breaking conservation rules in variation 2-2. Variation 3 and variant 1-1 has similar energy requirements because they are only different on sizes of north-facing openings. With the installation of photovoltaic panel, variation 1-2 and variation 4 has lower energy consumptions than the others, however, the lowest energy usage in variation 4 is obtained from violating conservation rules.

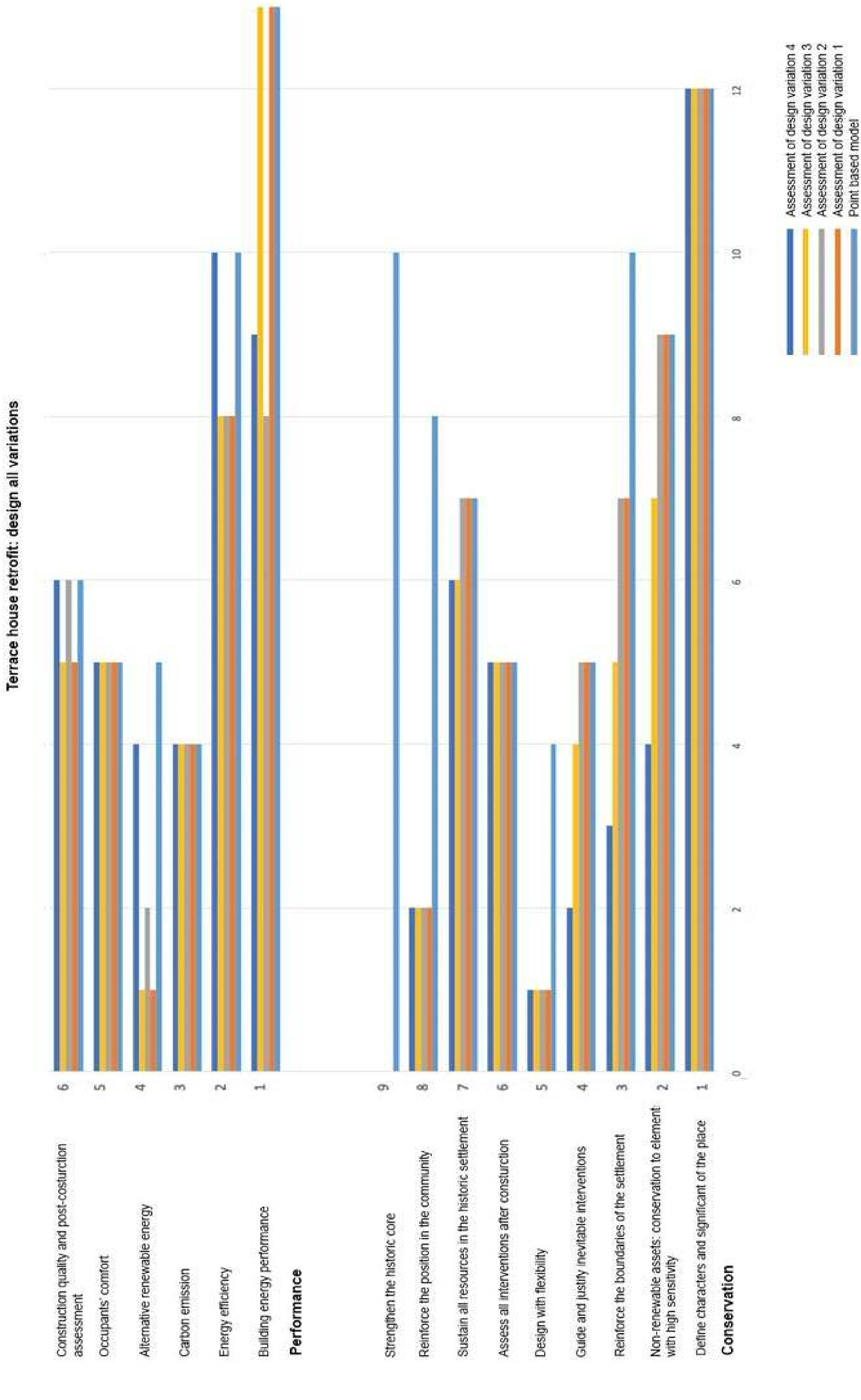


Figure 136: Bar chart revealing the completing status of each principle against the model

This bar chart reveals several facts: (1). In the conservation aspect, variation 3 and 4 appears to obtain less credits in principle 2, 3, 4, and 7 than variation 1 and 2. These principles are proposed and defined based on identifying and maintaining unique characters and non-renewable resources. The activities of less conservation requirements may affect the implement of them. (2). Conservation principle 5, 8, and 9 are not tested through all design variations in retrofit case, because these principles are applicable to non-domestic buildings rather than domestic ones. (3). In performance principles 1, variation 2 and 4 obtains less credit than variation 1 and 3 due to geographic condition, SAP result proves the total energy consumption may be affected by the orientation of openings. (4). Except variant 4, performance principle 2 and 4 are only partly fulfilled in other tests.

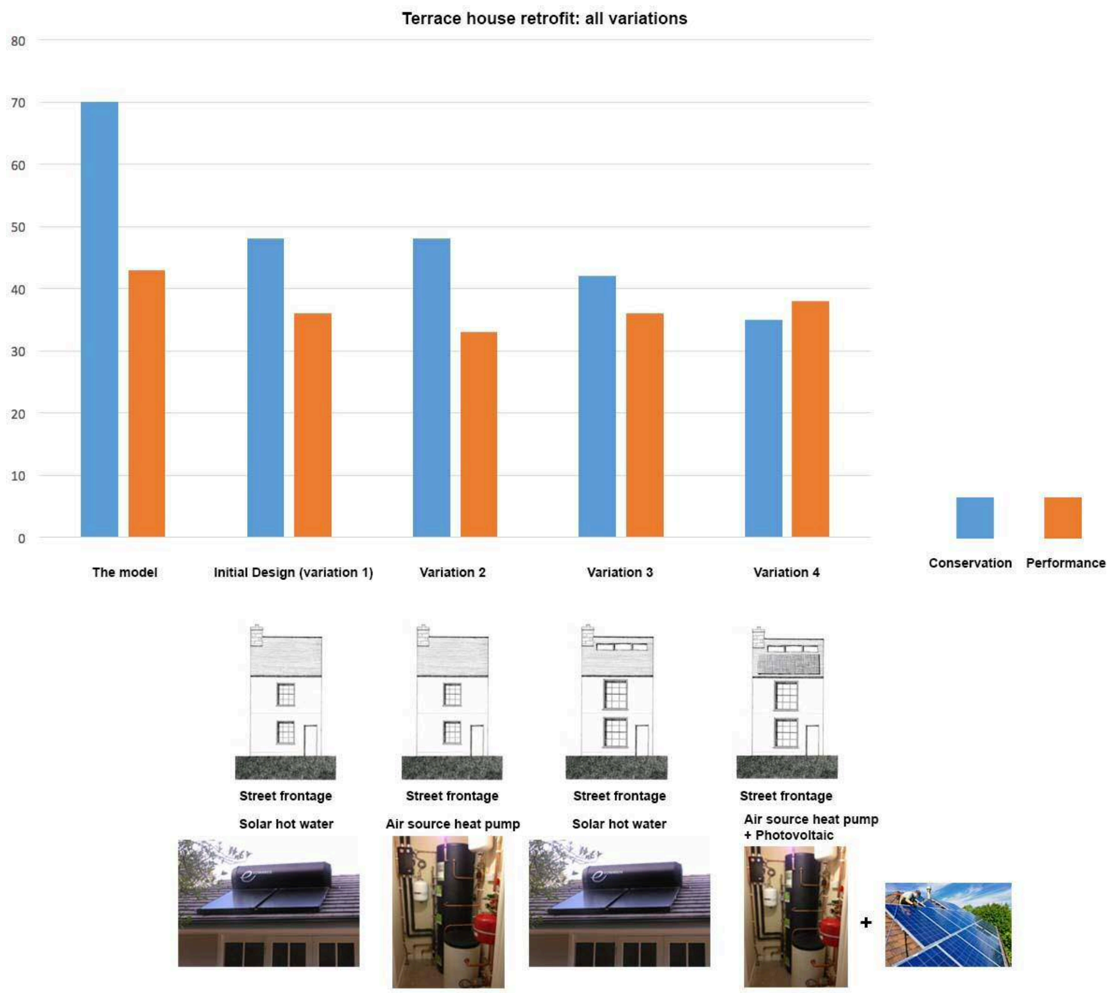


Figure 137: A summary of all variations: credits in conservation and performance aspects and key differences

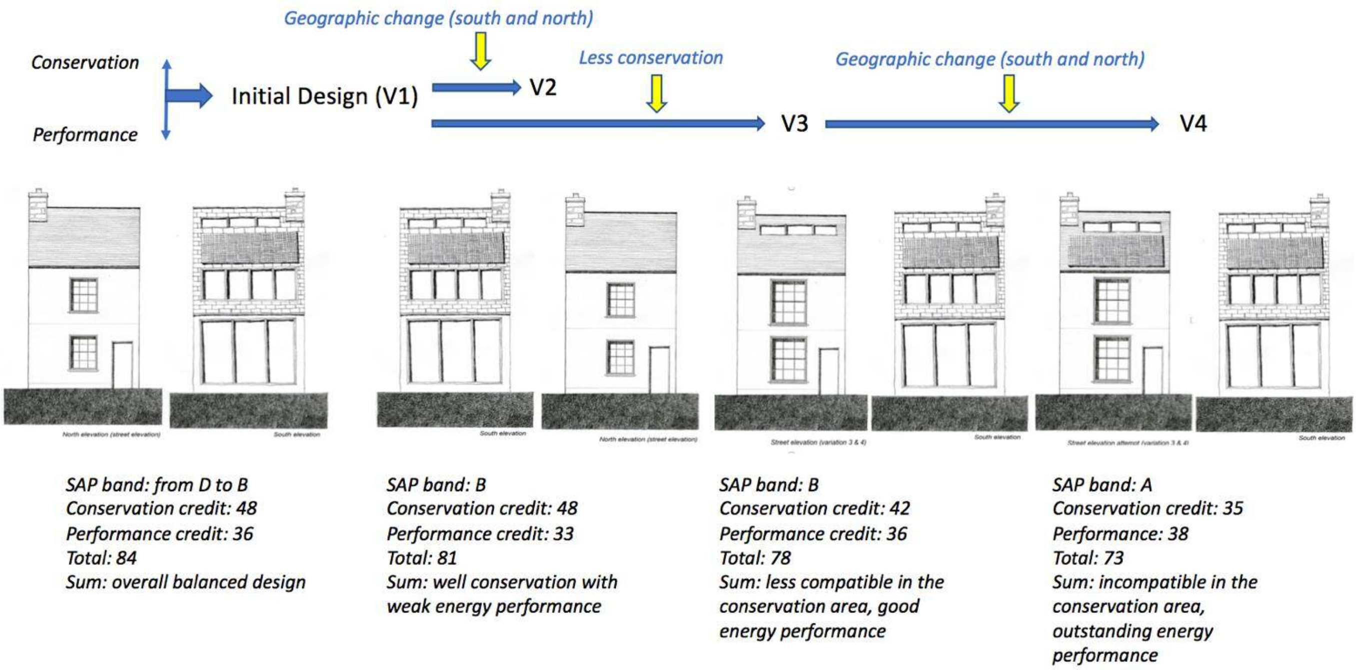


Figure 138: Diagrammatic summary of four variations with corresponding energy rate and credit

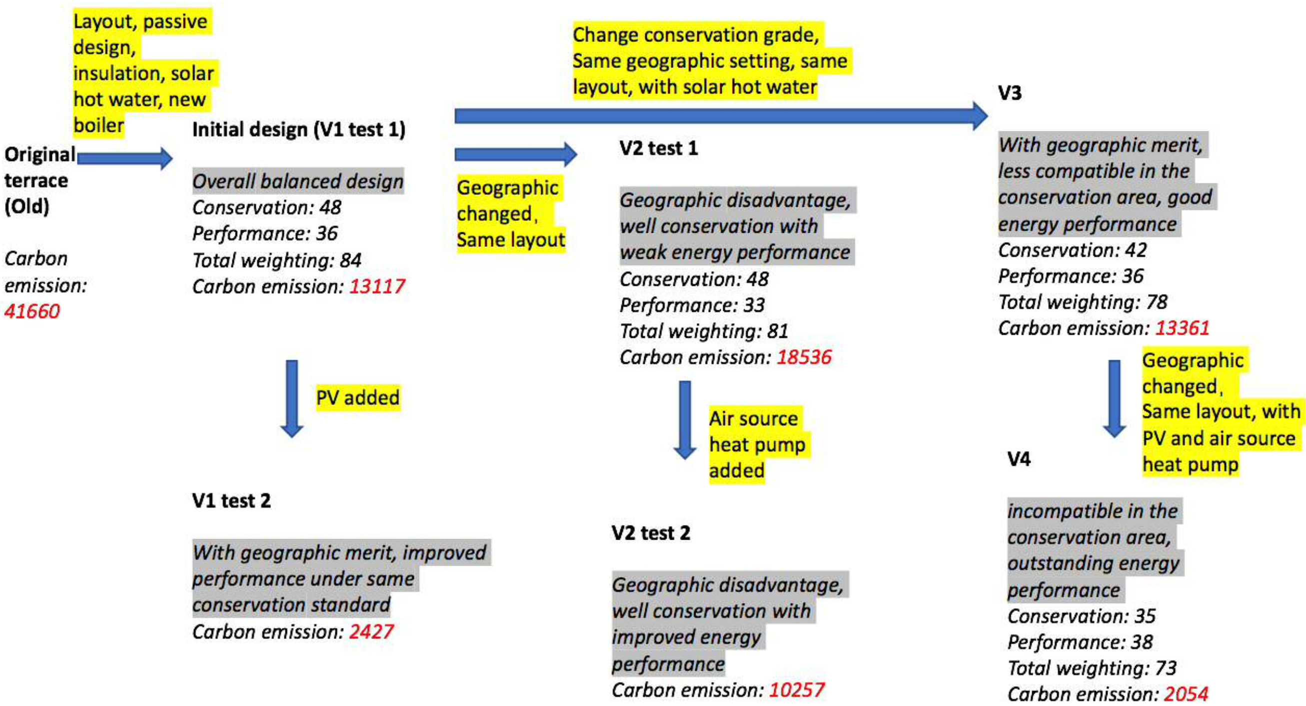


Figure 139: Diagrammatic summary for four variations: aesthetic implications, carbon emission, and point based weightings.

Above figure demonstrates how each variation presents in both conservation and performance aspects, plus a summary of key alterations in fabric and renewable energies. In the conservation aspect, both variation 1 and 2, sharing the same street elevation, obtain a same conservation score; the conservation credit is then dropped twice in variation 3 and 4 under the context and activities of less onerous conservation requirements. A degree of sensitivity is needed regarding site orientation. In the performance aspect, variation 1 and 3 shares same credit for having same orientation with huge benefits on passive design and solar hot water system. In a flipped orientation, variation 2 has the lowest credit in performance; while variation 4 reaches the highest under same physical condition, benefiting from two sets of renewable energy systems. Variation 1 has an overall sound appearance in both aspects, with the highest conservation and moderate performance. Variation 2 is slightly dropped in the performance due to disadvantages on orientation; the loss could be covered through seeking alternative suitable system within the site or offsite. Variation 3 obtains higher performance credits, but lower conservation ones. Variation 4 reaches the highest in performance but lowest in conservation. In the sustainable design, its is generally believed the carbon emission should be the lower the better, however in retrofit cases, it would be worth to uncover an intermediate section where a certain level of performance enhancement could be achieved without sacrificing conservation principles. Certain conservation principles should also be treated as the priority in retrofit cases.

Above analysis highlights several findings and a series of design recommendations in relation to the model, based on design practice of terrace retrofit:

- Although not listed as heritage buildings, a large stock of aged domestic buildings, as a group, are considered highly significant to the character and image of the towns in which they are located. In the meanwhile, with over 75% of buildings are domestic ones in most historic settlement, enhancement of energy performance on signal building could affect the overall carbon emission rate of the settlement.

- Conservation principles related to the maintenance of the identity and established image of the town and old buildings should be listed as tier one principle in a retrofit design.
- Some conservation principles are less applicable at design stage rather than at the planning stage, such as '*reinforce the boundaries', 'reinforce the position in the community',* and *'straighten the historic core'*.
- Aged domestic buildings have huge potential to contribute to environmental sustainability without material changes to appearance.
- It is possible to achieve low carbon fitting under the restriction of conservation principles in the case of domestic building retrofits.
- A degree of sensitivity is needed regarding orientation, particularly for new elements on street frontages.
- In retrofit, with established building fabric and geographic condition, a solid and constant building envelope upgrading without affecting external appearance should be the top concern in performance, such as using internal dry lining insulation. Rearranging building layout may consider conservation principles, views, and privacy as the priority rather than passive design. Architects may use other strategies in performance and insulation to solve the geographic disadvantages. It is always less flexible to apply performance enhancement approaches in historic buildings than new build.
- The introduction of renewable energy, such as photovoltaic panels in this design, may lay the visual impact on the roofscape, therefore affect the image on the streetscape. It is intolerant from conservation principles if these impacts are observed from street and change the visual image of the place. In variation 1 and 3, conservation principles could be compromised because new elements are in in a very low visibility from the street, therefore less likely to affect the

image of the settlement. It is worth the justify the potential visual impact of new elements at the design stage. Some systems with less visual impact, such as air source heat pump, may require space for installation. Centralised renewable energy supplement could be another solution for small historic sites with high sensitivity or high-density site.

- In terrace retrofit, most unfollowed performance principles, caused by fixed geographic conditions, are likely to be improved through design strategies; and the target carbon emission rate may also be met through design. However, most unfollowed conservation principles, caused by enhancement of building performance, are less likely to be improved or fixed through design strategies.

The original model evolved based on a reflection of each criterion as evident in terrace house retrofit designs in this chapter. Findings in the above section could update the model for retrofit cases:

- Conservation principles related to the maintenance of the identity and established image of the town and old buildings should be listed as tier one principles with guidance in a retrofit design.
- Credits on some performance principles could be calculated together instead of separate. Tests reveals variations with low energy performance credits could use high scores in renewal energy to offset some loss. The simulated carbon emission of these variations may still under the target emission rate.
- Architects may seek alternative design strategies in both aspects to achieve an overall balanced credit in a retrofit design. Although conservation rules do affect freedoms on design progress and energy performance, tier one conservation principles should always obey.
- Learn from discussions of each variation, variation 1 in the overall 74% of total credits may create a better balance between conservation and performance, especially without crucial lacking in any principle.

CHAPTER SEVEN: DESIGNS: NEW DOMESTIC BUILDING

7.1 Introduction

Continuing from the previous chapter, design of some new domestic buildings will be employed to test the model described in chapter four. The specific objectives of this chapter are the same as those for chapter six:

- To test the model proposed in chapter four through design;
- To critically review and report all design variations (precise, robust, clear); and
- To refine and modify the model in response to the findings from each design.

7.2 Precedent study

The design of new dwellings is prefaced by several precedent studies, based upon which some highlights and reviews for the design can be established. The slim house designed by Pierre d'Avoine Architects is reviewed due to a similar context of the continuous street front composed by terrace houses and the same objective of fitting a tight site. The triangle designed by Glenn Howells Architects is a most recently awarded design for establishing a low carbon code 4 house community. Both projects are based on UK townscapes.

Project: *Slim house*

Architect: *Pierre D'Avoine Architects*

The project is a concept design for creating contemporary houses by re-interpreting the traditional British urban terrace house. Designers are aiming to achieve great flexibility and comfort to advocate 21st century modern living (Figure 140, Figure 141, Figure 142). There are several points to highlight about the design:

- A single storey house with a double-height room in the front section facing the street, offering full scope for horizontal subdivision for offices, shop fronts.

- The linear sequence of the rooms fits the slim site in the historic urban centre.
- The garden roof with partially sheltered and private courtyards separated from the front street.
- Employment of prefabricated building methods are thought to be appropriate not only as the site is restricted but also because of policies and practices in contemporary house-building.
- Great variations in the street front elevations to suit a particular street context. (Figure 141) (Pierre d'Avoine Architects 2005).

Review

- The designer shows great sympathy for the street's image and fabric;
- Successful design approaches in form and space, especially in the inner courtyard; but
- A sustainable low carbon design is not employed.

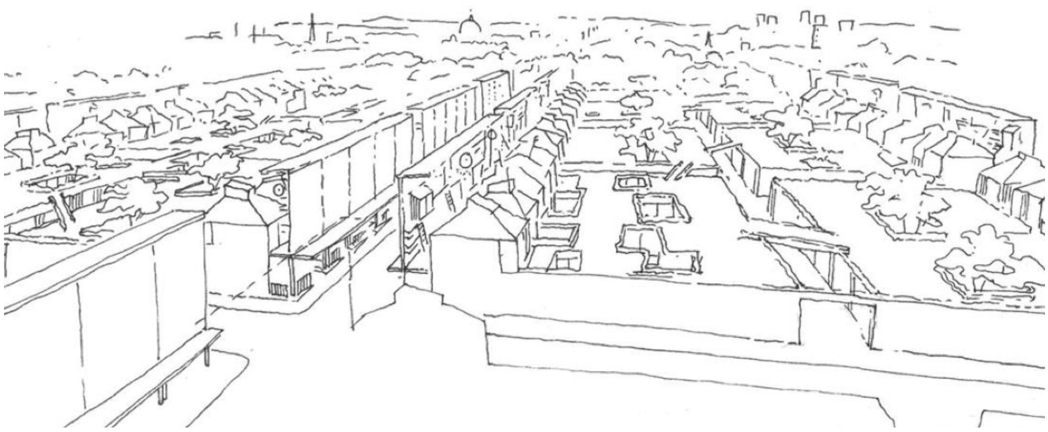


Figure 140: Concept drawing for the Slim House (Pierre d'Avoine Architects 2005)

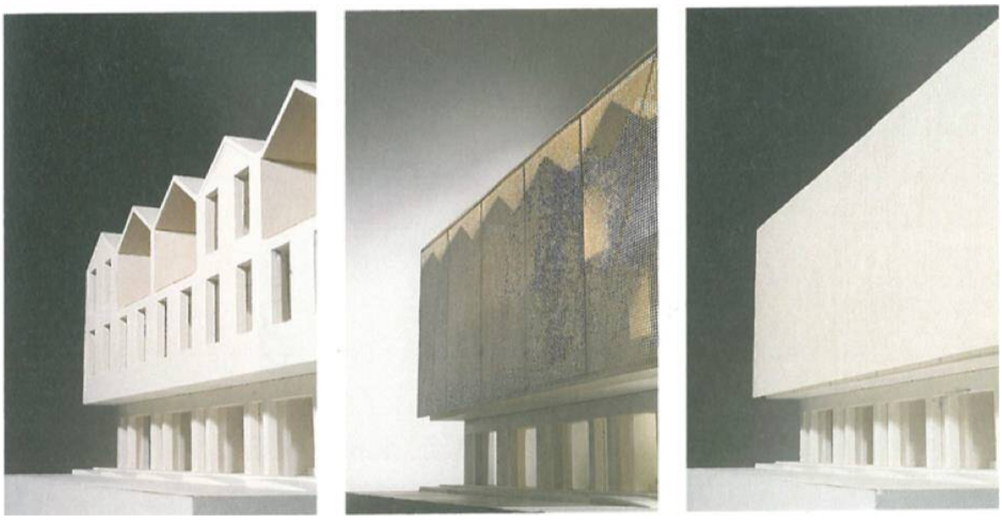


Figure 141: Slim house: variations in street front elevations (Pierre d'Avoine Architects 2005)

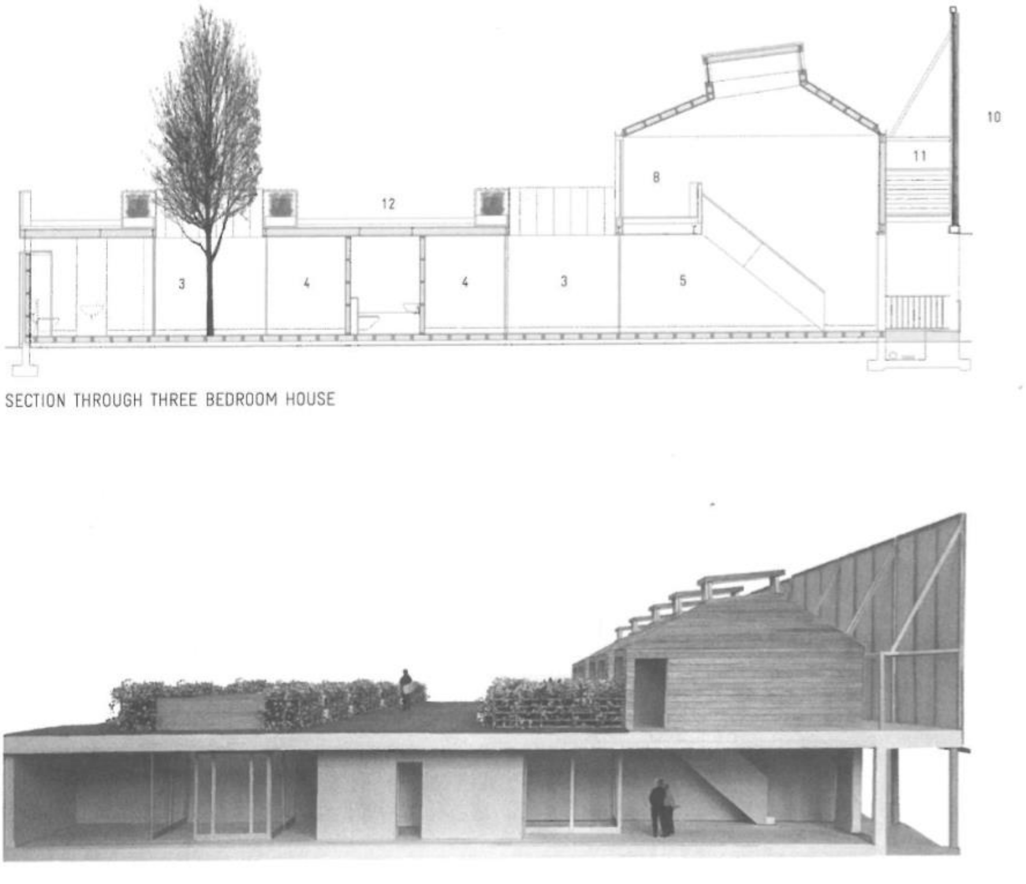


Figure 142: Slim house: section and model (Pierre d'Avoine Architects 2005)

Project: ***The triangle***

Architect: *Glenn Howells Architects*

The triangle is a design for affordable sustainable houses based on a re-interpretation of Swindon's 19th century railway townhouses on a constricted site to the north of Swindon station. The project contains four sets of 42 low carbon terraced cottages composed along the carefully designed landscapes. Each terrace is a timber-framed structure with Hemcrete external walls and a traditional lime render finishing. There are several design points to highlight:

- The houses achieved Code 4 for Sustainable Homes with lifetimes Homes standards and a Building for Life Gold Standard, and they can meet Level 5 by introducing photovoltaic panels;
- Natural materials and neutral finishes are applied;
- 2.6 metres ground floor to ceiling height to create a sense of spaciousness in the limited space;
- Carefully designed ventilation panel and ventilation cowl to overcome overheating in most passive homes.
- Well-designed landscape and a triangular open space in the centre of the site for the community. (Glenn Howells Architect 2011, Hartman 2011)

Review

- Simple elevations match Swindon's 19th century railway townhouses near to the site;
- Successfully sustainable low carbon design; and
- Slightly featureless with identical building façades for all 42 terraces.

Figure 143: The triangle: view over the central garden

Figure 144: The triangle: site model

Figure 145: The triangle: design of the terraces.

7.3 Context study

7.3.1 Programme

Creating new domestic buildings and small communities will have the following possible benefits, facilitating the development of the small historic settlement in the long-term:

- To manage public funding, since the historic centre possesses potential market value in both real estate and commercial activity that might attract corresponding private investment, instead of consuming public funding to regenerate unpleasant or disordered, ‘shabby’ areas;
- To propose a more efficient option in terms of cost, energy performance and carbon footprint, to replace, existing dwellings, such as social houses that are unworthy to maintain and retrofit, as rebuilding would be a much better choice;

- To attract new residences to the centre of the historic settlements, most of these being younger families who might appreciate contemporary buildings better fitted to modern life styles;
- To encourage an ‘urban renaissance’ by increasing the diversity of social and economic activities and demographic composition of the central area; and
- To prevent the sprawl of the historic settlement by reducing the burden of housing-demand on the edges of the settlement.

On employing a potential site for design a group of new domestic buildings in Llandeilo as the context to undertake the design practice and test the model, there are a few preferences of site, plot, and density on picking the site:

- A site with a reasonable width of street frontage opening in one of the characteristic street with Llandeilo’s typical streetscape and a strong sense of place; the inner Llandeilo was fully established in early 19th century, most streets in residential areas carry a 1800s to 1900s pattern;
- It is preferred the site could be within the conservation area, near the historic core or at the boundary if possible;
- A typical low to mid density area with burgage pattern for the surrounding street and neighbourhood;
- A site with enhancement necessary is preferred, such as areas highlighted in the townscape study for their blur images.
- A site under redevelopment should contain as little of existing buildings as possible to reduce carbon emission on demolition. The quality of original buildings (if applicable) must be evaluated before commencing the project; in the circumstances of containing any buildings with strong renovation values, a combined developing method of retrofit plus new build could be suitable.

The design standard is to create a group of comfort, contemporary, and low carbon dwellings in mid-density while preserving significant components of the area. The building appearance should be contemporary interpretation of the tradition.

Figure 146: This image is to recall the final drawing at the end of Chapter 5 regarding the location of 4 designs and their roles to maintaining and enhancing the historic settlement. The lower image is the View of street frontage in New Road, which is the north boundary of Llandeilo conservation area.

7.3.2 The identity of the town

A full description of the identity of Llandeilo is given in chapter five and chapter six (see sections 5.2.3, 5.2.5, and 6.3.2).

7.3.3 Site and building as found

The site selected to undertake the study was near the east boundary of New Road, at the junction of New Road and Bank Buildings (Figure 148). Bank Buildings is a narrow path, connecting Rhosmaen Street and New Road. The entire triangle, formed by Rhosmaen Street, Carmarthen Street and New Road, is described as the '*backlands*' in the 1976 Llandeilo conservation report. According to the townscape study, the '*backlands*' is a featureless and shabby area with a distorted image, comprising mostly of social houses in an unpleasant condition. Bank Buildings, cross through the east section of the '*backlands*' in a north-south direction. In chapter five, '*backlands*' is selected as an area with character, illustrated by serials vision in section 5.2.5.

North of the site, there is a wide opening onto New Road. At the boundary of the Llandeilo conservation area, New Road has been filled with domestic buildings since the 1850s. An old image (Figure 97) taken in 1900 shows freshly built 'modern' late Victorian style domestic terraces along New Road, the appearance of the road remains very similar to the look in nowadays, with colour washed façades still dominating the entire road. When compared with the other dwellings in central Llandeilo, the majority of houses in New Road have wider front openings, some with larger bay windows, are bigger in size, some with both front and back yards. Houses in New Road are also markedly diverse in style and façade: late Victorian style houses with front yard in lower density are located at the west end of New Road, dwellings in other parts of the road continue the simple and flat terrace façade in late 1800s to 1900s. Townscape study (Figure 73) demonstrates: the historic core of Llandeilo near the Church, King Street, and Market Street has the highest density than other sections in the conservation area, the average density within the conservation zone is greater than the peripheral area of Llandeilo.

There are four existing buildings on the site (Figure 147):

- A garage, reported as in need of urgent repainting or refurbishment in the 1972 conservation report.
- Two two-storey terraced houses with a traditional elevation.
- Two colour washed (now in a pink shade) semi-detached houses with a late Victorian façade to a higher standard.

Figure 147: Existing buildings in the site

It is noted this New Road site fits all preferences listed in 7.3.1 for undertaking the case study of design new domestic buildings.

By evaluating the colour washed semi-detached house in the site, Keeping the dwelling might bring more disadvantages for design and require heavy loads of regeneration works, including the street elevation. Its late Victorian style appearance with bay windows, arched openings and wide front openings stands out in this east section of New Road, slim, simple, and flat tradition terrace frontage are most commonly seen. Besides, the dwelling occupies almost 1/3 of street frontage of the entire site with a setback, that could increase difficulties for design and overall cost for construction.

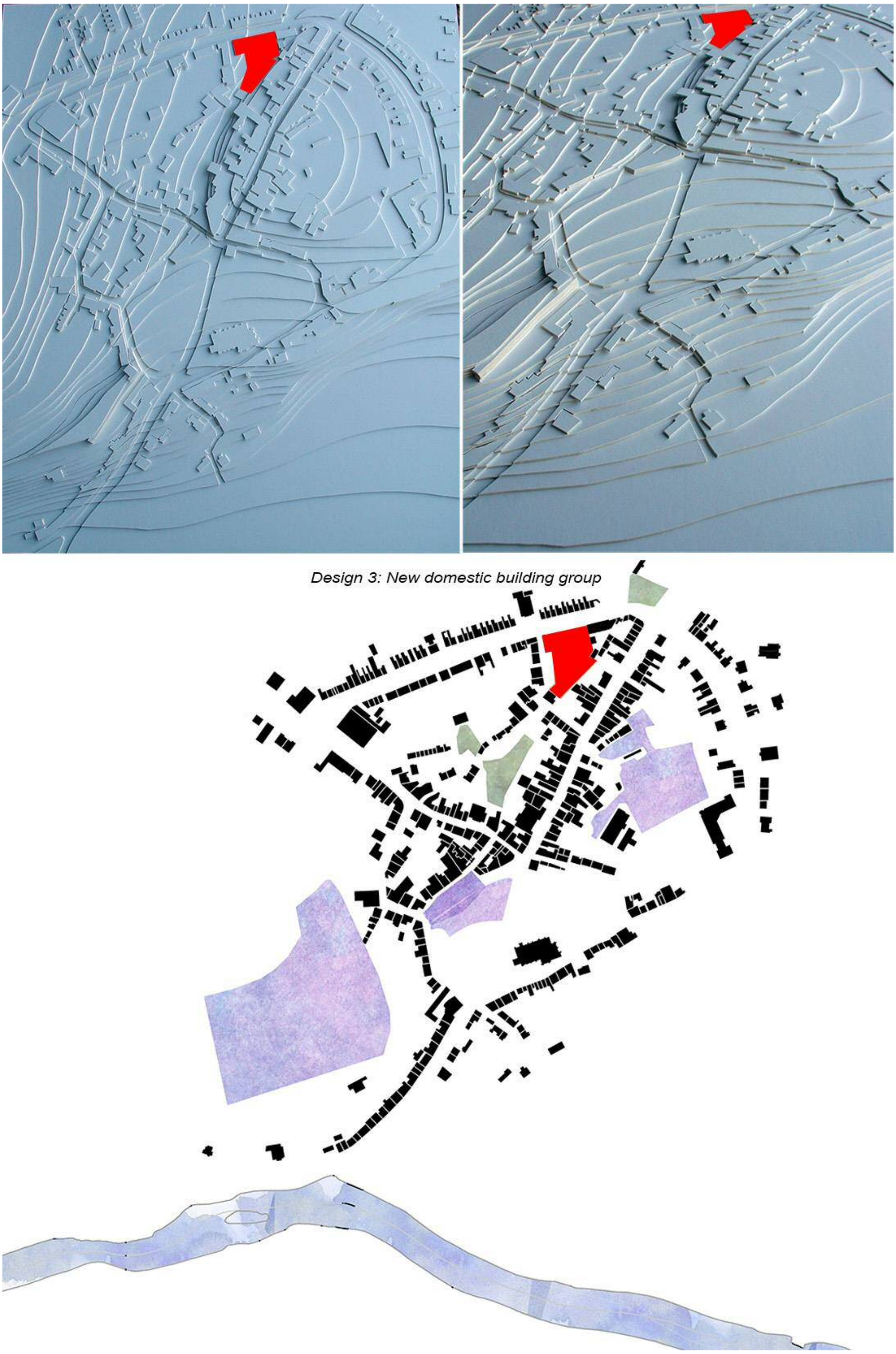


Figure 148: Site in Llandeilo, design 2

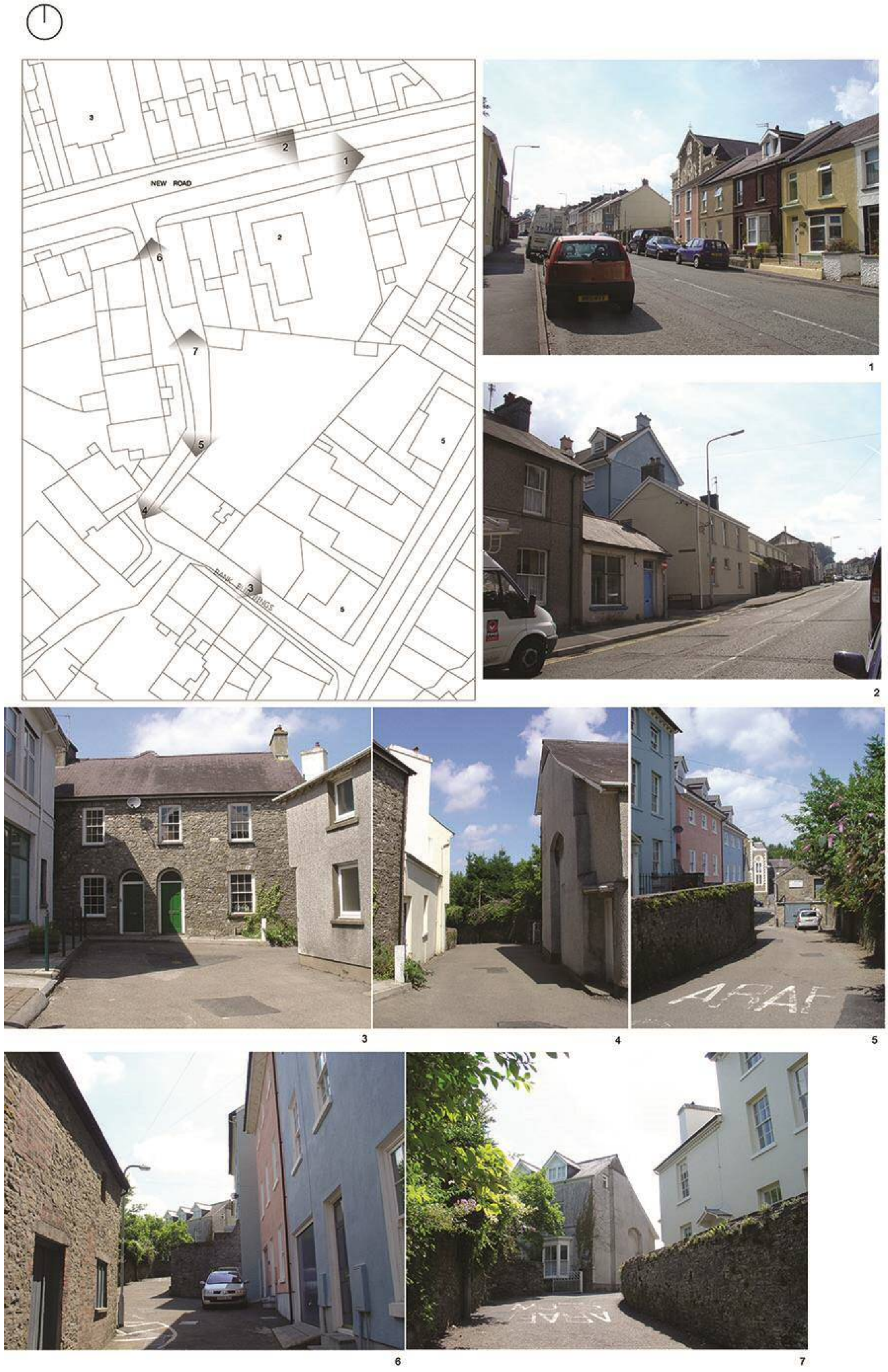


Figure 149: Bank Buildings site as found

7.4 Initial design (variation 1)

7.4.1 Design strategies and approaches

Design target and concept

The design aims to establish a medium-density community of affordable, low carbon, contemporary standard domestic buildings, containing four apartments and eight terraced houses with parking lots, in a small area. Medium-density refers to 25-50 dwellings per hectare, translating into 100-173 habitable rooms (Allen 2006). In this site of 2050m^2, a medium-density community is equivalent to 5 to 10 terrace houses. Several principles are applied to the design concepts, e.g. identifying the characters, creating consistent streetscape, and determining environmentally sustainable characteristics (Figure 150). Under the guidance of these principles, the designer attempted to:

- Recreate a continuous street elevation for New Road, in the form of a row of terraced houses with 'Llandeilo character';
- Establish a central garden or a shared area for use by the residents of all 12 dwellings; and
- Determine the best result for the passive design of all dwellings, considering the geographic conditions on site.

To fulfil all the objectives in site planning specified above. The proposed plan is as follows:

- To arrange eight terraces along New Road to establish a continuous street elevation; and apartments located parallel to the terraces south of the site;
- To construct north-south oriented terraced houses and apartments that are suitable for passive design; and
- To design the space established between the terraces and apartments as a central garden.

There are three aspects considered in the building design: *form and space, function (varieties), and performance.*

Figure 150: Siting and design concept. This drawing reveals the proposed arrangement of 12 dwellings on the site and the reason for such it. By placing 8 terrace houses along the street frontage of New Road may restore the continuity of the street, therefore contribute to the reinforcement of the boundary. Geographic conditions are also considered at this stage to benefit the passive design afterwards.

Form and space

Slim house

In order to fit the width of the eight terraced house into the 38-metre boundary permitted, the designer had to sacrifice the width of the houses, choosing a relatively slim layout of 4.5-metres per building. This 4.5-metre wide façade is narrower than the majority of the existing traditional terrace houses in Llandeilo. For instance, the dwelling that was the object of the retrofit discussed in design 1 has a 5.2-meters façade. The initial concern with a slim layout is the creation of effective interior space. Slim and long house plans have been analysed relatively often when discussing contemporary concept design; e.g. the slim house designed by *Pierre d'Avoine Architects* mentioned in the precedent study (Figure 142), and the slim house by *Alma-nac Collaborative Architecture* in south London (Figure 151). Both designers provided design strategies for treating slim and long interior spaces, offering solid evidence of positive results in terms of usable interior physical space after construction. Day lighting is another issue to consider when planning a slim house.

Figure 151: Slim house designed by *Alma-nac Collaborative Architecture*. The extension of a 2.3 meter-wide terraced house in south London (Frearson 2013)

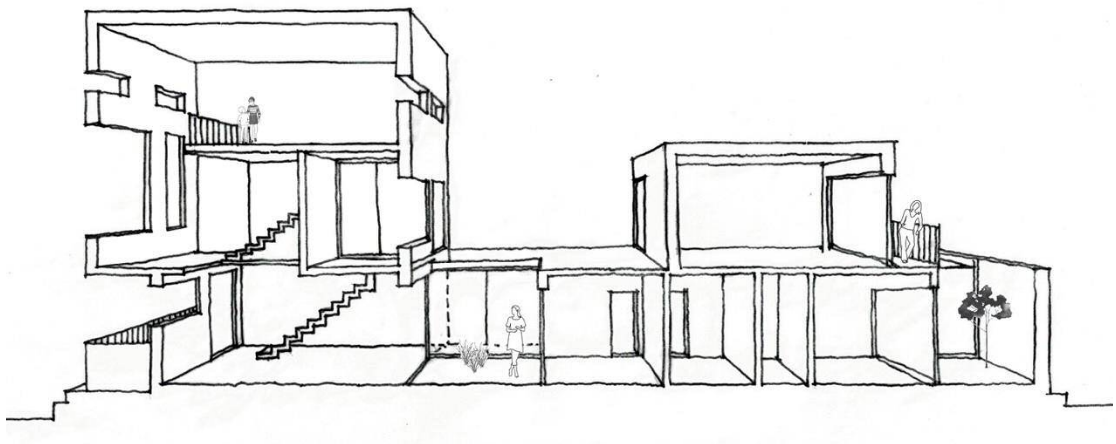


Figure 152: This drawing reveals the interior space of the proposed slim plan (type 2). Double storeys void spaces are used to reduce the sense of narrowness. The deep layout is break into two sections with an inner yard (terrace as in the first floor) in the middle.

Atrium for terraced houses

In order to improve the daylight factor when designing the interior space of a slim house, an atrium (inner garden) can be employed as an option. By adding a void of 3150mm long and 3600mm wide in the middle of the plan, a long house can be divided into two sections, creating a further south-faced elevation to ensure rooms are well-lit and can benefit from solar heat. It is important that the inner courtyard should be long enough, over 3 metres in this case, to ensure a sufficient angle for sunlight to reach the ground floor and the opposite wall in winter.

Inspired by the traditional Asian courtyard, the large outdoor atrium in the middle of the house blurs the boundary between the interior and the exterior. By replacing the solid partition wall with sliding full height glazing, a closure is formed by the courtyard, rooms and corridor. It is interesting to create a semi exterior space, together with elements like soil, water, and plants, within the house. (Figure 152, Figure 153)

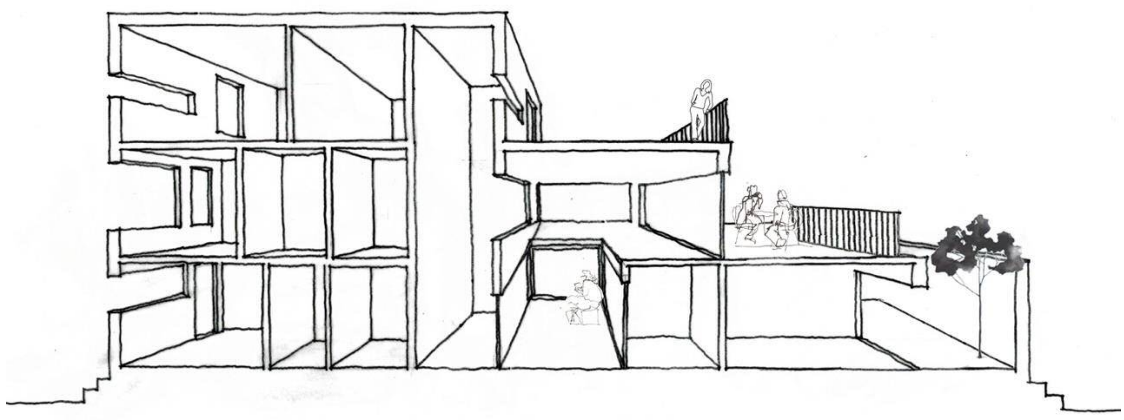


Figure 153: This drawings reveals the proposed atrium and roof terrace in house type 3.

Central Garden

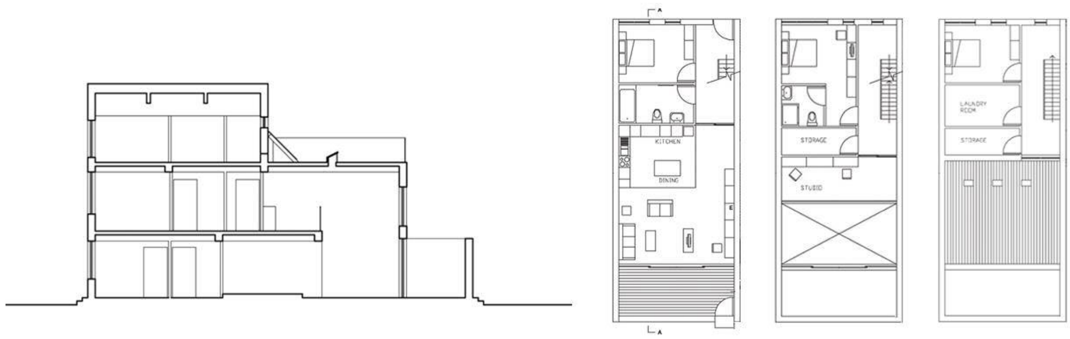
A central garden is an important component for medium-density dwellings, creating a shared space for all residences within the community. It also completes the design, by establishing traffic routes, cycle storage, wood pellet stores, grey water or rainwater collectors, spaces for bin compartments. The images show the small but quiet and tranquil central garden in Hayes in central Cardiff; a roof garden above a new shopping mall surrounded by apartments (Figure 154).

Figure 154: small central garden designed and created for high-density city centre apartment in Cardiff

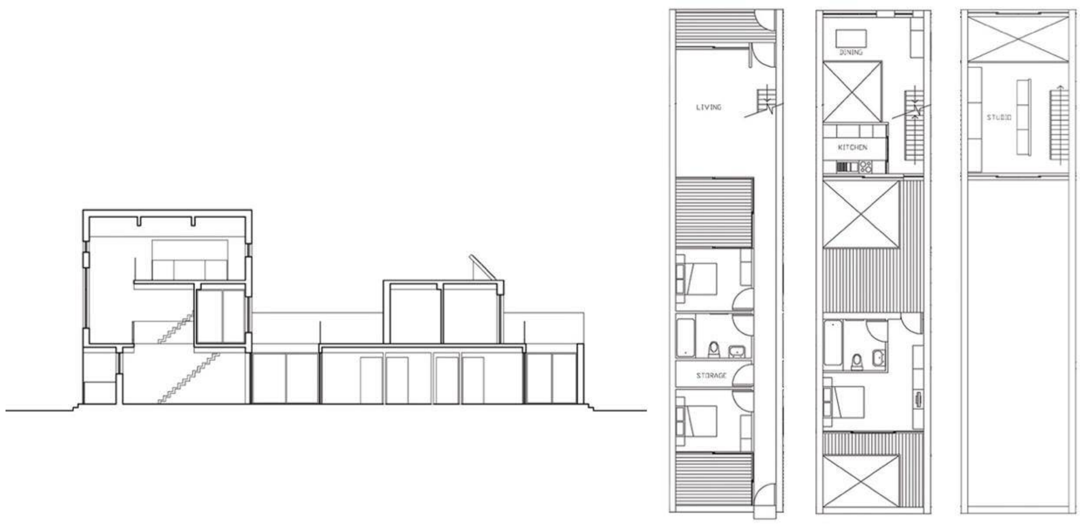
Function (varieties)

In order to reduce the sense that the space is featureless and boring, and to provide multiple choices which may be appropriate to Llandeilo eight terraced dwellings were categorised according to four different layouts.

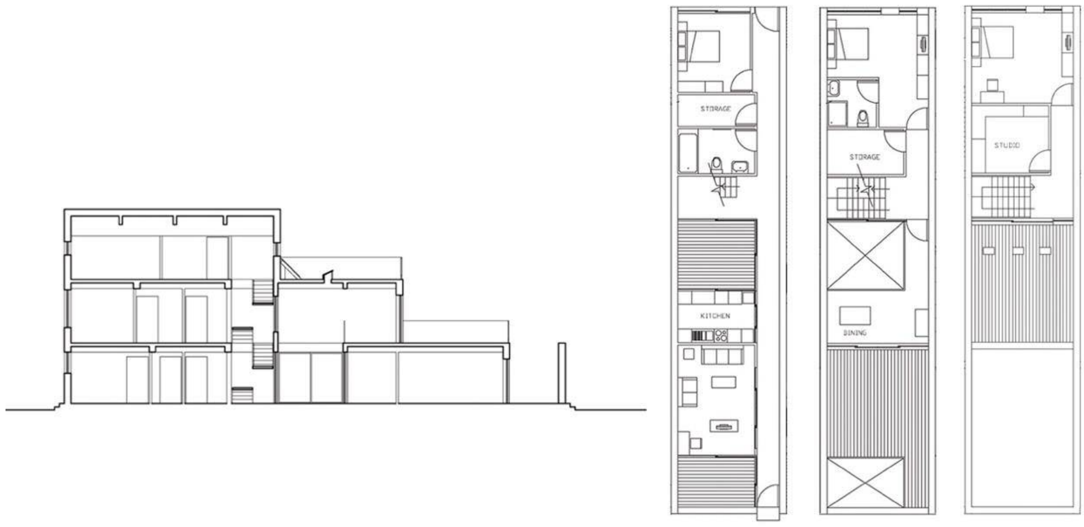
Type 1: Three-storey terraced house with three bedrooms, one en-suite, in the north section of the building. Living, kitchen and dining area located on the ground floor to the south. Two-storey height living space reduces the sense of being on a confined site. There is backyard and a roof garden on the second floor.



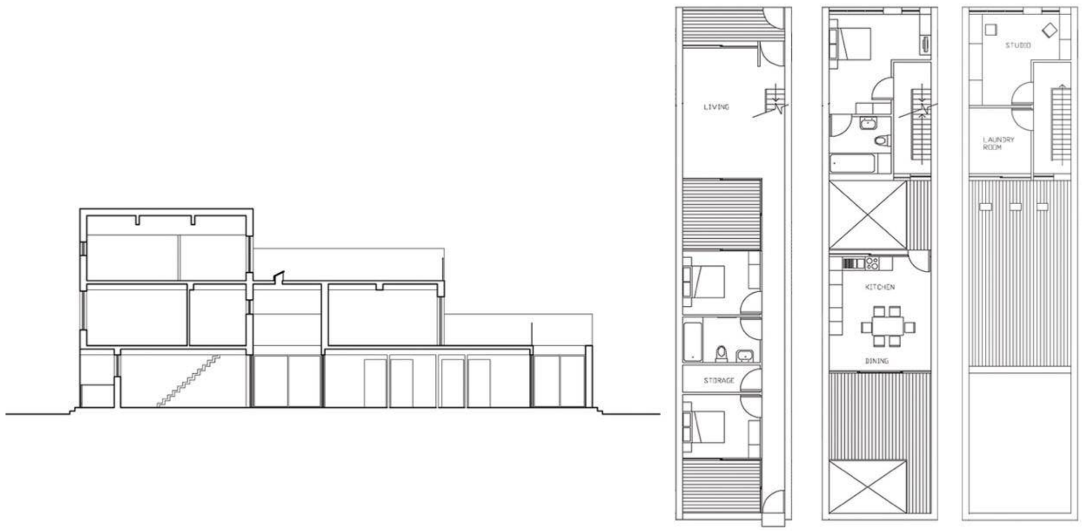
Type 2: Three-storey terraced house with living room and two bedrooms on the ground floor. Kitchen, dining, and master bedroom located on the first floor. There are enough outdoor terraces: front and back yard, two garden roofs, and an outdoor atrium in the middle of the house.



Type 3: Three-storey terrace house with three bedrooms, one en-suite, in the north section of the building. Living, kitchen and dining areas located on the ground floor in the south. There is an outdoor atrium and two roof gardens on each floor next to the study and a small family space.



Type 4: Three-storey terrace house with living area and two bedrooms on the ground floor. Kitchen, dining, and master bedroom located on the first floor. There are enough outdoor terraces: front and back yard, two garden roofs, and an outdoor atrium in the middle the house. The large roof garden south of the dining room can provide private external dining space on sunny days.



Performance

Passive design

Passive design aims to take the advantage of the local climate; it is an integral system including thermal insulation, thermal mass, ventilation, and shading. To maximise solar gain, rooms used most frequently during the daytime are placed in the south with direct solar heating; while bedrooms used mostly at night are to the north. This rule is followed when distribution rooms in all houses and apartments.

The building envelope is fully insulated with treatment at the joints to enhance energy performance and air tightness. The proposed U-value of the wall, glazing, and roof after fully insulation are 0.18W/m^{2}K, 0.9W/m^{2}K, and 0.13W/m^{2}K, which will be applied in SAP calculation.

Houses are designed higher (in three stories) in the north elevation, gradually becoming lower toward the south elevation. This design is to maximise ventilation and to guarantee the effects of solar gain and daylighting in the middle of the building. (Figure 155)

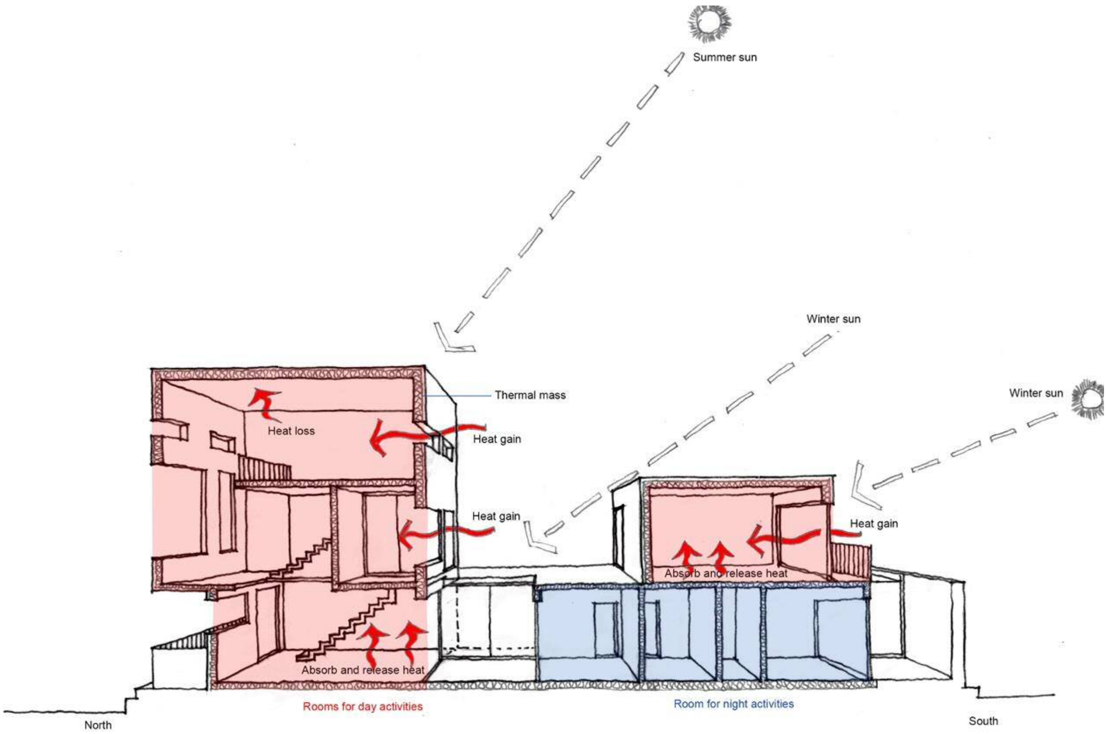


Figure 155: The employment of passive design in the study

Natural lighting

Natural lighting is a challenge for slim terrace houses, because the depth to which daylight penetrates from the window is 2.5-3 meters. The introduction of an inner courtyard in the middle of the building solves this problem.

Introduction of a new system and a zero carbon design

- A combined solar water system and photovoltaic system is normally the easiest option for a single domestic building, assuming the south facing roof is not street facing. There will be some conflicts raise if the south facing roof is street facing: PV and solar water collector panels must be installed at the south-facing roof to maximise results; on the other hand, the street facing roof must be preserved from installing panels to maintain the street's image. According to the technical specifications for the study of mainstream PV panels, to meet the annual electricity consumption needs of a single three-bedroom passive house, installation of approximately 143.36kwp photovoltaic panels should be ideal.
- For a small community of 12 dwellings, a biomass boiler installed on the site could be another option, providing a centralised hot water supply, for use as hot water, and for heating. Meanwhile, the construction of wood pellet storage on the site is also required.
- When enhancing energy performance by using renewable energy sources, zero carbon design also requires a reduction in portable water consumption, and on site treatment of waste (BREEAM 2011). Reduction of water consumption can be accomplished by use of a low water shower with 8 litres per minute and taps, installing a dual flush toilet, implementing rainwater collection with a purification system for the washing machine, toilet and irrigation, and building a grey water recycling system for toilet flushes.
- Onsite treatment of waste can be achieved by: maximising the use of recycled and reusable materials during the construction process, setting bin compartments within the house and on site, encouraging the classification of recycling and composting bins from landfill bins.

7.4.2 Design works

Image of New Road as found

Proposed elevation on New Road

Figure 156: New domestic building groups (New Road elevation) and surroundings before and after. This drawing reveals the new design reinforce the continuity of the origianl break street elevation. The design follows the origial roofline and a simple pattern street frontage.

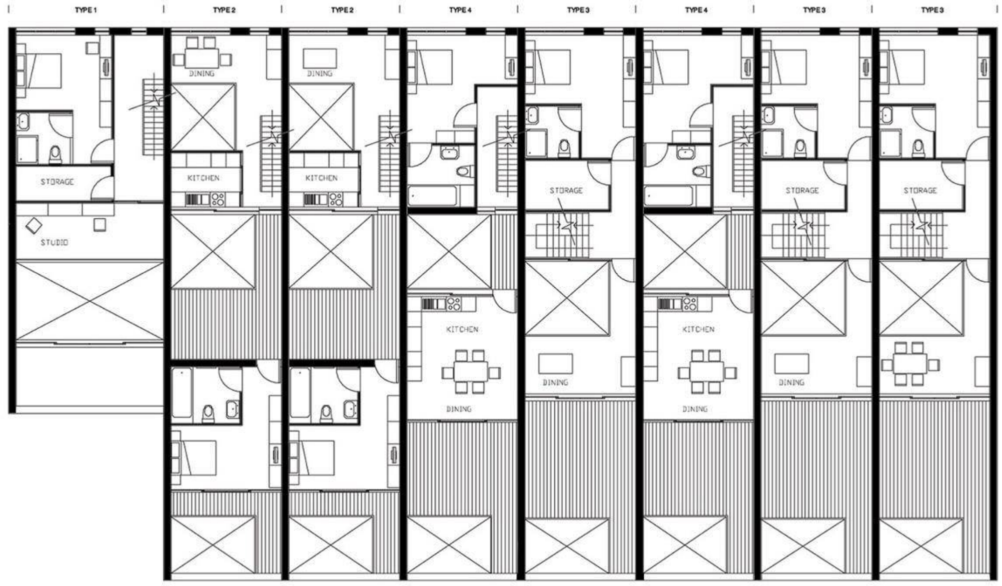
Image of Bank Buildings as found

Proposed design from inner garden (in Bank Buildings)

Figure 157: New Domestic building groups (Bank buildings inner garden) and surroundings before and after. This drawing reveals the buildings south elevation at the back of New Road, and possible proposed square for occupants. Considering the degree of exposure and sensitivity in the back elevation, large openings and photovoltaics are introduced to obtain solar gain and carbon reduction. The original sense of enclosure in the area is reduced after design.

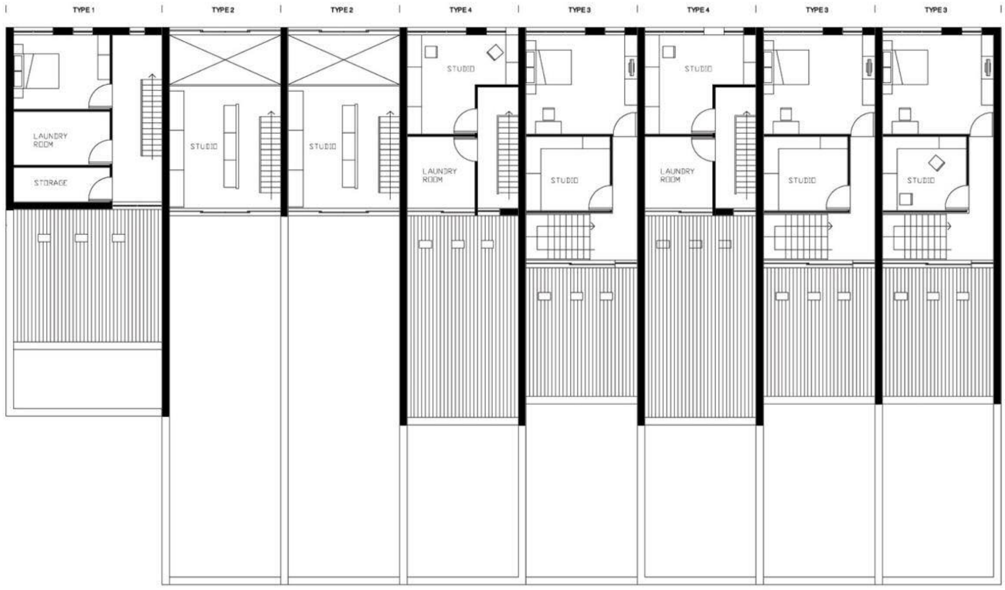
Figure 158: Full floor plan

GROUND FLOOR PLAN (THREE BEDROOM HOUSES)

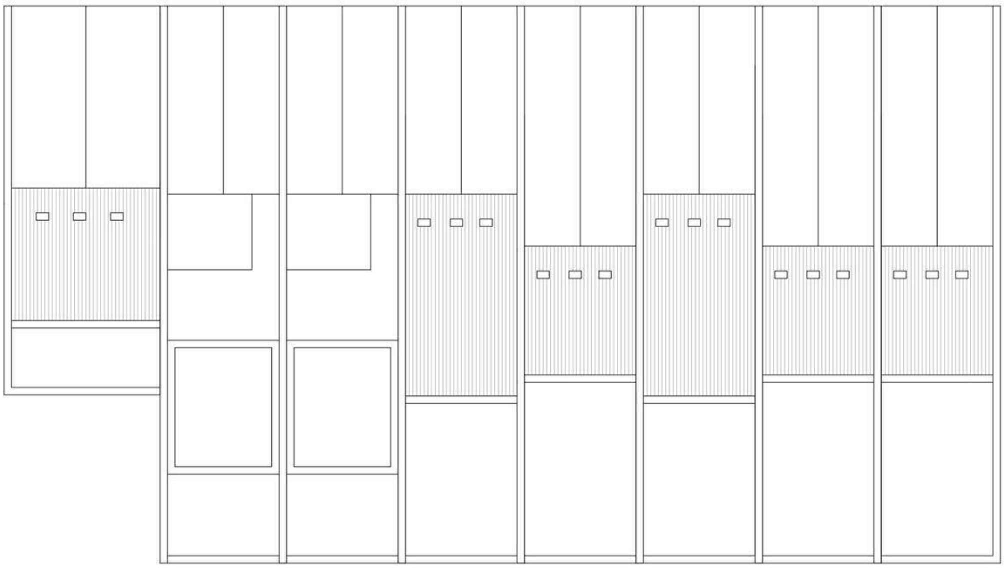


FIRST FLOOR PLAN (THREE BEDROOM HOUSES)

Figure 159: Row of terrace houses in 4 variants: ground floor and first floor plans. Large inner yards can be seen from this drawing.



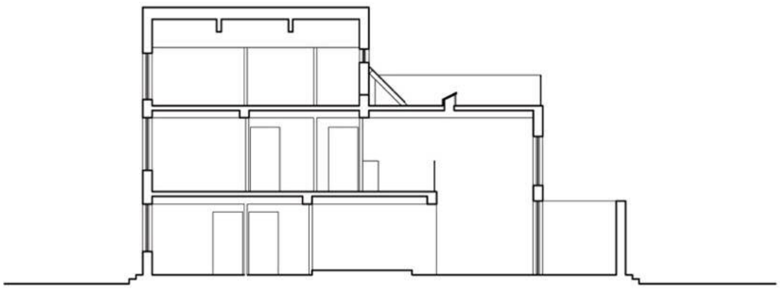
SECOND FLOOR PLAN (THREE BEDROOM HOUSES)



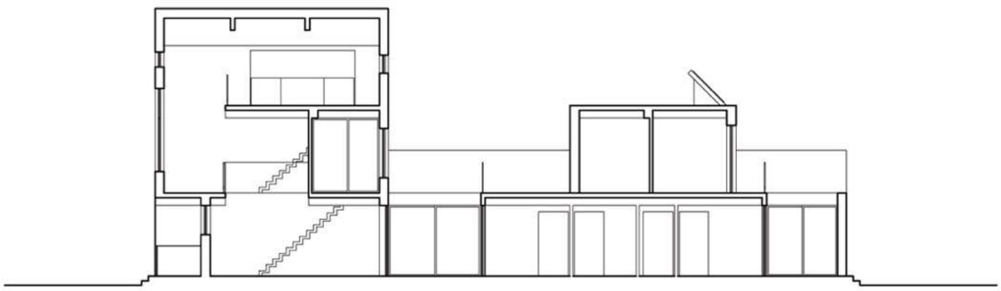
ROOF PLAN (THREE BEDROOM HOUSES)

Figure 160: Row of terraced houses in 4 variants: second floor plan, roof plan

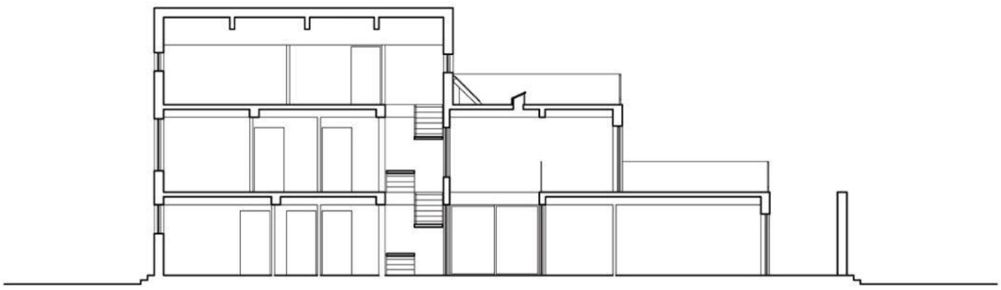
Figure 161: Row of terraced houses in 4 variants: north elevation, south elevation, sections EE and FF



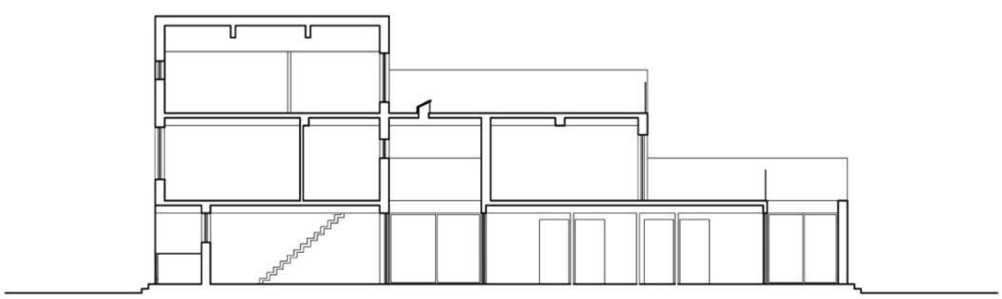
SECTION AA THROUGH HOUSE TYPE 1 1:200



SECTION BB THROUGH HOUSE TYPE 2 1:200



SECTION CC THROUGH HOUSE TYPE 3 1:200



SECTION DD THROUGH HOUSE TYPE 4 1:200

Figure 162: Terraced houses in 4 variants: north-south sections

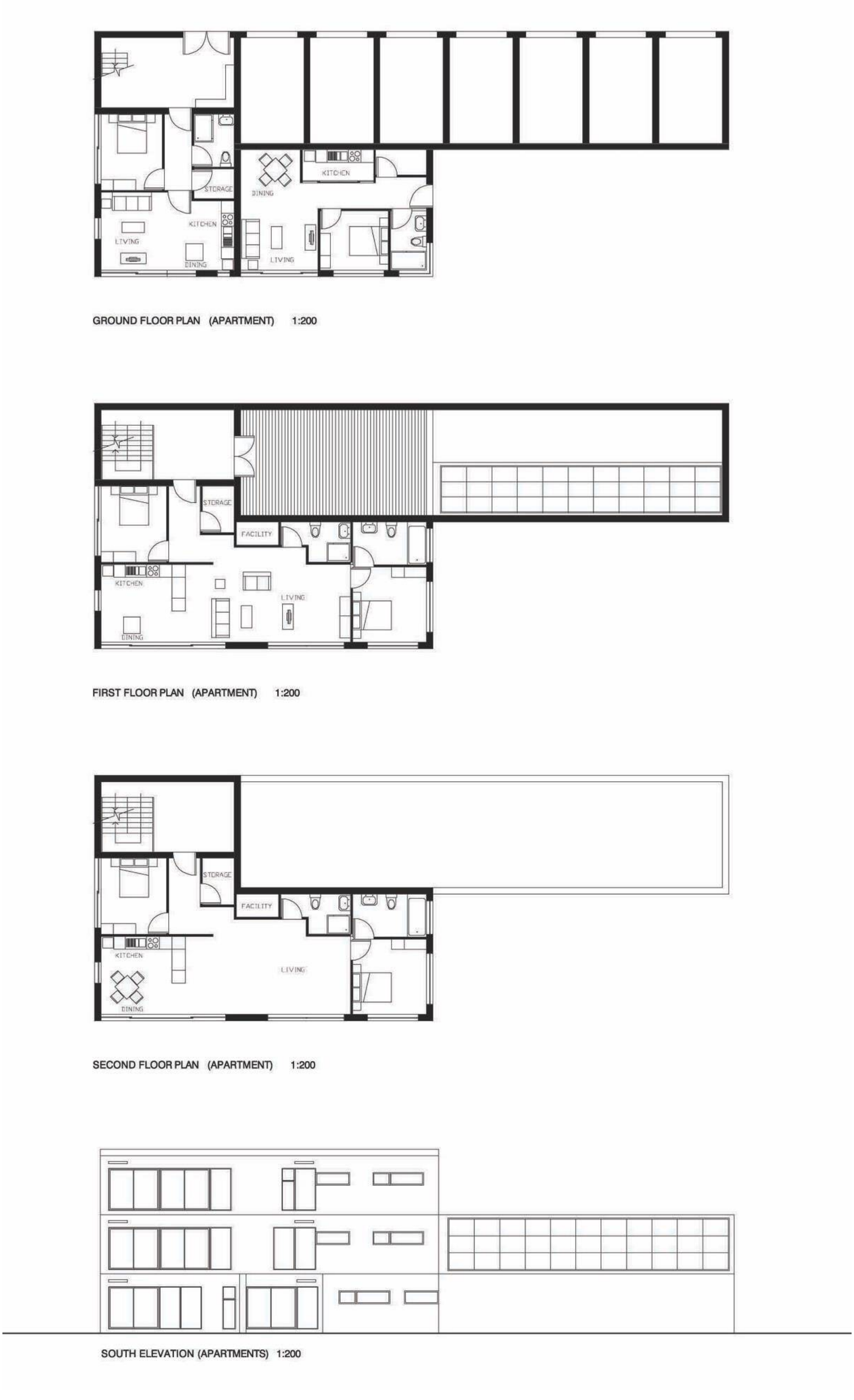


Figure 163: Apartments: plan and south elevation

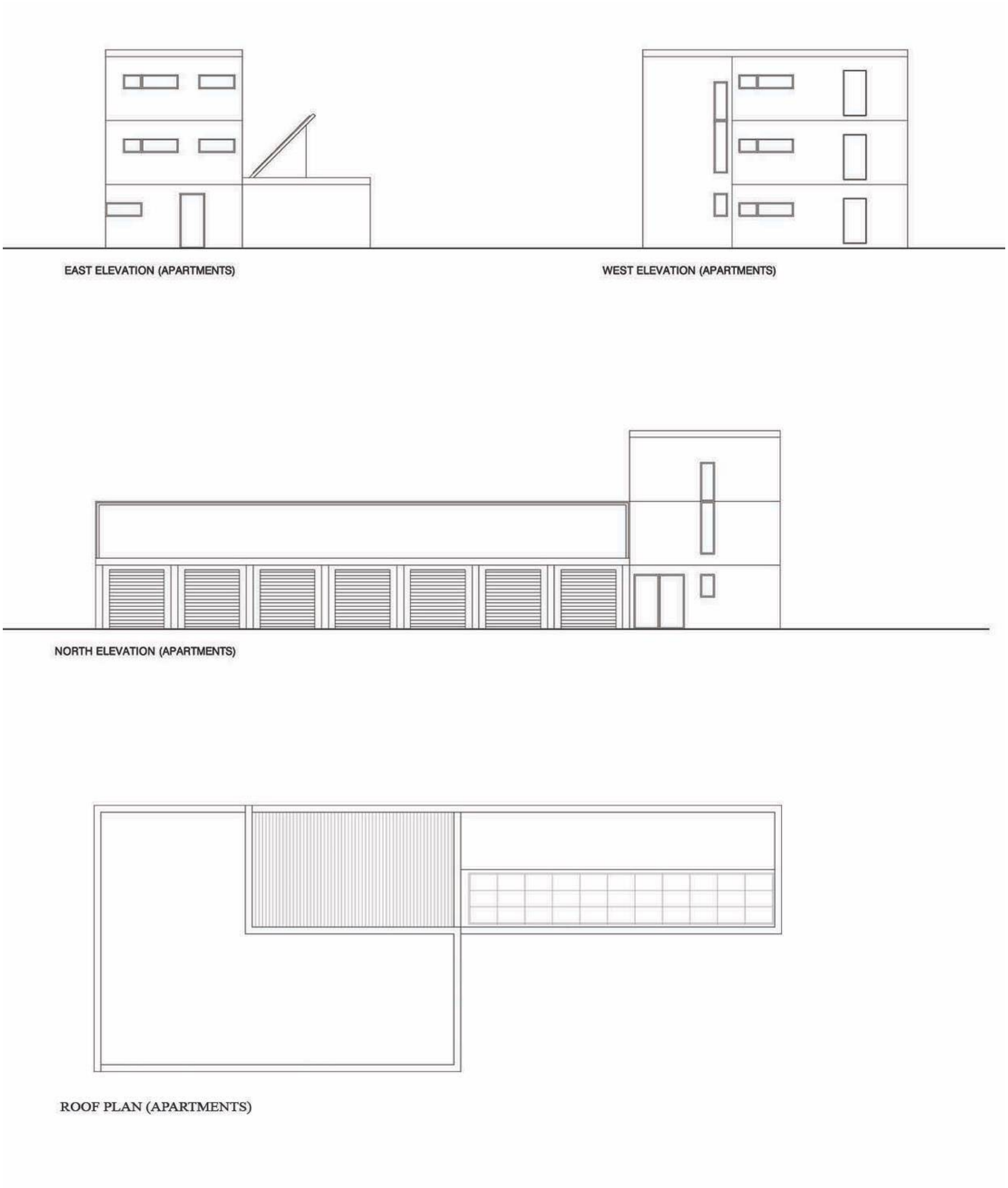


Figure 164: Apartments: east elevation, west elevation, and north elevation

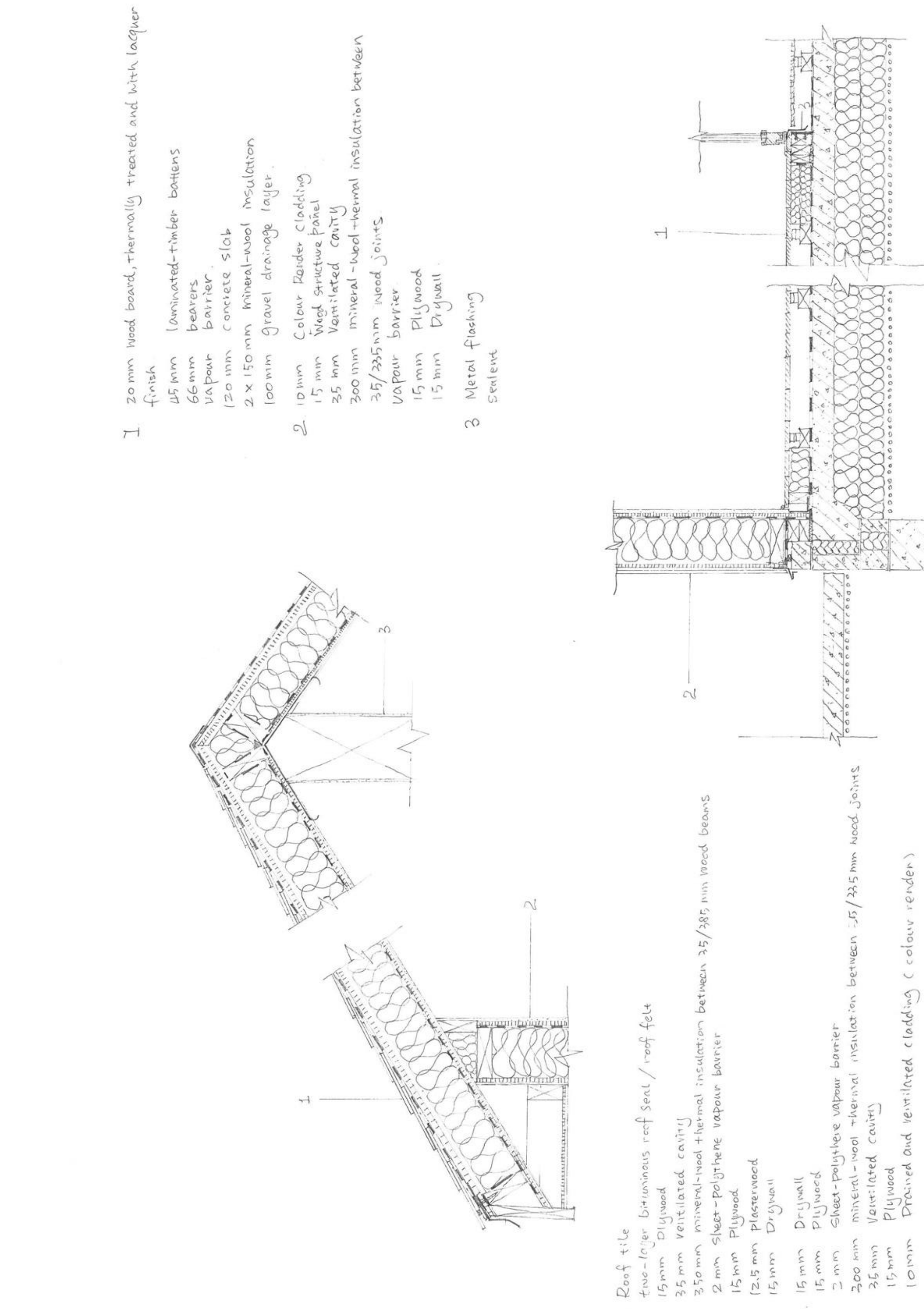


Figure 165: Detailed drawing 1 for low carbon fitting: roof insulation & floor insulation

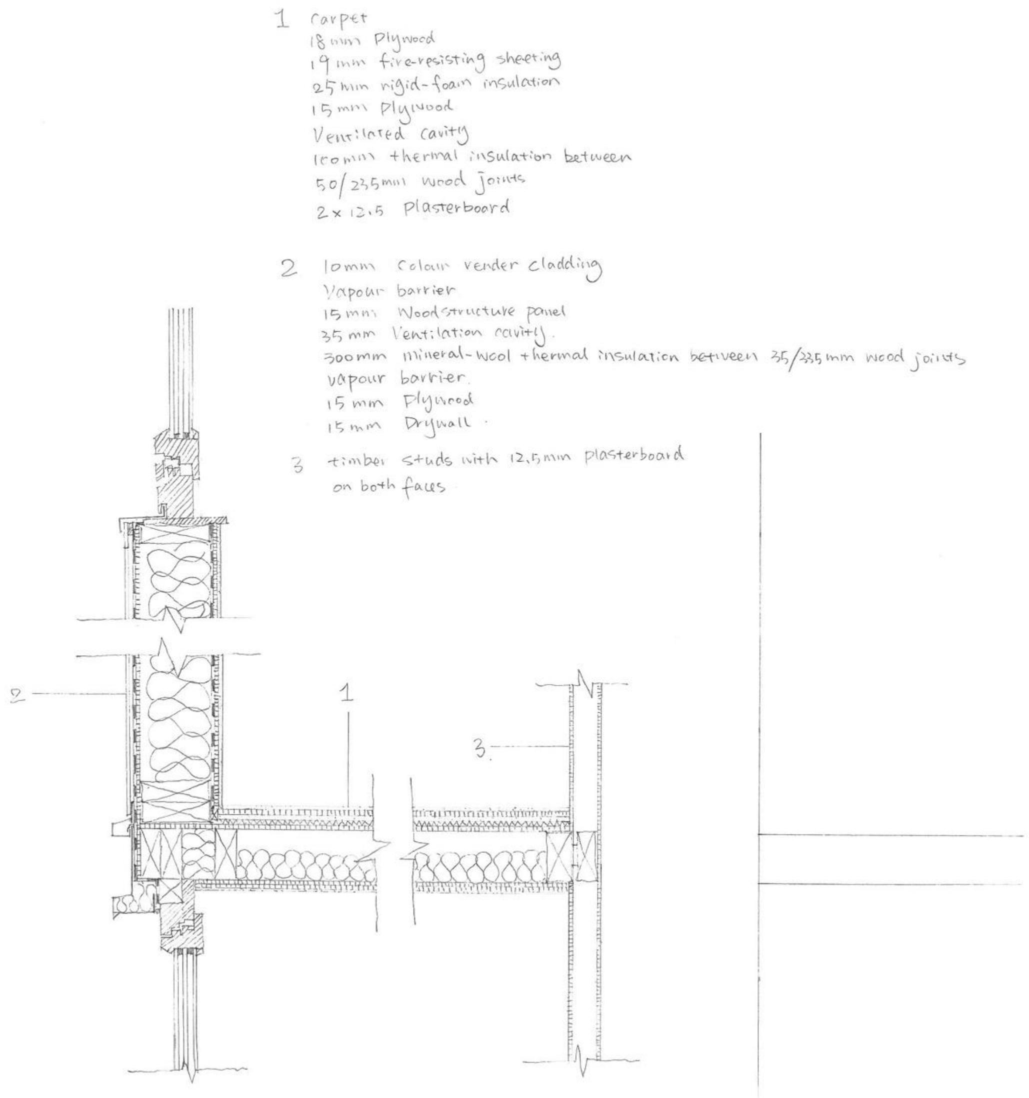


Figure 166: Detailed drawing for low carbon fitting: floor insulation and window joint

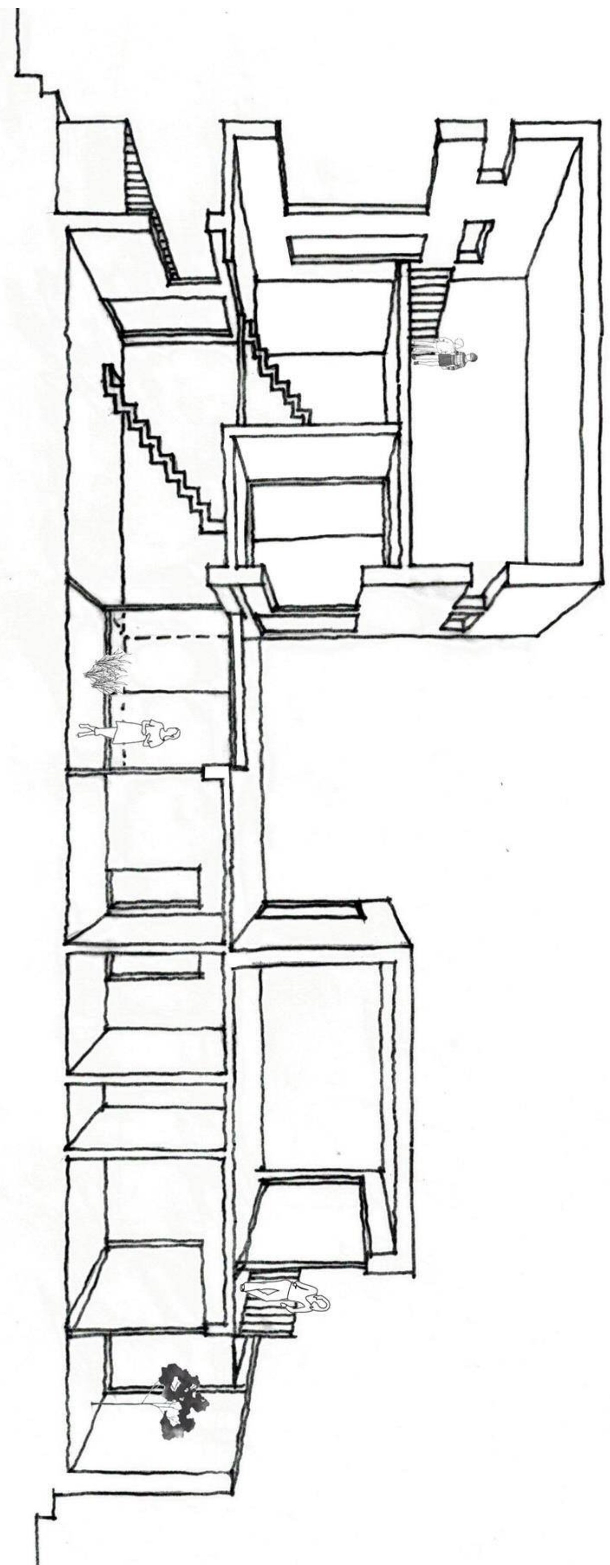


Figure 167: This perspective shows the interior space of the house (type 2) and the roof terrace.

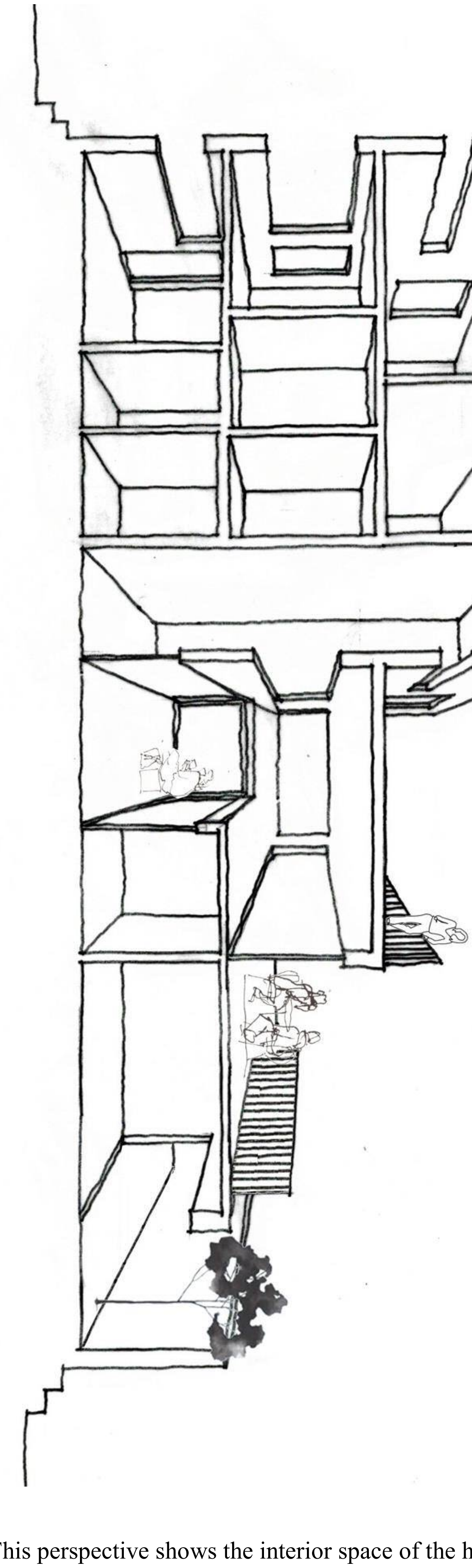


Figure 168: This perspective shows the interior space of the house (type 3) and the roof terrace.

7.4.3 Review of sustainability

The design result is simulated using the BRE recommended energy calculated tool at the design stage, which is standard assessment procedure (SAP). The SAP was completed via Energy Design Tools based on SAP 2012 standard; and the calculation is based on data about the building's physical condition, layout, and its location, to assess the carbon emission rate. The SAP test results are given in the table:

Table 14: the SAP test result for all domestic buildings in this design.

Round	Description of the building (with PV, and solar hot water)	Total energy required KWh/year	DER (Dwellings carbon emission rate) kg $CO^2/(m^2.year)$	TER (Target carbon emission rate) kg $CO^2/(m^2.year)$	SAP rating
1	Three bedroom terrace house type 1	5,489.02	9.10	12.81	96.32
1	Three bedroom terrace house type 2	4,159.73	7.99	13.42	97.23
1	Three bedroom terrace house type 3	6848	11.98	13.79	93.24
1	Three bedroom terrace house type 4	6,735.39	9.54	12.20	95.32
1	Apartments two-bedroom	1594	6.15	12.07	95.62
1	Apartments one-bedroom	-428	2.55	17.69	97.23

A complete copy of the SAP testing result appears in Appendix III.

The test result illustrates all 12 proposed dwellings could meet the carbon emission target. The test results are based on the installation of photovoltaic panels (a package of 4KWp panel for each terrace, and 2KWp panel for apartment) and solar hot water system (10m^2 south-facing 45^o panel for each terrace, and 5m^2 south-facing 45^o panel for apartment). Noted that the target carbon emission rate for new dwellings has been tighter since 2012 due to the release of new standard. Further carbon deduction could be achieved by installing a biomass boiler or an air source heat pump, testing in variation 3 and 4. With a tight building envelope and high energy performance, the house can be easily heated to comfort level.

7.4.4 Evaluation of the design against the model

It is useful to evaluate the design against the point-based framework proposed at the end of chapter 4 (Table 15); a bar chart is used to illustrate the completion status of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model (Figure 169). The evaluation result of all design attempts will then be discussed together at the end of this chapter:

Table 15: Evaluation of design attempt 1 (initial design) against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	
Mapping	5	5	
2 Non-renewable assets: Conservation to elements with high sensitivity	9	9	
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	3	
Create consistent streetscape	2	2	
Repeat building character and pattern	2	2	
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	5	
5 Design with flexibility			
Design could be revised or retracted	2	0	Renewal of constructed buildings is always possible, but this principle is not directly linked to this case.
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	5	
7 Sustain all resources in the historic settlement			
Materiality	1	1	
Building pattern	2	2	

Building details	1	1	
Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	A few large trees in the middle of the site could be preserved as part of the central garden.
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	2	New populations could be attracted by new houses in contemporary standard.
Economic boost	2	2	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	1	Small central garden
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	2	
Performance:			
1 Building energy performance			
Building position and orientation	1	1	
Building layout	2	2	
Passive design	3	3	
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	0	New system less energy consumption could be applied as an option.
Boilers and hot water	2	2	
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	
3 Carbon emission			
Airtightness	1	1	

Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	1	
Alternative heating (example: ground source heat pump)	2	0	Could be applied as an option.
Electric generation (example: photovoltaic)	2	2	
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25˚C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	0	New system less energy consumption could be applied as an option.
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	89	

Evaluation result reveals the new domestic building design attempt 1 is proposed under high fulfilment (79% completion in a total 113 credits) in both conservation and performance aspects, with 5 points higher than the credit of retrofit design variation 1. In nine conservation principles, '*define characters and significant of the place*' (principle 1) and '*post-construction assessment*' (principle 6) could not be assessed at the design stage: principle 1 can be evaluated through place-led townscape study and mapping in Chapter 5; although principle 6 is presumed as fulfilled in the evaluation, a full post-construction assessment should be completed by an accredit assessor in real project. Apart from above, conservation principles 3, 5, 8, and 9 are not fully achieved due to their limited relationship with domestic buildings. Compared to domestic retrofit, new domestic building development earns points on '*straighten the historic core*' and '*reinforce the position in the community*' for a few reasons: (1). The projects are likely to pick unpleasant or disordered sites in the conservation area, regenerating areas and uplifting the image of the entire settlement through commercial activities instead of public funds. (2). the newly built buildings with contemporary interior design may attract new residences or young families to settle in the settlement, then boosting local economy. (3). Projects in higher density are likely to provide more houses in the historic centre, reducing the burden of housing-demand in the peripheral area.

The design is also highly presented in performance: fully completed '*energy performance*', '*carbon emission'*, and '*occupancy comfort*' are achieved through constant insulation, passive design, natural ventilation, and installation of both photovoltaic and solar hot water. '*Post-construction assessment*' in performance (principle 6) is credited according to design proposal in the study, a full post-construction assessment should be completed by an accredit assessor in real project. Most point loss happens on heating with new energy source which is listed as a design option for other variations. Photovoltaic and solar hot water are both employed in this test, with panels installed on the roof terraces of houses and apartments.

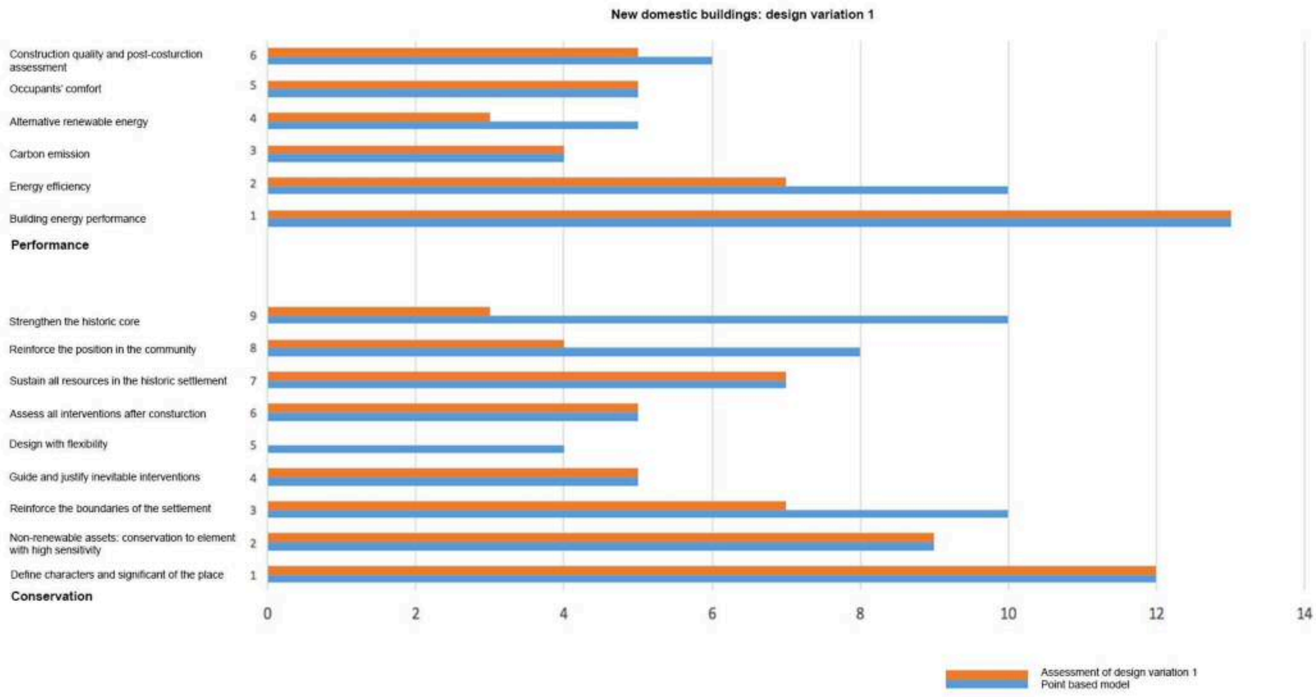


Figure 169: Bar chart revealing the completing status of each principles against the model in design attempt 1.

This chart shows principle 1, 2, 4, 6, and 7 in the conservation aspect and principle 1, 3, and 5 in the performance aspects are fully achieved. The point loss principles are principles 3, 5, 8, and 9 in the conservation aspects, because they are less related to domestic buildings. Other uncompleted principles in the performance aspect are principle 2, 4, and 6 due to the absence of heating with renewable energy. Variation 1 with 79% completion creates a better balance between conservation and performance, especially without crucial lacking in any related principle.

7.4.5 Analysis and discussion

There are several reflections regarding the design, energy assessment and evaluation:

- New domestic buildings and small communities will have several benefits in conservation, facilitating the development of the small historic settlement in the long-term.
- In this design, the conflicts and intensity exist between preserving townscape, image of streetscape, and context, and achieving low carbon emission result and a comfortable building interior environment. At the siting stage, it is highlighted that conservational principles of defining characters and maintaining the image of the settlement are in a higher tier than the rest. During the design, designer has re-evaluated the scale of how 'environmental but intrusive' the design can approach under consideration of several facts: (1), the geographic benefit of the site; (2), the level of obstruction when seeing the site from the street; (3), the degree of sensitivity of its location and exposure. Units in the north sections of the site with a street exposure are designed simply but 'traditional', to follow the typology of materiality and form in Llandeilo. When encounter a different site, this conflict must be re-evaluated based on the fact degree of exposure and surrounding.
- Similar to the retrofit case, the orientation of New Road site has advantages on passive design together with adopting higher tier of conservation principles. New Road frontage is the north boundary of the site opening to a main road, and all units proposed along the boundary would contain a north-facing street frontage. In order to create a continuous streetscape, solid front elevations with colour render are employed to match their neighbours of 1850s-1900s terraces. In the meanwhile, a solid north elevation also matches strategies of passive design. When encountering a site with a characteristic street on the south boundary or with flipped orientations, conflicts might exist between meeting passive design criteria and preserving the character and continuity of the street. By allocating current plan to a site with different geographic conditions, some other variations will be tested in the following, although it might be difficult to achieve the best results in terms of the passive design, the designer would still have higher flexibility than with a retrofit project.

7.5 Design variation 2

7.5.1 Changes and challenges

In order to test the case study through repeated methods, three variations are then reviewed, assessed on the context of the initial design works; the findings will then be discussed together at the end of this chapter. New domestic design variation 2 is under more onerous conservation requirements; however, the whole site is flipped 180 degrees with a hypothesis of south boundary in New Road. In order to control editable elements in the test, site plan and all physical parts of units and apartments will remain exactly the same as the initial design. Centralised air source heat pump installed on site might be employed to replace solar hot water and general heating, because there might be less available roof terraces suitable for placing photovoltaic, with low degree of street exposure, minor shading, and 45 degrees south-oriented. Alterations on the orientation of the site is under the hypothesis, only affecting building solar gain: imaging New Road becomes the south boundary of the site.

It is estimated the main challenges may address the appearance of building energy performance especially solar gain. All units are designed in a form of steps to maximise solar gain in the middle section of the house: highest in New Road side with three storeys, then gradually dropping down to one storey to backyards. With a 180 degree twisting, three-storey New Road elevation may block a large amount of sunlight for the rest of the house, especially for winter sun with lower angle. Atriums in the middle of the house might also be under shadows except few hours in the midday.

7.5.2 Review of sustainability

SAP simulation are summarised in the following, with detailed results included in appendixes III.

Table 16: A conclusion of energy simulation result through SAP: test 2

Round	Building Condition (Round 1-5 with PV; round 6-10 with air source heat pump supplying heating and hot water & PV)	Total energy required KWh/year	DER (Dwellings carbon emission rate) kg $CO^2/(m^2.year)$	TER (Target carbon emission rate) kg $CO^2/(m^2.year)$	SAP rating
2-1	Three bedroom terrace house type 1	8,396	11.98	12.81	94.09
2-1	Three bedroom terrace house type 2	7,657.23	11.80	13.85	94.33
2-1	Three bedroom terrace house type 3	10,919	12.58	12.74	92.60
2-1	Three bedroom terrace house type 4	11270	13.75	13.42	91.91
2-1	Apartments two-bedroom	6122	13.91	14.21	90.36
2-1	Apartments one-bedroom	2762	13.84	19.87	91.51
2-2	Three bedroom terrace house type 1	1,226	3.04	18.84	100.35
2-2	Three bedroom terrace house type 2	871.70	2.58	20.67	101
2-2	Three bedroom terrace house type 3	5,903.73	6.85	18.53	96.01
2-2	Three bedroom terrace house type 4	6295	7.63	19.78	95.46
2-2	Apartments two-bedroom	6295	7.63	19.78	95.46
2-2	Apartments one-bedroom	705.59	4.78	29.02	100.13

All 12 proposed dwellings are simulated under two groups of conditions: the first group of tests are based on regular combi boiler and photovoltaic panels installed 45 degrees south-oriented on roof terraces; while the second group of tests are based on the combination of air source heat pump and photovoltaic panels. Group 1 simulations are mostly on the edge of exceeding target carbon emission rate; however, with added heat pump, the carbon emission and energy consumption of all units drops dramatically, mostly even lower than simulation results of variation 1. Learn from simulations, changes on geographic condition of the site may affect passive design, solar gain, day lighting, approval on installing solar panels, then may alter the final carbon emission. For example, roof spaces suitable for solar panels and photovoltaic running in high efficiency are largely reduces after the changes on orientation. To offset some energy consumption, air source heat pump is then employed in group 2 simulation. Restrictions on air source heat pump mainly address enough exterior and interior space for fitting the heat pump and the water tank. Centralised heat pump supplying a group of dwellings could be a suitable solution to a mid to high density domestic area.

7.5.3 Evaluation of the design against the model

By employing the same evaluation method through the test, the proposed variation 2 is now scored based on the point-based framework (Table 17); a bar chart is also used to illustrate the completion status of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model (Figure 170).

Table 17: Evaluation of design variation 2 against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	
Mapping	5	5	
2 Non-renewable assets: Conservation to elements with high sensitivity	9	9	
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	3	
Create consistent streetscape	2	2	
Repeat building character and pattern	2	2	
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	5	
5 Design with flexibility			
Design could be revised or retracted	2	0	Renewal of constructed buildings is always possible, but this

			principle is not directly linked to this case.
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	5	
7 Sustain all resources in the historic settlement			
Materiality	1	1	
Building pattern	2	2	
Building details	1	1	
Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	A few large trees in the middle of the site could be preserved as part of the central garden.
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	2	New populations could be attracted by new houses in contemporary standard.
Economic boost	2	2	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	1	Small central garden
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	2	
Performance:			
1 Building energy performance			
Building position and orientation	1	0	
Building layout	2	2	Benefit form atriums
Passive design	3	2	Benefit form atriums
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	The terraces should still be able to receive enough solar gain with atriums.
Solar protection	1	1	

2 Energy efficiency			
Heating and cooling system	3	2	Air source heat pump.
Boilers and hot water	2	1	Air source heat pump.
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	
3 Carbon emission			
Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	0	Use air source heat pump to supply hot water.
Alternative heating (example: ground source heat pump)	2	2	Air source heat pump.
Electric generation (example: photovoltaic)	2	2	PV is still able to install on south facing location on site.
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25°C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	1	Air source heat pump
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	90	

A total evaluation result of variation 2 is 90 out of 113 (80%) which is one point higher than the total credit of variation 1. The completion rate in the conservation aspect (52 out of 70) remains the same as the initial design: principles 3, 5, 8, and 9, are not fully achieved, because these principles are less related to domestic buildings. Although a hypothetical site with different orientations is applied, a credit of 38 out of 43 is achieved in the performance aspect, which one point higher than that of variation 1. There is obvious point loss in principle 1 '*energy performance*' caused by geographic alterations, even the building envelope is fully insulted. Some point switch happens between solar hot water and heating with new energy source (air source heat pump). by picking a suitable renewable energy system, it is possible to achieve carbon deduction without breaking conservation principles.

Impacts on performance caused by three-storey south facing building front may not be illustrated through evaluation, however it should be assessed through daylight simulation.

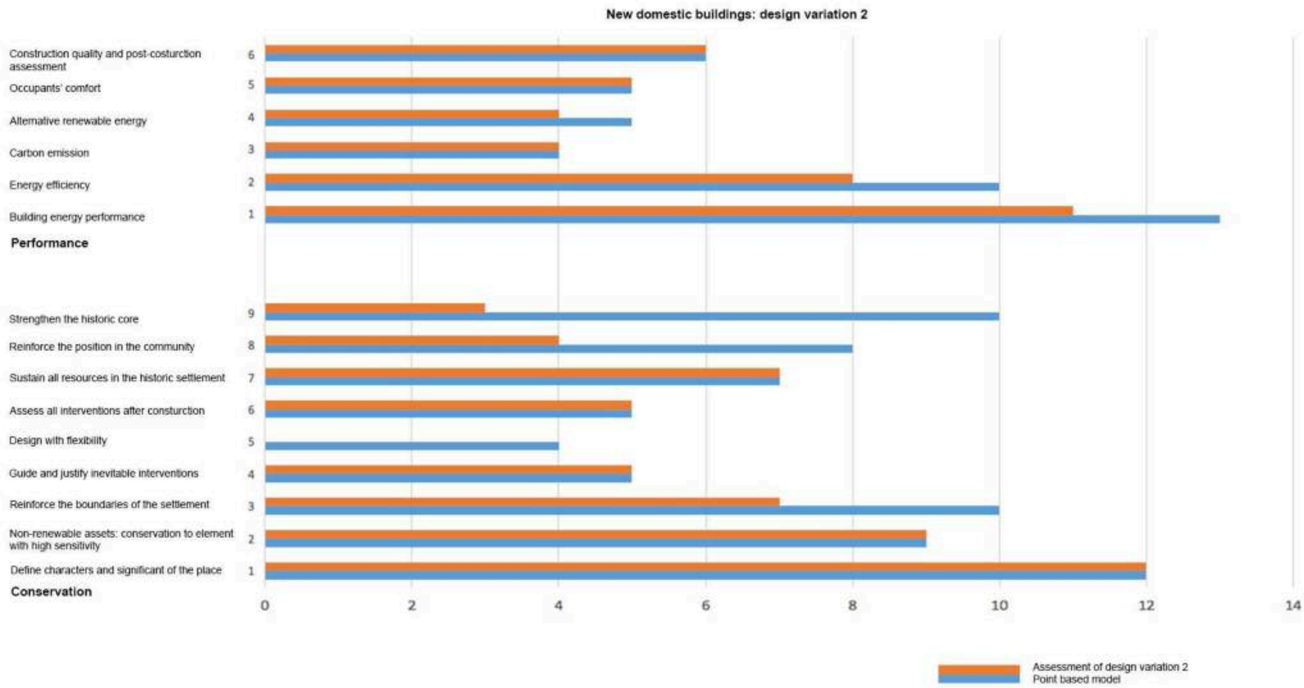


Figure 170: Bar chart revealing the completing status of each principles against the model in design variation 2.

The chart shows variation 2 is evaluated to an overall satisfaction in most conservation and performance principles. There are a few changes on the completing status in performance principle 1, 2, 4, and 6. The fulfilment of principle 1 building energy performance is dropped to 85% (11 out of 13): solar gain of the entire house may be partly blocked by the three-storey south facing front section of the building; however, atriums in the middle of the house could introduce day lighting and solar heat to the surrounding interior spaces. On the other hand, principle 2, 4, and 6 are completed in a higher rate than variation 1. With limited suitable roof terraces for installing photovoltaic, solar hot water is replaced by centralised air source heat pump, providing both hot water and heating.

7.5.4 Analysis and discussion

Several reflections were made after the design, energy assessment and evaluation:

- Geographic condition of the site may impact building's total energy consumption, especially selection of renewable energy systems. However, compared to retrofit design, the architect may have greater freedom to unite the criteria for carbon cutting and conservation principles through the design. All performance elements, including building envelope, passive design strategies, systems consuming new energy source, renewal energies, and occupant's comfort should be considered in the early stages of the design to achieve better results.
- Planning of centralised heating and hot water system consuming new energy source could be easily applied at the planning stage for a small group of dwellings. Special treatment on pipe insulation to prevent heat loss in the middle should be concerned through design strategies. Centralised renewable energy is now recognised as a practical, easy, and economic solution for mid-high density dwellings.

7.6 Design variation 3

7.6.1 Changes and challenges

The changes of variation 3 and 4 addresses 'level of conservation', especially on elements with high sensitivities (conservation principle 2): variation 3 is under less onerous conservation requirements, with New Road as north boundary of the site; while variation 4 has a hypothetical south boundary on New Road under the same ground of less onerous conservation requirements.

With higher tolerances on breaking conservation criteria, modification of building fabric in the street elevation is possible, such as enlargement of openings, or using alternative materials, then finally leading to alteration of the overall appearance. The evaluation of variation 3 and 4 in conservation aspects will be based on a conceptual proposal instead of on a new design practice. For eight terraces with New Road frontage façade, the overall size of openings on road elevations will be enlarged 30%, all triple-glazed to guarantee a tight building envelope. Other physical conditions including layouts, back elevations, sections, and building materials remain the same as the initial design. Figure 171 is an example of a low carbon contemporary terrace with less conservational street frontage. Designed by Simon Feneley Architecture, this group of terraces is distinctive from their neighbour of Victorian terraces in forms, design languages, materials, texture, and details. It is claimed that sustainable materials, high levels of thermal and acoustic insulation, and air source heat pump are applied in the project to ensure the houses have low carbon emissions (Feneley Studio, 2011). However, by fitting this group of dwellings in Llandeilo conservation area, it might significantly change streetscape and unique characters of the historic settlement.

Figure 171: Three modern terrace houses next to a Victorian terrace in London (by Simon Feneley Architecture) (Feneley Studio, 2011).

It is estimated main challenge exists on gaps between conservation and performance, which might leads to correspondingly point loss in the conservation aspect for variation 3 and 4.

Drawings of New Road elevations could be used to illustrate possible differences in appearance and visual impacts (Figure 172). With 30% enlarged windows in New Road elevation, the new proposed buildings deliver a stronger sense of contemporary and transparent, whilst the original elevation inherits and interprets the tradition.

Figure 172: Comparison of New Road elevation with 30% enlarged openings.

7.6.2 Review of sustainability

SAP simulation are summarised in the following, with detailed results included in appendixes III.

Table 18: the SAP test result for all domestic buildings in this design: test 3

Round	Description of the building (PV, solar hot water, enlarged openings)	Total energy required KWh/year	DER (Dwellings carbon emission rate) kg $CO^2/(m^2.year)$	TER (Target carbon emission rate) kg $CO^2/(m^2.year)$	SAP rating
3	Three bedroom terrace house type 1	5,661	9.32	12.91	96.17
3	Three bedroom terrace house type 2	4,318	8.19	13.56	97.09
3	Three bedroom terrace house type 3	7,572.91	9.68	11.98	94.98
3	Three bedroom terrace house type 4	6516	9.33	12.28	95.48
3	Apartments two-bedroom	1402	5.72	12.03	95.82

3	Apartments one-bedroom	-539	2.16	17.7	97.4

The test result illustrates all 12 proposed dwellings could meet the carbon emission target. The test results are based on the installation of photovoltaic panels and solar hot water system. Noted the simulation results are very similar to results of variation 1, probably because both variations are under the same geographic condition and are equipped with same renewal energies. Although openings on the north elevation (New Road elevation for terraces, and central garden elevation for apartments) are enlarged 30%, the total heat loss is barely affected because the U-value of triple-glazed windows are around 0.9W/m^{2}K.

Though may not learn from SAP, from aspects of user's experience, the daylight factor in roadside rooms could be significantly improved with larger openings, especially for type 2 and 4 units with a living space in the front section of the house. The enhancement of daylight factor could be verified through daylight factor estimation.

7.6.3 Evaluation of the design against the model

The point-based framework is once again employed to evaluate the design variation 3 (Table 19); a bar chart is also used to illustrate the completion status of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model (Figure 173).

Table 19: Evaluation of design variation 3 against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	
Mapping	5	5	

2 Non-renewable assets: Conservation to elements with high sensitivity	9	5	Front elevation with contemporary appearance and large openings.
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	1.5	Colour render surface, pitched roof, building simply.
Create consistent streetscape	2	2	
Repeat building character and pattern	2	1	Colour render surface, pitched roof, building simply.
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	3	Less achieved.
5 Design with flexibility			
Design could be revised or retracted	2	0	Renewal of constructed buildings is always possible, but this principle is not directly linked to this case.
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	3	Design will less conservation should be critically assessed.
7 Sustain all resources in the historic settlement			
Materiality	1	1	
Building pattern	2	1	
Building details	1	0.5	
Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	A few large trees in the middle of the site could be preserved as part of the central garden.
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	2	New populations could be attracted by new houses in contemporary standard.
Economic boost	2	2	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			

Public spaces	4	1	Small central garden
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	2	
Performance:			
1 Building energy performance			
Building position and orientation	1	1	
Building layout	2	2	
Passive design	3	3	
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	0	New system less energy consumption could be applied as an option.
Boilers and hot water	2	2	
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	
3 Carbon emission			
Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	1	
Alternative heating (example: ground source heat pump)	2	0	Could be applied as an option.
Electric generation (example: photovoltaic)	2	2	
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25˚C)	1	1	
Ventilation	1	1	
Daylight	1	1	

Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	0	New system less energy consumption could be applied as an option.
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	77	

In this table, the total score (77 out of 113) and the conservation credits (40 out of 70) are both dropped compared to evaluations of variation 1 and 2. There are five conservation principles affected by alterations on road elevation: principle 2 '*elements with high sensitivity*', principle 3 '*reinforce the boundaries*', principle 4 '*guide and justify interventions*', principle 5 '*post-construction assessment*', and principle 7 '*sustain all resources*'. It is concerned a contemporary street elevation may affect the streetscape, character and distinctiveness of the place. Under the same building physical condition and geographic condition, the achievement of performance's points remains the same as the variation 1 (37 out of 43). the point loss principles in the performance aspect are principle 2, 4, and 6, under the reason of heating system. Air source heat pump employed in test 2 could be an additional option for heating and hot water supplement to further offset carbon emission and to add points in the performance aspect.

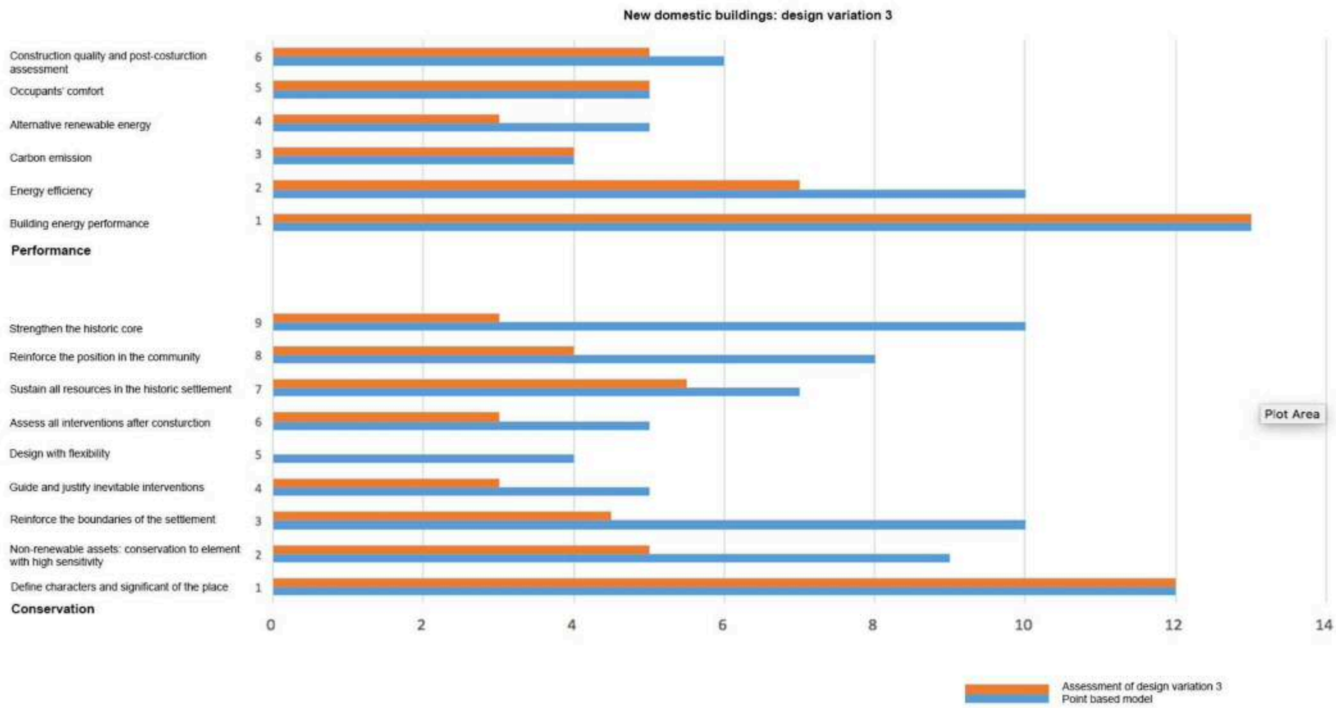


Figure 173: Bar chart revealing the completing status of each principle against the model in design variation 3.

This chart shows this variation is failed to complete almost all conservation principles, excepting principle 1 not assessed at design stage. principle 1 is completed by apply place-led townscape study and mapping in Chapter 5. The overall drops in the conservation aspects are likely caused by alterations of building front elevation with less conservation concerns. The overall appearance in performance remains a high levels of accomplishment as other variations.

7.6.4 Analysis and discussion

Several reflections were made after the design, energy assessment and evaluation:

- Defining the character and maintaining the identity of the town and the site's surroundings should be listed as a tier one principle during the design of new domestic buildings.

- The overall appearance of the elevation and its visual impacts may jump to an opposite direction with modification or replacement of some small elements. In this variation, with 30% enlargement of all front openings, all terraces started to obtain a contemporary appearance instead of their original simple classic look. The initial design adopts visual elements such as solid appearance, colour washed surface, a stiff look of rectangles instead of arches, interpreting and rephrasing through modern language and materials. The proposed group of units does not stand out from their neighbours, however all units are designed under 2010s concept instead of mimic the tradition. It might be important for architect to careful review and justify the final appearance of the design, especially elevations with high level of conservational sensitivity. The performance enhancement should not sacrifice conservation rules.

7.7 Design variation 4

7.7.1 Changes and challenges

Same as last test, variation 4 is under less onerous conservation requirement, and a hypothetical south boundary on New Road. With higher tolerances on breaking conservation criteria, it is estimated the conservation credits might be very similar to variations 3. The simulation result for variation 2 shows it is important to employ heating system with renewable energy to offset heat loss from large glazing in the north elevation and insufficient solar gain in the south. With installation of photovoltaics plus centralised air source heat pump, this test may achieve a high score in the aspect of performance, especially on energy efficiency and renewable energy.

7.7.2 Review of sustainability

SAP simulation result is summarised in the following, with detailed results included in appendixes III.

Table 20: the SAP test result for all domestic buildings in this design: test 4

Round	Description of the building (PV, air source heat pump, enlarged openings)	Total energy required KWh/year	DER (Dwellings carbon emission rate) kg $CO^2/(m^2.year)$	TER (Target carbon emission rate) kg $CO^2/(m^2.year)$	SAP rating
4	Three bedroom terrace house type 1	1,334	3.16	18.99	100.22
4	Three bedroom terrace house type 2	707.87	2.44	20.45	101.18
4	Three bedroom terrace house type 3	5,642.77	6.67	18.31	96.25
4	Three bedroom terrace house type 4	6087	7.48	19.59	95.67
4	Apartments two-bedroom	3679	8.28	21.75	95.89
4	Apartments one-bedroom	787	5.06	29.63	99.92

Benefited from the installation of both centralised air source heat pump and photovoltaic, most terraces in variation 4 have the lowest energy consumption through all tests for this case study. Apartments have a different trend in total energy consumption due to their size. In this variation, centralised air source heat pump supplies both heating and hot water for all units and apartments; photovoltaic panel are installed on roof terraces with 45 degrees south facing, connecting to the main power grid.

Although may not learn from SAP, from aspects of user's experience, the daylight factor in roadside rooms could be significantly improved with larger openings, especially for type 2 and 4 units with a living space in the front section of the house. The enhancement of daylight factor could be verified through daylight factor estimation.

7.7.3 Evaluation of the design against the model

The evaluation of variation 4 follows the same methods as above: the point-based framework (Table 21) and a corresponding bar chart (Figure 174) is used to illustrate the completion status of each principle, with red bar standing for assessment of this design attempt and blue bar standing for the model.

Table 21: Evaluation of design variation 4 against the model

Criteria	**Available Credits**	**Credits**	**Comments**
Conservation:			
1 Define characters and significant of the place			
Townscape study	7	7	
Mapping	5	5	
2 Non-renewable assets: Conservation to elements with high sensitivity	9	5	Front elevation with contemporary appearance and large openings.
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3	1.5	Colour render surface, pitched roof, building simply.
Create consistent streetscape	2	2	
Repeat building character and pattern	2	1	Colour render surface, pitched roof, building simply.
Establish a few key buildings at the boundary	3	0	Not related to domestic buildings
4 Guide and justify inevitable interventions	5	3	Less achieved.
5 Design with flexibility			
Design could be revised or retracted	2	0	Renewal of constructed buildings is always possible, but this principle is not directly linked to this case.
Ability of fitting other functions	2	0	Not related for a domestic building
6 Assess all interventions after construction	5	3	Design will less conservation should be critically assessed.
7 Sustain all resources in the historic settlement			
Materiality	1	1	

Building pattern	2	1	
Building details	1	0.5	
Craftsmanship	1	1	
Landscape	1	1	
Vegetation	1	1	A few large trees in the middle of the site could be preserved as part of the central garden.
8 Reinforce the position in the community			
Infrastructures	4	0	Not related
Attraction of new populations	2	2	New populations could be attracted by new houses in contemporary standard.
Economic boost	2	2	Construction projects and possible new populations may boost local economy.
9 Strengthen the historic core			
Public spaces	4	1	Small central garden
Infrastructures	2	0	Not related
Varieties	2	0	Not related
Reduce areas with blur image	2	2	
Performance:			
1 Building energy performance			
Building position and orientation	1	0	
Building layout	2	2	Benefit form atriums
Passive design	3	2	Benefit form atriums
U-value of building envelope	3	3	
Natural lighting	1	1	
Ventilation	1	1	
Solar gain	1	1	The terraces should still be able to receive enough solar gain with atriums.
Solar protection	1	1	
2 Energy efficiency			
Heating and cooling system	3	2	Air source heat pump.
Boilers and hot water	2	1	Air source heat pump.
All other appliances	2	2	
HVAC systems	1	1	
User's behaviour	1	1	
Lighting	1	1	
3 Carbon emission			

Airtightness	1	1	
Carbon emission during construction period (example: demolition, material delivery)	2	2	
User's behaviour	1	1	
4 Alternative renewable energy			
Solar hot water	1	0	Use air source heat pump to supply hot water.
Alternative heating (example: ground source heat pump)	2	2	Air source heat pump.
Electric generation (example: photovoltaic)	2	2	PV is still able to install on south facing location on site.
5 Occupants' comfort			
Indoor pollutants	1	1	
Comfortable temperature (around 25˚C)	1	1	
Ventilation	1	1	
Daylight	1	1	
Full insulation without drought	1	1	
6 Construction quality and post-construction assessment			
Insulation	1	1	
Heating and cooling system	1	1	Air source heat pump
Boilers	1	1	
All other appliances	1	1	
Airtightness	1	1	
Treatment of droughts	1	1	
Total	113	78	

According to the evaluation, the total credit of 78 out of 77 is one point higher than that of variation 3. Both variation 3 and 4 have obtained a 40 out of 70 in the conservation aspect, because they are assessed based on the same front elevation. Point loss addresses on principle 2, 3, 4, 6, and 7 related to the level of intervention and preservation of distinctive streetscape and visual image. Although without any new elements such as photovoltaic panels from street view, it is concerned a sense of contemporary intervention may change the character the place. Credits for performance (38 out of 43) remains the same as variation 2.

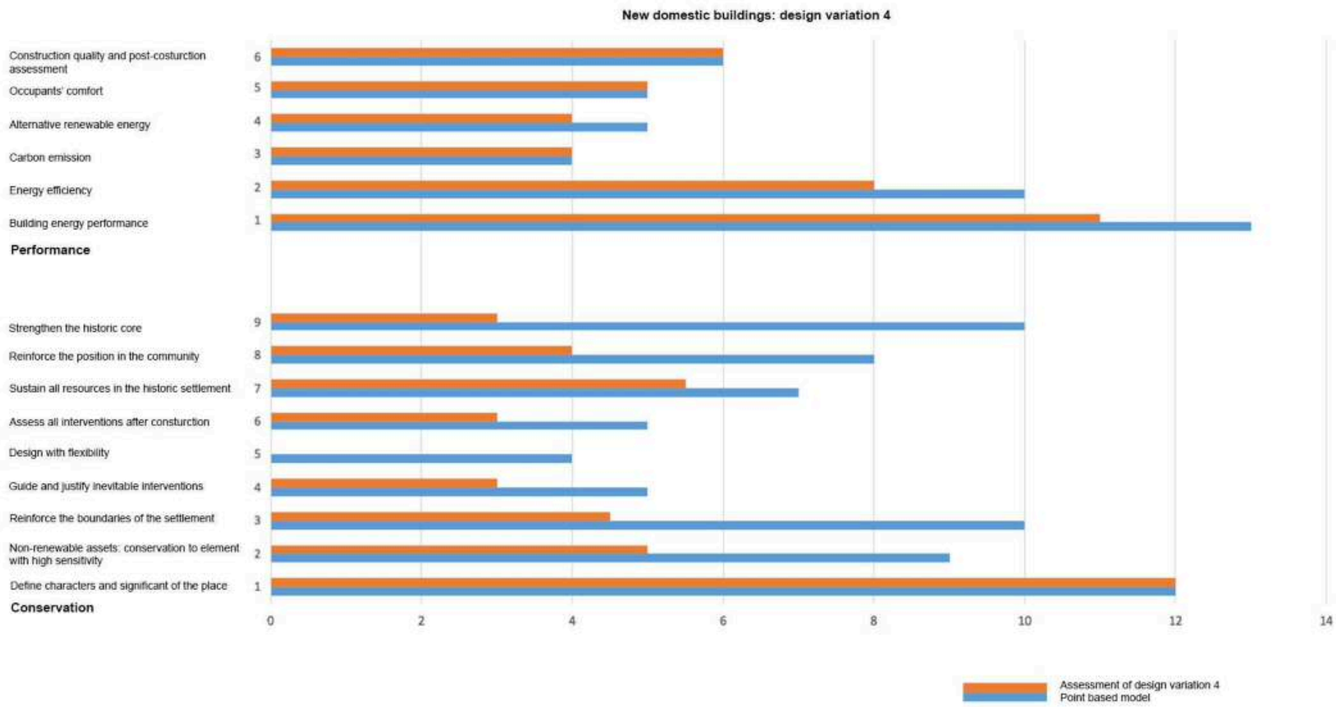


Figure 174: Bar chart revealing the completing status of each principle against the model in design variation 4.

This chart shows an unbalanced points distribution for this variation: in the conservation aspect, almost all principles are unfollowed, except principle 1 which is not assessed at the design stage; while majority of performance principles are achieved. The point loss in performance principle 1 is caused from building's orientation and heat loss from north-facing Frenching windows, however, point gain in other performance aspects especially in principle 2 and 4 may offset the loss.

7.7.4 Analysis and discussion

Several reflections were made after the design, energy assessment and evaluation:

- In this variation, breaking of most conservation criteria does not bring an extremely high credit in achievement of performance; and the simulated carbon emission rates are similar to variation 2 test 2 on the same ground of centralised air source heat pump and photovoltaic panel. Noted flexible design strategies may be applied in domestic new building design to achieve both conservation and carbon cutting.

7.8 Findings and discussion

To assist discussions and achieve findings, two tables (Table 22, Table 23) are employed: one for displaying evaluation credits of all variations against the model; another for demonstrating SAP results of all design variations. The trends of simulated energy consumptions through all design variations are drawn in Figure 175 .Two bar charts (

Figure 176, Figure 177) are used again to illustrate the completion rate in each principle and categorised total credits of all variations.

Table 22: Matrix of credits covering all new-build variations

Principles	**Available credits**	**Test 1**	**Test 2**	**Test 3**	**Test 4**
Conservation					
Principle 1: Characters & significant	12	12	12	12	12
Principle 2: Elements with high sensitivity	9	9	9	5	5
Principle 3: boundary	10	7	7	4.5	4.5
Principle 4: Guide interventions	5	5	5	3	3
Principle 5: Flexibility	4	0	0	0	0
Principle 6: Post-construction Assessment	5	5	5	3	3
Principle 7: Sustain all resources	7	7	7	5.5	5.5
Principle 8: Position in community	8	4	4	4	4
Principle 9: Historic core	10	3	3	3	3
Sum (conservation)	**70**	**52**	**52**	**40**	**40**
Performance					
Principle 1: Energy performance	13	13	11	13	11
Principle 2: Energy efficiency	10	7	8	7	8
Principle 3: Carbon emission	4	4	4	4	4
Principle 4: Renewable energy	5	3	4	3	4
Principle 5: Occupant's comfort	5	5	5	5	5

Principle 6: Post-construction Assessment	6	5	6	5	6
Sum (performance)	**43**	**37**	**38**	**37**	**38**
Total	**113**	**89**	**90**	**77**	**78**

Illustrated by the Table 22, the total score could be categorised to two groups: test 1 and 2 in a higher credit, and test 3 and 4 in a lower benchmark. Both test 1 and test 2 reaches a same credit of 52 in the conservation aspect and also a similar final score; while test 3 and test 4 are much lower. Noted modified road front elevation may change the overall appearance of the group of terraces, then jeopardise the continuous streetscape with a sense of place. All variations obtain similar performance credits, marked as 37 and 38. In variation 2 and 4 with disadvantages in geographic condition, installation of both photovoltaic and heating system with new energy source may greatly offset extra carbon consumption. New dwelling design provides huge freedom on fulfilling performance requirements, especially for design of a small community. Design strategies applied at planning or siting stage may fit the building group into a tight carbon emission band under most geographic conditions.

Overall, all tests are completed over a rate of 50% for this framework containing all principles: variation 3 with the worse appearance has a 68% completion; and variation 2 reaches 80% which is the highest in all. Learn from discussions of each variation, both variation 1 and 2 with 79% and 80% completion obtains a better balance between conservation and performance, especially without crucial point loss in any relative principle.

Table 23: A conclusion of simulation result through SAP

Round	Building Condition	Total energy required KWh/year	DER (Dwellings carbon emission rate) kg $CO^2/(m^2.year)$	TER (Target carbon emission rate) kg $CO^2/(m^2.year)$	SAP rating

	Three bedroom terrace house type 1				
1	North New Road facing, PV, solar hot water	5489	9.10	12.81	96.32
2-1	South New Road facing, PV	8396	11.98	12.81	94.09
2-2	South New Road facing, PV, air source heat pump	1226	3.04	18.84	100.35
3	North New Road facing, PV, solar hot water, enlarged north openings (30%)	5661	9.32	12.91	96.17
4	South New Road facing, PV, air source heat pump, enlarged south openings (30%)	1334	3.16	18.99	100.22
	Three bedroom terrace house type 2				
1	North New Road facing, PV, solar hot water	4159	7.99	13.42	97.23
2-1	South New Road facing, PV	7657	11.80	13.85	94.33
2-2	South New Road facing, PV, air source heat pump	871	2.58	20.67	101
3	North New Road facing, PV, solar hot water, enlarged north openings (30%)	4318	8.19	13.56	97.09
4	South New Road facing, PV, air source heat pump, enlarged south openings (30%)	707	2.44	20.45	101.18
	Three bedroom terrace house type 3				
1	North New Road facing, PV, solar hot water	6848	11.98	13.79	93.24
2-1	South New Road facing, PV	10919	12.58	12.74	92.60
2-2	South New Road facing, PV, air source heat pump	5903	6.85	18.53	96.01
3	North New Road facing, PV, solar hot water, enlarged north openings (30%)	7572	9.68	11.98	94.98
4	South New Road facing, PV, air source heat pump, enlarged south openings (30%)	5642	6.67	18.31	96.25
	Three bedroom terrace house type 4				
1	North New Road facing, PV, solar hot water	6735	9.54	12.20	95.32
2-1	South New Road facing, PV	11270	13.75	13.42	91.91

2-2	South New Road facing, PV, air source heat pump	6295	7.63	19.78	95.46
3	North New Road facing, PV, solar hot water, enlarged north openings (30%)	6516	9.33	12.28	95.48
4	South New Road facing, PV, air source heat pump, enlarged south openings (30%)	6087	7.48	19.59	95.67
	Apartments two-bedroom				
1	North Central garden facing, PV, solar hot water	1594	6.15	12.07	95.62
2-1	South Central garden facing, PV	6122	13.91	14.21	90.36
2-2	South Central garden facing, PV, air source heat pump	3524	8.03	21.05	96.15
3	North Central garden facing, PV, solar hot water, enlarged north openings (30%)	1402	5.72	12.03	95.82
4	South Central garden facing, PV, air source heat pump, enlarged south openings (30%)	3679	8.28	21.75	95.89
	Apartments one-bedroom				
1	North Central garden facing, PV, solar hot water	-428	2.55	17.69	97.23
2-1	South Central garden facing, PV	2762	13.84	19.87	91.51
2-2	South Central garden facing, PV, air source heat pump	705.59	4.78	29.02	100.13
3	North Central garden facing, PV, solar hot water, enlarged north openings (30%)	-539	2.16	17.7	97.4
4	South Central garden facing, PV, air source heat pump, enlarged south openings (30%)	787	5.06	29.63	99.92

This table summarises SAP results through all simulations in each type of dwellings. In six different dwellings, they all have the highest carbon consumption and emission found in the first simulation of variation 2; on the contrary, the lowest SAP happens in variation 4 except for two apartments. It is estimated the small apartments are more serious affected by heat loss from large north-facing openings in variation 4. By sharing the same orientation plus same heating and hot water system, variation 1 and variation 3 contains extremely similar simulation result in total carbon consumption and emission; and small increase in energy consumption is cause by heat loss from enlarged north openings. By twisting the site 180º, removal of solar panel and heat loss from large north-facing French windows may affect the carbon emission, as shown in test 2-1. The carbon emission of variation 2 first simulation jumps to the highest, the rate is then dropped dramatically in all tests after adding air source heat pump to supply heating and hot water. Further reduction happens in variation 4 with the combination of air source heat pump and photovoltaic. The test result illustrates all 12 proposed dwellings could meet the tight carbon emission target in majority variations, except a few dwellings in test 2-1.

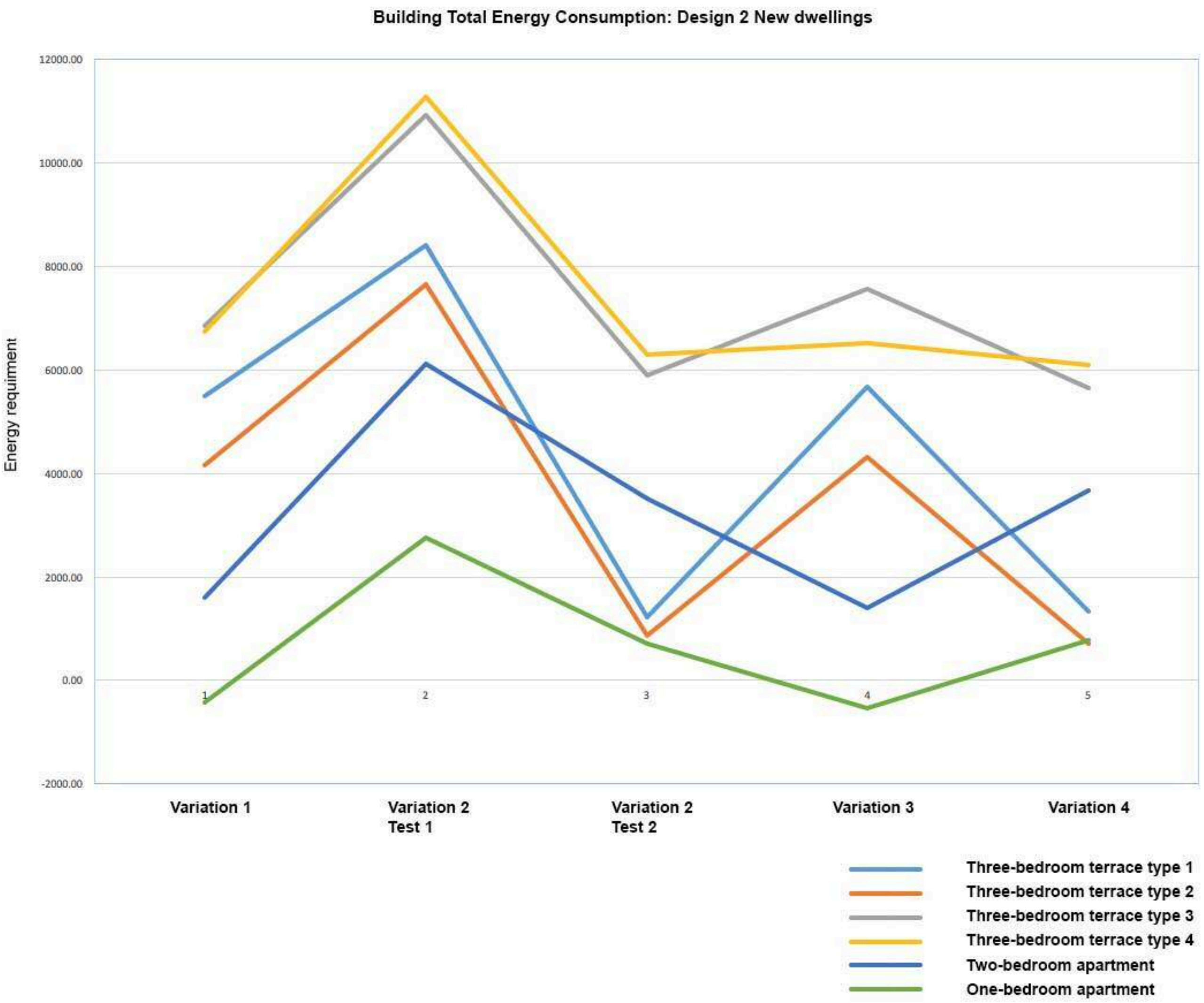


Figure 175: Building total energy consumption through all design variations (containing all dwelling types in the design)

This figure reveals a trend of building's total energy consumption through all tests. It appears two apartments have different trends in variation 3 compared to terraces, which might because small apartments are more serious affected by heat gain from large south-facing openings in variation 3. Both variation 1 and variation 2 test 2 under onerous conservation requirements has a similar energy consumption, although they have opposite geographic conditions. With a twisted orientations and heavy conservation restrictions, the energy consumption of test 2-1 jumps to the peak on the basis of test 1-1. By taking air source heat pump to supply heating and hot water, the result drops significantly without breaking conservation rules in variation 2-2. Variation 3 and variant 1-1 has similar energy requirements because they are only different on sizes of north-facing openings. With the installation of photovoltaic panel, variation 4 of all terraces has the lowest energy consumptions than the others. Noted both terrace retrofit and new-build cases have drawn similar trends in total energy consumption through all tests.

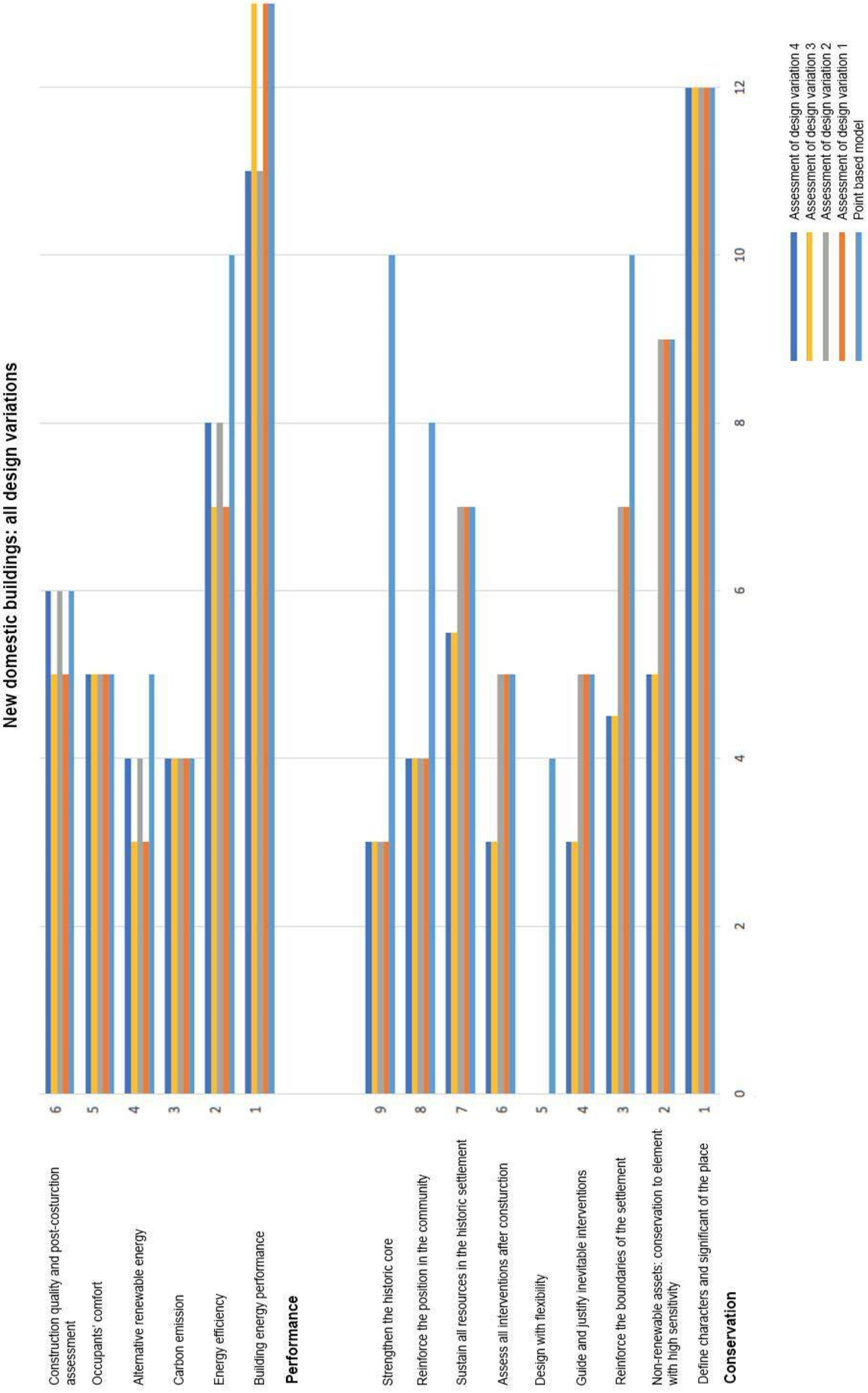


Figure 176: Bar chart revealing the completing status of each principle against the model

This bar chart reveals several facts: (1). In the conservation aspect, variation 3 and 4 appears to obtain less credits in principle 2, 3, 4, 6, and 7 than variation 1 and 2. These principles are proposed and defined based on identifying and maintaining unique characters and non-renewable resources. The activities of less conservation requirements may affect the implement of them. (2). Conservation principle 3, 5, 8, and 9 are not fully tested through all design variations, because these principles are applicable to non-domestic buildings rather than domestic ones. (3). In performance principle 1, variation 2 and 4 obtains less credit than variation 1 and 3 due to geographic condition, SAP result proves the total energy consumption may be affected by the orientation of openings. (4). Variation 2 and 4 reaches a higher score in performance with added points on principle 2, 4 and 6.

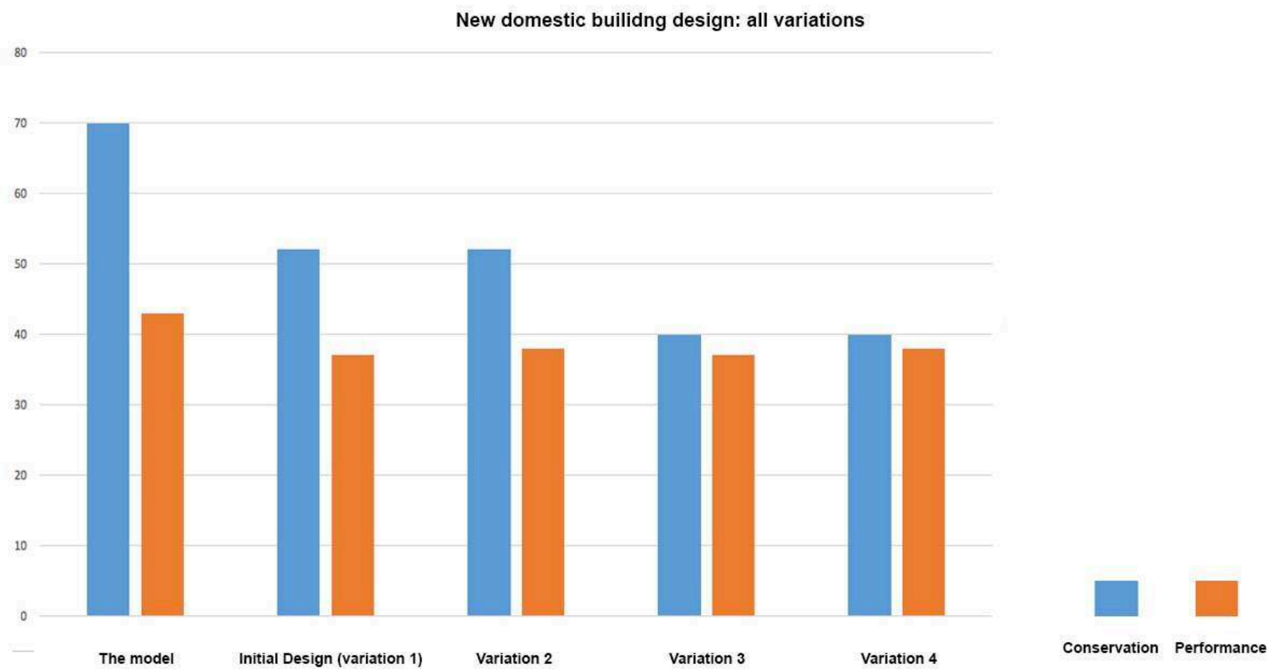


Figure 177: A summary of all variations: credits in conservation and performance aspects

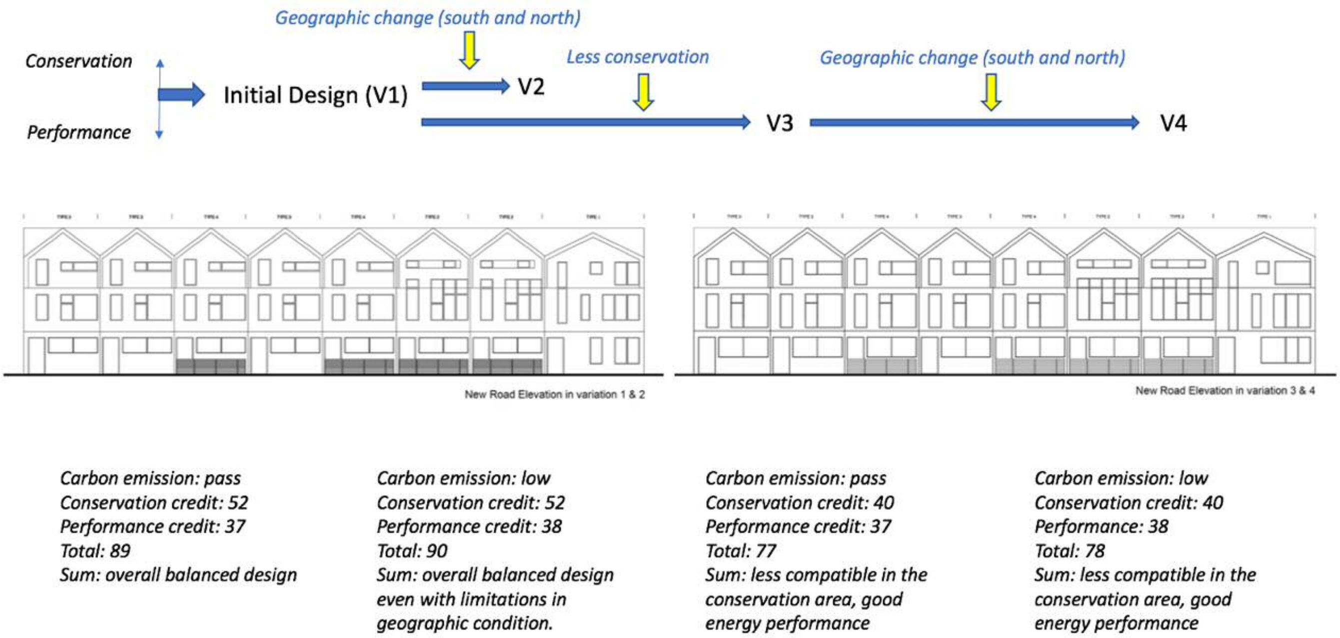


Figure 178: Diagrammatic summary of four variations with corresponding energy rate and credit

Above figure demonstrates how each variation presents in both conservation and performance aspects. In the conservation aspect, both variation 1 and 2 obtains the same conservation score from simple and classic road elevations which is interpreted from the place; the conservation credit is then dropped dramatically in variation 3 and 4 under the context and activities of less onerous conservation requirements. A townscape study plus careful verification of surrounding streetscape in the degree of sensitivity is needed at planning and siting stage. The preservation and maintenance of historic characters is also crucial in new dwelling design, complied through interpretation of the place. In the performance aspect, variation 1 and 3 earns same credit for having same geographic condition with huge benefits on passive design. However, the performance scores in variation 2 and 4 are slightly higher than the others, even with a flipped orientation. Noted new dwelling design has great freedom on engaging design strategies to achieve performance enhancement. In this design, planning of centralised heating and hot water system consuming new energy source could be easily applied at the planning stage for development of a small group of dwellings.

The design of new dwellings for the centre of historic settlement highlighted several findings and design recommendations relating to the model:

- Establishment of new dwellings in the centre of a historic settlement benefits the small historic settlement in the long term (reasons refer to section 7.3.1);
- Design of new dwellings can be guided by conservational principles; ensuring, they will be less likely to damage the distinctiveness of the settlement. Townscape study and review may help architects to rephrase local characters to design languages with a sense of contemporary.
- Maintenance of the town's identity and that of surrounding sites should be listed as a tier one principle when designing new dwellings.
- Contemporary materials and design languages could be engaged when design in a historic settlement. However, it might be important for architect to careful review and justify the final appearance of the design, especially elevations with high level of exposure.
- The performance enhancement should not sacrifice conservation rules.
- Compared with a retrofit design, the new building provides greater flexibility for architects wishing to unite the criteria for carbon cutting and conservation principles through the design.
- Performance principles and related design strategies must be considered in the early stage of the design (planning and siting stage) to achieve a better result.
- Planning of centralised heating and hot water system consuming new energy source could be easily applied at the planning stage for development of a small group of dwellings. Special treatment on pipe insulation and heat loss in the middle should be concerned and reduced through design strategies. Centralised renewable energy is now recognised as a practical, easy, and economic solution for mid-high density dwellings.
- This may have been compromised in the case study design as the design aimed for levels of densification which may have been too high for a 'backland' site.

- Further studies will include a cost analysis detailing the possibility of installing a water tank or a grey water system on site to reduce water consumption.
- Further studies regarding the landscape design will aim to create a better sense of a small community. In the design, a large portion of the central garden is paved, resulting from the arrangement of garages together with apartments to the south of the site. Adding green beds or pots, or planning a traffic route to reduce pavement use could support creation of a central garden for occupants.
- Discussions concerning the possibility of allocating more dwellings at the site require further study. It might be more difficult to design a higher density dwelling in a historic centre that embraces conservation, ensuring a well-designed building interior, exterior space, and a passive design. It will be the conservational principle that guides and controls the details of the project at the proposal stage, such as the density.
- If the height of building and the density of the community could be lowered than the proposed, there would be a better physical fit for the site.

This chapter has described how the original model of principles informed the new domestic building design. The findings for all tests and following discussions share some common points, and suggest updates to the model for new designs:

- Conservation principles related to maintenance of the town's identity should be listed as a tier one principle when designing new dwellings. A place-led townscape study on characters and distinctiveness should be completed by architects before design approaches. It is advised to use design concept and language interpreted from the place.
- In designs for new building, architects may experience greater freedom to unite criteria for performance and to employ conservation principles throughout the design phase. Criteria on performance should be considered together with conservation principles in the early design stages to achieve the best results.

- The architect plays a role in the design of new buildings in a historic settlement to bridge the gap when conflicts occurs. ‘Architect + Conservation’ stands for review, study, and sympathy of local distinctiveness, rephrasing through contemporary design languages; ‘Architect + Performance’ represents carbon cutting and maximising occupants’ comfort through design strategies.
- Credits on some performance principles could be calculated together instead of separate. Tests reveals variations with low energy performance credits could use high scores in renewal energy to offset some loss. The simulated carbon emission of these variations may still under the target emission rate.

CHAPTER EIGHT: FINDINGS AND DISCUSSION

8.1 Introduction

This chapter contains all the reflections and findings from the literature study (from chapter 2 to 4), the town study (chapter 5) and the case study designs (chapter 6 and 7). The study was designed to meet the overarching aim of realising conservation objectives while also to meet the enhancement and sustainability requirements of a historic settlement, by addressing and reconciling conservation principles and design criteria in performance, through design. The findings reveal that principles and strategies raised in both dimensions can be arranged into a hierarchy, applying through design, to fulfil the request for the conservational regeneration of the historic settlement but that some accommodation from each aspect is required.

8.2 Findings and discussion

8.2.1 Introduction

Chapter 2 presented theories related to describing and identifying the image of urban settlements since the 1960s, outlining the significance of the historic settlement in the creation of place and identity. The conservation legislation developed also emphasises the process by which distinctive urban characteristics should be identified and treated as assets; detailing also how inevitable interventions must be guided and justified. However, minimal detail is provided in the reviewed legislation concerning how such guidance could be effectively achieved. Meanwhile, in order to reduce the carbon footprint of the historic settlement to align with increasingly stringent carbon reduction targets, the method followed when applying these sustainable measures must be considered. Reviews on current 'code for sustainable homes' and trends of nearly zero-energy target in 2020 then zero carbon in 2050 shows detailed regulations, assessment tools, and sophisticated measures have been established and refined to reduce the carbon footprints of buildings and to improve the built environment in general. The fulfilment of zero carbon target would greatly relay on both 'new build' and 'historic building regeneration', especially the large proportions of aged domestic building in the historic settlement. However, current official conservation guidance, appraisals, and frameworks contain very limited information about these criteria, measures and tools when encountering historic settlements, particularly when reducing carbon footprints and improving environmental quality on the scale of buildings.

In chapter 3, a review of Caminada's themes and his practices in Vrin revealed it is possible to achieve conservation aims and enhance a place while also guaranteeing environmental sustainability through design. Caminada's key themes are the interpretation of place, siting key infrastructures within the settlement core, drawing on typology and interpretations of traditional constructions to perform in a contemporary way, while also being sourced locally. Caimada's themes reveals some differences between architects' standard and conservation principles when engaging a place. Caminada's themes also contribute to refining and rephrasing conservation principles from aspects of architects when formulating the model described in chapter 4.

In the context of the reviews above, a 'model' for design embracing all the principles and guidance from conservation and performance-based code, rephrased by architects, is constructed in Chapter 4. The model reveals overlaps and gaps affecting the principles from both agendas, which are as follow. The target of conservation in general is to preserve a site from change; however, as the literature review shows, changes occur for a range of reasons. A dominant historical approach, in particular to assessment of the historic settlement tends to distance change and in particular actions leading to sustainability. With involvement of architect, the setup of 'Architect + Conservation' targets on enhancing buildings and places through design; and the literature revealed that the way in which settlements were characterised privileged theories of 'place' over history. By employing architect to rephrase conservation principles, some differences are revealed: architects apply different methods (place-led) to capture the image and atmosphere of a settlement rather than the traditional conservation appraisals of identifying the characters; architects work on the interpretation of the '*traditional*' materials and elevations to develop new '*traditions*'; architects are concerned with the boundaries of settlements due to their importance in containing sprawl. In addition, performance-based code now becomes a new participator in the conservation progress to ensure tight carbon emission targets are met, by providing solutions and measures to develop low carbon buildings and settlements. Principles and guidance listed in the building performance aspect address on the physical environment of buildings, providing corresponding solutions on building's physical components, therefore arising possible concerns on conservation of the building fabric, silhouette and roofscapes. Although majority of the codes apply full or partial exemptions to listed or monuments buildings with historic interest, the codes pay minimum concerns on aged buildings with unique urban characteristics, or a historic settlement as the whole piece. With the involvement of architect, the setup of 'Architect + Performance' focus on creating buildings with high standard of comfort, low energy consumption, and low carbon emission, also engaging all principles in the agenda of conservation.

This model guides the following portion of the study and has been tested according to two designs of domestic building, including both retrofits and new projects, all encompassing four variations under different levels in both agendas:

Chapter 5: Townscape study
Chapter 6: Design: domestic building retrofit
Chapter 7: Design: new domestic building

In each design, four variations are reflected and evaluated against the model. Then at the end of each design phase, the design is analysed and discussed with cross comparison of all variations, leading to findings relating to the role of principles from each agenda play in the conservation and enhancement treatment applied to the historic settlement.

8.2.2 Findings relating to the conservation principles

Findings raised at the end of townscape study (see 5.5) and in each design (as shown in 6.8 and 7.8) reveal some conservation principles given the highest priority when applied in conjunction with performance principles, architects' design concept, and other briefing frameworks, especially for retrofit designs on buildings with significance within the conservation area. However, design practice reveals some problems and limitations when evaluating the design against some principles. For example, not all principles are tested in the design procedure, indicating some principles may guide a different stage rather than design stage; and a few principles are only applicable in certain types of buildings, e.g. non-domestic buildings.

Findings from all the designs reveal principles related to maintenance of the town's identity and character as a distinctive place, such as '*non-renewable assets: conservation to elements with high sensitivity' (principle 2)*, and '*sustain all resources in the historic settlement' (principle 7)*, which are in a higher tier than the others, and should be consistently considered in any work at all stages. The priority of these principle should be only applicable for design cases within the conservation area; for sites in the peripheral of the settlement, restrictions from the principles may reduce, under the request of further study.

- Principle 2, *non-renewable assets: conservation to elements with high sensitivity. This principle* reinforces the diverse value of the components and features of the historic settlement and their non-renewable characters. In most current circumstances, designers are mainly responsible for identifying the value of the environment and the buildings. To help designer identifying these significances, English Heritage established several guidelines; however these critical guidelines are written in an exploratory way, too general, and unclear. In the study, the designer, from the view of an architect, assesses elements with high sensitivity at both the building and the settlement scale for each design. In the retrofit design, the medieval burgages pattern provides physical records of history; and its simple street-facing façade with chimney, contributes to the character of streetscape, then townscape. In the new dwelling design case, the proposed New Road elevation may place significant impact to the streetscape, then townscape; plus the assessment of the 'backlands' site could be critical before design approaches. Principle 1 is now used to guide the place-led townscape study, identifying and defining the distinctiveness of the place in a clearer way. On the basis of townscape study in the identification stage, findings reveal principle 2 should be applicable to all steps in the design stage, together with principle 4 and 7. The overall conservation credit is also greatly related to scores of principle 2 and 7.

- Principle 7, *sustain all resources in the historic settlement*. Being rephrased from an original conservation criterion, this principle now contains sub-points including detailed architects' concern and general conservation points, such as building patterns, materiality, details, craftsmanship, vegetation, and landscape. Highlighted in both English Heritage and Cadw's conservation principles, it was original raised to indicate that a historic settlement is a mixture of physical remains, history, and culture, engaged in revolutionary rather than static processes. Therefore, design for developments within a historic settlement must carefully assess and verify the potential influence that might arise from intervention. Findings reveal principles 2 and 7, although targeted on elements with different degree of sensitivity, are two interlinked principles; they share similar increase and drop trends through all evaluations. With the supports of principle 1 at the identification stage, both principle 2 and 7 should be applicable to all steps in the design stage.

Findings from all the designs reveals two principles may not guide procedures in the design stage, listed as: '*define characters and significant of the place' (principle 1)*, and '*Assess all interventions after construction' (principle 6)*. As a vital background of the entire conservation procedure, principle 1 should be applied during townscape study in the identification stage, before all planning and design happens. Principle 6 should guide post-construction assessment after the construction stage.

- Principle 1, *define characters and significant of the place*. Noted from the literature review, most current conservation appraisals have limitations on accurately delivering the distinctiveness and sense of each settlement due the range of methods applied. In most conservation appraisals, texts, maps and photographs are employed to describe and imagine the character and identity of a settlement, from its typology, pattern, and detailing. However, architects have explored methods like analytical sketches and drawings, together with photographs to capture character and convey atmosphere and sense of place. Social and cultural aspects of place may also be incorporated and there is a growing tendency to include a broader ecological analysis. Tested through townscape studies and design practices, a combination of both conservation appraisal and architects' methods might more accurately rephrase the context and identity of a historic settlement, and this is vital in the conservation process. In other words, a more multi-layered appraisal of the settlement may be necessary and this was attempted in Chapter 5 as a preface to the designs.
- Principle 6, a*ssess all interventions after construction.* Although not tested through design, mandatory post-construction assessment could be an effective method to take account of any alterations between design and construction. Post-construction assessment in both conservation and performance aspects may be combined, testing the completion the design details, the construction quality, building performance and airtightness, all systems including heating and boilers, and protection of surround space including vegetation and landscape.

It is also apparent that there are four principles that are non or partial applicable to domestic designs and are tested with limitations.

- Principle 3, *Reinforce the boundaries of the settlement*. As a conservation principle being rephrased by architects, this principle now covers a broad range of benefits: control of town sprawl, establishment of a clear image for observers with ‘inside’ and ‘outside’, creation of enclosure, and efficiently distribution of limited resources and funding for conservation. The principles could guide several design procedures, mostly happened at the planning stage. In the tests, some sub-points under this principle are evaluated, because both retrofit and new-build sites are located at the boundary of the settlement.
- Principle 5, *Design with flexibility*. The principle is established to ensure: (1), added contemporary elements to any existing building could be able to retracted without harming the original structure when treating listed building retrofit; (2), designers could consider possible further or alternative functions non-domestic buildings could serve in the design stage. With both design cases not fitting to the proposed situation, this principle is not tested in the study.
- Principle 8, Reinforce the position in the community. This principle should be highlighted in the early planning stages to guide distribution of funds and development proposals. The conservation and enhancement proposal should be assessed from the point of view of the settlement in the community: it should not harm the role of the regional centre or rural service centre that the settlement serves. This principle is not only applicable to quality and quantity of public buildings and infrastructures which is not related to the study; it also covers boosting of local economy, and the population, which are partially tested in the new-build case. Finding in design reveals the establishment of new dwellings in the centre of a historic settlement may attract new population, then boost economy for the small historic settlement.
- Principle 9, Strengthen the historic core. The principle should also be listed in the planning stage to guide planning scheme and development proposals. It refers to reinforcement of the identity of a historic settlement and sense of place, through preservation and restoration of key buildings or a group of buildings as central points in a settlement and public spaces to enhance the core. In details,

the principle covers public areas, infrastructures, blur areas, and design with variations. Through design, it has been observed that this principle is partially tested in domestic new-build case for its improvement of a blur area.

Aside from above principles, principle 4, *guide and justify inevitable interventions*, appears overlapped with other two principles, thus could be combined with the others. Listed as a key conservation principle by English Heritage and Cadw, the guideline defines principle 4 as 'decision about change must be reasonable, transparent, and consistent' (Cadw 2011, English Heritage 2008). However, through the test, it appears to be overlapped with principle 2 '*conservation to elements with high sensitivity'* and principle 7 *'sustain all resources in the historic settlement'*. Under the guidance, assessment and evolution of all tested design proposals are achieved through fulfilling all other principles, especially 2 and 7. In the meanwhile, similar increase and drop patterns are found for principle 2, 4, and 7 through all tests, depending on their conservation observing conditions. It is assumed this principle could be combined to principle 2 and 7.

The modified lists of conservation principles are:

1. Define characters and significant of the place;
2. Non-renewable assets: conservation to elements with high sensitivity;
3. Reinforce the boundaries of the settlement;
4. Design with flexibility;
5. Assess all interventions after construction;
6. Sustain all resources in the historic settlement;
7. Reinforce the position in the community;
8. Strengthen the historic core.

By correcting and adopting all conservation principles into the full planning and design procedures, their new distributions are shown as follows:

Table 24: The application of conservation principles in planning and design procedure in the historic settlement

Identification stage:	
Townscape study & mapping	Principle 1: Define characters and significant of the place;

Planning stage:	
Town planning & Proposal of planning scheme	Principle 3: Reinforce the boundaries of the settlement; Principle 7: Reinforce the position in the community; Principle 8: Strengthen the historic core;
Design stage:	
Site planning (if applicable) & Design	Principle 2, non-renewable assets: conservation to elements with high sensitivity. (higher priority) Principle 6, sustain all resources in the historic settlement. (higher priority) Principle 4, Design with flexibility (if applicable)
Construction and post-construction stage:	
Construction & Occupancy permit application	Principle 5, assess all interventions after construction.

The point-based evaluation system is also revised and divided into four stages that represent different phases of design process. The weighting of points given to each categories has been re-evaluated to reflect the importance in the hierarchy of decisions from strategic planning given the highest level to post-occupational given the lowest level. Equally combined points are rewarded to some combined principles.

Table 25: Revised point-based framework in conservation aspect

Criteria	**Available Credits**	**Credits**	**Comments**
Identification stage:			
Conservation:			
1 Define characters and significant of the place			
Townscape study	12		
Mapping	10		
Planning stage:			
Conservation:			
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3		
Create consistent streetscape	2		
Repeat building character and pattern	2		
Establish a few key buildings at the boundary	3		
7 Reinforce the position in the community			

Infrastructures	4		
Attraction of new populations	2		
Economic boost	2		
8 Strengthen the historic core			
Public spaces	4		
Infrastructures	2		
Varieties	2		
Reduce areas with blur image	2		
Design stage:			
Conservation:			
2 Non-renewable assets			
Conservation to elements with high sensitivity	9		
Guide and justify inevitable interventions	8		
4 Design with flexibility			
Design could be revised or retracted	2		
Ability of fitting other functions	2		
6 Sustain all resources in the historic settlement			
Materiality	1		
Building pattern	2		
Building details	1		
Craftsmanship	1		
Landscape	1		
Vegetation	1		
Construction and post-construction stage:			
Conservation:			
5 Assess all interventions after construction	6		
Total conservation points	84		

8.2.3 Findings on the performance principles

Through a townscape study (see 5.5) and design case studies (as shown in 6.8 and 7.8), there are some findings relating to performance principles: six principles guide the creation of low carbon consumption, low environmental impact building in which the interior environment emphasises the occupants' comfort. Under strict conservation guidance especially in retrofit cases, the overall performance credits could be held in a stable rate through design strategies. Tests reveals design variations with low energy performance credits could use high scores in renewal energy to offset some loss. The simulated carbon emission of these variations may still under the target emission rate. Findings also reveal that there are extra limitations on engaging performance enhancement in retrofit cases than new building cases within the conservation area. When designing new buildings, architects may have more freedom to unite performance principles together with other criteria, through design. To maximise the efforts of carbon cutting, these principles should be involved at the early conceptual design stage. Principles in performance-based code for sustainable buildings now guide designs of new buildings as a mandatory requirement; and the carbon deduction solutions are no longer based only on a single building instead of on a community scale. In the conservation area of a historic settlement, if conflicts occur between performance rules and conservation principles 2 and 7 (as a priority), higher tier conservation principles must be followed, while architects may use other design strategies to improve the overall building performance and to ensure the target carbon emission rate be met through design.

Building performance is now on a par with conservation and in some ways may be seen to occupy the ethical high ground.

- Principle 1, *Building energy performance*. The findings of the retrofit design reveal that the enhancement of building energy performance and airtightness could be fulfilled under restrictions in conservation; although, there may be strong limitations on passive design depending on the building's orientation and degree of sensitivity on its south elevation, as tested through retrofit variation 2 and 4. It is easier to create constant and solid insulation and to apply passive design in new buildings at the planning stage. Within an established site plan or geographic condition, there are potential conflicts between good energy performance and preservation on the streetscape of the settlement, as shown in the new-build design variation 3 and 4. As shown in retrofit case variation 4 and new-build case variation 4, in order to achieve best passive design result, design may lay impact to visual images of the building and the street frontage. In retrofitting design, it might be difficult to retrofit insulation internally in some circumstances; however, insulating externally may bring faults to the building itself and impacts to the overall image of the settlement, as shown in the English Heritage (2014) reports. Therefore, this principle should be carefully evaluated based on the appraisal at early design stage under the preservation principles.

- Principle 2, *Energy efficiency*. This principle contains the energy efficiency of heating and cooling systems, boilers, HVAC, lighting, all other appliances, and occupants' behaviour when using these appliances and their basic sustainable knowledge. Same as most other performance principles, energy efficiency should be reviewed at early design and site planning stage for retrofit and new designs. Findings from design practices reveals there are more limitations on selecting and fitting suitable and energy efficient heating and cooling systems or boilers in retrofit cases than new-build cases. For the small site or areas in mid-high density, centralised heating and hot water supplement could be a solution, with special treatment on pipe insulation and heat loss at planning stage. Findings through all tests reveals this principle could be combined with principle 1 building energy performance in the evaluation system. Both principles target on different aspect of the building, but are complementary in rating. As shown in retrofit case variation 1, 3, 4 and all new-build case variations, buildings with less credits on energy performance are likely to have a high energy efficiency score, e.g. using high energy rating heating and boiler to offset point loss on passive design.
- Principle 3, *Carbon emission*. This principle contains three key elements of airtightness, carbon emission during construction period, and occupant's behaviour, covering stages from design to post-construction. In the study, SAP is employed to simulate carbon emission rate based on design proposals related to principle 1, 2 and 4. Both retrofit and new-build cases show the target carbon

emission rate could be met under slight alterations of design strategies, even under the condition of obeying all conservation principles in higher priority. Therefore, it is possible to fit the entire historic settlement into a tight agenda of carbon reduction based on the government's White Paper on Energy. A question about cost is also raised through design. According to 'EnerPHit Standard' (Passivhaus Trust 2016), it is highly likely that a big financial premium will be generated when undertaking 'deep' retrofitting of older buildings for carbon reduction; the cost might exceed new build in some circumstances (Antonelli 2012).

- Principle 4, *Alternative renewable energy*. Findings from all designs reveal the larger site has greater potential and flexibility for installing renewable energy, as shown in the new-built case; while for a single building or a tight site, the introduction of alternative energy will be restricted from conservational principles and spaces, such as the retrofit case. New elements from renewable energy also lay visual impacts on the characteristics of the building and streetscape, as proved in all designs. Introducing renewable energy must be carefully verified at planning and design stage regarding visual impact and exposure of new elements. In the study, the street frontage was evaluated with higher sensitiveness to new elements, therefore, installations were located at all rear roofs to avoid direct visual exposure. In order to fit the entire historic settlement in the tight carbon emission band, centralised heating and hot water supplement consuming new energy source could be a solution for small sites or mid-high density areas, with special treatment on pipe insulation and heat loss at site planning stage, as shown in the new-build case. It could also guide advanced town-scale carbon cutting scheme in the town planning stage under certain conservation rules.
- Principle 5, *Occupants' comfort*. This principle shares similar findings as principles 1. In the retrofit designs, the fulfilment of the principle is restricted by the conservational principles at a higher level, affecting the original building's physical condition, and the orientation of the site; while new

buildings could more easily create a high standard building interior. One consequence of retrofitting insulation and adding airtightness is the threat of condensation and mould (The Scottish Government 2012), which might affect occupant's wellness. This involves collaborative work from both architects and environmental engineers since design stage.

- Principle 6, '*Post-construction' assessment*. This principle covers all physical components related to building environment, which is a final assessment and evaluation of all principles before occupancy. It is important that users' educations on system operation and basic sustainable knowledge must be done at this stage as well. Occupant's behaviour is also a curial condition affecting building carbon emission in use.

The refined lists of performance principles are:

1. Building energy performance and efficiency;
2. Carbon emission;
3. Alternative renewable energy;
4. Occupants' comfort;
5. 'Post-construction' assessment.

By correcting and adopting all performance principles into the full planning and design procedures, their new distributions are shown as follows:

Table 26: The application of performance principles in planning and design procedure in the historic settlement

Identification stage:	
Townscape study & mapping	
Planning stage:	
Town planning & Proposal of planning scheme	Principle 3, Alternative renewable energy;
Design stage:	
Site planning (if applicable) & Design	Principle 1, Building energy performance and efficiency; Principle 3, Alternative renewable energy; Principle 4, Occupants' comfort;
Construction and post-construction stage:	

Construction & Occupancy permit application	Principle 5, 'Post-construction' assessment; Principle 2, Carbon emission.

The point-based evaluation system is also revised and divided into four stages that represent different phases of design process. The weighting of points given to each categories has been re-evaluated to reflect the importance in the hierarchy of decisions from strategic planning given the highest level to post-occupational given the lowest level.

Table 27: Revised point-based framework in conservation aspect

Criteria	**Available Credits**	**Credits**	**Comments**
Identification stage:			
Planning stage:			
Performance:			
3 Alternative renewable energy			
Solar hot water	1		
Alternative heating (example: ground source heat pump)	2		
Electric generation (example: photovoltaic)	2		
Design stage:			
Performance:			
1 Building energy performance and efficiency			
Building position and orientation	1		
Building layout	2		
Passive design	3		
U-value of building envelope	3		
Natural lighting	1		
Ventilation	1		
Solar gain	1		
Solar protection	1		
Heating and cooling system	2		
Boilers and hot water	2		
All other appliances	2		
HVAC systems	1		
User's behaviour	1		
Lighting	1		
3 Alternative renewable energy			

Solar hot water	1		
Alternative heating (example: ground source heat pump)	2		
Electric generation (example: photovoltaic)	2		
4 Occupants' comfort			
Indoor pollutants	1		
Comfortable temperature (around 25°C)	1		
Ventilation	1		
Daylight	1		
Full insulation without drought	1		
Construction and post-construction stage:			
Performance:			
2 Carbon emission			
Airtightness	1		
Carbon emission during construction period (example: demolition, material delivery)	2		
User's behaviour	1		
5 Construction quality and post-construction assessment			
Insulation	1		
Heating and cooling system	1		
Boilers	1		
All other appliances	1		
Airtightness	1		
Treatment of droughts	1		
Total performance points	47		

8.2.4 Discussion

Drawn from design studies and findings, two domestic cases undertook in Llandeilo are probably a good reflection of reality in relating to the conflicts between conservation and performance. Hence, two hypothetic variations in reversed geographic condition are addressed to ensure the comprehensive evaluation and appraisal of the hypothesis. In most current circumstances, designers are mainly responsible for identifying the value of the environment and the buildings. In the study, the author, from the view of an architect, assesses elements with high sensitivity at both the building and the settlement scale for each design; and all design approaches are selected under the author's best knowledge background from both conservation and performance aspect, to balancing and bridging conflicts between conservation and performance.

Approaches rooted in conservation may restrict creative design, plus setting barrier to the enhancement of building performance, especially for building envelop. Take the typical English terrace as an example, its conservational solid building façade with single-glazed sash window are one of the majority cause of large winter energy bills, because the building could not obtain enough solar gain on a sunny winter day while constantly loss heat through single-glazed windows. In the tests, all design works are created under careful evaluation of building and settlement's conservation value. Strict conservation rules are only applicable to these essential elements rather than all historic components. Comparing between retrofit design variation 2 and 4, higher conservation rules may establish harsh barrier to building performance, especially in a site without geographic benefit. Introductory of renewable energy or applying energy efficient boiler are employed in the tests as the back-up plan in the study to offset excessive carbon emissions. These restrictions from conservation aspects are normally less obvious in new built works rather than retrofit projects.

On the contrary, approaches rooted in performance may harm the distinctiveness of the building and the place, hence jeopardise the conservation scheme. For instance, some components from renewable energy, such as photovoltaic discussed several times in the study, may hard to merge into a historic streetscape in high visual exposure. In retrofitting cases, some approaches on improving building envelope are addressed on existing building envelope, which may alter some essential elements and appearance of building façade.

8.2.5 The model

In the context of the findings and discussions above, it was revealed that all principles have variable priority depending on the planning and design procedures.

Conservation principles have traditionally dominated all intervention activities in the historic settlement; however, the intensity of some less significant principles might reduce if the significance hinges only on a past tradition of historical fact. This is where place may be considered over historic facts. In the design tests, the street frontage in the conservation zone has higher sensitivity subjecting to change, because it is directly linked to the maintenance of streetscape, therefore the place. Compared to the street frontage, back elevation of the building and high level roof location without direct visibility from the street could be upgraded to fulfil low carbon fitting or enhancement. Design approaches such as upgrade windows, create conservatory, and admitted rooflights are applied whilst conserving the original building envelopes. Conservation principles are vital in the identification and town planning stage when regenerating a historic settlement.

Performance principles are direct solutions and strategies to achieve environmental sustainable and low carbon emission in both building and settlement scale. The code for sustainable buildings are now tightened the band for carbon emission in world wildly. By adopting these principles in collaboration with conservation rules, the historic settlement may have the chance to meet tight carbon emission target in the near future. Performance principles mostly guide the project in design, construction, and post-construction stage; however, employment of renewable energy may happen at town planning stage.

Architects play an important role in enhancing conservational practices, notably by assisting collaboration between two. Architects support detailed methods and strategies to bridge the limitations in conservation principles. Meanwhile, architects utilise performance principles, representing them through design according to more complex conservation rules.

The model has been revised and divided into four categories that represent different phases of the design process. The weighting of points given to each of the categories has been re-evaluated to reflect the important in the hierarchy of decisions from strategic planning given the highest level to post occupational given the lowest level.

The model can be represented as follows:

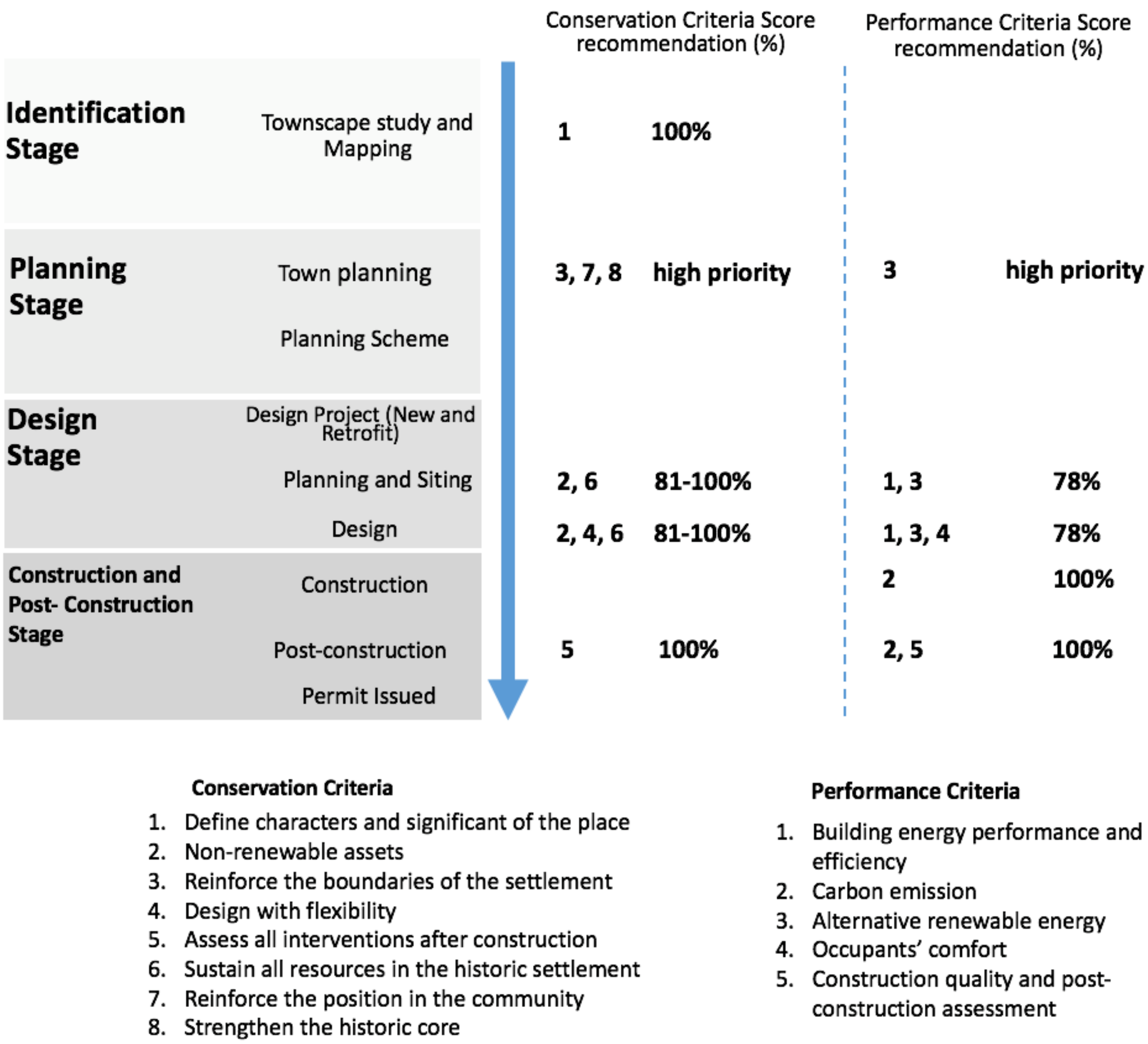


Figure 179: Model for creative design embracing conservation and environmental sustainable in the historic settlement

In order to guide the full planning and design procedure in the historic settlement, all principles are categorised into five stages, based on their hierarchy and significance:

Firstly, in the identification stage, it is important to identify the significance, character and identity of the settlement through townscape study and mapping, guided by conservation principle 1. The findings and result in this stage will be used to support all following stages. A fulfilment of 100% for principle 1 is recommended as shown in Chapter 5.

Having successfully passed the identification stage, at the planning stage, all development and enhancement proposals will be reviewed according to conservation principles 3, 7, 8 and performance principle 3. Proposals fulfilling these principles will have a higher priority in terms of approval. Planning scheme should also be reviewed and amended according to above principles.

Moving into the design stage, the design procedure is split into two steps: (1). In the planning and siting step, designers would follow two conservation principles in a priority (principle 2 and 6), and two performance rules (principle 1 and 3). (2). In the design step, three conservation principles (principle 2, 4, and 6) plus three performance rules (principle 1, 3, and 4) are employed to guide the practice. In the design stage, recommended achievement rating for conservation principles is 100% as shown in retrofit variation 1, 2 and new-build variation 1, 2. If the rate drops lower than 81% as retrofit variation 3, the design proposal might impact the significant of the place. It is suggested a rate over 78% could be reached for performance principles to ensure the final carbon emission and user's comfort, see retrofit variation 1,3 and all new-build variations.

At the construction and post-constriction stage, performance principle 2 is employed to guide construction works, with a recommended 100% completion.

All established projects must undertake the post-construction evaluation based on conservation principles 5 and performance principle 2 and 5, with a recommended 100% completion for all principles.

The intensity of these principles will reduce as the site moves further away from the historic core.

The completion rate of all principles will be calculated according to the point-based framework which is part of the assessment tool. The point-based design matrix is also revised into four stages, given re-evaluated weighting of points:

Table 28: Revised point-based framework

Criteria	**Available Credits**	**Credits**	**Comments**
Identification stage:			
Conservation:			
1 Define characters and significant of the place			
Townscape study	12		
Mapping	10		
Planning stage:			
Conservation:			
3 Reinforce the boundaries of the settlement			
Maintain the unique character of the conservation area	3		
Create consistent streetscape	2		
Repeat building character and pattern	2		
Establish a few key buildings at the boundary	3		
7 Reinforce the position in the community			
Infrastructures	4		
Attraction of new populations	2		
Economic boost	2		
8 Strengthen the historic core			
Public spaces	4		
Infrastructures	2		
Varieties	2		
Reduce areas with blur image	2		
Performance:			
3 Alternative renewable energy			

Solar hot water	1		
Alternative heating (example: ground source heat pump)	2		
Electric generation (example: photovoltaic)	2		
Design stage:			
Conservation:			
2 Non-renewable assets			
Conservation to elements with high sensitivity	9		
Guide and justify inevitable interventions	8		
4 Design with flexibility			
Design could be revised or retracted	2		
Ability of fitting other functions	2		
6 Sustain all resources in the historic settlement			
Materiality	1		
Building pattern	2		
Building details	1		
Craftsmanship	1		
Landscape	1		
Vegetation	1		
Performance:			
1 Building energy performance and efficiency			
Building position and orientation	1		
Building layout	2		
Passive design	3		
U-value of building envelope	3		
Natural lighting	1		
Ventilation	1		
Solar gain	1		
Solar protection	1		
Heating and cooling system	2		
Boilers and hot water	2		
All other appliances	2		
HVAC systems	1		
User's behaviour	1		
Lighting	1		
3 Alternative renewable energy			
Solar hot water	1		
Alternative heating (example: ground source heat pump)	2		
Electric generation (example: photovoltaic)	2		
4 Occupants' comfort			
Indoor pollutants	1		

Comfortable temperature (around 25˚C)	1		
Ventilation	1		
Daylight	1		
Full insulation without drought	1		
Construction and post-construction stage:			
Conservation:			
5 Assess all interventions after construction	6		
Performance:			
2 Carbon emission			
Airtightness	1		
Carbon emission during construction period (example: demolition, material delivery)	2		
User's behaviour	1		
5 Construction quality and post-construction assessment			
Insulation	1		
Heating and cooling system	1		
Boilers	1		
All other appliances	1		
Airtightness	1		
Treatment of droughts	1		
Total	131		

CHAPTER NINE: FURTHER WORK

9.1 Introduction

This chapter concludes the thesis by reflecting on the outcomes of this study and suggesting recommendations for further work.

9.2 Conclusion

In conclusion, this thesis has revealed that principles from two agendas of conservation and performance, could be integrated in a certain order through architects, to reconcile conservation and enhancement in a historic settlement. Furthermore, a model for embracing conservation, enhancement, and environmental sustainability illustrates how the gaps and limitations in two aspects can be bridged through design.

By discussing all the findings, tracing overlaps, gaps, and duplications in in the proposed model, and representing them through a rewriting and rearrangement into four stages, the new model (see Figure 180) was created to guide planning and design procedures in the historic settlement. The first stage of identifying comprises key principles to help the designer to identify the significance of a settlement and to maintain it. Once the first stage is successfully passed, in the next stage of planning, three conservation principles and one performance criterion are set up to guide the distribution of development funding and the formation of planning scheme. During this stage, projects that may reinforce the edge, strengthen the core, or establish whether new infrastructures will be given priority in terms of approval. On the foundation of not affecting significance of the settlement, town-scale schemes on installation renewable energy could also be assessed and verified. The third stage is design, which includes two sections of planning and design, three conservation principles and two performance rules may guide this stage repeatedly to ensure the quality of the design and its capacity to meet contemporary standards and carbon emissions targets. At the construction stage, one performance principle is employed to monitor the construction process. After these four stages, the established project must then undertake a post-construction evaluation based on two performance principles and one conservation rules to evaluate the final result before occupancy permit is issued.

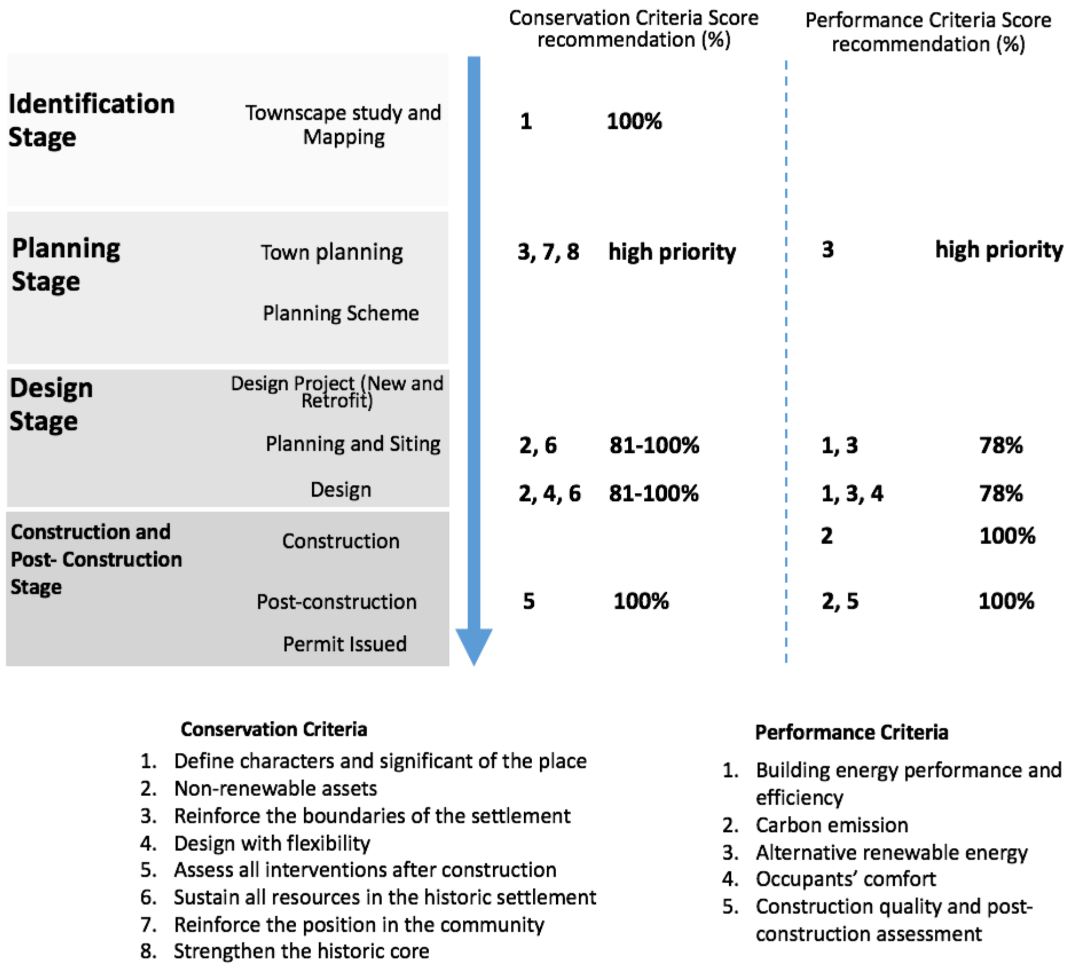


Figure 180: Model for creative design embracing conservation and environmental sustainable in the historic settlement

The study was developed from a new into old study, inspired from Caminada's designs and the distinctive image of small English and Welsh historic towns. The insensitive development of these towns resulting in the crushing of the historic atmosphere together with a sense of place which prevailed in the post-war period in Britain partly inspired the conservation movement. Whilst this movement has now been able to mitigate against the worst of poor design in the cores it has not promoted an effective way to design for enhancement. Most recently large scale peripheral development has added new problems. Cullen in 'The Concise Townscape' (1960) responded by introducing theories of Townscape as a framework for analysis and design. In addition the need to respond to climate change has added further to meet low carbon emission targets. In the context of this study, the conservation and enhancement of a historic settlement requires collaborative work from conservationists, architects, and environmental engineers, due to the limitations in each group.

It was found that all reviewed legislations, principles, frameworks and guidelines have two gaps: firstly, there is a lack of detailed and practical methods to justify and guide interventions in the historic settlement. In the second place, they failed to give full gravity to environmental sustainability particularly in reference to carbon reduction during the conservation process. In particular, effective siting and positioning of renewable technologies needs attention and this was an area that proved difficult to test through the design case studies. This study might fill in the missing sections by providing possible methods and introducing performance principles into the conservation process.

9.3 Further work

The thesis has produced several findings through testing the model in the author's design from the perspective of the architect. However, further work involving the collaboration of conservationists, planners, architects, and environmental engineers to test the new model beyond the limitations of this study would further benefit current legislation.

The model for characterisation studies adopted by official bodies such as CADW and English Heritage (conservation led) whilst historically authoritative, in particular was discovered to be too narrow to contribute effectively in meeting the aims of enhancement of place and sustainability. It was realised during the study process, that fully understanding a place together with its key components, is a broad scale challenge; and there is more exploration of space and methods needed to accurately identify and capture the image of a historic settlement. The study employed Conzen's analysis method through mapping and Cullen's serial vison and analytical sketching. Norberg-Schulz's description of the understanding of the atmosphere of a place demands experience of a large number of settlements with a great variety of patterns, layout, and building characteristics. This involves additional investment in terms of both time and cost.

One potential use of the research would be to suggest that the changes to characterisation studies mentioned above could also be followed by a study for historic settlements which based on the analysis might provide a framework of code for design.

The conservation of a historic settlement has profound social and economic benefits, which are also linked to the preservation of place. Methodological limitations affect the depth to which sustainability studies have been taken but even so these reveal the impact that goals for sustainability can have on aspects of conservation. More early stage robust and used friendly assessment techniques are needed so that settlement scale predictions can be made. The research shows that the range of techniques needed for integral design are broad and are currently not possessed by one professional group. There are established courses on sustainable building conservation to fill gap between preserving the historic context and sustainable design (WSA MSc course) in building scale, by offering design technique and strategies; further explorations on the settlement scale is still absent, together with skills in identification of place and place-making.

The study stops short of calculations about cost, including construction costs and the cost of introducing alternative renewable energy to achieve carbon reductions, again due to time limitations. The author did become aware through the study, however, how difficult it is to find reliable guidance on costs; and further work on this aspect might provide a clearer outline of the potential implications of achieving these low carbon results.

The study only tests the model through two domestic building cases, due to time and knowledge limitations on correct energy assessment method may applied to evaluation the carbon emission. Although some design practices and works related to non-domestic cases has been done during the study, the result may not be assessed and evaluated in a precise and robotic way without a final carbon emission simulation. With joining of non-domestic buildings, some conservation principles might be tested more comprehensively. It is also estimated severe conflicts between two agendas may exist with non-domestic buildings. Further work on this aspect might provide a broad test of the model.

The proposed model in Chapter 8 covers five common objectives in designing a design code, that is distinctive places, continuity and coordination, public realm quality, creative interpretation, and sustainable design. Although not be called as a design code at this stage, it could be developed to a design code with more detail restrictions on both street and block level and building level, such as some sub-point used in the rating system. More elements need to be added as well to finalise a design code, such as drawings, diagrams, tables, etc. The model delivered in the study could also be used to influence or guide current design coding when encounter small historic settlement.

REFERENCES:

Archer, B. (1995 January). The nature of research. Co-design, Interdisciplinary Journal of Design, pp. 6-13.

Allen, K. (2006), Driven by necessity, Inside housing, year 2006, issue 37.

Ashworth, G. J. & Larkham, P. J. (ed) (1994). Building a new heritage: Tourism, Culture and Identity in the New Europe, London, Routledge.

Asquith, L. (Editor) & Vellinga, M. (Editor). (2006). Vernacular Architecture in the Twenty-First Century: theory, education, and practice, Oxon, Taylor & Francis

APPLEYARD, D. (1979). The Conservation of European Cities, MIT Press.

ASHWORTH, G. J. (1997). Struggling to control the past, Tourism concern.

Aston, M. & Bond, J. (1976). The landscape of Towns. Dent.

Acts of Parliament (1967). The Civic Amenities Act (1967). The Stationary Office.

Acts of Parliament (1990). Planning (Listed Building and Conservation Areas) Act (1990). The Stationary Office.

Antonelli, L. 2012, EnerPHit - The passive house approach to deep retrofit, on Green building blogs, http://www.greenbuildingadvisor.com/blogs/dept/green-building-blog/enerphit-passive-house-approach-deep-retrofit

Bertram, P. (2010). Evidence of material difference. Copenhagen: Institute of Design and Communication, The Royal Danish Academy of Fine Arts, School of Architecture.

Beresford, M. (1988) New towns of the middle ages: town planation in English, Wales and Gascony, Sutton Pub Ltd.

Borgdorff, H. (2007). The debate on research in the arts, Dutch journal of music theory, year 2007, volume 12, number 1.

BRE Trust. (1993). BRE housing design handbook: energy and internal layout, Watford, Building Research Establishment.

BRE Trust. (1993). BRE housing design handbook: energy and internal layout, BRE.

BRE Trust. (2006). Sustainable refurbishment of Victorian housing, Bracknell, IHS BRE press.

BRE Trust. (2006). Part L explained – The BRE guide, Bracknell, IHS BRE press.

BRE Trust. (2006). Sustianable refurbishment of Victoria housing, BRE Press.

BRE Trust (2006). BREEAM Schools 2006: Pre-assessment estimator, BRE Press.

BREEAM (2008). BRE Environmental & sustainability standard (BES 5051 issue 3.0), BRE Press.

BRE Trust. (2012). Lessons learned from community-based microgeneration projects: the impact of renewable energy capital gain schemes, Bracknell, IHS BRE press.

Banks, N. (2008). Implementation of Energy Performance Certificates in the Domestic Sector. UKERC

Cadw. (2011). Conservation Principles: for the sustainable management of the historic environment in Wales. Cadw.

Cadw. (2013). Aberystwyth: Understanding Urban Character. Cadw.

Cadw. (2013). Condition & Use Survey of Listed Building in Wales (2013 Update). Cadw.

Cadw. (2013). Historic Environment Strategy for Wales: headline action plan. Cadw.

Cadw. (2013). Historic Environment Strategy for Wales. Cadw.

Cadw. (2014). Cefn Mawr and District: Understanding Urban Character. Cadw.

Cadw. (2015). Merthyr Tydfil: Understanding Urban Character. Cadw.

Cadw. (2015). Pembroke: Understanding Urban Character. Cadw.

Cadw. (2015). Strategic Action Plan for Historic Places of Worship in Wales. Cadw

Cadw. (2016). Llangollen: Understanding Urban Character. Cadw

Cadw (2009). Aberdare: Understanding Urban Character. Cadw.

Cadw (2011). Blaenau Ffestiniog: Understanding Urban Character. Cadw.

Cadw (2010). Caernarfon Waterfront: Understanding Urban Character. Cadw.

Cadw (2010). Denbigh: Understanding Urban Character. Cadw.

Cadw (2009). Dolgellau: Understanding Urban Character. Cadw.

Cadw (2009). Flint: Understanding Urban Character. Cadw.

Cadw (2012). Pontypool: Understanding Urban Character. Cadw.

Chapman, D. & Markham, P. J. (1992). Discovering the art of relationship urban design, aesthetic control and design guidance. University of Birmingham City.

Carmona, M. 2009. Design Coding and the Creative, Market and Regulatory Tyrannies of Practice. Urban Studies. London

Congress For the New Urbanism, (1999). Charter of the New Urbanism. McGraw-Hill Professional. https://www.cnu.org/who-we-are/charter-new-urbanism

Candy, L. (2006). Practice Based Research: A Guide, CSS Report. Sydney: University of Technology.

Coombs, S. (2015) The development of the building envelop using Welsh-grown timber: A study through prototyping. WSA, Cardiff University.

Cullen, G. (1959). Gordon Cullen interviewed by Sue Pechey in the Cultural context of unemployment oral history project [sound recording].

Cullen, G. (1961). The Concise Townscape. Oxford, The Architectural Press.

Cullen, G. (1974). Vivat Ware: Strategies to Enhance a Historic Centre, East Hertfordshire District Council.

CANIGGIA, S. M. A. G. (1986). L'approche morphologique de la ville et du territorie, Zurich, Eidgenossische Technische Hochschule.

Carlo, G. D. (1970). 'Una precisazione', Casabella Continuita.

Caminada, G (2007). Meaningful Architecture in a Globalised World. In: Hagen Hodgson, P. & Toyka, R. (Editor) The Architect, the cook and good taste', Birkhäuser Basel.

Caminada, G. A. (2008). Gion A. Caminada, Denkmalstr, Luzeern, Quart Verlag GebH.

Carmarthenshire County Planning Department. (1972). Llandeilo Conservation Area: appraisal and recommendations. Carmarthenshire County Planning Department.

Civic Trust (1980a) 'Legislating for enhancement: the Trusts' greatest Act', Civic Trust News. p. 4

Civic Trust (1980b) Local Government Planning and Land Bill, Civic Trust News 77.

Civic Trust (1988) 'The Lord Duncan-Sandys, CH', Planning Outlook 8. pp. 2-3.

Collins Dictionaries (1988). Collins English Dictionary. London and Glasgow, Collins.

Carter, H. (1965). The towns of Wales: a study in urban geography, Univeristy of Wales Press.

Cuthbert, A. R. (2011). Understanding cities: method in urban design, London, New York, Routledge.

Conzen, M.R.G. (1960) Alnwick, Northumberland: a study in town-plan analysis, Publication No. 27, Institute of British Geographers, London.

Conzen, M.R.G. (1962) `The plan analysis of an English city centre', in Norborg, K. (ed.) `Proceedings of the I.G.U. symposium on urban geography, Lund, 1960', Lund Studies in Geography B vol. 24 pp. 383-414

Conzen, M.R.G. (1968) `The use of town plan analysis in the study of urban history', in Dyos, H.J. (ed.) The study of urban history Leicester University Press.

Conzen, M.R.G. (1978) Analytical approaches to the urban landscape, in Butzer, K. W. (ed). Dimensions of human geography, University of Chicago Department of Geography Research.

Conzen, M.R.G. (1988) `Morphogenesis, morphological regions and secular human agency in the historic townscape, as exemplified by Ludlow', in Denecke, D. and Shaw, G. (eds) Urban historical geography Cambridge University Press, Cambridge.

Disch, P. & CH, N. (ed) (1994). Luigi Snozzi: Construzioni e Progetti – Buildings and projects, ADV Publishing House.

Department for Communities and Local Government. (2008). Definition of zero carbon homes and non-domestic buildings. Communities and Local Government Publications.

Department for Communities and Local Government. (2010 November). Code for sustainable homes: technical guide. RIBA Publishing.

Department for Communities and Local Government, (2011 July). Zero carbon non-domestic buildings, DCLG Publications.

Department for Education and Employment (DfEE), (1999). Building bulletin 90: Lighting design for schools, Crown.

Department for Education and Employment (DfEE) (1999). Building bulletin 99: Briefing Framework for Primary School Projects, Crown.

Department of Environment, Transport, Regions (DETR) (2000). Our towns and cities: the future, delivering an urban renaissance. Crown.

DfES (2003) Building schools for the future: Consultation on a new approach to capital investment, Crown.

Department for Environment, Food and Rural Affairs (2009). Guidance on how to measure and report your greenhouse gas emissions, Crown.

Department for Communities and Local Government. 2006. Preparing Design Codes: A Practice Manual. RIBA Publishing. London

Department for Communities and Local Government. 2006. Design Coding in Practice: An Evaluation. The Bartlett School of Planning, UCL. London.

Dobby, A. (1978). Conservatio and Planning. London, Hutchinson & Co Limited.

DRW-R, LCRI. (2013). Learning. Welsh School of Architecture.

Dyfed Cultural Service Department & The national Library of Wales (1991). Llandeilo, Llandovery and The upper Tywi Valley: in old photographs. Alan Suttton Publishing Ltd.

D'Avoine, P. & Melhuish, C. (2005) Housey Housey: a pattern book of ideal homes, Black Dog Publishing Limited.

Der Bundesrat (2013). Bundesgesetzblatt Jahrgang 2013 Teil I Nr. 67, ausgegeben zu Bonn am 21. November 2013. Berlin.

English Heritage. (2008). Conservation Principles, Policies and Guidance: for the sustainable management of the historic environment. English Heritage.

English Heritage. (2011, revised in 2012). Understanding Place: Character and context in local planning. English Heritage.

English Heritage. (2010, revised in 2012). Understanding Place: Historic area assessments in a planning and development context. English Heritage.

English Heritage. (2010). Understanding Place: Historic area assessments: principles and practice. English Heritage Publishing.

English Heritage. (2013) Strategic Environmental Assessment, Sustainability Appraisal and the Historic Environment, English Heritage Publishing.

English Heritage (2014), External wall insulation in traditional buildings: case studies of three large-scale projects in the North of England, English Heritage Publishing.

English Heritage. (2015) The setting of Heritage Assets: Historic environment good practice advice in planning: 3 English Heritage Publishing.

Edwards, B. (2005). Rough Guide to Sustainability. RIBA Enterprises Ltd.

Environment, Community, and Local government. (2011). Building Regulation 2011: Technical guidance document L. Conservation of fuel and energy – dwelling. The stationary office.

East Suffolk County Council. Planning Dept. (1970). Conservation in Bungay : townscape appraisal and policy statement. East Suffolk County Council (County Planning Department)

FETHI, I. (1993). Conservation in the Islamic world: current practice and critical lessons. In: BARAKAT, S. (ed.) Architecture and Development in the Islamic World. York: Pre-publication

Forest, W. & Heal, A. (2009). Low Carbon Retrofit: solutions for a holistic optimal retrofit (SHOR) – 1980s urban semi-detached house. RIBA Publication

Forster, W., Heal, A. & Thomas, R. (2007 June). Building simply: challenges and dilemmas. Architecture Research Quarterly, Volume 11, issue 02, pp. 138-150

Friedman, Avi. (2012). Fundamentals of sustainable dwelling, NW, Washington, DC 20009, Island Press.

Feneley Studio. 2011. Cadogan Terrace. http://www.feneleystudio.com

Friedman, Avi. (2014). Planning small and mid-sized town: designing and retrofitting for sustainability, Abingdon, Oxon, Routledge.

Friedrich, P. J. (2007). "Liugi Snozzi – Monte Carasso." from http://www.bopitz.de/theorie.html.

Frearson, A. (2013). 'Slim House extension by Alma-nac' from http://www.dezeen.com/2013/02/02/slim-house-extension-by-alma-nac/

Fallen, D. (2005). Why Research-oriented design isn't design-oriented research, Umea University.

GAUZIN-MULLER, D. (2002). Sustainable architecture and urbanism - concepts, technologies, examples. Birkhauser publishers for architecture.

GIROUARD, M. (1990). The English Town -- A History of Urban Life, New Haven and London, Yale University Press.

Grant, Jill. (2006). Planning the Good Community: New Urbanism in Theory and Practice, Oxon, Routledge, Taylor & Francis

Glenn Howells Architect (2011). The triangle project. From http://glennhowells.co.uk

Heal. A (2010). Building Simply: an investigation into the potential for building simply in the UK. Welsh School of Architecture, Cardiff University.

Heriot-Watt University, School of the Built Environment (2007) Design at the heart of house-building. The Scottish Government, Edinburgh.

HM Government. (2015). The Building Regulation 2010: Conservation of Fuel and Power Approved Documents L1A. NBS, Part of RIBA Enterprise Ltd, Crown copyright.

HM Government. (2015). The Building Regulation 2010: Conservation of Fuel and Power Approved Documents L1B. NBS, Part of RIBA Enterprise Ltd, Crown copyright.

HM Government. (2015). The Building Regulation 2010: Conservation of Fuel and Power Approved Documents L2A. NBS, Part of RIBA Enterprise Ltd, Crown copyright.

HM Government. (2015). The Building Regulation 2010: Conservation of Fuel and Power Approved Documents L2B. NBS, Part of RIBA Enterprise Ltd, Crown copyright.

HINDLE, P. (2002). Medieval Town Plans, Princes Risborough, Shire Publications Ltd.

Helbrecht, I. (Editor) & Dirksmeier, P. (Editor). (2012). New Urbanism: Life, Work, and Space in the New Downtown, Oxon, Routledge, Taylor & Francis

Hartman, H. (2011). The triangle, Swindon, Wiltshire, by Glen Howells Architects. AJ Year 2011, issue 11.

Hauberg, J. (2011) Research by Design - a research strategy, Architecture & education journal, year 2011, no. 5

Imrie, R. and Street, E. (2006) The attitudes of architects towards planning regulation and control. Project Paper No. 3, Papers in 'The Codification and Regulation of Architects' Practices', Kings College London.

Jacobson, M. Z. (2009). Review of Solutions to Global Warming, Air Pollution, and Energy Security.

Jones, P. & Alexander, D.K. (2001). Dayligh modeling: the sky dome, pages 1-2, Welsh School of Architecture.

KEINER, M. 2005. History, Definition(s) and models of sustainable development [Online]. ETH e-Collection. Available: http://e-collection.ethbib.ethz.ch/cgi-bin/show.pl?type=bericht&nr=416.

Katz, Peter. (1993). The New Urbanism: Toward an Architecture of Community. McGraw-Hill Education

Krier, L. (1984). "Critiques" and "Urban Components". In: LARICA, M. & Macdonald, E. (ed.) The Urban Design Reader. 3rd ed. Oxon: Routledge.

LARICA, M. (2007) Typology and Morphology in Urban Design. In: LARICA, M. & Macdonald, E. (ed.) The Urban Design Reader. 3rd ed. Oxon: Routledge.

Lavin, Sylvia. (1992). *Quatremère de Quincy and the Invention of a Modern Language of Architecture*, MIT Press.

Lloyd, T., Orbach, J. & Scourfield, R. (2006). Carmarthenshire and Ceredigion, in Pevsner Architectural Guide: Buildings of Wales, Yale University Press.

LOWENTHAL, D. (1996). Possessed by the past: the heritage crusade and spoils of history, London, Free Press.

Lowenthal, D. (1996). Possessed by the past: the heritage crusade and spoils of history. London, Free Press.

LYNCH, K. (1960). The Image of the City, Cambridge, Massachusetts, The MIT Press.

Larkham, P.J. (1999) `Organicism, evolution and urban form: on the problems of borrowing from other disciplines', Urban Morphology vol. 3 no. 1 pp. 49-51

Larkham, P.J. (1988b) `Changing conservation areas in the English midlands: evidence from local planning records', Urban Geography vol. 9 pp. 445-465

Larkham, P.J. (1990) Conservation and the management of historical townscapes, in Slater, T.R. (ed.) The built form of Western cities Leicester University Press, Leicester

Larkham, P.J. (1991) The changing urban landscape in historical areas Occasional Publication no 29, School of Geography, University of Birmingham

Mayer, H. & Knox, P.L. (2009). Small Town Sustainability - Economic, Social, and Envrionmental Innovation, Birkhauser Verlag AG.

McDonald, N & Laustsen, J (2013). A Comparative Analysis of Building Energy Efficiency Policies for New Buildings, Global Building Performance Network (GBPN).

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties. (2013). Integrale tekst van het Bouwbesluit 2012 zoals dit luidt met ingang van 1 juli 2013. Deze tekst is samengesteld uit de Staatsbladen 2011, 416; 2011, 676; 2013, 75 en 2013, 244.

Masser, I., Sviden, O. & Wegener, M. (1994). ‘What new heritage for which new Europe’ in Ashworth, J. L. and Larkham, P. J. (eds) Building a New Heritage: Tourism, Culture and Identity in the New Europe, London: Routledge.

MILLAR, P. (1995). Heritage management for heritage tourism In: MEDLIK, S. (ed.) Managing Tourism. second ed. Oxford: Butterworth-Heinemann.

MOUDON, A. V. (1994). "Getting to Know the Built Landscape: Typomorphology" from ordering space: types in architecture and design. In: LARICA, M. & Macdonald, E. (ed.) The Urban Design Reader. 3rd ed. Oxon: Routledge.

Martin, C. & Watson, M. (2001). Side by side testing of eight solar water heating systems. London, DTI.

McCarter, R. (Editor) (2013). Carlo Scarpa, Phaidon Press.

Muthesius, S. (1982). The English terraced house, New Haven and London, Yale University.

Miller, D. (2015) Is modern architecture ruining Edinburgh? Conservationist calls for city to be stripped of UNESCO World Heritage Status due to newbuild 'blunders', Dailymail 13/02/2015, from http://www.dailymail.co.uk/travel/travel_news/article-2950676/Conservationist-calls-Edinburgh-stripped-UNESCO-World-Heritage-Status-newbuild-blunders.html

Norberg-Schulz, C. (1981). Genius Loci: towards a phenomenology of architecture, Rizzoli.

Norberg-Schulz, C. (1981). The Phenomenon of Place. In: LARICA, M. & Macdonald, E. (ed.) The Urban Design Reader. 3rd ed. Oxon: Routledge.

ODPM (2003-2004). The Role of Historic buildings in Urban Regeneration, The English Heritage.

Office for National Statistics. 2016. Towns and cities analysis, England and Wales.

ORBASLI, A. (2000). Tourists in Historic Towns: urban conservation and heritage management, New York, E&FN Spon.

ODPM (2004). Government Response to ODPM Housing, Planning Local Government and the Regions Committee Report on the Role of Historic Buildings in Urban Regeneration, ODPM

O'Donnell + Tuomey Architects (1998). Ranelagh Multidenominational school Project. From: http://odonnell-tuomey.ie

O'Donnell + Tuomey Architects (2007) Ranelagh Multidenominational school extension project. From: http://odonnell-tuomey.ie

O'Donnell + Tuomey Architects (2015) St Angela's college project. From: http://odonnell-tuomey.ie

Passell, Aaron. (2013). Building the New Urbanism: Places, professions, and profits in the American metropolitan landscape, Oxon, Routledge, Taylor & Francis

Parker, M. &Whitfield, P. (1998). The Rough Guide to Wales, Rough Guides.

Powe, N., Hart, T. & Shaw, T. (2007) Market Town: roles, challenges and prospects, Oxon, Routledge.

Pierre d'Avoine Architects, (2005) Slim house project. Available: http://www.davoine.net

Passivhaus Trust, 2016, EnerPHit Standard, certification criteria for refurbished buildings, on http://www.passivhaus.org.uk/page.jsp?id=20

Research by Design - International Conference (2000). - Delft University of Technology - Faculty of Architecture, in cooperation with the EAAE/AEEA, November 1-3.

Ross, M. (1996). Planning and the Heritage: Policy and procedures. London, E&FN Spon.

Reynolds, J. P. (1975). Heritage Year in Britain: the aims and objectives of conservation. In Town planning review, Vol . 46, No. 4. pp. 355

Statutory Office (2017). Building Regulations (Amendment) Regulations 2017. Government Publications. Dublin.

Schultz, Anne-Catrin (2007). Carlo Scarpa: layers, Teritiary University

Sedgemoor District Council (2002). The Cornhill Indoor Market, Bridgwater [Online]. Cornhill. Available: http://www.sedgemoor.gov.uk/index.aspx?articleid=7424&textonly=True.

Sepe, Marichela. (2013). Planning and place in the city: mapping place identity, Milton Park, Abingdon, Oxon, Routledge.

Smith, C. S. (1981). A search for structure. Cambridge, Massachusetts, and London, England: The MIT Press.

Slater, T.R. (1984) `Preservation, conservation and planning in historic towns', Geographical Journal vol. 150 no. 3 pp. 322-334

Slater, T.R. and Shaw, G. (1988) Historical geography and conservation planning in British towns, in Denecke, D. and Shaw, G. (eds) Urban historical geography: recent progress in Britain and Germany Cambridge University Press, Cambridge

Segal, W. (1985). Street Theatre: The Half Moon shines on. AJ. Year 1985. Issue 08, pp. 14-33

The United Nations Conference on Environment and Development (UNCED) and E. A. Parson and P. M. Haas, (1992). “A Summary of the Major Documents Signed at the Earth Summit and the Global Forum,” UNCED. pp. 12-18.

The Royal Town Planning Institute. (1994). The character of conservation areas: a study commissioned from Chesterton Consulting and the University of Central England, London, The Royal Town Planning Institute.

The Duchy of Cornwall. (2015). Poundbury Factsheet. Dorset County Council

The Duchy of Cornwall. (2010). Poundbury: Economic Impact Assessment. Dorset County Council

The Scottish Government (2012), Solid wall insulation in Scotland: exploring barriers, solutions and new approaches, The Scottish Government.

Thomas, Randall. (2003). Sustainable urban design: an environmental approach, Milton Park, Abingdon, Oxon, Spon Press.

Thomsen, M. R. and Tamke, M. (2009). Narratives of Making: thinking practice led research in architecture. *Proceedings of the Conference Communicating (by) Design,* Brussels.

Tiesdell, S., Oc, T. & Heath, T. (1996). Revitalizing Historic Urban Quarters. London, Architectural Press.

Towers, G. (2005). An introduction to urban housing design: at home in the city, Lanacre house, Jordan Hill, Oxford, Architectural Press.

Unwin, R. (1909). Town Planning in Practice. London, Fisher Unwin.

Urban Design Group. 2012. Design Coding: Diffusion of Practice in England. Bartlett School of Planning, UCL, London.

VIDLER, A. (1976). The Third Typology Oxon, Routledge.

Vienna University of Technology. 2016. test Nearly Zero-Energy Building Strategy 2020. Intelligent Energy Europe.

Wales Rural Observatory, (2007). SMALL AND MARKET TOWNS IN RURAL WALES AND THEIR HINTERLANDS. WALES RURAL OBSERVATORY.

Waterfield, P. (2006). The energy efficient home: a complete guide, Ramsbury, Marlborough, Wiltshire, The Crowood Press.

Whitehand, J.W.R. (1987) `M.R.G. Conzen and the intellectual parentage of urban morphology', Planning History Bulletin vol. 9 no. 2 pp. 35-41

Whitehand, J.W.R. (1992) `Recent advances in urban morphology', Urban Studies vol. 29 pp. 617-634

Whitehand, J.W.R. (2001) `British urban morphology: the Conzenian tradition', Urban Morphology vol. 5 no. 2 pp. 103-109**

Web (2009). "Shanghai Xintiandi ". from http://www.trip98.com/html/zhongguojingdian/shanghai/2009/0630/3547.html.

WESTBY, J. (2011). Malmesbury Market Cross [Online]. Malmesbury. Available: http://devonvisitor.blogspot.com/2011/04/malmesbury-market-cross.html.

Williams, S. & Clear, C. (2015). Mitigation, adaption, resilience managing climate change risk through BREEAM. BRE Press.

World Commission on Environment and Development (WCED), (1987). Our Common Future, New York: Oxford University Press. P. 8

Worskett, R. (1975). ‘Great Britain: progress in conservation’, Architectural Review CL VII, 935. pp. 9-18

Zhong, J. (2008). Shanghai Xintiandi. From http://www.nipic.com/show/1/75/ca9a4208838bb3a5.html.

APPENDIX

Appendix I: Llandeilo Listed Buildings list

1. (FORMER HOREB) WESLEYAN CHAPEL, RHOSMAEN STREET - Llandeilo

2. ANGEL HOTEL, RHOSMAEN STREET - Llandeilo

3. BANDSTAND IN PENLAN PARK, CARMARTHEN STREET - Llandeilo

4. BANK HOUSE - 2 Llandeilo, Llandeilo

5. BYRE RANGE (FORMERLY STABLES) TO NE.OF DYNEVOR HOME FARMHOUSE, DYNEVOR PARK - Llandeilo

6. CAFE ROYALE, KING STREET - Llandeilo

7. CORN BARN TO N.OF DYNEVOR HOME FARMHOUSE, DYNEVOR PARK - Llandeilo

8. DAIRY COTTAGE AT DYNEVOR CASTLE (NEWTON HOUSE) - Llandeilo

9. DEER ABBATOIR IN PARK TO S.OF DYNEVOR CASTLE (NEWTON HOUSE) DYNEVOR PARK - Llandeilo

10. DOVECOTE TO S.OF COURTYARD RANGES AT DYNEVOR CASTLE (NEWTON HOUSE) DYNEVOR PARK - Llandeilo

11. DYNEVOR HOME FARMHOUSE (FORMERLY NEWTON FARMHOUSE) DYNEVOR PARK - Llandeilo

12. FORMER NATIONAL SCHOOL, CARMARTHEN STREET - Llandeilo

13. FORMER PROVISION MARKET (PREMISES OF BROCKINGTON & SCOTT LTD.)CARMARTHEN STREET - Llandeilo

14. FORMER READING ROOM & LIBRARY, RHOSMAEN STREET – Llandeilo (Public Hall and Literary Institute, next to 115 Rhosmaen street, Fountain Fine Art)

15. FORMER SCHOOL HOUSE, CARMARTHEN STREET - Llandeilo

16. FOUNTAIN IN CENTRE OF TERRACED GARDEN ON WEST SIDE OF PLAS DINEFWR, DYNEVOR PARK - Llandeilo

17. GATES & GATEPIERS TO PENLAN PARK, CARMARTHEN STREET - Llandeilo

18. GREEN HALL, NEW ROAD - Llandeilo

19. ICE HOUSE TO THE N.OF DYNEVOR CASTLE (NEWTON HOUSE) DYNEVOR PARK - Llandeilo

20. INNER COURTYARD RANGES AT DYNEVOR CASTLE (NEWTON HOUSE) DYNEVOR PARK - Llandeilo

21. LLANDEILO BRIDGE (INCLUDING CAUSEWAYS) (partly in Dyffryn Cennen community) - Llandeilo

22. Llandeilo Railway Bridge (partly in Dyffren Cennen community) - Ffairfach, Llandeilo

23. LLWYNHELIG HOUSE, LLWYNHELIG – Llandeilo (SA19 6AZ)

24. LOW STONE WALLS & GATES TO HA-HA SURROUNDING PLAS DINEFWR, DYNEVOR PARK - Llandeilo

25. MIDLAND BANK CHAMBERS, RHOSMAEN STREET - Llandeilo

26. MIDLAND BANK, RHOSMAEN STREET - Llandeilo

27. MILESTONE, RHOSMAEN STREET - Llandeilo

28. MILESTONE, RHOSMAEN STREET - Llandeilo

29. NATIONAL WESTMINSTER BANK, RHOSMAEN STREET – Llandeilo (54)

30. NO.1 BANK TERRACE (THE OLD BANK) - Llandeilo

31. NO.1 GEORGE HILL - Llandeilo

32. NO.1 GEORGE STREET - Llandeilo

33. NO.115 RHOSMAEN STREET (INCLUDING TUNNEL PASSAGE & REAR RANGE TO RIGHT) - Llandeilo

34. NO.121 RHOSMAEN STREET (DYFED COUNTY COUNCIL SOCIAL SERVICES DEPARTMENT) - Llandeilo

35. NO.127 RHOSMEN STREET (GOLDSMITH, JEWELLERS, SILVERSMITHS) - Llandeilo

36. NO.13 BANK BUILDINGS - Llandeilo

37. NO.14 BANK BUILDINGS - Llandeilo

38. NO.2 KING STREET - Llandeilo

39. NO.21 BRIDGE STREET - Llandeilo

40. NO.22 CARMARTHEN STREET (CAMBRIAN HOUSE) - Llandeilo

41. NO.23 BRIDGE STREET (WATERLOO VILLA) - Llandeilo

42. NO.23 CHURCH STREET (STEPNEY HOUSE) - Llandeilo

43. NO.24 BRIDGE STREET - Llandeilo

44. NO.24 CHURCH STREET (MOUNT PLEASANT) - Llandeilo

45. NO.25 BRIDGE STREET - Llandeilo

46. NO.26 CARMARTHEN STREET (BRISKEN HOUSE) - Llandeilo

47. NO.3 BANK TERRACE - Llandeilo

48. NO.3 RAILWAY TERRACE - Llandeilo

49. NO.4 ABBEY TERRACE - Llandeilo

50. NO.4 BANK TERRACE - Llandeilo

51. NO.4 CHURCH STREET - Llandeilo

52. NO.4 KING STREET - Llandeilo

53. NO.4 RAILWAY TERRACE - Llandeilo

54. NO.5 ABBEY TERRACE - Llandeilo

55. NO.5 BANK TERRACE (SIX BELLS) - Llandeilo

56. NO.5 GEORGE HILL - Llandeilo

57. NO.5 KING STREET (PEPPERCORN) - Llandeilo

58. NO.6 GEORGE HILL - Llandeilo

59. NO.6 KING STREET (VETERINARY SURGERY) - Llandeilo

60. NO.60 RHOSMAEN STREET (DEWI PRICE AND CO. SOLICITORS)- - Llandeilo

61. NO.64 RHOSMAEN STREET (SNIFTERS) - Llandeilo

62. NO.66 RHOSMAEN STREET - Llandeilo

63. NO.7 GEORGE HILL - Llandeilo

64. NO.7 KING STREET (TOWY HOME DECOR) – Llandeilo

65. NO.70 RHOSMAEN STREET - Llandeilo

66. NO.72 RHOSMAEN STREET (JOHN FRANCIS CHARTERED AUCTIONEERS, WALTER JAMES & SON ESTATE AND INSURANCE AG - Llandeilo

67. NO.72A RHOSMAEN STREET (HOUSE TO REAR OF NO.72) - Llandeilo

68. NO.8 GEORGE HILL - Llandeilo

69. NO.9 BANK TERRACE (MYRTLE HILL) - Llandeilo

70. NO.9 CARMARTHEN STREET (HILL HOUSE) - Llandeilo

71. NO.9 GEORGE HILL - Llandeilo

72. OLD DYNEVOR CASTLE, DYNEVOR PARK - Llandeilo

73. OUTER COURTYARD RANGES AT DYNEVOR CASTLE (NEWTON HOUSE) DYNEVOR PARK - Llandeilo

74. OUTHOUSE OPPOSITE NO.70 RHOSMAEN STREET - Llandeilo

75. PARISH CHURCH OF ST.TEILO - Llandeilo

76. PLAS DINEFWR, INCLUDING SW.SCREEN WALL, DYNEVOR PARK – Llandeilo

77. PREMISES OF LLEWELLYN HUMPHREYS, CHARTERED SURVEYORS & ESTATE AGENTS, KING STREET - Llandeilo

78. PROSPECT HOUSE, NEW ROAD – Llandeilo (SA19 6DB)

79. RED COTTAGES, A40 (N.SIDE) DYNEVOR PARK - Llandeilo

80. RED COTTAGES, A40 (N.SIDE) DYNEVOR PARK - Llandeilo

81. SALEM WELSH CALVINISTIC METHODIST CHAPEL, NEW ROAD - Llandeilo

82. ST.TYFI'S CHURCH (NOW INTERPRETATION CENTRE) DYNEVOR PARK - Llandeilo

83. STABLE BLOCK AT LLWYNHELIG HOUSE, LLWYNHELIG - Llandeilo

84. STRETCH OF WALLING & ARCHWAYS BETWEEN NOS. 5 & 7 ABBEY TERRACE - Llandeilo

85. SUMMER HOUSE AT PLAS DINEFWR, DYNEVOR PARK - Llandeilo

86. THE CASTLE HOTEL, RHOSMAEN STREET – Llandeilo (113)

87. THE CAWDOR ARMS HOTEL, RHOSMAEN STREET – Llandeilo (72 Rhosmaen Street Llandeilo)

88. THE KING'S HEAD, BRIDGE STREET - Llandeilo

89. THE SALUTATION INN, NEW ROAD – Llandeilo (33 NEW ROAD)

90. THE TUCK SHOP, RHOSMAEN STREET – Llandeilo (129 RHOSMAEN STREET)

91. WELL, INCLUDING CHURCHAYRD WALL FOR 10m WEST AND 20m EAST, CHURCH STREET – Llandeilo

Appendix II: calculation of SAP for design 1 terrace house retrofit

Test 1-1 Original building

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	55.04
SAP Band	D
Environmental Impact Rating	44.18
Environmental Impact Band	E
Primary Energy (total)	41,660.69kWh/yr
Primary Energy (area weighted)	366.12kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1-2 after retrofit

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	81.04
SAP Band	B
Environmental Impact Rating	80.96
Environmental Impact Band	B
Primary Energy (total)	13,117.50kWh/yr
Primary Energy (area weighted)	115.28kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1-3

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	94.96
SAP Band	A
Environmental Impact Rating	94.02
Environmental Impact Band	A
Primary Energy (total)	2,427.25kWh/yr
Primary Energy (area weighted)	25.65kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	74.59
SAP Band	C
Environmental Impact Rating	73.00
Environmental Impact Band	C
Primary Energy (total)	18,536.17kWh/yr
Primary Energy (area weighted)	162.90kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-2

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	84.08
SAP Band	B
Environmental Impact Rating	85.08
Environmental Impact Band	B
Primary Energy (total)	10,257.00kWh/yr
Primary Energy (area weighted)	90.14kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

---

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 3-1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	80.99
SAP Band	B
Environmental Impact Rating	80.60
Environmental Impact Band	B
Primary Energy (total)	13,361.17kWh/yr
Primary Energy (area weighted)	117.42kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

---

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 4-1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	97.20
SAP Band	A
Environmental Impact Rating	96.45
Environmental Impact Band	A
Primary Energy (total)	2,054.14kWh/yr
Primary Energy (area weighted)	18.05kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

---

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Appendix III: Calculation of SAP for design 3 (new dwellings)

Variation 1

Test 1 House type 1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	96.32
SAP Band	A
Dwelling Carbon Emission Rate (DER)	9.10 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.81 $kgCO_2/m^2$
Environmental Impact Rating	93.73
Environmental Impact Band	A
Primary Energy (total)	5,489.02kWh/yr
Primary Energy (area weighted)	31.55kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1 House type 2

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	97.23
SAP Band	A
Dwelling Carbon Emission Rate (DER)	7.99 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	13.42 $kgCO_2/m^2$
Environmental Impact Rating	94.86
Environmental Impact Band	A
Primary Energy (total)	4,159.73kWh/yr
Primary Energy (area weighted)	26.63kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1 House type 3

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	93.24
SAP Band	A
Dwelling Carbon Emission Rate (DER)	11.98 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	13.79 $kgCO_2/m^2$
Environmental Impact Rating	89.93
Environmental Impact Band	B
Primary Energy (total)	6,848.81kWh/yr
Primary Energy (area weighted)	35.86$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1 House type 4

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.32
SAP Band	A
Dwelling Carbon Emission Rate (DER)	9.54 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.20 $kgCO_2/m^2$
Environmental Impact Rating	92.80
Environmental Impact Band	A
Primary Energy (total)	6,735.39kWh/yr
Primary Energy (area weighted)	37.91$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1 Apartments two-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.62
SAP Band	A
Dwelling Carbon Emission Rate (DER)	6.15 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.07 $kgCO_2/m^2$
Environmental Impact Rating	97.30
Environmental Impact Band	A
Primary Energy (total)	1,594.89kWh/yr
Primary Energy (area weighted)	16.27kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 1 Apartment one-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	97.23
SAP Band	A
Dwelling Carbon Emission Rate (DER)	2.55 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	17.69 $kgCO_2/m^2$
Environmental Impact Rating	100.68
Environmental Impact Band	A
Primary Energy (total)	-428.30kWh/yr
Primary Energy (area weighted)	-8.92kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Variation 2

Test 2-1 House type 1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	94.09
SAP Band	A
Dwelling Carbon Emission Rate (DER)	11.98 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.81 $kgCO_2/m^2$
Environmental Impact Rating	90.58
Environmental Impact Band	B
Primary Energy (total)	8,396.30kWh/yr
Primary Energy (area weighted)	48.25$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-1 House type 2

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	94.33
SAP Band	A
Dwelling Carbon Emission Rate (DER)	11.80 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	13.85 $kgCO_2/m^2$
Environmental Impact Rating	90.74
Environmental Impact Band	B
Primary Energy (total)	7,657.23kWh/yr
Primary Energy (area weighted)	49.02$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-1 House type 3

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	92.60
SAP Band	A
Dwelling Carbon Emission Rate (DER)	12.58 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.74 $kgCO_2/m^2$
Environmental Impact Rating	89.03
Environmental Impact Band	B
Primary Energy (total)	10,919.72kWh/yr
Primary Energy (area weighted)	57.17$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-1 House type 4

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	91.91
SAP Band	A
Dwelling Carbon Emission Rate (DER)	13.75 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	13.42 $kgCO_2/m^2$
Environmental Impact Rating	87.96
Environmental Impact Band	B
Primary Energy (total)	11,270.15kWh/yr
Primary Energy (area weighted)	63.43$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-1 Apartment two-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	90.36
SAP Band	B
Dwelling Carbon Emission Rate (DER)	13.91 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	14.21 $kgCO_2/m^2$
Environmental Impact Rating	89.84
Environmental Impact Band	B
Primary Energy (total)	6,122.08kWh/yr
Primary Energy (area weighted)	62.47$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-1 Apartment one-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	91.51
SAP Band	A
Dwelling Carbon Emission Rate (DER)	13.84 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	19.87 $kgCO_2/m^2$
Environmental Impact Rating	92.57
Environmental Impact Band	A
Primary Energy (total)	2,762.90kWh/yr
Primary Energy (area weighted)	57.56$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-2 House type 1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	100.35
SAP Band	A
Dwelling Carbon Emission Rate (DER)	3.04 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	18.84 $kgCO_2/m^2$
Environmental Impact Rating	98.71
Environmental Impact Band	A
Primary Energy (total)	1,226.70kWh/yr
Primary Energy (area weighted)	7.05kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-2 House type 2

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	101.00
SAP Band	A
Dwelling Carbon Emission Rate (DER)	2.58 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	20.67 $kgCO_2/m^2$
Environmental Impact Rating	99.07
Environmental Impact Band	A
Primary Energy (total)	871.70kWh/yr
Primary Energy (area weighted)	5.58kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-2 House type 3

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	96.01
SAP Band	A
Dwelling Carbon Emission Rate (DER)	6.85 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	18.53 $kgCO_2/m^2$
Environmental Impact Rating	94.58
Environmental Impact Band	A
Primary Energy (total)	5,903.73kWh/yr
Primary Energy (area weighted)	30.91kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

---

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-2 House type 4

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.46
SAP Band	A
Dwelling Carbon Emission Rate (DER)	7.63 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	19.78 $kgCO_2/m^2$
Environmental Impact Rating	93.83
Environmental Impact Band	A
Primary Energy (total)	6,295.90kWh/yr
Primary Energy (area weighted)	35.43kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

---

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Type 2-2 Apartment two-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	96.15
SAP Band	A
Dwelling Carbon Emission Rate (DER)	8.03 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	21.05 $kgCO_2/m^2$
Environmental Impact Rating	94.59
Environmental Impact Band	A
Primary Energy (total)	3,524.41kWh/yr
Primary Energy (area weighted)	35.96kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 2-2 Apartment one-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	100.13
SAP Band	A
Dwelling Carbon Emission Rate (DER)	4.78 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	29.02 $kgCO_2/m^2$
Environmental Impact Rating	98.32
Environmental Impact Band	A
Primary Energy (total)	705.59kWh/yr
Primary Energy (area weighted)	14.70kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Variation 3

Test 3 House type 1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	96.17
SAP Band	A
Dwelling Carbon Emission Rate (DER)	9.32 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.91 $kgCO_2/m^2$
Environmental Impact Rating	93.52
Environmental Impact Band	A
Primary Energy (total)	5,661.75kWh/yr
Primary Energy (area weighted)	32.54$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 3 House type 2

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	97.09
SAP Band	A
Dwelling Carbon Emission Rate (DER)	8.19 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	13.56 $kgCO_2/m^2$
Environmental Impact Rating	94.66
Environmental Impact Band	A
Primary Energy (total)	4,318.38kWh/yr
Primary Energy (area weighted)	27.65$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 3 House type 3

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	94.98
SAP Band	A
Dwelling Carbon Emission Rate (DER)	9.68 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	11.98 $kgCO_2/m^2$
Environmental Impact Rating	92.38
Environmental Impact Band	A
Primary Energy (total)	7,572.91kWh/yr
Primary Energy (area weighted)	39.65kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 3 House type 4

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.48
SAP Band	A
Dwelling Carbon Emission Rate (DER)	9.33 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.28 $kgCO_2/m^2$
Environmental Impact Rating	93.02
Environmental Impact Band	A
Primary Energy (total)	6,516.01kWh/yr
Primary Energy (area weighted)	36.67kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 3 Apartment two-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.82
SAP Band	A
Dwelling Carbon Emission Rate (DER)	5.72 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	12.03 $kgCO_2/m^2$
Environmental Impact Rating	97.56
Environmental Impact Band	A
Primary Energy (total)	1,402.31kWh/yr
Primary Energy (area weighted)	14.31kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 3 Apartment one-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	97.40
SAP Band	A
Dwelling Carbon Emission Rate (DER)	2.16 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	17.70 $kgCO_2/m^2$
Environmental Impact Rating	100.93
Environmental Impact Band	A
Primary Energy (total)	-539.95kWh/yr
Primary Energy (area weighted)	-11.25kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Variation 4

Test 4 House type 1

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	100.22
SAP Band	A
Dwelling Carbon Emission Rate (DER)	3.16 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	18.99 $kgCO_2/m^2$
Environmental Impact Rating	98.58
Environmental Impact Band	A
Primary Energy (total)	1,334.74kWh/yr
Primary Energy (area weighted)	7.67kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 4 House type 2

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	101.18
SAP Band	A
Dwelling Carbon Emission Rate (DER)	2.44 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	20.45 $kgCO_2/m^2$
Environmental Impact Rating	99.24
Environmental Impact Band	A
Primary Energy (total)	707.87kWh/yr
Primary Energy (area weighted)	4.53kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 4 House type 3

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	96.25
SAP Band	A
Dwelling Carbon Emission Rate (DER)	6.67 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	18.31 $kgCO_2/m^2$
Environmental Impact Rating	94.83
Environmental Impact Band	A
Primary Energy (total)	5,642.77kWh/yr
Primary Energy (area weighted)	29.54$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 4 House type 4

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.67
SAP Band	A
Dwelling Carbon Emission Rate (DER)	7.48 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	19.59 $kgCO_2/m^2$
Environmental Impact Rating	94.04
Environmental Impact Band	A
Primary Energy (total)	6,087.33kWh/yr
Primary Energy (area weighted)	34.26$kWh/yr/m^2$

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 4 Apartment two-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	95.89
SAP Band	A
Dwelling Carbon Emission Rate (DER)	8.28 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	21.75 $kgCO_2/m^2$
Environmental Impact Rating	94.33
Environmental Impact Band	A
Primary Energy (total)	3,679.45kWh/yr
Primary Energy (area weighted)	37.55kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.

Test 4 Apartment one-bedroom

Results

A summary of the results of your SAP 2012 assessment are listed below. To generate a report with a more detailed breakdown, select the reports required and click "Generate". This will create PDFs of the selected reports for submission purposes.

SAP Rating	99.92
SAP Band	A
Dwelling Carbon Emission Rate (DER)	5.06 $kgCO_2/m^2$
Target Carbon Emission Rate (TER)	29.63 $kgCO_2/m^2$
Environmental Impact Rating	98.11
Environmental Impact Band	A
Primary Energy (total)	787.10kWh/yr
Primary Energy (area weighted)	16.40kWh/yr/m^2

Upgrade to a full subscription to view Input data, Overheating assessments, Compliance checklists and SAP Worksheets

Energy Performance Certificates and Lodgement:

If you are an accredited energy assessor with Quidos then you can use Energy Design Tools to lodge SAP 2012 reports. Just enter your membership number and password in the profile page to get started.