Is Radical Innovation in Architecture Crucial to Sustainability?

Lessons from Three Scottish Contemporary Buildings

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Radical innovation is largely recognised as a medium for advancement, a source of growth for economies, and a trigger for progress in different economic sectors. Often, this type of innovation is identified with technological advancements, disruptive phenomena and the creation of new systems and dynamics. Yet, within the context of a changing world, in which principles of economic, environmental and social sustainability are largely adopted as common objectives, a reflection on the type of progress and the need for radical innovation is necessary with the aim of informing on their impacts and effectiveness. This work presents an analysis of a number of contemporary Scottish architectural designs, developed under the aegis of sustainability principles, and explores the types of sustainable innovations introduced and the results achieved by analyzing the type of design change that triggered specific sustainable results, demonstrating alternative innovation strategies, other than the radical one. This analysis provides a basis for discussion on the need for radical innovation in the context of sustainable architecture and explores the role of other types of innovation against the results achieved. This discussion could contribute to a better understanding of the current state of practice in architectural design, as well as in policy making in regard to the design and management of the future built environment.

Keywords: Innovation, Sustainability, Architecture, Environment, Development, Scotland

Introduction

It is since 1987, with the publication of the Brundtland Report (WCED, 1987), that the global community has formally recognised the necessity of sustainable social, environmental and economic development. Since then, many efforts have been made to implement strategies to apply sustainability principles to many fields. In this context, the field of architecture and urban design has faced a paradigmatic shift in many instances, from the proposals for new design strategies to the development of novel management systems for emerging social, environmental and economic challenges (Hensel and Nilsson, 2016; Kibert, 2016). These changes are explored by relying on the understanding of the role of innovation, conceived as a design change. Innovation, and in particular radical innovation, described through a medium of advancement has been explored by many authors (Emmitt, 1997; Gann, 2000; Henderson and Clark, 1990; Lindgren, 2016; Slaughter, 1998; Winch, 1998; Gambatese and Hallowell, 2011). In particular, within the field of architecture, Brownell (2015) reported that radical innovation through global investment in research-and-development is perceived as the key to determine the transformations that would affect the built environment. Radical innovation has been in fact identified with new core design concepts development embodied in components that are linked together in a new architecture (Henderson and Clark, 1990) and with disruptive effects on products and practice. The aim of this work is to examine the relation between types of innovation and impacts generated in the context of sustainable architecture, discussing the idea that other types of innovation, other than the radical one, can support and generate sustainable development, without necessarily incurring disruptive phenomena, but rather by relying on the optimization of the current state of practice and resources. To this end, the innovation theory of Henderson and Clark (1990) – and later discussed by many other authors (Slaughter1998; Lindgren, 2016, Gambatese and Hallowell, 2011) - which defines other types of innovation such as incremental, modular, architectural and system, is used to assess design innovations in three case studies of sustainable building projects in Scotland, UK. The design characteristics of these buildings are explored in terms of type of innovation and impacts, with the aim of understanding the role of different types of innovation and design choices in relation to sustainability objectives. This understanding can contribute to better informed design decisions in the context of sustainable design of buildings, as well as to the discussion about the role of different types of innovation within the context of sustainable development.

From the concept of progress to the definition of sustainable future – the potential role of innovation

Innovation, a process of implementing new ideas to create value, is recognised as crucial to foster changes and stimulate progress (Latin: *progressus* - to advance, to go forward). In the context of a changing world that faces structural challenges, the nature of progress has been debated, and a shift towards a sustainable vision of the future was proposed in the late '80s by defining sustainable development as the '*development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs'* (WCED, 1987). This vision has stimulated thinking about types of innovation that may be required to support progress towards a more sustainable development. Radical innovation, in particular, is recognised as a medium of advancement, a source of growth for economies and a trigger of progress (Sood and Tellis, 2005; Gambatese and Hallowell, 2011, Coccia, 2017). Often, this type of innovation is linked with technological advancement, disruptive phenomena and the creation of new systems and dynamics (Tellis, Prabhu, Chandy, 2009; Winch, 1998). Ahlstorm (2010) associates radical innovation and deconstruction of existing systems in favour of technological advancement with development models based on unlimited growth and resource exploitation (Ahlstorm, 2010). The awareness of the limits of growth, raised in the '70s by Meadows, D., Meadows, D., Randers, J. and Behrens, W. (1972), is influencing approaches to innovation which consider resources as limited (Becker, 2013) and require types of innovation which contribute to sustainable development.

Innovation, considered as a change in design, has been classified according to a number of characteristics. Henderson and Clark (1990) defined different types of innovation, such as incremental, modular, architectural and radical. Slaughter (1998) further explored types of innovation in the construction industry and defined a spectrum of innovation types, from incremental to radical, introducing the concept of system innovation. Slaughter (1998) places radical and incremental innovation at the extremes of the spectrum.. In the case of incremental innovation, the improvement refers to individual components, but the core design concepts and their relationships remain unchanged (Henderson and Clark, 1990). Slaugther (1998) adds - referring specifically to the construction industry - that incremental innovation is a small change, built on existing knowledge and experience, whereas radical innovation is a breakthrough in science or technology that often changes the character and nature of an industry. According to Slaugther (1998), the impacts of different types of innovation vary: incremental innovation produces predictable impacts within a limited range of interaction with other components; conversely, radical innovation generates impacts that may affect both the system and the structural organisation, due to its inner nature of entirely modifying the approach and the solutions to given phenomena. Modular, architectural, and system innovation are progressively positioned within the spectrum, between incremental and radical innovation at both ends. They indicate the degree of changes, either in core design concepts and/or their relationships, and their increasing impacts. Other authors have then extended this concept by exploring innovation in products, processes and systems (Gambatese and Hallowell, 2011; Koskela and Virjhoef, 2001; Lindgren, 2016).

The challenges for sustainable development in the field of architecture

In the context of sustainable development, the challenges in the field of architecture are widely discussed and influenced by the actions proposed in Agenda 21 of the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 (UN, 1992a) to address a range of social, economic and environmental challenges (Cardonna, 2014; Hensel and Nilsson, 2016). The United Nations Framework on Climate Change in 1997 (UN, 1992b) and the subsequent Kyoto Protocol (UN, 1997) for reducing emissions of greenhouse gasses (GHG) in the countries which signed it, focused on reducing the causes of climate change. The Kyoto Protocol objectives were reiterated and extended in the Paris Agreement in 2015 (UN, 2015).

As a result, many countries have developed frameworks and regulations with the aim of contributing to this environmental challenge. In 2013, the European Commission released the European Performance of Building Directive (EC, 2013), a legislative document that promotes the improvement of energy performance in buildings. The building sector is responsible for almost 40% of total primary energy consumption in developed countries (Berardi, 2017; Orme, 2011). This percentage includes energy demand for space heating and cooling, hot water production, lighting, cooking and other appliances. In addition, considering the global warming effect of a persistent increase of GHG emissions, the energy consumption for space cooling is rising in several countries (Givoni, 1994; Santamouris, 2007).

Building activities play a crucial role in the economic development of countries (Ruddock, 2009) by generating links on multiple levels: firstly, with the activities carried out around a specific building project; secondly, with other industries related or connected to these activities; and thirdly, with the economic environment in the long-term (Pearce, 2003; Turin, 1980). Pearce (2003) suggests that improving the built environment is critical to social sustainability and improving quality of life. Woodcraft et al. (2012) explain that there is a need for *'... a process for creating successful places that promote wellbeing, by understanding what people need from the places they live and work. Social sustainability combines design of the physical realm with design of the social world – infrastructure to support social and cultural life, social amenities, systems for citizen engagement and space for people and places to evolve'*.

In response to these environmental, economic and social challenges, architects are producing innovative design solutions that convey the values of sustainability and aim to achieve related performance targets. The number of design approaches proposed in the field has progressively increased. Guy and Farmer (2001) identified at least six approaches to sustainability in architecture: eco-technic, eco-centric, eco-aesthetic, eco-cultural, eco-medical, and eco-social. Lee (2011) highlighted at least twenty-five approaches to design changes required in the context of sustainable architecture. Each of these approaches proposed design changes (innovation) in different categories of the projects and processes, resulting in often non-uniform design solutions and leading to the discussion and definition of debated positions on design changes and approaches to the design of sustainable architecture (Hosey, 2012). For instance, Hosey (2012) points out that the aesthetics of sustainability – defined here as a set of principles conveying the idea of sustainability - is not easily definable within purely design boundaries. This seems to be due to a number of reasons: the complexity and multi-disciplinarity of the concept of sustainability; the plurality and fragmentation of design approaches; contradicting political views on sustainability itself; and challenges in re-organising and evolving the practice around the stimulus that sustainability generates (Hensel and Nilsson, 2016; Kibert, 2016).

Within this context, the ability to rely on innovation conceived as design change can represent a response to the call for re-thinking the way in which we envision and design our built environment. While radical innovation is generally associated with the concept of progress and disruptive phenomena (Winch, 1998), the aim of this work is to reflect on different types of innovation in the design of buildings as strategic sustainable development opportunities, and see whether these strategies can trigger design solutions able to optimise the use of resources through incremental improvements, as opposed to their exploitation. Specifically, the aim of this work is to argue that design processes should strategically address types of innovation according to the objectives and the sustainable development opportunities that are identified in the context of projects' development, rather than pursue radical innovation as the main solution.

The objectives of this work are to answer the following questions:

(1) Which types of innovation other than the radical one can produce sustainable results?
(2) Which type of building characteristics can be used as a strategic ground for creating sustainable buildings?
(3) Is it possible to identify links between type of innovation, building design characteristics and sustainability results achieved?

Answers to these questions have a potential to initiate a greater variety of design changes or innovation strategies, to indicate a range of types and categories of innovation for creating sustainable architecture, and envision future scenarios for design of sustainable buildings.

Research Method

To achieve the established objective, this work relies on the analysis of three case studies of buildings that have been recently awarded and recognised as successful sustainable building projects in Scotland, UK. These three case studies are explored by analyzing the type of innovation utilized in each feature of the building and the sustainability results that they achieved. The purpose of this analysis is to highlight the relation between type of innovation, building characteristics, and sustainability results. The understanding of these links can help in reflecting on the nature of innovation against project objectives, and ultimately in assisting to define the type of future built environment we are envisioning.

The analysis was organized around: 1) the identification of sustainable building design characteristics in three case studies of buildings; 2) the assessment of the type of innovation applied to each building design characteristic by relying on the innovation theory proposed by Henderson and Clark (1990), and later expanded by Slaughter (1998), and 3) the identification of links between type of innovation, building design characteristics and sustainability results achieved.

The identification of building properties relies on the index provided in the European Standard UNI EN 16627:2015 (CEN, 2015) which identifies the building design characteristics, elements and services that are considered when making decisions about the design of energy efficient buildings. They are: dimensions, shape, floor number, access and circulation, structure, environmental control systems and water treatment. The index is used as a base for completing the description, yet a degree of flexibility is maintained in case of critical innovative features not covered by the index. The reason for this flexibility is based on the fact that every building is different (Turin, 1980, Lindgren 2016), and therefore flexibility is needed in order to gauge the complexity of each project. To this end, other aspects such as environmental context, orientation, and architectural characteristics (e.g. relation between opaque and transparent components, or volumetric configuration) have been added to the list, as they may generate impacts regarding social, environmental and economic aspects. For each project analysed, all building design characteristics, elements and services have been described on the basis of both architectural documents provided by the architects, and interviews carried out with them, as well as by conducting at least one site visit to each building project. The interviews were conducted by recording the building delivery experiences reported by the architects and by assessing with the architects the degree of innovation of each building characteristic in relation to the context. The projects' outcomes were checked by observing the building characteristics during the building site visits.

The type of innovation is explored for each of them by carrying out an analysis based on the classification of innovation types proposed by Henderson and Clark (1990), and later developed by Slaughter (1998). This classification identifies five types of innovation, namely, incremental, modular, architectural, system and radical. It can be applied to a product, processes or systems (Gambatese and Hallowell, 2011), but in the context of this work it is applied only to buildings, perceived as products. Therefore, building design characteristic, elements and services have been analysed to identify a level of innovation as classified above and defined in the Table 1. Moreover, by relying on the spectrum of types of innovation proposed by Slaughter (1998), a numeric score for each type of innovation has been introduced here in order to assess the designs solutions on a scale from standard practice (0) to radical innovation (5). In the context of buildings, the category of incremental innovation can be identified in any building project, as every building is unique (Turin, 1980) to a certain degree. Incremental innovation based on previous experience always occurs, even if standard design solutions are utilised (for example, by simply locating a building in a new site, different conditions have to be considered both in the design and in the construction process). Modular innovation is also a common type of design change, which generally can be identified as a limited innovative solution in specific project areas or components (for example, in a new type of door, or windows, or other individual elements). Architectural innovation can be found in the relationship between different building components or spaces (for example, in an innovative volumetric arrangement, or in the organisation of access and circulation). The innovation type defined as a 'system innovation' can be found in the relationship between site characteristics, orientation, selection/design of doors and windows, environmental control system (solar panels, photovoltaic systems, ventilation systems, et cetera) and water treatment. Radical innovation is considered a breakthrough in science or technology that would allow to change the entire nature of the industry.

Table 1: Type of Innovation, Adapted by Slaughter (1998)

INNOVATION TYPE	DEFINITON	SCORE
INCREMENTAL	Incremental innovation is a small change, based upon current knowledge and experience.	1
MODULAR	Modular innovation entails a significant change in the design concept of a component, but leaves the links to other components and systems unchanged.	2
ARCHITECTURAL	Architectural innovation involves a small change within a component, but major changes in the links to other components and systems.	3
SYSTEM	System innovation is identified through its integration of multiple independent innovations that must work together to perform new functions or improve the facility performance as a whole.	4
RADICAL	Radical Innovation is a breakthrough in science or technology that often changes the character and nature of the industry.	5

Finally, the sustainability results achieved were identified and assessed. These results were explored by relying on post-occupancy evaluations, energy rating certifications, interviews carried out with the designers and participants in the design development process. The results were explored within the social, environmental and economic domains on the basis of the sustainability goals listed as examples in Table 2, aligned with the sustainable development goals defined by the United Nations Development Programme (UNDP, 2015). These results were explored by relying on a scale of results parameters, to which a scoring system was assigned from – 1 to 4. Such scale was based on results from negative to positive in all the three analytical areas of impact , by relying on a series of parameters as showed in table 3.

Table 2: Type of results and parameters

AREA OF IMPACT	TYPE OF RESULTS	RESULTS PARAMETERS	SCORE
Environmental	emission reduction, resource generation, waste reduction, indoor environmental quality, outdoor environmental quality, embodied-energy, material use	Environmental problems	-1
		No environmental change	0
		Knowledge acquisition	1
		Sustainability results achievement	2
		Technological performances advancement	3
		Resources generation	4
Social	social inclusion, wealth, education, safety, cultural diversity, personal development, cultural development	Social problems	-1
		No social changes	0
		Knowledge acquisition	1
		Social objectives achievement	2
		Social Improvement	3
		Extra benefit generation	4
Economic	competitive advantage (lower production cost), comparative advantage (lower price and/or improved usability) property/land value increase, reduced maintenance cost	Economic Loss	-1
		No economic change	0
		Savings achieved	1
		New jobs created	2
		Increased revenue	3
		Market expansion	4

The following table shows the definition of the parameters used to assess the impact (Jones, 1989; Maneschi, 1998; Ruddock, 2009) that was generated in terms of economic, environmental and/or social development.

Table 3: Parameters and definitions according to areas of impact

AREA OF IMPACT	PARAMETERS	DEFINITION
Environmental	Environmental problems	Negative environmental impacts of the project
	No change in the environmental impact	No change in the local natural environment during and after the project development
	Knowledge acquisition	Knowledge acquisition related to environmental performance of the project (e.g. post-occupancy evaluation)
	Sustainability results achievement	Achievement of the goals set during the phase of project's objectives definition
	Technological performances advancement	Patent acquisition or generation of technological innovative systems
	Resources generation	Generation of resources from renewables or through recycling of resources not present before the project development (e.g. energy from renewables, recycling of water, etc.)
Social	Social problems	Negative social impacts of the project
	No change in the social impact	No change in local social relationships during and after the project development
	Knowledge acquisition	Knowledge acquisition related to the social impact of the project (e.g. through surveys of the building users, local community or/and nationally)
	Social objectives achievement	Achievement of social goals set during the phase of projects objectives definition
	Social Improvement	Reduction or elimination of negative social behaviours (e.g. crime, vandalism, sectarianism, etc.)
	Social benefit generation	Increase of positive social behaviours (e.g. strengthening of community relationships, increased volunteerism, increased social tolerance, etc.) on local or/and national level; public recognition of positive social impacts
Economic	Economic Loss	Negative revenue balance
	No economic change	No change in local or/and national economy during and after the project development
	Savings achieved	Reduced costs/m2 of the building construction, use and maintenance compared to similar buildings
	New jobs created	New jobs created internally and/or in the community to provide products and/or services for the continuous use of the building
	Increased revenue	Increased revenue (e.g. through improved performance in building use) in comparison with similar buildings/uses
	Market expansion	New products or services offered to a wider section of an existing market or a new demographic, psychographic or geographic market

The identification of these three analytical areas allows the discussion on the role of innovation, areas of building design that can support sustainable development, and links with possible results. This is relevant because it can shed light on design options and policy making alternatives in terms of sustainable development.

The Analysis

The context of the analysis

Scotland, like many other European countries, has responded to the call for sustainable development with a number of strategies that included the engagement of public institutions, private entities, professional practices and universities. The Scottish Government has published a number of laws, policies and strategic recommendations for creating more sustainable built environment such as the Low Carbon Building Strategy for Scotland in 2007 (updated in 2013) (Scottish Government, 2013a), the Climate Change (Scotland) Act 2009 (Scottish Government, 2009a), Scotland's Climate Change Adaptation Framework (Scottish Government, 2009b), and the Energy Efficiency Action Plan (Scottish Government, 2010). These recommendations aimed to revise and set new building standards and stimulate innovation, by exploring a wide range of topics, such as setting CO_2 emissions reduction targets, defining sustainable delivery processes, suggesting more inclusive delivery processes, promoting the design of low carbon buildings, and suggesting technological solutions. Scotland's architectural practices have responded by establishing the Scottish Ecological Design Association (SEDA) which aims to promote "design of communities, environments, projects, systems, services, materials and products which enhance the quality of life and are not harmful to living species and planetary ecology" (SEDA, 2010) by undertaking research and producing publications, and by supporting a high number of projects developed under the aegis of sustainability. The recent SEDA publication *'100 Sustainable Scottish Buildings'* (Atkins and Stephen, 2017) presents a number of contemporary building projects that evidence the efforts of Scottish architects in answering the call for sustainable development. Scottish universities undertake research in sustainable building design and collaborate with practitioners through knowledge exchange projects such as CIC Start Online (2009-2013), which produced 70 reports on feasibility studies and academic consultancies and disseminated them through interactive webinars, online conferences and articles, including a book which provides an overview of all the outputs (Dimitrijevic, 2013).

Within this context, three case studies of Scottish sustainable building projects have been selected for the analysis. The selected buildings have been recently completed in Scotland and have either received international awards or had been developed on the basis of a brief that included sustainability targets. These three projects are publicly funded. The rationale for selecting public projects has to do with the opportunity to foster innovation and to communicate the values of sustainable buildings (Nigra, 2010) by setting positive examples, as well as with the fact that the Scottish Government has issued guidelines on procurement of publicly funded buildings in Scotland (Scottish Government, 2013b), and therefore has set requirements for these types of projects. In particular, these guidelines highlight a range of existing environmental assessment tools used by the public sector (e.g. BREEAM, EcoHomes, Standard Assessment Procedure (SAP) and the National Home Energy Rating); encourage design solutions that maximise thermal efficiency, reduce carbon emissions, reduce floor area, use locally sourced materials and promote sustainable production; and recommend collaboration between project clients, designers, contractors, as well as sharing of data and outcomes of successful sustainable projects. The buildings analysed are: the South Lanarkshire College Low Carbon Teaching Building, the Culloden Battlefield Visitor Centre, and the Robert Burns Birthplace Museum.

Case Study 1 - South Lanarkshire College Low Carbon Teaching Building, East Kilbride, Scotland, UK

Introduction – Case Study 1

The South Lanarkshire College Low Carbon Teaching Building (Fig. 1) was designed by the Scottish firm Austin-Smith:Lord. It achieved the *BREEAM 'Outstanding' rating* *for the design stage under the 2014 Scottish Building Standards,* and opened in 2016. The building achieved significant positive environmental, economic and social results. Specifically, it achieved a 100.8% reduction in CO_2 emissions compared to the 2010 legislative requirements for reducing emissions of GHG (South Lanarkshire College, 2016). It was completed within the budget. The project and the building were and still are used as a learning experience both by the client team and the students who monitored the building performance as part of their teaching and learning curriculum. The reduction in CO_2 emissions was achieved by ensuring that building orientation enables an optimal use of the micro-climatic site conditions, as well as by installing high levels of thermal insulation, a ground source heat pump, photovoltaic panels and a rainwater harvesting system. The selection of building materials aimed to reduce the heating load requirements by using building thermal mass to prevent internal overheating. The reduced heating load and the installation of renewable energy generation systems make the building 'carbon neutral' in operation. To achieve these results, the design focused on optimal building orientation and internal layout (specifically, by distributing corridors and rooms so to take a maximum advantage of micro-climatic site characteristics). In addition, the selection of construction systems and specification of building materials and elements (by relying on the use of traditional technologies such as steel structure, plywood sheeting boards, recycled concrete blocks, brick, weatherboard, recycled paper for insulation); and high-quality doors and windows (openable windows and electrically secured door locks) contributed to the achievement of environmental goals. The solutions adopted represent examples of careful architectural design accompanied by innovative construction system, ventilation and heating systems, and windows that, as a whole, contribute to the desired environmental results without impinging on the economic aspects of the project, established in the initial budget. As the client and the end users participated in the project development (at many design reviews, in the briefing stage of the project, and during construction through a number of site visits planned as teaching and learning experience for the future building users), there was a greater social inclusion both in envisioning, developing and using the building, which is perceived today as a learning experience in the application of sustainable design principles.

Figure 1: South Lanarkshire College Low Carbon Teaching Building

Analysis - Case Study 1

Table 4 shows the analysis conducted on the South Lanarkshire College Low Carbon Teaching Building. In the first column, the architectural design characteristics and building elements and services are described by using the index explained in the method section. In the second column, the identification of the innovation type is carried out by considering if architectural design characteristics and innovations in building elements and services corresponded to a definition of incremental (I), modular (M), architectural (A), system (S), or radical (R) innovation departing from standard practice (see Table 1). To carry out this assessment, interviews with the project architect, site visit and literature reviews on local construction systems and practice were undertaken. In the last columns, sustainability results are identified and assessed in terms of environmental, social and economic impacts.

Table 4: Analysis of South Lanarkshire College Low Carbon Teaching Building

BUILDING		INNOVATION					SUSTAINABILITY																	
							ENVIRONMENTAL						SOCIAL						ECONOMIC					
CATEGORY	DESCRIPTION	Type					Results						Results						Results					
		(I)	(M)	(A)	(S)	(R)	-1	0	1	2	3	4	-1	0	1	2	3	4	-1	0	1	2	3	4
Context Characteristics:																								
Urban	-																							
Rural	The building is located in a semi-rural area	■							■						■					■				
Architectural Design Characteristics:																								
Typology	Education Building	■							■								■				■			
Design Approach	BREEAM as environmental guideline				■						■							■			■			
Building orientation	North-East/Sout-West	■								■				■						■				
Dimensions	above 500 sqm - three floors	■								■				■						■				
Shape	L-Shaped	■								■					■					■				
Access and circulation	Stairs and main corridor located to optimize solar exposure				■					■					■						■			
Construction System:																								
Foundations	Concrete slab	■						■						■						■				
Vertical loadbearing structure	Steel frame	■						■						■						■				
Horizontal loadbearing structure	Steel frame	■						■						■						■				
Envelope	Facing brickwork, cavity, breath membrane, plywood, recycled paper insultation, timber battens, gypsum duraline plasterboard			■							■				■						■			
Roof	Profiled metal roofing system, vapour control layer, plywood, timber stud beam, thermoflex timber insulation, Intello plus membrane, vapour barrier			■							■				■						■			
Stairs	Main access from main entrance	■						■						■						■				
Secondary elements:																								
Door and Windows	Openable windows to have an total opening area of not less than 1/30th of floor surface		■							■							■			■				
Partitions	Thirteen types of walls with different layers of plasterboard, gypsum or brick finishes, and different types of insulation according to the needs and suspended ceiling system, lay in mineral fibre ceiling tiles, ecophone gedina system			■							■				■					■				
Building services:																								
Water system	Dual flush toilets, flow restrictors on all taps, leak detection on all incoming water supplies				■					■					■					■				
Lighting system	LED lighting fittings		■						■					■						■				
Heating system	Underfloor heating system with heat pump				■							■		■							■			
Ventilation system	Natural and Mechanical Ventilation. Natural Ventilation via openeable windows in the North, East and West, combined with stack ventilation in the corridor and in the atrium. Assisted mechanical ventilation is also provided.				■						■						■			■				
Fire control system	SVP stacks wrapped in 25mm insulation and ducts covered with two layers of plasterboard. Rockwool cavity barrier cavity closers around the perimeter of the curtain walling in windows and doors				■						■			■						■				
Sewage and water treatment system	Rainwater harvesting collection				■						■					■					■			
Energy generation from renewables	Heat Pumps				■							■			■						■			
Lifts/escalators	Standard	■						■						■						■				
Building management system	BMS system to control and monitor the rest of the building service				■						■				■						■			
		Incremental	Modular	Architectural	System	Radical	Environmental problems	No environmental change	Knowledge acquisition	Sustainability achievement	Technological advancement	Resources generation	Social problems generation	No social changes	Knowledge acquisition	Social objectives achievement	Social Improvement	Extra benefit generation	Economic Loss	No economic change	Saving achievement	New jobs creation	Increased revenue	Market expansion

As showed in table 4, in the case of the South Lanarkshire College Low Carbon Teaching Building no radical innovation in architectural design was identified. Most of the innovation in the building corresponded to the definition of 'system innovation' (Henderson and Clark, 1990; Slaughter, 1998). For instance, innovations in building services, such as the use of heat pumps, the underfloor heating system, the ventilation system, the walls stratigraphy and rainwater treatment created a system of multiple innovations to increase the environmental performance of the building. Beside contributing to the indoor quality of the environment, this system of innovation also had an impact on the social level by becoming an example for the teaching and learning activities undertaken in the building. Modular and architectural innovation also occurred in architectural characteristics (e.g. dimensions and shape) or structure (construction details) that maintained, in the instance of innovation impact, their independence from the rest of the building. Building components such as the roof, the partitions, and the outer envelope contributed to the environmental performance of the building, as well as to the social domain, both by contributing to the indoor quality of the environment, and by providing visible features to communicate the sustainability principles on which the building design was based. Construction systems such as a concrete slab for foundations and steel frame as a loadbearing system fall into the category of incremental innovation, as they are standard solutions commonly utilized in the industry. Within the economic domain, the project had a positive impact in terms of complying with the set budget and by providing an experience for the team at work, and therefore developing a comparative advantage.

Case Study 2 - Culloden Battlefield Visitor Centre, Culloden Moor, Inverness, Scotland, UK

Introduction – Case study 2

The Culloden Battlefield Visitor Centre was designed by Gareth Hoskins Architects and completed in 2007. The brief for the project was to highlight the huge impact the Battle of Culloden had on the history of Scotland. Specifically, the brief called for the restoration of the Battlefield to how it looked in 1746 and the construction of a state-of-the-art visitor centre with an interactive exhibition that could enhance the historic value of the site, celebrate the memory of a very significant event in Scottish history, and introduce principles of sustainability in its design.

The building was awarded, mentioned, and shortlisted for a number of prizes including: the Civic Trust & Commendation, RIAS Andrew Doolan Award Best Building in Scotland (Special Mention), World Architecture Festival (Culture - Shortlisted), the Wood Awards (Highly Commended), Inverness Architectural Association Award (Shortlisted), Glasgow Institute of Architects Award (Winner), RIBA Awards Regional Awards (Shortlisted), Scottish Design Awards (Finalist for Best Public Building and Northern Exposure). These awards highlighted a range of achievements such as: the building's completion within budget; an interpretative journey of the historic events through well-designed circulation in and outside the building to celebrate the memory of the historic event; application of environmental design principles in the building orientation; optimal use of the micro-climatic characteristics of the site; and the use of local building materials and passive environmental design strategies.

As the building is situated in a conservation area, Historic Scotland, Scottish National Heritage, the Royal Fine Arts Commission and The Highland Council had to be consulted. The consultations greatly influenced the design choices due to a number of strict parameters for building location, height, views and materials (Sust. Architecture + Design Scotland and Forestry Commission Scotland, 2010). The orientation of the building was decided according to the passive house design approach, the relation between space organisation and lighting, heating and ventilation. Specific decisions, such as the building orientation, contributed to the overall design and functions of the environmental control systems, allowing the passive house approach, which led to positive environmental results in terms of reduction of GHG emissions and quality of both indoor and outdoor spaces. The building layout and circulation routes in internal and external spaces are organised around the narrative of the progression of the historic events of the Culloden Battlefield. These design decisions enhanced the communication of historic facts (Bennet, 2008). The design aspects contributed to creating a significant social impact as the building is recognised as an important monument commemorating a battle that is identified as significant for Scottish identity and history. Local building materials, such as stone and timber, were largely used. This design decision affected other decisions regarding the construction systems and details, as well as manufacturing and construction methods. The use of local timber produced positive results in terms of sourcing materials within a limited radius, and therefore reducing GHG emissions, as well as stimulating local economy and industry by triggering new manufacturing processes, exploring new products, and learning new building techniques.

Figure 2: Culloden Battlefield Visitor Centre

As for the previous case study, the Culloden Battlefield Visitor Center building is described and analysed in the following table. Each building characteristic is explored in terms of type of innovation and sustainability results.

Table 5: Analysis of the Culloden Battlefield Visitor Centre

BUILDING		INNOVATION					SUSTAINABILITY																	
							ENVIRONMENTAL						SOCIAL						ECONOMIC					
CATEGORY	DESCRIPTION	Type					Results						Results						Results					
		(I)	(M)	(A)	(S)	(R)	-1	0	1	2	3	4	-1	0	1	2	3	4	-1	0	1	2	3	4
Context Characteristics:																								
Urban	-																							
Rural	The building is located on the very site of the Culloden Battlefield			■					■									■			■			
Architectural Design Characteristics:																								
Typology	Museum	■						■									■					■		
Design Approach	Application of passive house system				■				■								■				■			
Building orientation	North-West/South-East																							
Dimensions	2400 sqm	■						■							■						■			
Shape	Double 'L' Plan Layout	■																						
Access and circulation	Circulation is either external or internal to see the battlefield or the building as part of the visiting experience to recreate the movement of the battle of the Jabobite clans				■				■								■				■			
Construction System:																								
Foundations	Concrete slab	■						■						■						■				
Vertical loadbearing structure	Steel frame	■						■						■						■				
Horizontal loadbearing structure	Steel frame	■						■						■						■				
Envelope	Highly insulated timber walls and roofs. External walls are mainly clad with untreated Scottish Larch and Caithness Stone and field stones salvaged from the site.				■						■				■						■			
Roof	Wave shaped form. The roof is covered with a tpo membrane. More than 1000sqm are used as a public viewing terrace and are covered with an intensive green roof system.				■						■				■						■			
Construction details	The steel structure is bolted to assist its deconstruction and timber panels are demountable		■						■						■						■			
Stairs	Not required as the building is one floor and access to the roof is via slope	■						■						■						■				
Secondary elements:																								
Door and Windows	Oiled British oak joineries		■						■					■						■				
Partitions	Internal timber linings are made from untreated Scottish Larch with all other joinery made from oiled British Oak. Large internal and external floor areas are covered with local Caithness flagstones.				■						■				■							■		
Building services:																								
Water system	Low flush toilets, infrared controlled urinals and water saving taps are used throughout the building.				■						■				■						■			
Lighting system	Natural light and high efficiency lighting with automatic lighting controls. Lighting in the exhibition includes efficient halogen lamps to minimise UV damage to artifacts on display			■							■				■					■				
Heating system	Massive Insulation and a fully automated woodchip boiler system provides space heating and hot water generation.				■							■			■						■			
Ventilation system	A passive ventilation system was developed, combining opening windows and low-level vents, with high-level ventilation via parapets and roof cowls. The system is generally wind-driven, orientated towards the battlefield/prevailing wind. Low speed plate fans, concealed within the roof cowls, provide increased airflow for extreme conditions.				■							■			■							■		
Fire control system	As by code	■						■						■						■				
Sewage and water treatment system	Waste water is processed in a modern aerated water treatment plant. The tanks are entirely concealed below ground.				■				■						■					■				
Energy generation from renewables	Woodchips are supplied by the Scottish School of Forestry – harvested from sustainably managed forest within a 10km radius of the building- and should save approximately 55% of the total CO2 output of the building.				■							■			■							■		
Lifts/escalators	Not required as the building is one floor and access to the roof is via slope	■						■						■						■				
Building management system	A sophisticated ethernet-based building management system monitors and controls energy use in the building. Building performance can be assessed and improved through separate sub-metering of hot and cold water, zoned electrical loads, and gas consumption (LPG).				■						■				■						■			
		Incremental	Modular	Architectural	System	Radical	Environmental problems	No environmental change	Knowledge acquisition	Sustainability achievement	Technological advancement	Resources generation	Social problems generation	No social changes	Knowledge acquisition	Social objectives achievement	Social Improvement	Extra benefit generation	Economic Loss	No economic change	Saving achievement	New jobs creation	Increased revenue	Market expansion

The table above shows that there was no radical innovation in the building design. System innovation occurred in the building concept, shape, building services and type of construction. The integration of building systems, orientation, shape and type of construction contributed to achieve sustainability results, such as the GHG emission reduction, as well as to provide a pleasant indoor environmental quality, which contributed to the positive results on the social level as well. The social results are very significant in this project, which represents an achievement in trying to fill the gap between the historical perceptions of the battle of the parties involved. This was possible because of the architectural characteristics, such as the volumetric organisation of the building and its size, as well as the building shape and the circulation, which represent architectural innovations. All these aspects enabled creating a unique space for the visitors, who are guided through internal and external spaces to understand better the meaning of the Culloden battle. The selected construction materials contributed both to the application of a passive energy system, and to the increased economic activity of the local industries. This latter benefitted from the generation of both comparative and competitive advantage (Maneschi, 1998), by participating in a new innovative project and by augmenting their output in terms of production. Modular innovation occurred in specific components such as in the use of oiled British oak doors and windows. The building concrete slab and steel frames can be categorized as incremental innovation, as they comply with the standard practice, and therefore generate minimal impacts in terms of economic (Norman and Verganti, 2014).

Case Study 3 - The Robert Burns Birthplace Museum, Alloway, Ayr, Scotland, UK

Introduction – Case Study 3

The Robert Burns Birthplace Museum was designed by Simpson & Brown Architects and commissioned by the National Trust of Scotland to celebrate the birthplace of the

Scottish poet Robert Burns. The brief for this project called for a high degree of attention toward sustainability, encompassing environmental, economic and social aspects in the design of a new museum, as part of the master plan for the Burns National Heritage Park. The aim of the master plan was to link together and enhance the experiences of visiting the places related to the poet's life. The building is designed on the intersection of the axes that symbolise the connection between the museum and the existing Burns Cottage (the original place of birth of Robert Burns), which is located not far away in Alloway, Ayr. The sustainability goals were achieved by using passive house environmental control strategies and local materials; carefully designing the building orientation to maximise the exposure to natural light and ventilation; expressing aesthetics that relate to sustainability principles, such as the use of local materials; and including the local community by providing educational, recreational and gathering spaces. Local building materials, such as untreated timber, communicate the environmentally sustainable design approach. The orientation of the building made it possible to organise the layout and spatial distribution in order to optimise natural lighting and ventilation by exposing the opening to favourable wind directions and lighting conditions, e.g. the window in the South-East elevation. The context characteristics and the building orientation influenced the specification of environmental control systems, the selection of doors and windows, and architectural design. The Main Gallery has an open plan in which natural light and lighting systems are combined to control their impact on the artifacts exhibited in the museum. The shape of this gallery also enables natural ventilation through a 'stack effect' in combination with fans. This system brings air from the gardens and circulates it through the building via concrete pipes buried two meters below ground, providing cooler air in summer and warmer air in winter due to the constant temperature of the ground at this depth. Moreover, this process allows for a better control of humidity levels and reduces heating input. The ground source heat pump also provides warm water for the underfloor heating system in public spaces. The reception hall and the café have natural ventilation and light. The whole structure is clad with untreated Scottish Douglas-fir horizontal boards, sourced and processed in Moray, which is close to the museum. Timber is also largely used in the building to underline the transition between spaces and to create links with the overall architectural design characteristics. As in the previous case study, the use of Douglas-fir stimulated local production and manufacturing.

The architectural shape and layout are organised in a way that enables different circulation and use of the building. The main hall, café and an external pergola facing the gardens are used largely by the community for a number of events during the year, independently from the regular museum activities. These design features support social inclusion and sense of belonging, not only due to the building's role in celebrating a local poet, but also by providing a gathering space.

Figure 3: Robert Burns Birthplace Museum

Analysis – Case Study 3

Table 6 shows the analysis conducted on Robert Burns Birthplace Museum, by following the same methods used in the previous case studies.

Table 6: Analysis of the Robert Burns Birthplace Museum

BUILDING		INNOVATION					SUSTAINABILITY																	
							ENVIRONMENTAL						SOCIAL						ECONOMIC					
CATEGORY	DESCRIPTION	Type					Results						Results						Results					
		(I)	(M)	(A)	(S)	(R)	-1	0	1	2	3	4	-1	0	1	2	3	4	-1	0	1	2	3	4
Context Characteristics:																								
Urban	-																							
Rural	The building is located in a semi-rural area																							
Architectural Design Characteristics:																								
Typology	Museum																							
Design Approach	Orientation of building axes in relation to other significant places of the life on Robert Burns in the close area of its birthplace and application of passive house strategies																							
Building orientation	North-West/South-East																							
Dimensions	500 sqm																							
Shape	Rectangular symmetric plan																							
Access and circulation	The existing walkway bordering the main road and linking the Cottage Site at the north end of the village and the New Museum Site at the south end, has been enhanced. New access points have been provided to enhance existing paths																							
Construction System:																								
Foundations	Concrete slab																							
Vertical loadbearing structure	Timber structure sourced locally																							
Horizontal loadbearing structure	Timber structure sourced locally																							
Envelope	South-East elevation is glazed, while the rest of the envelope is clad with untreated Scottish Douglas-fir horizontal boards																							
Roof	Green roof with sedum																							
Construction details	Douglas-fir structure interlocking system as joints																							
Stairs	Not required as the building is a single floor																							
Secondary elements:																								
Door and Windows	Window frames assembled in Kilmarnock and locally sourced																							
Partitions	Green Douglas-fir structure, European redwood panels and external wall panels as filled with 250mm of recycled paper (cellulose).																							
Building services:																								
Water system	Standard																							
Lighting system	Black box quality of the space has offered absolute control to the exhibition																							
Heating system	This naturally tempered air enters the building via a basement plant room where additional cooling or warming is provided by the ground source heat pump system installed under the new car park on the North-east side of the site.																							
Ventilation system	The air filling the gallery space circulates by natural convection, or 'chimney stack effect' assisted by fans when required.																							
Fire control system	As by code																							
Sewage and water treatment system	Standard																							
Energy generation from renewables	Heat pump																							
Lifts/escalators	Not required as the building is a single floor																							
Building management system	None																							
		Incremental	Modular	Architectural	System	Radical	Environmental problems	No environmental change	Knowledge acquisition	Sustainability achievement	Technological advancement	Resources generation	Social problems generation	No social changes	Knowledge acquisition	Social objectives achievement	Social Improvement	Extra benefit generation	Economic Loss	No economic change	Saving achievement	New jobs creation	Increased revenue	Market expansion

Radical innovation was not found in the project. Instead, system innovation was detected in the areas of architectural design characteristics and building services. For instance, the building orientation contributed to develop a passive energy design approach for the building, which was actualised also by using natural ventilation and heat pumps. These individual innovations, by working as a whole system, contributed to the achievement of positive environmental sustainability results, such as the GHG emission reduction, and the achievement of a positive indoor air quality as by code. Moreover, the architecture characteristics of the building, such as the spatial organization and the relation between opaque and transparent envelop surfaces helped defining a space for the local community use within the museum. Positive environmental impact is achieved by the use of local materials such as the Douglas-fir, mainly for the structural elements, or the European redwood panels and recycled paper for thermal insulation in external walls. Along with the positive environmental impacts, the selected materials had a positive economic impact for the local industry and a positive social impact as they contribute to create an image of sustainable architecture to communicate its value to the users. Architectural and system innovations have produced not only positive environmental results, but also beneficial social and economic impacts. As in the previous case study, the use of local materials has produced both comparative and competitive advantage for the local industry participants who took part in the building realization. Moreover, the project had a strong social impact by generating extra benefit for the community, providing not only a museum but also a gathering space.

Discussion

As an answer to the first research question of this work, the analysis of three case studies allows a reflection on type of innovations, other than the radical one, that can be used to create sustainable buildings. The analysis shows that sustainability results were achieved despite the absence of radical innovations in architectural design. These results encompassed environmental aspects such as CO_2 emissions reduction, economic aspects such as a stimulus for the use of local materials, technologies, and sustainable delivery processes, and social aspects such as the design of more inclusive spaces, which all comply with the targets set by Scottish Government. The achievement of these results relied mostly on architectural innovation (for example, the creation of more community inclusive spaces through definition of appropriate spaces, accesses, internal layout and volumetric organization) and system innovation (building orientation, environmental control system), and to same extent also to the modular innovation (for instance, in the use of specific timber in door elements) and incremental innovation (in the use of a concrete slab or timber frames), but with minor impacts. Incremental innovation is recognized as slower changes, generally based on existing solutions improvement (Norman and Verganti, 2014). The identified architectural innovations are mostly related to the visible features of the buildings (e.g. shape, volumetric arrangement, ratio of opaque and transparent surfaces, finishes, materials), and therefore contribute to the understanding of the value of sustainability design choices, and to its diffusion (Nigra, 2017). This type of innovation type seems to be aimed at a long-term impact on a social level. A clear example is the Culloden Battlefield Visitor Centre in which the shape and the volume of the building, as well as the internal layout, contributed to communicate the historic significance of the battlefield. System innovations, generally recognized as context-dependent (Hellström, 2003), seemed to be, in the three projects, targeting mostly environmental aspects by creating a system of innovative design solutions in different part of the building (windows, doors, heating systems, ventilation systems, water collection systems) that contributed to the reduction of usage of natural resources and CO_2 emissions. The system type of innovation seemed to be strategic and long-term, producing slower and long-lasting effects. For instance, in the case of the South Lanarkshire Low Carbon Teaching Building, in which environmental control features are visible - as a design choice – the ability of teaching sustainability aspects to the students by observing and understanding their own building is enhanced. Other system innovations noticed in the case studies were developed through specification of building materials, construction systems, doors and windows, and through architectural design. For instance, local materials – especially timber – were used on the above projects and stimulated local economies in terms of production and manufacturing. Despite a vast variety of timber in Scotland, it is relatively under-utilised in the UK with the demand for higher quality timber fulfilled mainly by imports (Price and Macdonald, 2012). This may be in part due to the lack of interest from local growers because of low demand and to the perceptions of poor form (Price and Macdonald, 2012). Therefore, specifying local timber in buildings can be considered as an economic stimulus to encourage both growing, manufacturing and market openings. The use of other traditional materials (such as plywood sheet boards, steel structures or stone) had positive results regarding the economy of scale by increasing the demand for those materials. Moreover, the post-occupancy evaluations conducted by the architects of the three buildings showed that the buildings' users responded positively to the spatial, access and circulation organisation, to the shape and the visual relations that the designs created internally and between indoor and outdoor spaces, and to the narrative and values that the buildings aimed to communicate through their layout and architectural characteristics. The users' positive feedback provided evidence of social value of each project. The architectural design features vary on each project and often represent an architectural type of innovation.

The case studies analysis answers the second research question - whether particular building design approaches and characteristics could be used as a strategic ground for achieving sustainability results. To answer this question, this work has presented some examples of the results achieved in the three case studies by assessing the buildings according to the parameters in table 3. Among all the results, it is possible to observe that aspects such as context and architectural design characteristics (see specific sub-categories in Table 4, 5 and 6) have the potential to produce positive **social impacts** if the social objectives were addressed by providing functional spaces; by engaging with clients and users throughout the project; by providing flexible spaces for continuous community use; if the building communicates sustainability values and intent through its visible features; and if the project has received a public recognition of its positive social impacts. The context and the architectural design characteristics have also the potential to produce positive **environmental impact**s by providing healthy and comfortable indoor environments; by adapting to the surrounding and optimising the micro-climate characteristics; by applying environmental design schemes and concepts by relying on low energy consumption building services; by reducing the exploitation of primary resources; and by using renewable sources of energy and local materials. This latter building design characteristic, in conjunction with the construction systems has also the potential to produce positive **economic impacts** by contributing to the creation of new local jobs during and after construction; by stimulating or strengthening local economic development through new knowledge and experiences, and in some cases, by opening new markets. Similarly, building services can produce positive environmental impacts (as the ones mentioned for the context and architectural design characteristics), as well as positive social impacts (e.g. when the indoor quality of the environment contributes to users' wellbeing, and when the use of sustainable building services displays their value to the users and therefore has an educational role. In terms of economic impact, building services can reduce whole-life cycle costs by monitoring and defining an appropriate behaviour in terms of energy consumption, and by producing, in certain cases, extra sources of energy to trade off. Shedding light on sustainable development opportunities in building projects contributes to the strategic planning of architectural design that can achieve sustainability goals.

In response to the last research question - whether it is possible to identify a relationship between type of innovation and building design characteristics - the analysis allows the following reflection. Incremental, modular and system innovations are most likely to produce positive environmental results, for example, through optimisation of building orientation, the use of passive lighting and ventilation strategies, or the use of renewable resources. Design decisions related to a building structure, construction details and systems, building materials, the number of floors, building height and size also contribute to the environmental performance and impact of a building. They offer opportunities to apply strategies related to embodied energy and energy use, thermal control, easy construction and streamlined logistics. Along with the design decisions, building construction processes can also offer the opportunity to achieve positive economic results (Gann, 2000; Winch, 1998; Winch and Campagnac, 1995, Ruddock 2009). The use of certain building materials such as local timber (if it was not used before locally for building purposes) can trigger new manufacturing processes, knowledge acquisition, and competitive benefits, contributing to the economic growth of local and/or national industries. The last pattern of design change is concerned with the design concept development, building shape and size, architectural characteristics and access. These design decisions offer the opportunity to communicate values and design intent through visible features and, therefore, can have higher impact on the social response and related results. The understanding of types of innovation, their relationship with the results achieved, and the pattern of innovation in specific project areas can contribute to a more informed design management aimed at optimising the opportunities for economic, social and environmental sustainability of building projects. In particular, as was shown in the analyses of the three Scottish case studies, the understanding and the knowledge of the social, environmental and economic conditions of the context are a critical starting point to foster sustainable innovation. In the Scottish context, positive results were achieved without relying on radical innovation in architectural design but in the specification of innovative building services that reduce environmental impacts. Yet, other socio-technical and environmental contexts may require radical innovations in architectural design to achieve sustainability goals.

Conclusions

The challenges that our planet is facing today are complex, multi-fold and ever changing (United Nations Development Programme 2015). The field of architecture, in line with many others, is called to define new technical solutions, envision scenarios and propose innovative approaches. Although innovation is largely discussed as a medium of advancement and progress (Emmitt, 1997; Gann, 2000; Henderson and Clark, 1990; Lindgren, 2016; Slaughter, 1998; Winch, 1998; Gambatese and Hallowell, 2011), its nature (in terms of type) against specific development objectives remains an area of possible further exploration. This work, in line with Leach et al. (2012) has shed light on the importance of diversity of innovation. This exploration is significant to demonstrate that certain sustainability results are possible and valuable without necessarily relying on disruptive solutions typical of radical innovation, and that a design management process aimed at achieving sustainability results can lead to better informed project development strategies based on the optimisation of type of innovation defined in relation to specific projects objectives. Incremental and modular innovation can produce slower changes by improving existing solutions (Norman and Verganti, 2014) and by producing a long-lasting and robust effect on the industry without changing its nature. Architectural and system innovation can represent the opportunity to optimise the whole building systems by establishing carefully planned relations between parts of building, in such a way to achieve efficiency through the improvement of the links between existing solutions. Relying on the improvement of existing solutions, both in parts of the building characteristics and links, as opposed to the disruptive solutions, can represent a pre-requisite for sustainable progress. These approaches require the ability to identify the most appropriate types of innovation in specific contexts, and in relation to the specific sustainable development objectives; as well as the ability to define well-planned and managed development processes, able to highlight links that exist between types of innovation and potential social, economic, and environmental effects already during the preliminary building programming phase.

Understanding these strategic opportunities of different types of innovation can contribute to the development and management of our future sustainable built environment by informing designers, policy makers, industry participants, and management and consultancy entities. Yet, it remains crucial to explore further the direction of change (Leach et al., 2012) that any innovation can lead to. Leach et al. (2012) suggest that clear goals and principles driving development policies and innovation strategies need to address the kind of transformation we envision for our future, as well as consider the trade-offs that often lie beneath complex environmental, economic and societal contexts. Within this context, in a 'Mumfordian' way, architecture, on one hand can still be considered the reflection of the societal changes that we decide to address, and on the other hand it has the role of communicating the changes by providing appropriate responses to the emerging societal needs.

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