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Regenerative sustainability for the built environment – from vision to reality: an introductory chapter

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ABSTRACT

Regenerative sustainability is emerging as an alternative discourse around the transition from a 'mechanistic' to an 'ecological' or living systems worldview. This view helps us to re-conceptualize relationships among humans' technological, ecological, economic, social and political systems. Through exploration of 'net positive' or 'regenerative' development lenses and the traditional sustainability literature, the conceptualization and approaches to achieve sustainable development and ecological modernization are expanded to articulate and to explore the evolving sustainability discourse, 'regenerative sustainability'.

This ***Special Volume of Journal of Cleaner Production (SV)*** is focused upon various dimensions of regenerative sustainability (e.g. regenerative design, regenerative development, and positive development) applied to the urban built environment at scales, which range from individual buildings, neighbourhoods, and urban developments to integrated regional sustainable development. The main focus is on how these approaches and developments are evolving, how they can help us to prevent or adapt to climate change and how these approaches are likely to evolve in the next two to three decades. These approaches are addressed in four themes: (1) reviewing the theoretical development of the discourse of regenerative sustainability, its emerging principles and practices, (2) explaining how it can be measured and monitored, (3) providing encouraging practical pathways and examples of its implementation in multiple cultural and climatic contexts, and (4) mapping obstacles and enablers that must be addressed to help to ensure that more rapid progress is made in implementing the transitions towards an urban built environment that supports genuinely sustainable societies.

1. Introduction

One of the central narratives of the modern world is to control nature and our external surroundings for the benefit of humankind. In 1997 Dryzek argued that this long-dominant discourse in the world was the discourse of industrial society, which he called industrialism. Industrialism is characterized by commitment to 'growth in the quantity of goods and services, and to the material well-being, which that growth brings'. Dryzek (1997) claimed that, in essence, all political and economic systems of the last two hundred years were within the broader discourse of industrialism. The latter part of the 20th century saw the burgeoning of a new, broader discourse, called environmentalism, compared to which the discourse of industrialism has become much more dominant. Major politico-economic systems—for example, liberalism, conservatism, socialism, Marxism and fascism—are all subsets of the broad discourse of industrialism (Dryzek, 1997). The broad environmentalism discourse can be subdivided based on whether terms are reformist or radical in their departure from typical industrialist terms of reference, and whether they are prosaic—taking the system as a given—or imaginative—seeing that the system is in need of dramatic changes. These subdivisions were explored and articulated by Dryzek (1997) and have undergone

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several revisions during the past two decades as the discourse evolved (see Dryzek, 2005, 2013).

One of the prominent discourses that is reformist and imaginative in its outlook is sustainability, and this perspective has seen exponential development in both the academia and professional world. Much of this concerns the continued appearance of environment pollution, health risks, endangered species, devastated eco-systems, spreading deserts and increasing frequency and severity of climate-related destruction and other inter-related problems, all having been addressed in papers published in *Journal of Cleaner Production* during its 23-year history.

In the built environment discipline, the *green building* concept of 'doing less harm' or, 'reducing the degenerative consequences' of human activities on human health and upon the integrity of ecological systems, are both important key phrases in defining sustainable buildings and developments. These approaches are grounded in a mechanistic and reductionist worldview (du Plessis, 2012), and were criticized by Cole (2012), as being not only an insufficient requirement for charting an ecologically sustainable future but as also an insufficient aspiration for challenging and empowering design professionals and their clients to be increasingly creative. In particular, when large-scale urbanization, industrialization and a high-technology-driven society become the mainstream, relationships among human beings' technological, ecological, economic, social, political, cultural, and ethical systems must be questioned and re-conceptualized. One of the 'problems' with the concept of 'sustainability', and in particular 'sustainable development' is that its precise description is elusive, and variable depending upon the actors and the circumstances, since "… astute actors recognize that its terms should be cast in terms favourable to them" (Dryzek, 2013:148). For some authors, 'ecological modernization' has helped us to begin to redress the shortcomings of 'sustainable development' and "… it refers to the restructuring of the capitalist political economy along more environmentally sound lines, but not in a way that requires an altogether different kind of political-economic system" (Hajer, 1995 cited in Dryzek, 2013: 170).

During recent decades the trajectory of 'regenerative development' (Reed, 2007; Mang and Reed, 2012; Cole, 2012; du Plessis, 2012; Hes and Du Plessis, 2014), 'regenerative design' (McDonough and Braungart, 2009) and 'positive development' (Birkeland, 2012) has attracted increased interest as a discourse for reframing and re-conceiving 'green building' practices. Evidence from several research and development themes are motivating many to shift from addressing issues such as climate change, green buildings, regional carrying capacity, infrastructure design and development, urban community planning, and social justice, *in isolation* to working with them simultaneously and *holistically* from a systems perspective. This provides an alternative to seeking to solve individual problems with the objective of causing 'less harm' or even 'net zero' solutions that minimize or mitigate harmful human activities. Instead, the objective is to engage and to empower people to focus upon integrated, system's approaches for creating and re-creating buildings, neighbourhoods, urban areas and regions through a 'net positive' or 'regenerative' lens in the expectation that this will increasingly yield synergistic benefits far beyond the current norms. The heart of regenerative development is the concept of place and humanity's role in it. It promotes a co-evolutionary, partnered relationship between humans and natural systems rather than a managerial one and, in so doing, builds, rather than diminishes, the social and natural capitals to *'grow the caring'* required to make sustainability real (Cole, 2012).

Du Plessis' (2012) 'regenerative sustainability paradigm' is an alternative environmental discourse, which evolved from considerations involving the transition from a 'mechanistic' to an 'ecological' or living systems worldview, and which relates to approaches that support the mutually beneficial co-evolution of humans and natural systems in a partnered relationship (Cole, 2012). The essence of regenerative sustainability in the built environment is to propose a co-evolutionary, partnered relationship between human and natural systems, which are designed to build sustained social and natural capital to achieve a holistic goal in 'ultimate co-benefit'. It re-conceptualizes the relationships among human technological, ecological, economic, social and political systems. Based on the exploration and questioning of developments in the context of 'net positive' or 'regenerative' and the traditional sustainability literature. Various actors, including academics, real estate developers, architects, urban planners, contractors, market salesman, politicians, and the general public, have contributed to finding pathways to support regenerative sustainability.

This SV contains a compilation of high quality research articles designed to increase the theoretical and the practical understanding in rethinking sustainability towards regenerative sustainability. The main focus of the planners of this SV was to engage researchers and practitioners in theorizing regenerative sustainability and to catalyse implementation of the emerging knowledge of it in the 'real world.'

2. Reasons for this special volume

The purposes of this SV was to contribute to the discourse on regenerative sustainability (e.g. regenerative design, regenerative development, and positive development) applied to the urban built environment at scales that range from individual buildings, neighbourhoods and urban development to integrated regional sustainable development. The focus was on how these approaches and developments are evolving, how they can help us to prevent or adapt to climate changes and to explore how these approaches are likely to evolve in the next two to three decades.

Developing these ideas into implementable solutions involves regenerative sustainability thinking in decision-making process. Entities such as eco-cities, low carbon cities, knowledge cities, smart/intelligent cities and regenerative neighborhood/community/cities have been proposed and are being tested as integrated socio-technical answers to environmental concerns in urban development practice. What do these entail, how are these being implemented and how do they relate to regenerative sustainability?

Addressing these questions required consideration of a variety of issues concerning theory and practice. From a theoretical perspective, this included the origins and fundamental foundations involved; related theoretical and concepts; definitions and roles of baselines and benchmarks; characteristics, policies and emphases; contrasts with green building; co-benefits from implementation; and trans-disciplinary approaches.

In terms of practice, the main considerations related to implementation and management of the processes involved. Firstly, development of the necessary techniques involved, including identification of relevant indicators of performance, assessment approaches, thresholds and targets at various scales; use of baselines and benchmarks on multiple spatial, temporal and functional scales and enhanced skills in integrating the interconnected systems involved. Second, the approaches that support regenerative practices in terms of governance and policy regimes, models and other tools at different scales, with particular emphasis on the roles and relationships with stakeholders (real estate developers, investors, architects, etc.) in exploring ecological, economic and social possibilities. Finally, is the need to understand and anticipate the barriers involved, the enablers and opportunities for implementation of supporting technologies, identify co-benefits and the

solutions needed to work in harmony with ecological and human systems.

3. Overview of the papers included in this SV

This SV of the JCLP was designed to address the objectives of (1) documenting the theoretical development of the term regenerative sustainability, its emerging principles and practices, (2) explaining how it can be measured and monitored, (3) providing encouraging practical pathways and examples of implementation in multiple cultural and climatic contexts, and (4) mapping obstacles and enablers that must be understood and addressed to that more rapid progress can be made in implementing the shift towards an urban built environment that supports the vision of a sustainable society articulated by the proponents of 'regenerative sustainability'.

Many of the 30 papers of the SV contributed to multiple aspects, as shown in Table 1. The remainder of this section highlights how each contributed to the four themes.

3.1. Theme 1: theory and definitions of regenerative sustainability and related concepts

The "fossil fuel revolution" has been argued as being the most significant event in the entire history of humankind. It led to industrialism rising to the dominant discourse of the 19th and 20th centuries. As Christian (2005) put it in his seminal, *Maps of Time*: *an Introduction to Big History*," Learning how to use coal and oil to generate steam power or electricity has been the equivalent of finding several whole new continents for human exploitation." Citing Wrigley (1990), Christian stated that in Britain alone the energy extracted from coal ca. 1820 was equivalent to the amount of energy that could have been extracted using traditional technologies from an area of forest greater than all of Britain's pasture and arable land taken together. "… the amounts of energy used by human societies increased by about five times in the 19th century and then by another sixteen times in the 20th century" (Christian, 2005: 346). The exponential increase in production brought about by the then new technologies changed the world utterly, with a vast increase in prosperity that for many continues to increase today in industrialized and industrializing nations. However, as was pointed out in **Bayulken and Huisingh**'s *A literature review of historical trends and emerging theoretical approaches for developing sustainable cities (Part 1)*, spatial and urban development policies and trends have also changed extensively over this time and policies that were based on economic growth along with rapid urban population have been increasing irreversibly and negatively affecting most urban eco-systems globally, prompting what is now largely accepted as human-induced climate change. As they explained, concepts such as sustainable development (SD) and ecological modernization (EM) have been among the most discussed responses but, in spite of some relatively successful positive contributions to urban policies, most notably in Northwest Europe, questions remain as to whether these concepts have effectively and sufficiently catalysed the promotion of sustainable urban development more broadly. In seeking to find answers, they explore the evolutionary aspects and the shortcomings of EM and SD within the overarching sustainability paradigm. In doing this, they reviewed the historically significant antecedents and outlined a vision for needed transitions, by addressing the emerging theoretical approaches aimed at underpinning new urban development policies and procedures, and contextualizing the evolution of regenerative or net positive developments in broader cultural, geographical and temporal contexts.

In recent decades, metropolitan areas worldwide have been engaged in a multitude of initiatives aimed at upgrading urban infrastructure and services to create better environmental, social and economic conditions and to enhance the attractiveness and competitiveness of cities. As a result, many new categories of 'cities' have entered the policy discourse, including the 'sustainable city'; 'green city'; 'digital city'; 'intelligent city'; 'smart city'; 'information city'; 'knowledge city'; 'resilient city'; 'eco-city'; 'low carbon city'; 'liveable city'; and even combinations such as 'low carbon eco-city' and the 'ubiquitous eco-city'. Each of these terms was designed to capture and conceptualize key aspects of ongoing urban sustainability efforts, although policy makers, planners and developers often use the terms interchangeably.

De Jong, Joss, Schraven, Zhan and Wejinen's *Sustainable-smart-resilient-low carbon-eco-knowledge cities*: *making sense of a multitude of concepts promoting sustainable urbanization* investigated this in terms of the reflection of the wider policy debate in academic discourse through bibliometric analysis of the literature to find subtle conceptual differences and a web of interrelationships between the categories. A sustainable city, for example, is the most frequently occurring and by far the largest and most interconnected node, most intricately linked with the eco-city and green city families of concepts. The more narrowly defined low carbon cities and especially smart cities are rapidly gaining in popularity. In this case, the low carbon city, essentially represents a subset of the sustainable city concept; while the smart city stands out as a new set of concepts in which prominent features are social inclusion, the role of the internet in creating new businesses and jobs for the provision of high quality services and the empowerment of citizens with information – positioning the smart city as a distinct category of urban modernization ambitions and initiatives.

Regenerative design and development calls for a shift from a 'mechanistic' to the 'ecological' or living systems worldview that has emerged from living systems sciences over the last fifty years. The challenge for design practitioners educated and now working in a field mainly shaped by a mechanistic worldview is two-fold: first, to develop an understanding of how life and living systems work and, second, to translate that understanding into applications. The benefit of rising to this challenge is that understanding natural systems offers powerful insights into how to work across different scales of the built environment. Compared with current sustainability models, the ecological worldview provides a new interpretation of sustainability, with the objective to cultivate relationships, which provide both life-support and life enhancing conditions for the global human community within healthy eco-systems. This concept has been well described and investigated within the book 'Designing for hope: pathways to regenerative sustainability', which explored with more than 50 professionals and abundant case studies, the new practices that go beyond contemporary notions of sustainability and green design. The authors documented and highlighted what some forward thinking/working designers who are planning and implementing through their more sustainable developments from the perspective of a reductionist alternative. **Zhang and Wu**'s book review o.

In line with their findings, **Zhang and Wu's** book review of Hes' and du Plessis' "Designing for Hope" *Are ways ahead for regenerative sustainability?* offers an insightful and interesting discussion. Of particular relevance is there comment that '*from the perspective of the ecological worldview*, *the approach to solving problems is in holistic and dynamic ways*, *requires us to build upon the worldview*, *which is illustrated by biomimicry*, *permaculture*, *and positive development to participate more effectively in the natural evolution of our planet*.' Their contribution to the methodologies and techniques in presenting regenerative sustainability is highlighted and the suggestion of how to 'learn from', how to 'work with', how to 'design for', and how to 'co-evolve with' nature. Additionally, the authors provide access to the tools and actions for achieving regenerative

Table 1
Papers in this Special Volume classified into its four main themes.

No	Author(s)	Title	Theme 1	Theme 2	Theme 3	Theme 4
1.1	Bayulken and Huisingh, 2015a	A literature review of historical trends and emerging theoretical approaches for developing sustainable cities (Part 1)	X			
1.2	De Jong et al., 2015	Sustainable-Smart-Resilient-Low Carbon-Eco-Knowledge Cities; Making sense of a multitude of concepts promoting sustainable urbanization	X			
1.3	Zhang and Wu	Book review for "Designing for Hope"	X			
1.4	Benne and Mang, 2015	Working Regeneratively Across Scales—Insights from Nature Applied to the Built Environment	X			
1.5	Du Plessis and Brandon, 2015	An ecological worldview as basis for a regenerative sustainability paradigm for the built environment	X			
2.1	Ding et al., 2015	An Inclusive Model for Assessing the Sustainability of Cities in Developing Countries – Trinity of Cities' Sustainability from Spatial, Logical and Time Dimensions (TCS-SLTD)		X		
2.2	Peng et al., 2015	An alternative model for measuring the sustainability of urban regeneration: The way forward		X		
2.3	Xia et al., 2015	Comparison of sustainable community rating tools in Australia		X		
2.4	Heravi et al., 2015	Evaluation of Sustainability Indicators of Industrial Buildings Focused on Petrochemical Projects		X		X
2.5	Wu et al., 2015	A review of benchmarking in carbon labelling schemes for building materials		X		
2.6	Allouhi et al., 2015	Energy consumption and efficiency in buildings: Current status and future trends		X		
2.7	Cao et al., 2015	A comparative study of environmental performance between prefabricated and traditional residential buildings in China		X		
2.8	Son and Kim, 2015	Early prediction of the performance of green building projects using pre-project planning variables: data mining approaches		X		
3.1	Bayulken and Huisingh, 2015b	Are lessons from eco-towns helping planners make more effective progress in transforming cities into sustainable urban systems: A literature review (Part 2 of 2)			X	
3.2	Zhang et al., 2015	'Turning green into gold': a framework for energy performance contracting (EPC) in China's real estate industry		X	X	X
3.3	Perales-Momparler et al., 2015	Regenerative built environment		X	X	X
3.4	Chao et al., 2015	Water Consumption Characteristics at a Sustainable Residential Development with Rainwater sourced Hot Water Supply		X	X	
3.5	Pearce, 2015	Phosphorus Recovery Transition Tool (PRTT): A transdisciplinary framework for implementing a regenerative urban phosphorus cycle			X	X
3.6	Tam et al., 2015	Best Practice of Prefabrication Implementation in the Hong Kong Public and Private Sectors		X	X	
3.7	Cobut et al., 2015	The environmental footprint of interior wood doors in non-residential buildings –part 1: life cycle assessment			X	
3.8	Cobut et al., 2015	Reducing the environmental footprint of interior wood doors in non-residential buildings – Part 2: Ecodesign			X	
4.1	Al-Saleh and Mahroum,2015	A critical review of the interplay between policy instruments and business models: greening the built environment a case in point		X		X
4.2	Lam et al., 2015	Applicability of the Clean Development Mechanism to the Hong Kong building sector			X	X
4.3	Labanca et al., 2015	Energy efficiency services for residential buildings: market situation and existing potentials in the European Union			X	X
4.4	Persson and Grönkvist, 2015	Drivers and barriers to low-energy buildings in Sweden			X	X
4.5	Ruparathna and Hewage, 2015	Sustainable procurement in the Canadian construction industry: Current practices, drivers and opportunities			X	X
4.6	Qian et al., 2015	Modelling the Green Building (GB) Investment Decisions of Developers and End-users with Transaction Costs (TCs) Considerations		X		X
4.7	Chiang et al., 2015	The nexus among employment opportunities, life-cycle costs, and carbon emissions: A case study of sustainable building maintenance in Hong Kong		X		X
4.8	Olazabal and Pascual, 2015	Urban low-carbon transitions: cognitive barriers and opportunities			X	X
4.9	Heiskanen et al., 2015	Demonstration buildings as protected spaces for clean energy solutions – the case of solar building integration in Finland			X	X

development. The second contribution of the book lies in its successful utilization of real-world cases, thereby, making novel knowledge more understandable and acceptable. An abundance of realistic pictures, practical cases and clear citations are presented to concretely and vividly demonstrate the feasibility of implementing and building upon the theories and techniques described.

Benne and Mang's *Working regeneratively across scales – insights from nature applied to the built environment* contribution is to consider the key and interrelated principles of living systems and how they translate into design and development practices using examples of how actual projects work across multiple scales. The first principle considered is the nested or *holarchic* nature of living systems and their inseparability from their environment. Mapping a design project as a socio-ecological system nested within its immediate and larger contexts shifts designers' attention to the unique and distinctive character of the project environment and the reciprocal influences of projects and the environment. A second principle, that the self-organizing and self-regenerating capacity of ecosystems depends on their members carrying out their systemic roles, provides the basis for defining and designing a distinctive and generative role for a project within its place. This role enabled the project to be both more valuable and valued as a source of greater viability and vitality and, drawing on the first principle, to have a positive influence across different scales of nested wholes. The

third principle relates to the webs of dynamic flows and metabolic exchanges that enable life to continuously produce, repair, and perpetuate itself. Using insights gained from the understanding of the essence of a place, design practitioners were able to identify transformative nodal points within those webs where targeted *acupuncture interventions*, sometimes small, can influence the health and renewal of the whole system. In doing this, the authors first summarized how working from an understanding of living systems principles provides insights into working regeneratively across and within different scales. Second, it addressed the need for a shift in the role of designers and for new capabilities to be developed in order to incorporate these insights into new development and design practices. Finally, the authors highlighted some of the challenges design practitioners might face when implementing living systems approach within the complexity of multidisciplinary design projects.

It has been argued that, in order to move development into a positive curve towards sustainability, society needs to change the dominant discourse within which it operates That such a shift from a mechanistic to an ecological or living systems worldview is already happening is becoming increasingly apparent. It was suggested that the purpose of the sustainability paradigm flowing from this worldview is not to conserve the *status quo* or meet ill-defined human needs, but to strengthen the health, adaptive capacity and evolutionary potential of a fully integrated global social-ecological system. In this way, it can continue regenerating itself, thereby creating the conditions for a thriving and abundant future – not only for the human species, but for all life forms. **Du Plessis and Brandon's** *An ecological worldview as basis for a regenerative sustainability paradigm for the built environment* response is to examine: how we interpret sustainability from the ecological worldview. They provided guidelines and the regenerative strategies needed for the built environment in order for planners to adapt to coming changes in the planetary system. The question asked is, how does this sustainability paradigm, with its focus on regenerating the whole of the social-ecological system within which we are working, change our stewardship of the built environment? This was addressed by the findings of two separate studies: an extensive literature review to define the meta-narratives of the ecological worldview; and an empirical analysis of the built environment from academic and practitioners' perspectives. The correlation between the practical and theoretical positions of the second study and the values and praxeology of the ecological worldview from the first were combined to provide a framework for discussing the implications of regenerative sustainability for the production of the built environment – for how it is created, the technologies used and how it is evaluated.

3.2. Theme 2: performance assessment of regenerative sustainability

The increasing awareness of the need to improve built environments in declining urban areas worldwide has raised the popularity of urban regeneration as a research topic. Various tools, such as questionnaire surveys, the analytic hierarchy process and fuzzy set theory, have been developed to measure the sustainability of urban regeneration and ensure that it follows the principles of sustainable development. Having an indicator system in place designed to evaluate whether progress towards the goal of net positive ecological gain was realized is key for being able to initiate corrective action where necessary, as well as for keeping participants motivated in continuing to move towards their goals. However, these studies, which rely on the indicator system, assume that urban regeneration is a static and isolated state during the assessment process. Eight different papers are included in this Sv volume, which are related to theme 2, the first three of which deal with the level of cities and neighbourhoods and the other five with measuring environmental performance at the level of buildings in various ways.

In the first paper, by **Ding, Zhong, Shearmur, Zhang and Huisingh**, *An Inclusive Model for Assessing the Sustainability of Cities in Developing Countries – Trinity of Cities' Sustainability from Spatial, Logical and Time Dimensions (TCS-SLTD)* is presented. This tool can review and monitor progress in environmental performance over time based on a multi-dimensional analysis. Since this can also be applied to cities in developing countries rapidly growing in size, Xian, a major city in Western China and a former imperial capital city is the ideal empirical test-bed for its application. The authors show how the model could assist urban planners and policy makers in developing countries in the performance of integrated assessment for urban sustainability.

Peng, Lai, Li and Zhang's *An alternative model for measuring the sustainability of urban regeneration*: *the way forward* introduces fuzzy set theory and Monte Carlo simulation to solicit the critical measurement indicators needed to provide a unified basis for comparison. The entropy method is used to determine the weights of relevant critical measurement indicators to avoid subjective judgement. A general decision-making framework for dynamic monitoring of urban regeneration is then developed based on the dynamic change of sustainability of urban regeneration (Vk) and urgency of urban regeneration (Uk). Four scenarios are discussed based on the four quadrants generated by Vk and Uk, which enable sustainable urban regeneration to be identified and compared through the Vk-Uk coordinate system, and the best practices of urban regeneration determined for global promotion. The model provides an improvement on existing studies by being able to accommodate the fuzzy and subjective nature of the indicator assessments of urban regeneration sustainability. An additional benefit is the potential of the decision-making framework to assist policy-makers in determining the sustainability of ongoing urban regeneration as well with the dynamic and long-term monitoring involved.

In their contribution *Comparison of sustainable community rating tools in Australia*, **Xia Chen, Skitmore, Zuo and Li** address the similarities, differences and advantages of three different sustainability rating community tools in Australia. The three under their looking glass are: a. the *Green-Star Communities PILOT*, b. the *Enviro-Development* and c. the *VicUrban Sustainability Charter*. These are not so much the internationally recognized and disseminated rating tools promoted by large corporations and NGOs, but were developed locally on the ground. The comparison is not so much intended to benchmark them, but rather to show how each can be used differently to address diverse local challenges and to assist with the evaluation and decision-making with differential qualities, strengths and weaknesses.

It is widely accepted that the construction sector can be a major contributor to sustainable development, and its importance in encouraging environmental protection, economic growth and social advancement is well established. Many divisions of the construction industry are accustomed to the sustainable development concept, especially where environmental issues are involved, but they are not adequately responsive to its economic and social aspects. Of these divisions, industrial buildings have attracted the least attention, because many developing and even developed countries require growth in industrial areas. This highlights the need for studying sustainability in industrial buildings to accomplish sustainable development goals. **Heravi, Fathi and Faegh's** *Evaluation of Sustainability Indicators of Industrial Buildings Focused on Petrochemical Projects*, investigates and identifies three such indicators (environmental, social, and economic) for the phases:

construction, operation and maintenance and demolition. They target a specific subsector that has attracted less than average attention: industrial buildings, and within that subset even more specifically they focus upon those in the petrochemical industry. Their paper is designed to investigate and to identify sustainability indicators (environmental, social and economic) for the phases buildings may be in: construction, operation and maintenance, and demolition. They also explore the correlation of individual indicators with the main aspects of sustainability, and towards the end compare their findings with those in previous studies by using a structural equation model.

The next paper to touch on the theme of measurement and assessment is the one written by **Wu, Feng, Pienaar and Xia**. In their *A review of benchmarking in carbon labelling schemes for building materials*, they highlight that the building and construction sector is a major contributor to global GHG emission and is under pressure to improve its performance. Wu et al. point to the possibility of introducing a carbon-labelling scheme to encourage benchmarking and competition among players in the industry and to trigger a transition to a low carbon future by switching consumer-purchasing habits to low carbon alternatives. They examine various types of benchmarks and labelling practices and provide practical advice for successful implementation.

The sixth contribution to theme 2 comes from Allouhi, Fouih, Kouksou, jamil, Zeraouli and Mourad. Like the previous two, the building sector is central in their analysis. Based on recent data on the world energy consumption in both residential and commercial buildings, current status and future trends in energy consumption and greenhouse gas emissions are reported, analysed and discussed for a selection of countries around the world. This analysis leads to the identification of a few key parameters that have a particularly large impact on sustainability and are therefore shortlisted for policy interventions.

Another contribution on advancing sustainability in building and construction in this pack was written by Cao, Li, Zhu and Zhang. They are specifically interested in the potential of prefabrication technology to reducing resource depletion, health damage and ecosystem damage. In order to generate clarity on this issue, they made a systematic comparison between the environmental performance of prefabricated residential buildings (PRB) and traditional residential buildings (TRB). Using a variety of analytical methods and techniques including life-cycle assessment (LCA), construction environmental performance assessment, building health impact assessment and social willingness to pay, they come to the conclusion that indeed there are advantages to using PRB, especially for realizing a reduction in resource depletion.

In' Early prediction of the performance of green building projects using pre-project planning variables: data mining approaches', Son and Kim from Chung-Ang University in Seoul use their impressive data mining skills to find out with which prediction models cost and schedule performance of green buildings can be best established in advance. They used a support vector machine (VSM), a back-propagation neural network (BPNN), a C4.5 decision tree algorithm (C4.5) and a logistic regression (LR) and come to the conclusion that SVM is most accurate, sensitive and specific and that performance of green building projects is mostly dependent on the quality of definition in the pre-project planning phase.

3.3. Theme 3: pathways towards urban models that support regenerative sustainability

Eco-town developments have provided testing grounds to improve on urban policies and practices in the Northern and Western European countries since the early 1990s. Widely discussed is the extent to which they have helped transition towns and cities into more sustainable systems in the larger urban context through educational, experiential, societal diffusion and changes in governance processes. Countries in different cultural and geographical contexts with rapid urbanization rates seek to establish similar developments with relatively less knowledge of the contextual and procedural differences in the eco-towns' processes or the reasons for their varying levels of impact. **Bayulken and Huisingh's** *Are lessons from eco-towns helping planners make more effective progress in transforming cities into sustainable urban systems*: *A literature review (Part 2 of 2)* summarized and systematized the insights that have been obtained from 'eco-town' based urban developments in the Northwestern Europe with particular emphasis on examples from The Netherlands, Sweden and Germany. The review focused on: the contexts in which the demonstration eco-towns were developed since the emergence of planned communities in the early 20th century; and the typologies, processes and frameworks through which the eco-towns were initiated, built, governed and evolved. The wide diversity of frameworks and processes that have played roles in the relative successes and/or failures is analysed and insights obtained into their procedures and the aspects associated with the diffusion of the lessons into broader urban planning and development methods. The findings suggested that political commitment, timing, financial aspects, physical qualities, stakeholder involvement and environmental planning are key elements in achieving the eco-towns' goals, Future research was recommended to critically analyse the impact of these historically new urban development models and frameworks in order to create more effective approaches for achieving positive outcomes for all societies within ecological boundaries.

There is a growing interest in a sustainable built environment, and green technologies are gaining worldwide attention. However, their implementation usually requires more investment than the use of traditional technologies and with a generally very long payback period. In China, most developers sell their properties and subsequently transfer the ownership to customers. Hence, a crucial problem for promoting the country's green construction is that developers cannot obtain economic profits ("gold") when implementing "green" technologies. Other stakeholders, such as property management companies, are also hesitant to adopt green technologies because of the large investment involved and their lack of experience. **Zhang, Wu, Feng and Xu's** '*Turning green into gold*': *a framework for energy performance contracting (EPC) in China's real estate industry* approach this problem by careful sharing of the risks involved. The framework was developed by conducting a focus group meeting with three experienced representatives from developers, property management and energy service companies. A real-life case study that included both an energy efficient system retrofit and a new construction project was used to estimate the costs and benefits involved and demonstrate and verify the framework. The results showed that the framework could support the application of green technologies in both types of projects, with both economic and environmental benefits being gained for the project stakeholders and society as a whole.

Urban drainage patterns are altered by increasing urbanization and rapid conveyance and discharge of runoff, leading to increased flood risk, diminished aquifer recharge and degradation of receiving waterways – effects that are expected to escalate with climate change. In response, alternative and more sustainable drainage practices with a holistic approach have been developed, although their wide-scale implementation has been limited largely due to socio-institutional barriers. **Perales-Momparler, Andrés-Doménech, Andreu and Escuder-Bueno's** *Regenerative built environment* presented an innovative, regenerative, urban stormwater methodology for transition management to overcome this at the

city level. This involves two main enablers; (1) a structured set of activities, the 'wheel', to guide and document the process, which was steered by a group of regional actors; and (2) a visual and effective set of indicators that monitor and assess the progress achieved and identify strategies for advancement. A case study of its successful application to Benaguasil, a Mediterranean city was described which indicated that, by integrating the views and strategies from actors at different but interconnected scales and following a structured but flexible methodology, it has a promising future ahead and with good progress having been achieved in only a few years.

The use of water-efficient appliances and inclusion of alternative water sources in urban residential developments is becoming increasingly necessary to meet the growing demands on conventional urban water supplies while minimizing the amount of environmental damage caused by water consumption. In Australia, this mainly focuses on the relative use of mains water, collected rainwater and hot water, where a minimum 1 kL capacity rainwater tank specified in the Building Code of Australia allows rainwater to be fed into the hot water supply when necessary. **Chao, Umapathi and Saman's** *Water consumption characteristics at a sustainable residential development with rainwater sourced hot water supply* served as the basis of a case study on an initiative commissioned by the State Government in 2009 to study the effects of innovative Water Sensitive Urban Design (WSUD) featured in Lochiel Park, South Australia, such as increasing the minimum size of tank to 1.5 kL and allowing rainwater to be fed into the hot water supply in winter. This involved the development of a model designed to embrace sustainable planning principles and technologies in the form of an extensive post-occupancy monitoring program of actual residential water and energy usage. The water consumption of 59 houses was analysed and quantified through real-time monitored data collected over three years between 2010 and 2013, incorporating the monitored usage of mains water, collected rainwater and hot water usage. The analyses documented the annual average total water consumption per household at the Park to be significantly lower than the South Australia's state capital, Adelaide, and the national averages by about 24% and 16% respectively, while average mains water consumption was lower by 36% and 29% respectively. Rainwater contributes 6–10% of the total water use in the summer and up to 26% in the winter, with an average annual contribution of around 14%. A significant part of the saving was attributed to the increased minimum rainwater tank capacity and by feeding rainwater into the hot water supply. Although a reduced hot water demand was also prompted by having efficient fixtures and rainwater supply depends on climate, rainwater fed into hot water supply saved 40% of hot water consumption annually. Greater rainwater utilization in hot water is possible if tank sizing and a greater roof catchment area can match household winter hot water demand, rather than having a single minimum requirement across all households as in the current regulations. The outcomes verified the effectiveness of the WSUD features and will be useful for future strategic planning and design initiatives for implementation of similar developments on a larger scale.

The anthropogenic use of phosphorus has emerged as a one of the major drivers of global environmental change (see Stefan et al., 2015). The finite supply of the nutrient, geographical concentration of the remaining supply and continuing occurrences of eutrophication and harmful algal blooms (caused, in part, by excessive phosphorus outflows into the environment) are causes for immediate concern. As a response, there is increasing recognition that phosphorus entering waste streams should be recovered as a resource rather than disposed of as a pollutant. While phosphorus recovery technology and strategies have been outlined in some detail in the existing literature, none have explicitly addressed the reasons why these processes have not been implemented on any scale. In addition, the potential for urban systems to play a role in creating a holistic management system for phosphorus has received little recognition to date.

Pearce's "*Phosphorus Recovery Transition Tool (PRTT): a transdisciplinary framework for implementing a regenerative urban phosphorus cycle* facilitates analysis of the context, drivers, barriers, and implementation of phosphorus recovery technologies in urban areas. The framework tool consists of five guiding questions, the answers to which present an opportunity for researchers, decision makers, and community stakeholders to explicitly identify what and how changes to the current system can be made. The approach provides a means of producing the knowledge necessary for facilitating the transition to an urban phosphorus recovery regime that is relevant for both practice and academics, and has the potential for adaptation to the future understanding and management of other resource cycles such as nitrogen, water, and energy.

Buildings have been built in one place and reassembled in another throughout history. Modern prefabrication, in the form of *industrialized* or *system* building has been developing since the 1970s, with the technologies having been further developed and improved over the past 30 years. Although the successful implementation of quality control and construction efficiency has been addressed with support from the public sector, the technologies have received little attention from the private sector due to the need for dimensional coordination and design standardization. In Hong Kong, this situation changed in 2002, when the government introduced new incentives schemes, such as gross floor area concessions to encourage private developers to adopt prefabrication techniques. Today, Hong Kong is a world leader in quality prefabricated construction and **Tam, Fung, Sing and Ogunlana's** *Best practice of prefabrication implementation in the Hong Kong public and private sectors* discusses and evaluates these through leading case studies. The adoption of prefabrication, construction methods and their cost effectiveness were investigated and the effective implementations for the sectors were explored. The findings further our understanding of best practice in the implementation of prefabrication and provide encouragement for its further improvement and implementation in the industry.

Ecodesign is a concept that emerged few decades ago in response to the larger concept of sustainable development. Multiple tools exist to address eco-design, such as life cycle assessment (LCA), a comprehensive, robust and recognized evaluation tool that enables the product environmental profile to be identified. **Cobut, Beauregard and Blanchet's** *Reducing the environmental footprint of interior wood doors in non-residential buildings – part 1: life cycle assessment* explored the cradle-to-grave environmental profile of an interior wood door in the North American context. According to their result, the main contributor to the product impacts was the acquisition and production of raw materials, especially the particleboard component. The other life stages that have a noticeable influence on door's environmental impacts are shipping and end-of-life management. Based on previous LCA results on interior wooden doors, **Cobut, Beauregard and Blanchet's** *Reducing the environmental footprint of interior wood doors in non-residential buildings – Part 2: Ecodesign* proposed an ecodesign strategy based on the generation and evaluation of alternative scenarios involving three selected targets for environmental improvement of particleboard components, transportation and end-of-life. For the particleboard manufacturing, apart from pine tannins in panel manufacture, the use of adhesives based on bio-sourced resources appeared to be inconclusive, while switching from road to rail transportation, as well as having a local supplier was found to decrease the overall environmental impact of the doors. The most notable alternative seems to be the end-of-life recycling scenario,

where the reutilization of the door core in the door manufacturing process was claimed to be a great benefit in avoiding the need for new raw materials. Developing services around door recovery and remanufacturing, therefore, appears to provide a promising means of reducing the environmental impacts of door manufacture and usage. This is a readily viable and realistic scenario.

3.4. Theme 4: obstacles, benefits and enablers for the implementation of regenerative sustainability

Policy instruments introduced with the objective of promoting environmental sustainability are often designed and evaluated in terms of their impact with regard to facilitating technological changes. Most 'green' policy instruments that were designed in recent decades have targeted facilitation of the development and adoption of greener processes, goods and services. Concurrent business models have sought to create and capture value arising from this policy-induced transition to more environmentally sustainable practices. Both such policy instruments and the business models are, however, often evaluated more in terms of their impact on the development and adoption of innovations and less in terms of their impact on behavioural change.

Al-Saleh and Mahroum's *A critical review of the interplay between policy instruments and business models*: *greening the built environment a case in point* addressed this from a behavioural perspective. Instead of looking at policy instruments from a technology-push and demand-pull perspective, they were sampled in terms of 'sticks', 'carrots' and 'sermons' and the business models that have emerged in response to these types of policy regimes are critical reviewed. This revealed that most responses to sticks may be characterized as *buck-passing*, i.e. passing costs to others and skirting around the stick of regulation; responses to carrots are opportunistic *carpet-bagging* aimed at capturing a temporary gain; and, finally, responses to sermon-orientated awareness campaigns have a tendency to *diffuse* even in the absence of supportive fiscal conditions.

Under the Kyoto Protocol's Clean Development Mechanism (CDM), countries worldwide are cooperating in countering climate change by emissions trading, which produces a win–win situation by effectively "regenerating" a cleaner environment in developing countries, although efforts in developed countries may still not meet their committed carbon reduction targets.

According to the CDM rules, energy efficiency improvement projects in the building sector are valid for emissions trading but, although the potential energy savings are significant, only a limited number of building projects have been registered as CDM projects. **Lam, Chan, Yu, Cam and Yu's** *Applicability of Clean Development Mechanism to the Hong Kong building sector* investigated this further by reviewing the implementation of CDM and its advantages and disadvantages – Hong Kong being chosen due to its eligibility for the CDM and yet still a non-starter.

The results of a questionnaire survey supplemented by interviews with the stakeholders indicate the major hindrances to be the lack of financial incentives, inadequate knowledge of emissions trading and insufficient government support. This led to the recommendation that an inter-city emissions trading market covering mainland China and Hong Kong and suitable emission reduction targets should be established and to be initially led by the government. By creating an emission exchange centre, local emissions trading activities could be facilitated and job opportunities found. It was suggested that Hong Kong's highly skilled professional services and efficient business environment has the potential to make a significant contribution to emissions trading in the region while simultaneously paving the way for densely built cities such as Hong Kong to benefit environmentally and economically from a cleaner region in their vicinity.

Although a substantial economic energy saving potential exists in the residential sector of the European Union, the energy efficiency service (EES) market is much less developed than in other demand sectors such as industry or public/service. **Labanca, Suerkempe, Bertoldi, Irrek and du Plessis'** *Energy efficiency services for residential buildings*: *market situation and existing potentials in the European Union* analyses the current situation and existing potential for future expansion. A methodology mostly built upon literature review and interviews with a large number of acknowledged experts was developed and applied by a research consortium of 18 EU countries. This allowed the identification of encouraging development trends (particularly in Germany, Denmark, France, Flanders (BE), Hungary, Romania and UK specific market segments) where the possibility of aggregating the EES demand or of exploiting good relationships with customers have created investment opportunities. The assessment supported the development of a series of strategies and policy measures to overcome existing market development barriers. The more significant of these was the urgent need in many EU countries for energy efficiency policies supporting EES markets in the residential sector to increase trust between EESs and EES providers and, at the national level, stronger collaboration of governments or local administrations with banks to finance EESs.

Persson and Grönkvist's *Drivers and barriers to low-energy buildings in Sweden* investigated their existence and significance in the implementation of energy-efficient houses from the perspective of eleven construction companies that build low-energy buildings. This revealed the existence of a wide range of issues including internal pressures contributing to the choice of passive house construction within the companies and that personal commitment was central and perhaps the strongest driver. A general issue was the need to show both construction companies and potential customers that passive houses exist and are possible to build. Unlike the national building regulations, which are not concerned with energy consumption, the future building regulations from the European Union were identified as an important potential regulatory driver. Moreover, banks as well as real estate agents need to develop a more comprehensive view and serious life cycle energy considerations in their capital budgeting templates. The market was also identified as a promising mechanism even if the public has little interest in passive houses, and is about to become large enough to be a driver itself.

Procurement is a key process in construction project management and current construction procurement practices have been widely criticized for disregarding sustainability in the project life cycle. **Ruparathna and Hewage's** *Sustainable procurement in the Canadian construction industry*: *Current practices*, *drivers and opportunities* addresses this gap of knowledge in reviewing the sustainable procurement practices involved. Using a multi method research design comprising questionnaire surveys, document reviews and semi-structured interviews, data triangulation confirms: that sustainable procurement initiatives are rarely used in the Canadian construction industry, while environmental sustainability criteria occupy position of prominence; the lack of triple bottom line of sustainability in bid evaluation; and Government regulations are likely to be the main driver for sustainable procurement. It is anticipated that this study may be the first step in promoting the use of sustainable procurement in the Canadian construction sector.

Individual stakeholders steadfastly guard their own interests in any investment decision, which seldom considers any positive gains to society. Green buildings, branded as partial public goods, involve rational and irrational factors, incur extra transaction costs

(TCs) and affect the willingness of the stakeholders to take part. **Qian, Chan, Visscher and Lehmann's** *Modelling the Green Building (GB) Investment Decisions of Developers and End-users with Transaction Costs (TCs) Considerations*, through a "regenerative" lens, focused on a new conceptual game system involving transaction costs TCs for creating a more accessible green GB market by examining how to reduce the TCs incurred during the game to promote GB. As a result of developers and end-users negotiating and bargaining over the TCs caused by GB, the findings in comparison with the conventional counterpart are that 1) TCs are the overriding barriers impeding the development of the GB market – reducing TCs facilitate supply and demand in the GB market; 2) the equilibrium payoffs for the developer and the end-user are positively proportional to their bargaining powers; 3) strengthening the developer's bargaining power can increase the expected utility of developing GB; and 4) inauthentic GB products or credible developers resulted in higher TCs for the end-users and therefore lower payoffs. Therefore, minimizing the TCs incurred in GB decisions not only benefits the players but also provided net regenerative outcomes to society as a whole.

Hong Kong's construction industry is currently facing problems over its rapidly ageing workforce and labour shortage, an issue addressed in **Chiang, Li, Zhou; Wong and Lam's** *The nexus among employment opportunities, life-cycle costs, and carbon emissions: A case study of sustainable building maintenance in Hong Kong*. This illustrated how existing residential buildings can be repaired and maintained using alternative materials, in order to minimize life-cycle labour inputs, costs and carbon emissions. With different combinations of repair and maintenance materials, it was shown that two of these three objectives can be achieved at any one time by setting labour inputs, costs and carbon emissions as separate constraints. With this methodology, it was possible to identify materials that cost the least, emit minimum carbon levels, and to require the right amount of labour resources while simultaneously supporting the adoption of green technologies that suit the socio-economic and physical environment of regions such as Hong Kong.

Many and diverse actors with contrasting interests interact in urban sustainability transitions and their perceptions and values affect the potential uptake of transition strategies in urban systems. It is therefore, important to understand how actors view themselves involved in such processes. In approaching this, **Olazabal and Pascual's** *Urban low-carbon transitions: cognitive barriers and opportunities* addresses the importance of the cognitive dimension in urban sustainability transition policy practice. A case study of low carbon transitions for the city of Bilbao (Basque Country) explored the barriers and opportunities for an energy transition using the Q methodology, providing results suggesting that stakeholders' motivation and perceived capacity for change are related to four discourses of the: follower, visionary, pragmatist and sceptic. Also indicated was that the key to bringing about effective transition processes information exchange is communication and participation in decision-making processes, thereby bridging visionaries and pragmatists with decision-makers. The study contributed to identifying the attitudes of actors who can negotiate urban low-carbon transitions, and stresses the need to build a common shared cognitive vision of whether and how sustainable urban transformation can take place.

Demonstrations serve an important role in the promotion of sustainable technologies and **Heiskanen, Nissilä and Lovio's** *Demonstration buildings as protected spaces for clean energy solutions – the case of solar building integration in Finland* studied how demonstration sequences conducted over a long time span gradually contributed to niche development for clean energy technologies at the national level. An empirical analysis focused on building-applied solar demonstrations in Finland – a generally unfavourable context for such a technology. The findings showed that the demonstrations leverage sporadic windows of opportunity resulting from international developments, with the projects supporting three niche development processes of network building, different types of learning and the creation of visions and expectations, thereby preparing the ground for the uptake of solar technology in new buildings. However, the demonstrations did not have an immediate impact on mainstream practices due to weak continuity and a challenging socio-technical environment.

4. Conclusions

The papers contained in this SV provided a unique opportunity to explore in one volume, the breadth and depth of the emerging discourse of regenerative sustainability. This discourse is designed to reformulate the agenda of our industrialist urban development discourse, towards an approach that views the interactions between human-made and natural environments through a more holistic lens than the traditional sustainable development perspective. The imaginative perspectives articulated in the thirty papers in this SV provide a sound basis for exploring the Theory and Definitions of Regenerative Sustainability and Related Concepts, to articulate methods for Performance Assessment of Regenerative Sustainability, to elucidate Pathways towards Urban Models that Support Regenerative Sustainability, and to highlight potential Obstacles, benefits and enablers for the implementation of regenerative sustainability. The editorial team of this SV, solicits reader's feedback and recommendations for the next thousand steps!

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