Achieving a profitable low carbon transition: Learning from an entrepreneurial approach

Mr Daniel Conley, University of Adelaide, Adelaide, Australia. (corresponding author)

daniel.conley@adelaide.edu.au

+61 447 477 750

University of Adelaide

Adelaide, SA, 5005

Dr Karlson 'Charlie' Hargroves, Curtin University Sustainability Policy Institute, Curtin University, Perth (Thesis Advisor)

Professor Martin Lambert, Head of School, School of Civil, Environmental and Mining Engineering, University of Adelaide, (Thesis Supervisor)

Professor Peter Newman, John Curtin Distinguished Professor of Sustainability, Curtin University Sustainability Policy Institute, Curtin University (Thesis Supervisor)

Abstract

The cities of the world are growing at a rapid pace and as hubs of economic development, production, and consumption, cities must effectively navigate low-carbon transitions if the world is to mitigate the effects of climate change within the internationally agreed timeframe. Much of the technology needed to enable this low carbon transition has existed for decades, however progress has remained slow due to complex challenges within cities that cannot be overcome with traditional approaches. This paper will present the case that approaches taken by entrepreneurs, who operate in fast-paced and uncertain conditions, could be invaluable in informing low-carbon energy transitions at a city, national and regional level. Some schools of thought suggest that the capacity and responsibility to address climate change lies with governments through policy, while others suggest individual entrepreneurs are key to accelerating climate efforts, with a tendency to rely on such individuals rather than learning from and applying their approach. This paper presents a middle ground where policy makers, researchers, business, and civil organisations seek to learn from an entrepreneurial approach in order to accelerate the worlds low carbon transition. This paper presents an overview of key entrepreneurial approaches suited to accelerating the low carbon transition with a focus on urban infrastructure. Guidance will also be provided on how such an approach can be applied at a macro-level while also strategically supporting emerging bottom-up innovations occurring at the micro-level which play an important role in transitioning systems.

Introduction

For the first time in human history, over half of the world's population live in cities and projections estimate that by 2050, over two thirds of the predicted 9.7 billion people living on Earth will be living in urban areas (UN 2014; 2015). Urban land area is expected to triple between 2000 and 2030 (Seto *et al* 2012) and satisfying the basic needs of an increasingly urbanized population over the coming decades will require an estimated US$57 trillion of infrastructure investment between 2013 and 2030 - more than the entire value of global infrastructure in 2013 (McKinsey 2013).

In addition to the infrastructure challenges created by the massive trends of population growth and urbanization, and in parallel to looming resource scarcity and losses of biodiversity, a global consensus has been reached concerning the imperative to rapidly reduce global greenhouse gas emissions in an attempt to reduce the future impacts of human-induced climate change. While 197 governments agreed in 2015 at the Paris Climate Agreement that there is an environmental imperative, there is also overwhelming evidence emerging of the strong integrated economic and social benefits of achieving sustainable development (IRENA 2017).

Achieving the low-carbon agenda and ensuring a sustainable, resilient and prosperous future will require systemic industrial and social transformations (McCormick et al. 2013, Gaziulusoy et al. 2016, Voytenko et al. 2016). Cities are becoming increasingly complex and the field of sustainability transitions addresses the importance of considering both social and technical ('socio-technical') elements of systems when designing strategic interventions (Geels 2005, Hargroves 2015). This is important given that despite the availability of technologies, we are still yet to see satisfactory reductions in greenhouse gas emissions (IEA, 2011) or systemic change towards paths of sustainable development (Rockström et al., 2009; Baumgartner, 2011).

The entrepreneur however is said to thrive in complexity and uncertainty (Amolo & Migiro, 2014; Salient, Chaos, Sarasvathy), and successful entrepreneurs can act upon opportunities under conditions of scarce resources and limited capital to have new technological innovations rapidly deploy at scale across economies. By undertaking an initial review of system innovation, socio-technical transitions and entrepreneurship literature, this paper presents the potential for entrepreneurial thinking, actions and strategies to inform system-level policies and strategies for the acceleration of transitions towards low-carbon built environments. Entrepreneurs around the world are creating valuable solutions to issues facing society, and are doing so in contexts of increasing complexity, uncertainty and competition. Given the rapid need to reduce greenhouse gas emissions in the built-environment sector, it is clear that standalone solutions and best practices examples will not achieve these reductions in timeframes imposed by our planets changing climate and society's dependence upon it. There is an urgent need to accelerate the mainstreaming of innovative sustainable solutions and to have them spread systematically across cities and economies. Rather than observing the ability of the entrepreneur to innovate and deliver value in an individualistic way under uncertainty, this paper presents propositions for research into how the entrepreneurial approach can be applied at a systems level to strategically support sustainable technologies and accelerate economy-wide socio-technical transitions to a low carbon future.

The Need for a Low-Carbon Built Environment

The built environment sector is a large contributor to the global greenhouse gas emissions that must be rapidly reduced in order to mitigate the harshest potential impacts of human induced climate change (IPCC, 2014). This immediate need for response to climate change is included in a number of unprecedented issues facing society alongside resource scarcity and increasing uncertainty (Smith, Hargroves & Desha 2010). There is an increasing consensus that incremental improvements in technological efficiency and other means will be inadequate in achieving carbon reductions in necessary timeframes, and that radical transformative restructuring of urban life is required (Twomey & Gaziulusoy 2014; Ryan 2013; Hargroves 2015). Former UNFCCC Executive Secretary Christiana Figueres and colleagues recently urged the world that if emissions rise or even remain level beyond 2020 then the Paris climate agreements become almost unattainable (Figueres et al, 2017).

In order to accelerate transitions to low carbon operations in the built environment, transformative and systemic innovation is required over traditional 'business-as-usual' improvements (Wilson et al. 2014). Achieving this profound industrial and societal transformation will require strategies at levels of government, industry, education and society to be creative, robust and audacious (Hargroves 2016; McCormick, K *et al* 2016; Trencher at al. 2014, Mont et al. 2016). Such transformation will only be achieved through *"innovations that are directed to redesigning entire systems of practices and provisions, instead of individual products or processes"* (Sterrenberg et al 2013).

Socio-Technical Transitions Theory for Complex Systems

A World of Increasing Complexity: Cities

Cities and economies are being increasingly recognised as complex systems, where there is an emphasis on the interactions and feedbacks between various components which ultimately leads to collective or 'emergent' behaviours of these systems which cannot be reduced to the sum of the parts (Cilliers 1998, Batty 2005, Crawford 2016). Contrastingly, complicated systems (as opposed to complex systems) are a form of system which contain a number of intricate parts and are difficult to understand, however solutions can be determined through reductionist techniques and expert analysis due to the lack of emergent properties (Snowden & Boone 2007). Complicated things can be understood by isolating them, reducing them to their parts and understanding the predictable interactions between these parts (Cilliers 1998, Snowden & Boone 2007).

A number of factors lead to the emergence of unforeseeable properties and phenomenon in cities that are difficult to plan for, such as the interaction between different types of technologies, the interaction between civil infrastructure and the natural environment, and the behaviours of inhabitants. Cities are comprised of a large number of interconnected sub-systems which feature uncertainty, path-dependency (lock-in) and feedback amongst actors (Portugali, 2016) which are all properties of complex adaptive systems. For instance, the behaviour of the inhabitants of cities can create collective emergent properties, in comparison to the predictable behaviour of civil infrastructure, such as a bridge or building which in isolation are merely 'complicated' based on the above definitions (Portugali, 2016). It is therefore crucial to examine cities from a lens which appreciates both the emergent and the predictable behaviours, and find ways to stimulate innovation which harnesses both of these properties and the interactions between them. This approach forms part of 'Socio-Technical Transition' theory which is discussed below.

For example, Newman and Kenworthy (1999) warn of the predictable outcome of designing and operating cities based on a model of 'Automobile Dependence' where path-dependencies caused by placing the cars as a central artefact are causing predictable and avoidable impacts. In such an approach institutions, structures and practices are based on the use of the automobile, and when roads become more congested as a result, the response is to expand the road network to allow for more vehicles which creates a reinforcing feedback loop. This has consequences for the city as it inevitably results in rising levels of pollution and traffic congestion, which negatively impacts the environment through growing levels of air pollution and greenhouse gas emissions, the economy through lost productivity in congestion, and people's quality of life through respiratory illnesses related to particulate matter contained in vehicle pollution.

Such an example represents a complex challenge, where 'personal transport' represents a system which comprises of more than just road infrastructure and automobiles. As Geels (2005) describes, transport also comprises of rules and regulations, distribution networks, maintenance, road and fuel infrastructure, financing, culture and symbolic meaning, vehicles, industry structure, markets and user practices. Not to mention the interactions between land-use and transportation that further complicate the system. It is here in the wider system dynamic that the truly integrated and sustainable solutions are to be cultivated, however standard approaches are not equip to do so and an entrepreneurial approach is needed.

Considering the systems level in complex adaptive systems seeks to account for interconnectedness and emergent properties and differs from a reductionist methodology of breaking down a system into parts commonly used by engineers and planners (Meadows 2009; Crawford 2016). Systems thinking instead seeks to understand the interactions between components (Ackoff et al 2010) and how interventions can be designed that lead to preferred changes in the system (Patel and Mehta 2016; Newhofer 2003).

Socio-Technical Transitions and System Innovation

Achieving such preferred changes to underpin the alleviation of environmental impacts caused by current development efforts will require more than a technological fix and call for an intention shift in cultural and behaviours, regulations and codes, market conditions, infrastructure forms and so on. Such a system wide shift can be described as change of 'Socio-Technical Regime' (Geels 2005) with such a transition treated as being 'complex', meaning emergent properties are to be expected. This is due to the many interactions between actors including firms, industries, policy makers, consumers, engineers and researchers (Geels 2011). Conventional innovation theory suggests that entrepreneurs and firms are the main innovative force that drive the economy. However in order for a system wide change in short time frame it must be assumed that innovation is not solely achieved from the individual entrepreneur, but can in fact take place in the context of the entire system. This approach has been considered at national and regional levels (Twomey & Gaziulusoy 2013; Freeman and Perez 1998, Cooke & Uranga 1997), however there is little evidence in the literature of its consideration at a city level, resulting in socio-technical urban transitions (McCormick et al. 2013).

A key theory to base such a city focused approach is the Multi-Level Perspective (MLP) (Geels 2005) (see figure below) which suggests that changes in socio-technical regimes (for example the energy supply of a city) is a process which happens over multiple decades and begins with niche innovations that can out compete past market leaders (for example the discovery of electricity or the internal combustion engine) (Geels 2005). Emerging from the MLP with a focus on the niche level is Strategic Niche Management (SNM), which calls for the creation of policies and strategies to purposefully support emerging niche innovations (Kemp et al. 1998, Schot & Geels 2008). Research into this area cautions that this is can be either a slow and incremental process that does not lead to preferred system wide outcomes, or, when tried to be accelerated can lead to danger of failure or be misaligned with the existing economy with wider implications for society and the environment (Schot & Geels 2008).

A way to make such approaches more successful is the area of Transition Management (TM) which looks across all three levels of the MLP and is focused on a specific societal challenge rather than a particular technology (which is the focus of SNM). TM focuses on stakeholder engagement across all levels of society in parallel with continuous experimenting, learning and adapting (Twomey & Gaziulusoy 2013). Kemp et al. (2001) concludes it is important to 'steer' the dynamics of socio-technical change and maintain co-evolution of supply and demand to achieve outcomes that are desired by society. This co-evolutionary approach is a popular theme in innovation theory and describes the co-development of different sub-systems (such as technologies, institutions, social practices and business strategies) and attempts to overcome the traditional view that sustainability can only be achieved through either technology-orientated or behaviour-orientated approaches (Twomey & Gaziulusoy 2013; Geels 2005, Brand 2003).

Given the urgent need to rapidly reduce the carbon intensity of the built environment, economy wide transitions must not only be directed towards a preferred future for the first time in human history (Hargroves 2015), but they must also be accelerated. Given that past innovations have not been held to account for negative environmental impacts there is little precedent for intentionally steering economies to significantly reduced environmental damage and pollution. However using the MLP as a basis Dr Karlson Hargroves suggests an approach to induce and accelerate such a transition through strategic structural interventions.

Hargroves 2015 proposes that "in the case of low carbon technologies the process of niche technologies being diffused across economies needs to be assisted with appropriate interventions, by directly adjusting existing structures in the economy such as taxation and subsidies, along with creating support and capacity through in-direct measures such as industry led performance assessment and reporting systems, behaviour change, and renewal of education programs". Hence Figure A suggests that a set of interventions can be made to intentionally transition the socio-technical regime by creating 'structural interventions to open lock-in mechanisms for preferred niche innovation', that will influence the conditions for such preferred niche innovations (see the blue oval and arrow added below), such as changes to energy subsidies to no longer encourage fossil fuel investment but rather decentralised renewable sources of energy.

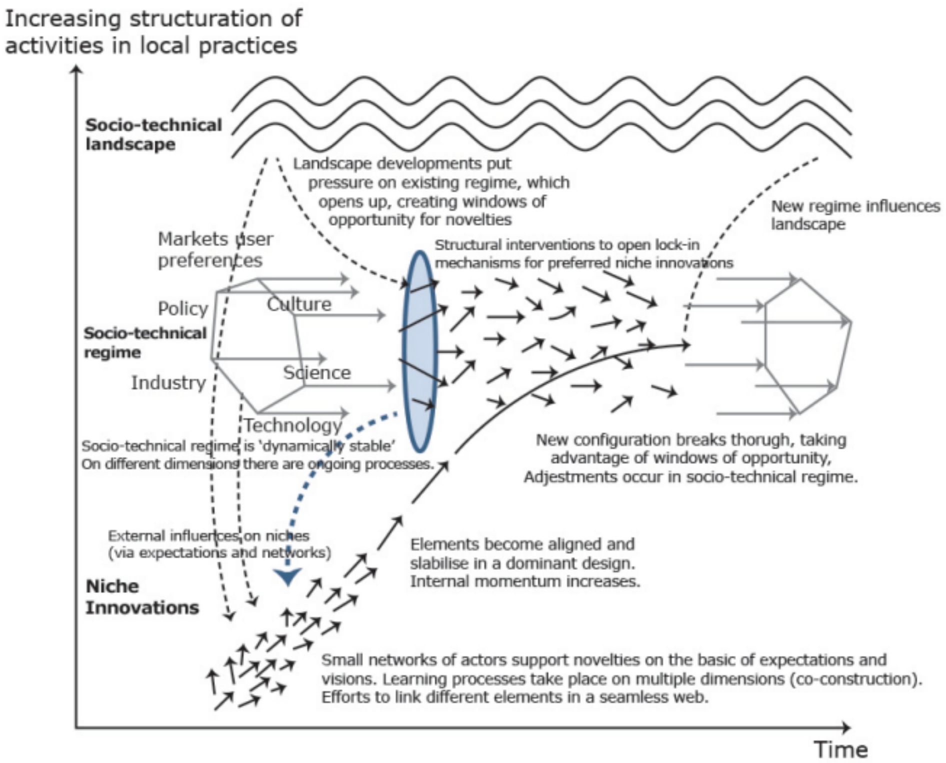

Figure A: A modified multi-level perspective on technology transitions to include structural interventions to open lock-in mechanisms for preferred niche innovations (Hargroves 2015, Based on Geels 2011).

What can we learn from entrepreneurs?

Entrepreneurship

Entrepreneurship is a growing discipline with a lack of consensus as to what definitively constitutes it (Hitt, Ireland, Sirmon, Trahms, 2011; Rauch, Wiklund, Lumpkin, Frese, 2009). Entrepreneurship involves creating value to obtain wealth (Knight 1921; Hitt, Ireland, Sirmon, Trahms, 2011) and involves the process of discovering, evaluating and exploiting opportunities (Shane & Venkataraman, 2000). In the face of resource scarcity and monetary constraints, entrepreneurs are seen to act differently from conventional actors within an economy and despite seemingly low levels of success across the many entrepreneur ventures this approach can give rise to staggeringly successful new business ventures such as Virgin Airlines, Tesla Motors, Uber, etc (Amolo & Migiro 2014). Fundamentally, entrepreneurs seek to quickly recognise opportunities and act in ways which can be unique to the situation in order to create value within an economy before others do, often linking invention to commercialisation with intentions of high-growth and scalable businesses (Global Entrepreneurship Network, 2017).

Insight into this approach may be found in the fact that the entrepreneurial 'start-up' phase can often be chaotic, and in order to successfully manage and survive this phase entrepreneurs must work with a range of individuals, entities and external subsystems (Patel & Mehta, 2016). Studies of expert entrepreneurs have revealed that they avoid beginning with concrete outcomes in mind, and instead have dynamic goals that can be adapted based on personal skillsets, collaborations and changes in conditions, referred to as an 'effectual' approach. This effectual reasoning inherently lends itself to risk and uncertainty (Sarasvathy, 2001) which are both challenges faced by cities in response to climate change.

Looking at climate change from an economics point of view it can been described as the result of market failure in relation to resources and the environment, particularly rooted in 'The Tragedy of the Commons', whereby individuals act on their own best interests in the short term and do not consider how these actions effect the longer term prosperity of the group (Hardin, 1968). This is particularly interesting for entrepreneurs as *'opportunities are inherent in market failure'* and thus the challenge of climate change can present an opportunity for entrepreneurs to create value while also protecting the environment (Frederick, O'Connor, Kuratko 2016). Theoretically, market failures, once recognised, also justify government interventions in market activity and innovation (Link, Siegel 2007; Link, Link 2009). However we are far from bringing the entrepreneurial approach into systems change as entrepreneurship theories and literature overwhelmingly regard entrepreneurial behaviour as 'individualistic', even in the case of the organisation, which still find their basis in individual motives and initiatives (Amolo & Migirio, 2014).

Literature is emerging however that is beginning to explore the broadly defined concept of 'Entrepreneurial Governance' that links the traits and approaches of entrepreneurs to the strategies implemented by governments and civil society (Link, A & J 2009, Olsson et al. 2015, Link, Siegel 2007). Particularly in regard to local governments, who often have less resources at their disposal, some governance efforts aimed at economic development and expansion have been branded entrepreneurial (Olsson et al. 2015; Wilks-Heeg et al 2003). Generally, entrepreneurs are motivated to take risks based on expectation of the potential for profit, however other types of entrepreneurs such as policy, social or civil entrepreneurs are motivated to reduce risks in order to see a preferred outcome at the level of the system (Pozen 2008, Olsson et al. 2015).

Entrepreneurship, Niche Innovations and System Transitions

Often without entrepreneurs, inventions (such as innovative design solutions) do not leave the university or research and development facility (Global Entrepreneurship Network 2017). What differentiates the engineer or designer from the entrepreneur is '*bringing that value to realization… between different actors or components within a system'* (e.g. Producer and consumer). Innovative design solutions which form niche innovations within society do not immediately 'overthrow' existing (and often inferior) practices which are locked in to the existing regime, even if they are profitable and in the longer term interest of the economy. Often these niche innovations do not ever replace the practices of the incumbents within the existing regime given market lock-effects (Geels 2005). This is especially the case regarding low carbon technologies which are well developed and available (Von Weizsäcker, 2009) but face significant barriers to market uptake.

In order to overcome lock-in effects of incumbent technologies in the interest of the greater good, firstly it must be clearly and widely understood that such an imperative exists and that it can be addressed in a manner that can strengthen the economy. Once this is achieved such a transition requires specifically designed policies and mechanisms to induce, support and mainstream preferred solutions. Hence given this is not the way current structures of the economy are set up it may take 'entrepreneurial thinking' and the associated strategies/interventions to inform strategic niche management and technology transitions at a systems level.

Conclusion

By undertaking an initial review of system innovation, socio-technical transitions and entrepreneurship literature, it is clear that there is a need for entrepreneurial thinking, actions and strategies to inform system-level policies and strategies for the acceleration of transitions towards low-carbon built environments. Entrepreneurs around the world are creating valuable solutions to issues facing society, and are doing so in contexts of increasing complexity, uncertainty and competition. Given the rapid need to reduce greenhouse gas emissions in the built-environment sector, it is clear that standalone solutions and best practices examples will not satisfy the timeframes imposed by our planets changing climate and society's dependence upon it.

References

Ackoff, R., Addison, H., and Carey, A. 2010. *Systems thinking for curious managers.* Triarchy Press, Portland

Amolo, J., and Migiro, O. 2014. *Entrepreneurship Complexity: Salient features of entrepreneurship.* African Journal of Business Management. Vol. 8(19). Page 832-841. October 2014.

Batty, M. 2005. *Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals.* Cambridge, MA: MIT Press.

Baumgartner, B. 2011. *Critical perspectives on sustainable development research and practice.* Journal of Cleaner Production, 19 (8) (2011), pp. 783-786.

Brand, R. 2003. *Co-Evolution toward sustainable development: Neither smart technologies nor heroic choices,* unpublished PhD thesis, The University of Texas at Austin, Texas, USA.

Brown, T., and Katz, B. 2009. *Change by design: how design thinking transforms organizations and inspires innovation*. Harper Business, New York

Cilliers, P. 1998. *Complexity and Postmodernism: Understanding Complex Systems.* Routledge.

Crawford, R. 2016. *What can complexity theory tell us about urban planning?* Research note 2016/2.

Figueres, C., Schellnhuber, H. J., Whiteman, G., Rockström, J., Hobley, A., Rahmstorf, S. 2017. *Three years to safeguard our climate.* Nature. June 2017, Pages 593-595.

Flood, R. 2010. *The relationship of 'systems thinking' to action research.* Syst Pract Action Res 23(4):269–284

Freeman, C., Perez, C., 1988. Structural crisis of adjustment, business cycles and investment behaviour. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. Pinter, London.

Frederick, H., O'Connor, A., and Kuratko, D. F. 2016. *Entrepreneurship: Theory, Process, Practice.* 4th Edition. Cengage Learning Australia Pty Limited.

Gaziulusoy, I., Ryan, C., McGrail, S., Chandlera, P., and Twomeyc, P. 2016. *Identifying and addressing challenges faced by transdisciplinary research teams in climate change research.* J. Clean. Prod. Volume 123, 1 June 2016, Pages 55-64.

Geels, F. 2005. *Technological Transitions and System Innovations: A Co-Evolutionary and Socio-Technical Analysis.* Book.

Geels, F. 2011. *The multi-level perspective on sustainability transitions: Responses to seven criticisms.* Environmental Innovation and Societal Transitions. Volume 1, Issue 1, June 2011, Pages 24-40.

Global Entrepreneurship Network. 2017. *Global Entrepreneurship Index 2017*. The Global Entrepreneurship and Development Institute, Washington, D.C., USA.

Hardin, G. 1968. *The Tragedy of the Commons.* Science 13 Dec 1968: Vol. 162, Issue 3859, pp. 1243-1248

Hargroves, K. 2015. *Carbon Structural Adjustment: Designing, Motivating, and Delivering an Economy-Wide Transition to Low Greenhouse Gas Emissions.* PhD Thesis, Faculty of Humanities, Curtin University Sustainability Policy Institute.

Hitt, M., Ireland, D., Sirmon, D., and Trahms, C. 2011. Strategic Entrepreneurship: Creating Value for Individuals, Organisations and Society. Article in Academy of Management Executive, May 2011.

IEA. 2011. *World Energy Outlook*. IEA, Paris.

IPCC. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IRENA. 2017. *Renewable Energy and Jobs: Annual Review 2017*. IRENA.

McCormick, K., Neij, L., Oksana, M., Ryan, C., Rodhe, H. and Orsato, R. 2016. *Advancing sustainable solutions: an interdisciplinary and collaborative research agenda.* Journal of Cleaner Production 123 (2016) 1-4.

Kemp, R., Rip, A., and Schot, J. 1998. *Regime shifts to sustainability through the management of niche formation: The approach of strategic niche management.* Technology Analysis & Strategic Management, 10(2): 175-98.

Link, A., and Link, J. 2009. *Government as Entrepreneur.* New York; Oxford: Oxford University Press 2009.

Link, A., and Siegel, D. 2007. *Innovation, Entrepreneurship, and Technological Change.* Edited by Albert N. Link, and Donald S. Siegel, OUP Oxford, 2007. ProQuest Ebook Central.

Martin, R. 2009. *The design of business: why design thinking is the next competitive advantage.* Harvard Business Press, Boston

Meadows, D. 2009. Thinking In Systems : a Primer. London, Sterling, VA:Earthscan.

McCormick, K., Anderberg, S., Coenen, L., and Neij, L. 2013. *Advancing Sustainable Urban Transformation.* Journal of Cleaner Production 50 (2013) 1-11.

Mckinsey&Company. 2013. *Infrastructure Productivity: How to save $1 trillion a year.* McKinsey Global Institute, McKinsey Infrastructure Practice.

Edbringa, E., Lehner, M., and Mont, O. 2016. *Exploring consumer attitudes to alternative models of consumption: motivations and barriers*. J. Clean. Prod. 123, 5-15.

Newhofer, F. 2003. *Systems thinking in education.* Forum 45(2):75-77.

Newman, P., and Kenworthy, J. 1999. *Sustainability and Cities: Overcoming Automobile Dependence, Island Press.*

Olsson, A., Westlund, H., and Larsson, J. 2015. *Entrepeneurial Governance for Local Growth.* In Kourtit, K., Nijkamp, P., Stouch, R, R., The Rise of the City: Spatial Dynamics in the Urban Century.

Patel, S., and Mehta, K. 2016. *Systems, Design, and Entrepreneurial Thinking: Comparative Frameworks.* Systems Practice and Action Research, Springer. DOI 10.1007/s11213-016-9404-5

Portugali, J. 2016. *What Makes Cities Complex?*. In: Portugali J., Stolk E. (eds) Complexity, Cognition, Urban Planning and Design. Springer Proceedings in Complexity. Springer, Cham.

Pozen, D. 2008. *We are all entrepeneurs now.* Wake Forest Law Review 43: 283-340.

Rauch, A., Wiklund, J., Lumpkin, G., and Frese, M. 2009. *Entrepeneurial orientation and business performance: An assessment of past research and suggestions for the future.* Entrepreneurship Theory and Practice, 33(3), 761-787.

Johan Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F., Lambin, E., Lenton, T., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., de Wit, C., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R., Fabry, V., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., and Foley, J. 2009. *A safe operating space for humanity*. Nature, 461, pp. 472-475.

Ryan, C. 2013. *Eco-Acupuncture: designing and facilitating pathways for urban transformation, for a resilient low-carbon future.* Journal of Cleaner Production, 50:189–99.

Sarasvathy, S. 2001. *Causation and Effectuation: Toward an economic shift from economic inevitability to entrepreneurial contingency.* Academy of Management Review. Vol. 26, No. 2, 243-263.

Schot, J and Geels, F. 2008. *Strategic Niche Management and Sustainable Innovation Journeys: Theory, Findings, Research Agenda, and Policy.* Journal of Technology Management and Strategic Management. Volume 20, 2008. Issue 5, Pages 537-554.

Seto, K., Güneralp, B., and Hutyra, L. 2012. *Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools.* Proc Natl Acad Sci USA 109(40):16083–16088

Shane, S., and Venkataraman, S. 2000. *The Promise of Entrepreneurship as a Field of Research.* The Academy of Management Review Vol. 25, No. 1 (Jan., 2000), pp. 217-226.

Smith, M. H., Hargroves, K., and Desha, D. 2010. *Cents and Sustainability: Securing Our Common Future by Decoupling Economic Growth from Environmental Pressures.* London, UK: Earthscan.

Snowden, D., and Boone, M. 2007. *A Leader's Framework for Decision Making.* Harvard Business Review. 2007 Nov; 85(11):68-76, 149.

Stern, N. 2006. *Stern Review on the Economics of Climate Change.* London, UK: HM Treasury.

Sterrenberg, L., Andringa, J., Loorbach, D., Raven, R., and Wieczorek A. 2013. *Low-carbon transition through system innovation: Theoretical notions and applications,* Pioneers into Practice mentoring program 2013.

Trencher, G., Yarime, M., McCormick, K., Doll, C., Kraines, S., and Kharrazi, A., 2014. *Beyond the third mission: exploring the emerging university function of cocreation for sustainability.* Sci. Public Policy 41 (2), 151-179.

Twomey, P., and Gaziulusoy, I. 2014. *Review of System Innovation and Transition Theories*. Working paper for the Visions & Pathways project, CRC Low Carbon Living.

United Nations. 2014. *World Urbanization Prospects,* United Nations.

United Nations. 2015. *World Population Prospects: 2015 Revision,* United Nations.

Voytenko, Y., McCormick, K., Evan, J., and Schliwa, G. 2016. *Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda.* J. Clean. Prod. Volume 123, 1 June 2016, Pages 45-54.

Von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C., and Stasinopoulos, P. 2009. *Factor Five: Transforming the Global Economy through 80% Increase in Resource Productivity.* London, UK: Earthscan.

Wilson, K., Desha, C., Bucolo, S., Miller, E., and Hargroves, K. 2014. *Emerging Opportunities for "Design Thinking" to Deliver Sustainable Solutions in the Built Environment.* The International Journal of Design Management and Professional Practice, 8(1), pp. 1-10.