School of Design and Built Environment

THE ROLE OF BUILDING REGULATION AS A POLICY INSTRUMENT FOR ACCELERATING THE TRANSITION TO A LOW CARBON BUILT ENVIRONMENT

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Author’s Declaration

I declare that this thesis is my own account of my research and contains as its main content work that has not previously been submitted for a degree at any tertiary education institution.

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[Author]

Abstract

Reducing carbon emissions from the building sector is a policy priority under the Paris Climate Accord. The challenge for policy makers is to deploy effective policy instruments targeting this sector. Building energy codes have been shown to deliver a combination of economic, environmental, societal and strategic benefits. Understanding the mechanics of building policy in the residential sector is instructive because of the sector's high levels of building activity, and diverse stakeholder considerations involving both consumers and industry professionals.

Although building energy codes provide an effective intervention in the property market their effectiveness is negated by problems of enforcement, compliance and operational factors. Addressing these impediments calls for tailored, multi-faceted policy packages to bridge gaps between presumptive performance objectives and results observed in practice for constructed and operating buildings. Here policy development is approached from two novel perspectives. Firstly, concepts derived from transition theory are utilized to illuminate the role of building energy codes in facilitating the emergence of low carbon residential buildings through socio-technical transition in the building sector. Australia's National Construction Code (NCC) is benchmarked against world's best practice using an internationally recognized assessment framework as an illustrative case study of such a transition process. Secondly, in a complementary analysis, building policy options are examined from the perspective of behavioural economics. Under this regime the decision-making processes of sectoral stakeholders are viewed from a socio-psychological perspective rather than an orthodox economic perspective. This perspective reveals how stakeholder decisions in relation to the design, construction and operation of energy efficient buildings diverge substantially from normative assumptions of energy and climate policies that are founded on conventional economic doctrines.

The research reveals significant implications for the framing of sectoral climate and energy policies such as those relying on building performance disclosure. In practice behaviourally attuned policy approaches show promise for contributing to innovative and potent building energy implementation mechanisms. Although

behaviourally-oriented techniques are now being applied worldwide in diverse domains they have yet to be extended substantively into the field of building energy performance and efficiency.

Australia's high *per capita* GHG emissions and rates of residential building construction provide a pertinent case study. Insights into the ongoing development of Australia's NCC provide a source of evidence-based analytical data for examining the efficacy of market-based energy efficiency measures such as carbon pricing. Conventional assumptions regarding presumptive consumer cost imposts of regulatory measures are misconceived on the basis of historical evidence.

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My dear wife Christine Barbara Enker whose unwavering support and understanding has helped me continue my studies despite significant personal challenges over these last six years.

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Dr Annie Matan: for setting the initial direction of my research practice.

Colleagues at the Victorian Building Authority who provided a solid technical grounding for my research.

Dedication

To my Dear Parents Mala and Maks Enker of Krynica, Poland whose desire to have a Doctor in the family may at last be realized.

List of publications constituting this thesis

Peer reviewed journal articles and conference papers

Appendix A: Energy Efficiency Journal article - **Enker, R.A**., Morrison, G.M, The potential contribution of building codes to climate change response policies for the built environment; *Energy Efficiency,* May 2020 (Enker and Morrison, 2020). Publication 1. (Double blind peer reviewed article).

Appendix B: Energy and Buildings Journal article - **Enker, R.A.**, Morrison, G.M, Analysis of the transition effects of building codes and regulations on the emergence of a low carbon residential building sector; *Energy and Buildings*, V156, December 2017, pp 40-50. Publication 2. (Double blind peer reviewed article).

Appendix C: Buildings Journal article - **Enker, R.A.**, Morrison, G.M, Behavioural facilitation of a transition to energy efficient and low carbon residential buildings; *Buildings* 2019, 9, 226. Publication 3. (Double blind peer reviewed article).

Appendix D: ASA 2015 conference paper - **Enker, R.A**., Reframing housing regulation: delivering performance improvement in conjunction with affordability; Conference Proceedings: Living and Learning: Research for a Better Built Environment 2015, pp 403-412. (Double blind peer reviewed manuscript).

Appendix E: CESB 2016 - Central Europe Towards Sustainable Building: Innovations for Sustainable Future 2016: **Enker, R.A**., Building energy policy: why dollars don't always make sense; *Conference Proceedings*, CESB 2016, Prague, Czech Republic, pp 1366-1373. (Blind peer reviewed manuscript).

Conference presentation and manuscript

Appendix F: Sustainable Engineering Society of Australia 2015 Conference: Enker, R.A., The evolution of building energy standards in Australia: a journey interrupted? *Conference Proceedings*, Adelaide, Australia, September 2015 (unpublished). (Blind peer reviewed manuscript).

Literature Review

Appendix G: Literature review: The role of building regulation as a policy instrument for the transition to a low carbon built environment.

Copyright release

Appendix H: Copyright waiver for the article attached as Appendix C is provided in Appendix H.

Author's Statement

All of the written materials submitted as part of this PhD by Publication were conceived and articulated by Robert Abraham Enker.

I also undertook the majority of the writing and analytical for each academic publication and conference presentation.

Signed
Date 03/02/2020

Co-author's statements

Publication 1
I, Robert Enker, contributed 80% to the publication entitled:

Enker, R.A., Morrison, G.M, *The potential contribution of building codes to climate change response policies for the built environment*; Energy Efficiency 2020 (Energy Efficiency Journal article - submitted; awaiting editorial approval)

Signature of Candidate: *Date:* 3/2/2020

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co- author, Gregory M. Morrison
Signature: *Date: 3/2/2020*

Publication 2

I, Robert Enker, contributed 80% to the publication entitled:

Enker, R.A., Morrison, G.M, *Analysis of the transition effects of building codes and regulations on the emergence of a low carbon residential building sector*; Energy and Buildings, V156, December 2017

Signature of Candidate: *Date:* 3/2/2020

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co- author, Gregory M. Morrison

Signature: *Date: 3/2/2020*

Publication 3

I, Robert Enker, contributed 80% to the publication entitled:

Enker, R.A., Morrison, G.M, *Behavioural facilitation of a transition to energy efficient and low carbon residential buildings*; Buildings 2019, 9, 226

Signature of Candidate: *Date:* 3/2/2020

I, as a co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

Co- author, Gregory M. Morrison

Signature: *Date: 3/2/2020*

Copyright release for this article is provided in Appendix H.

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Glossary of Terms

ABCB	Australian Building Codes Board
AHIDC	Australian Housing Industry Development Council
AHURI	Australian Housing and Urban Research Institute
ASBEC	Australian Sustainable Built Environment Council
BITs	Behavioural Insights Teams
CO_2	Carbon Dioxide
CRC LCL	Cooperative Research Centre for Low Carbon Living
CUSP	Curtin University Sustainability Institute
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certification
ETS	Emissions Trading Scheme
EU	European Union
GBPN	Global Building Performance Network
GHG	Greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPCC WG3	IPCC Working Group 3
NatHERS	Nationwide House Energy Rating Scheme (Australia)
NCC	National Construction Code (Australia)
OECD	Organisation for Economic Cooperation and Development
SLR	Systematic Literature Review
SME	Small to medium enterprise
UNEP	United Nations Environment Program
WBCSD	World Business Council for Sustainable Development

Selected websites referenced in this thesis

Organization	URL
Australian Building Codes Board	www.abcb.gov.au
US Building Energy Codes Program	https://www.energycodes.gov
Building Performance Institute Europe	http://bpie.eu
Behavioural Science and Policy Association	https://behavioralpolicy.org
Global Building Performance Network	www.gbpn.org
International Energy Agency: energy in buildings program	http://www.iea-ebc.org
Institute for Market Transformation	https://www.imt.org
Inter-Jurisdictional Regulatory Collaboration Committee	www.ircc.info
World Business Council for Sustainable Development	www.wbcsd.org
Building Codes Assistance Project	http://bcap-energy.org/
European Union: Energy Performance of Buildings Directive	https://www.epbd-ca.eu
Cooperative Research Centre for Low Carbon Living	http://www.lowcarbonlivingcrc.com.au

1 Introduction

This analysis critically examines the crucial linkage between global climate policy and building energy policy (Lucon O. and Liphoto, 2014) The contribution of greenhouse gas (GHG) emissions from the building sector to aggregate global emissions is not well appreciated or embedded in policy (Australian Sustainable Built Environment Council, 2010). As a consequence global climate policy does not sufficiently prioritize interventions in the building sector - expressed through the paradigm of a low carbon built environment - to a sufficient degree (McKinsey Company, 2009). This situation has improved to some degree after enactment of the Paris Agreement (UNFCCC, 2015); for example the Global Alliance for Buildings & Construction subsequently produced a "Roadmap towards low-GHG and Resilient Buildings" (Global Alliance, 2016).

There is also a degree of uncertainty, even controversy, concerning the appropriate instruments to be deployed for policy interventions in the building sector where these are intended to accelerate market uptake of energy efficient, low carbon buildings (Ürge-Vorsatz et al., 2007b), (Enker, 2015a), (Enker, 2019).

1.1 The need for this research

Although this PhD research has tended to focus on the Australian experience with building energy regulations and their overarching policy settings these are nevertheless viewed within their wider global setting (Enker, 2019). Quantitative data utilized in the research has been drawn from pertinent Australian examples. It is anticipated that lessons learnt from the Australian experience will undoubtedly have wider application for international energy agencies and building jurisdictions, and this study has been designed accordingly.

Since 2009 Australia has experienced an effective hiatus in the progressive reform of the national building code energy efficiency provisions applying to both residential and commercial buildings (Appendix F), (Australian Sustainable Built Environment Council, 2018b). This unfortunate interruption to ongoing code development appears to be founded on a number of challengeable assumptions that are critically examined in the course of this research. Related policy decisions have been predicated on assumptions such as the stifling effect of regulation on business dynamism; and the negative economic impacts of higher building energy efficiency standards.

The more significant and contestable of these assumptions is that increased regulatory stringency inevitably leads to unacceptable increases in construction costs with adverse impacts on local building construction. This assumption is in effect the corollary of a rationale insisting that environmental regulations are inevitably economically damaging (Appendix D).

A related proposition is that financial intervention in the property market will deliver intended mitigation of sectoral GHG emissions without the need for regulatory measures (Appendix E). Associated with such aversion to regulatory intervention is the contention that the provision of various forms of information to industry stakeholders and consumers will in itself achieve climate policy pertaining to the building sector (Appendix A).

Both these questionable assumptions reflect a failure to appreciate and account for the dynamism inherent in the construction industry and its capacity for progressive, systemic socio-technical development (Appendix B).

The Systematic Literature Review (SLR) (Appendix G) reveals that a gap exists in the evidence base needed to re-invigorate Australian building energy code development (Australian Sustainable Built Environment Council, 2018b, Australian sustainable Built Environment Council, 2018). The SLR also reveals that lessons learnt from international experience can make a substantial contribution to this mission (International Energy Agency, 2013a); but that such global lessons are yet to be absorbed by Australian policy makers despite being well documented in the literature (Australian Sustainable Built Environment Council, 2018b).

Therefore this analysis is designed to provide vital evidence for facilitating the resumption of Australia's national building energy code development process - after its decade-long hiatus (Australian Sustainable Built Environment Council, 2018b) A related objective is to ensure that such development continues unabated on a future trajectory that is consistent with international best practice (Australian Sustainable

Built Environment Council, 2018a). It is worth noting that the NCC was updated in 2019, as the first step in its transition to a formalized three-year revision cycle.

Examination of the SLR findings from an international rather than the Australian policy perspective goes further to highlight gaps in the literature that this research seeks to address. The SLR reveals such literature to be lacking in a critical analysis of policy level aspects – as compared with a more conventional technical focus (Rosenow et al., 2016c).

Although literature in the field does acknowledge the significance of addressing GHG emissions from the building sector as part of global climate change response strategies the case for deploying building energy codes as a pre-eminent policy instrument is neither apprehended nor particularly well made (Ürge-Vorsatz et al., 2007b). Alternative policy instruments such as financial measures and information programs tend to be given equal weight to regulations in a relatively uncritical manner.

Judicious and focused analysis of the relative merits of alternative policy instruments is worthwhile in order to better inform international policy makers and their subordinate regulatory agencies in the crucial task of developing climate policy for the built environment.

1.2 Climate policy and the built environment

Ratification of the Paris Climate Agreement on climate change (UNFCCC, 2015) has compelled signatory governments to commit to the introduction and implementation of substantive GHG emission abatement policies. The Organisation for Economic Cooperation and Development (OECD) (Organization for Economic Cooperation & Development, 2003, OECD., 2003) and numerous other authorities (International Energy Agency, 2013b, WBCSD, 2009) have highlighted the fact that the building sector contributes significantly to energy consumption and GHG emissions in the economies of developed countries. Energy use in the building sector has been estimated at 25–40% of the total in OECD member countries (Ürge-Vorsatz and Novikova, 2008, Lucon O. and Liphoto, 2014).

In the Australian setting a recent estimate of GHG emissions from residential and commercial buildings (Centre for International Economics, 2007) concludes that these contribute some 23% of the national GHG total. However, it is also worth noting that the Australian State of Victoria, which accounts for 25% of the national population, represents 40% of total Australian GHG emissions (Wilkenfeld, 2008).

More recent estimates of building sector emissions and the potential for a trajectory leading to zero-carbon building standards are available from studies undertaken by ASBEC (Australian Sustainable Built Environment Council, 2010, Australian Sustainable Built Environment Council, 2018a).

A key attribute of the building sector is that it offers significant prospects for GHG abatement of all sectors in developed economies (McKinsey Company, 2009). Improving the energy efficiency of buildings using conventional and proven technologies has been shown to deliver GHG abatement at an economy-wide cost saving (McKinsey Company, 2009). This contrasts with the significant cost burdens arising from abatement in other energy sectors such as advanced power generation systems; carbon capture and storage; or alternative energy supplies. Indeed, the World Business Council for Sustainable Development (WBCSD) makes the case for reform of the building sector by arguing that large and attractive opportunities exist to reduce buildings' energy use at lower costs and higher returns than other sectors.

Global estimates of the potential GHG mitigation from the world's buildings has shown that a reduction of almost 30% could be achieved cost-effectively by 2020 (Edenhofer, 2014), reinforcing the message that the building sector has the largest potential for abatement among all sectors.

The proposition of an effective nexus between climate change response and building energy policy is now well established. For example, two seminal studies defined cost curves for GHG mitigation options applicable to both the global and Australian economies (McKinsey Company, 2009, McKinsey Company, 2008). It is clear from these studies that the most cost-effective mitigation options (those with negative societal costs) are associated with improving the energy efficiency of buildings, their associated services and fittings. A subsequent study undertaken for the Australian

Sustainable Built Environment Council (ASBEC) (Australian Sustainable Built Environment Council, 2010) with an explicit economic focus concluded that improved building performance could not only make a significant contribution to national GHG emissions abatement objectives but would simultaneously deliver substantial material benefits for the national economy as a whole.

Research commissioned by the WBCSD provides further evidence for such a nexus (World Business Council for Sustainable Development, 2009); as do the report of the Intergovernmental Panel on Climate Change Working Group 3 (IPCC WG3) (Lucon O. and Liphoto, 2014); and analysis by (Ürge-Vorsatz et al., 2015)

Figure 1 illustrates the key role to be played by building energy policy in relation to the national climate change responses now being developed following ratification of the Paris Climate Agreement under the Framework Convention on Climate Change (UNFCCC, 2015). This schema suggests that the notional nexus between global climate initiatives to subordinate national policies focused on sectoral energy efficiency can be seen as a hierarchy in which these strategies necessarily thrust the building sector into a pivotal role in a global climate policy framework (Appendix A).

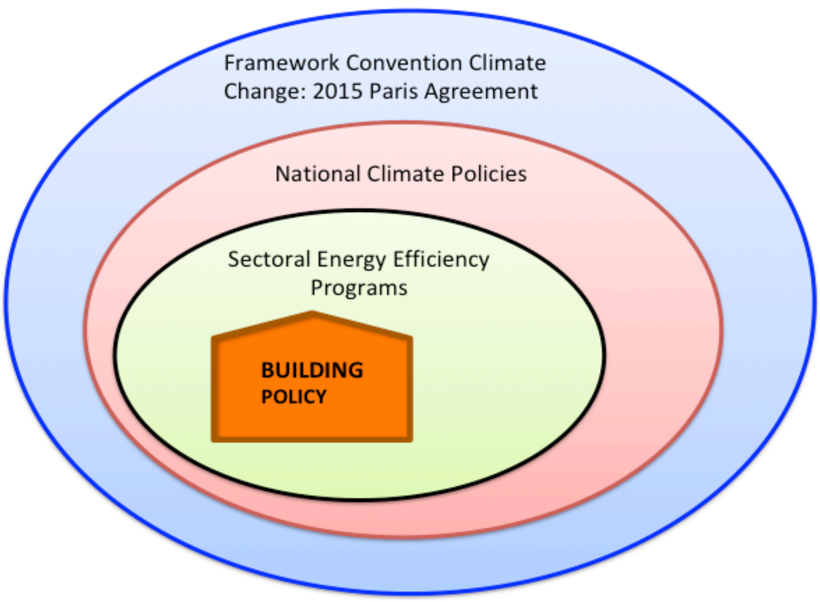

Figure 1 Conceptual policy hierarchy: harmonization of international climate policies to prioritize energy efficiency, highlighting contribution of the building sector to outcomes

1.3 Building energy policy implementation

Governments have identified a variety of available options once a decision has been made to apply national GHG abatement policy to the built environment (see Appendix A). At a peak policy level these are (United Nations Environment Program, 2007):

- Economic measures - financial incentives or penalties
- Direct regulation - performance standards enshrined in building codes, appliance standards and similar instruments
- Stakeholder communication campaigns - both targeted and broadly focused
- Enhancing industry delivery capacity – a specific form of information delivery

Comprehensive delineation of these policy options is set out in the European Union (EU) Energy Performance of Buildings Directive (EPBD) (European Union, 2012) as well as in analysis undertaken by the United Nations Economic Commission for Europe (United Nations Economic Commission for Europe, 2011).

In considering policy supporting the mitigation of GHG emissions from the building sector, Urge-Vorsatz (ürge-Vorsatz et al., 2007a) highlights the effectiveness of regulation compared with other policy interventions. Thus the Urge-Vorsatz analysis lays groundwork for the proposition that regulatory intervention should be a preferred policy instrument for government aiming to reduce emissions from the building sector. Other authoritative sources arrive at similar conclusions (Lucon O. and Liphoto, 2014) (International Energy Agency, 2013a) (Johansson, 2012). The observation made by IPCC WG) that GHG mitigation options for buildings have a range of co-benefits in addition to obvious savings in energy cost (Lucon O. and Liphoto, 2014) mirrors similar findings in the literature (International Energy Agency, 2013a). Significantly, these benefits include: economic stimulus, job creation, consumer cost savings, improved energy security, more comfortable and valuable dwellings (International Energy Agency, 2013a).

In its 2007 study the United Nations Environment Program (UNEP) (United Nations Environment Program, 2007) examined a variety of policy instruments including building codes and appliance standards, both of which were rated as high in emission reduction effectiveness. Commenting on the importance of building codes in improving energy efficiency, UNEP highlighted two potential limitations on building codes' effectiveness, firstly, difficulties with compliance and enforcement and secondly, application only to new buildings (Appendix A). It is noteworthy that UNEP also rated economic instruments such as carbon pricing and capital subsidies or grants as being relatively low in driving the abatement of GHG emissions from the building sector (United Nations Environment Program, 2007).

Evidence for the transformative role of building energy codes in relation to building energy performance is to be found in a report by the International Energy Agency (IEA) (Group of Eight Organization, 2008) and in Appendix B. The IEA report pointed out that buildings are long-lived assets with life expectancies of many decades; performance upgrades through refurbishment to improve performance only occurs at long intervals. In addition, designing buildings for energy efficiency in the first instance may be both simple and cost effective as subsequent performance improvements in service can be quite problematic (Group of Eight Organization, 2008). Appendix B provides a detailed discussion of the role of building regulation as an agent of systemic socio-technical transformation of the building sector.

Similar conclusions were reached by the WBCSD in its extensive study of options for transforming the market for energy efficient buildings (World Business Council for Sustainable Development, 2009). The Council's recommendations were twofold: firstly that energy efficiency provisions in building codes should be progressively tightened over time; and secondly that market forces were insufficient to achieve the urgent transformation that was necessary so that external intervention through government policy initiatives was essential.

1.3.1 Financial instruments

Conventional GHG abatement policies typically utilize financial instruments such as carbon pollution pricing, in the form of a carbon tax or emissions trading (ETS) regime, as a means of abating emissions from diverse sectors of developed nations' economies.

Application of this approach to the building sector is challenged by the analyses set out in Appendices A and C. These papers elaborate on the premise that operation of the building sector is beset with a large number of diverse and potent market failure mechanisms. Therefore policy interventions in the property sector that are functionally reliant on efficient operation of the sector in an economic sense are likely to have limited success precisely because of such intrinsic defects.

Successful policy interventions in the property sector should not rely wholly on economic instruments such as carbon taxes, ETS, or financial subsidies. Other complementary policy instruments must be deployed to enhance prospects for success. This finding ties in with a subsequent discussion of the need for integrated policy packages to be deployed in order to abate GHG emissions from the global building stock.

1.3.2 Regulatory intervention

The role of building energy codes as an instrument of climate policy is analyzed in Appendix A. Findings set out in this paper are central to the overarching research question being addressed here. It was shown clearly, in the course of economic analysis undertaken as part of Australia's regulatory development processes, that recourse to regulatory intervention in the national building market to give effect to government energy and climate change policy delivered clear economic benefits in terms of positive cost-benefit ratios. Mitigation of GHG emissions from the building sector is achieved at costs ranging from AUD3.6 per tonne CO_2 to a saving of AUD70 per tonne CO_2 (Appendix A: Table 4).

Further review of the literature reveals numerous further beneficial outcomes attributed to regulatory intervention in the building sector:

- Energy system security, lower infrastructure costs (Berry and Marker, 2015) (International Energy Agency, 2014), (Lucon O. and Liphoto, 2014)
- Economic growth, job creation and improved employment opportunities (Lucon O. and Liphoto, 2014) (International Energy Agency, 2014) (Victorian Building Commission, 2002a)
- Enhanced occupant comfort (Berry and Marker, 2015) (International Energy Agency, 2014)

- Increased property resale value (Department of the Environment, 2008)
- Reduced incidence of fuel poverty (Lucon O. and Liphoto, 2014), (International Energy Agency, 2014)
- Increased resilience in the face of extreme weather events (ABCB, 2014)

1.3.3 Information and communication programs

According to an analysis by the the IEA (Hood, 2011) policy initiatives that may be classified as information and voluntary approaches generally include:

- Rating labeling programs (which also overlap the regulatory classification)
- Public information campaigns
- Education and training: capacity building for industry
- Product certification and labeling
- Award programs

Within this category, governments in many jurisdictions have placed considerable emphasis on policy instruments that utilize performance rating and labeling of buildings as a vehicle for market intervention with the aim of reducing GHG emissions from buildings (Appendix C). The rationale behind this intervention pathway assumes that performance disclosure will lead to consequent changes in consumer behaviour. It is assumed that consumers will respond by purchasing or renting buildings with superior energy performance ratings. This shift in demand is then assumed to lead to uplift in the market value of favoured building types, increasing both demand and supply of these buildings.

Extensive analysis on the benefits of Energy Performance Certification schemes (EPC) for buildings as well as best practice implementation processes has been undertaken by the IEA (International Energy Agency, 2010). EPC also offers additional benefits such as increased public energy awareness, lower consumer costs and improved building data collection as an input to further policy development.

Some jurisdictions have attempted to employ wide-ranging consumer awareness campaigns in an attempt to raise public awareness of the need for grassroots action on GHG abatement through purchasing more efficient appliances, vehicles and dwellings (Environment Protection Authority of Victoria, 2011). Evidence for the effectiveness of such information campaigns appears to be equivocal (Ben-Shahar, 2014) (Olaussen et al., 2017) (Geller et al., 2006)

The EU energy performance disclosure program, termed the EPBD (European Union, 2016), is a prime example of this approach, and is implemented at considerable scale. Similar strategies have been employed by local jurisdictions such as the Australian Capital Territory (ACT Government, 2003) and the State of Victoria, Australia (Victoria, 2018). As a reflection on the potential contribution of Behavioural Economics to building policy, Appendix C is also concerned with the efficacy of programs such as the EPBD (European Union, 2016) at a detailed analytical level.

1.4 Research Design

1.4.1 Background

This research critically examines the role of best practice building codes, standards and regulations to act as an effective catalyst and enabler for societal transition to a low carbon built environment.

The study forms part of a broader research program aiming to examine the role of government policies in driving a low-carbon transformation of the building sector, the latter carried out under the auspices of Australia's Cooperative Research Centre for Low Carbon Living (CRC LCL).

The research seeks to inform and re-invigorate government policy interventions in Australia's property market. Such interventions should be directed toward improving building energy performance in the most effective and efficient manner possible. Currently regulation tends to be seen as an impediment to improving building performance, rather than a potential driving agent for the transformation of Australia's new and existing building stock a substantially reduced carbon footprint.

At a practical level the analysis draws upon the literature concerning international best practice in building energy regulations to provide a basis for benchmarking design and operational effectiveness of the local Australian regulatory regime (Appendices A and F). This research is potentially of direct relevance to agencies involved in the development and implementation of international building codes; as well as providing a basis for evaluating the stringency and effectiveness of the domestic regulatory regime in Australia. These findings also seek to inform the wider public policy debate concerning the public costs and benefits of environmental regulation.

The analysis opens by highlighting the salience of building sector GHG emissions in the global schema. With the corollary that sectoral emissions abatement by means of significant energy efficiency gains must also be seen as a crucial element of climate policy. Then the investigation progresses through a review of the policy instruments available to governments committed to intervening in the building sector.

1.4.2 Context

Classifying the theoretical basis of this PhD project is not straightforward because it is pitched at a multi-disciplinary policy level rather than having the essentially technical focus of typical literature in the field (as covered in the SLR, Appendix G).

The methodology used in this thesis is based on the investigation, review and critical analysis of information and quantitative data generally available in the public domain. Where appropriate, quantitative data has been sourced from official publications produced by Australian national and state governments and their subordinate agencies. Thus the analysis is generally dependent on secondary rather than primary data sources.

This approach mirrors that of Elbaz' research (Shimon and Adriana, 2016) in a similar socio-technical domain to that pertaining here. Specifically, Elbaz examined the use of behavioural tools to reduce electricity demand in residential buildings.

According to (Bickman, 2009) this form of applied research aims to make a contribution to actual public policy debates and decision-making processes. This is an appropriate definition of the strategic objectives of my thesis.

In the same vein (Hall, 2008) makes the point that one particular class of applied social research could well be classified as evaluative research whose purpose is to determine the effectiveness of a program or policy. This is the case here in that the objective is to delve deeply into global climate change response strategies in terms of their application to the building sector; and how these considerations inevitably lead onto examination of the role of policy instruments such as building codes.

Hall (2008) also supports clarification of the primary research question through subordinate questions to take the project forward and develop a conceptual framework for the research. According to (Hall, 2008) the conceptual framework for applied social research comprises the theoretical and methodological underpinnings of the research together with contextual information and data collection instruments. For this thesis, and based on (Hall, 2008), the conceptual framework is illustrated in Figure 2.

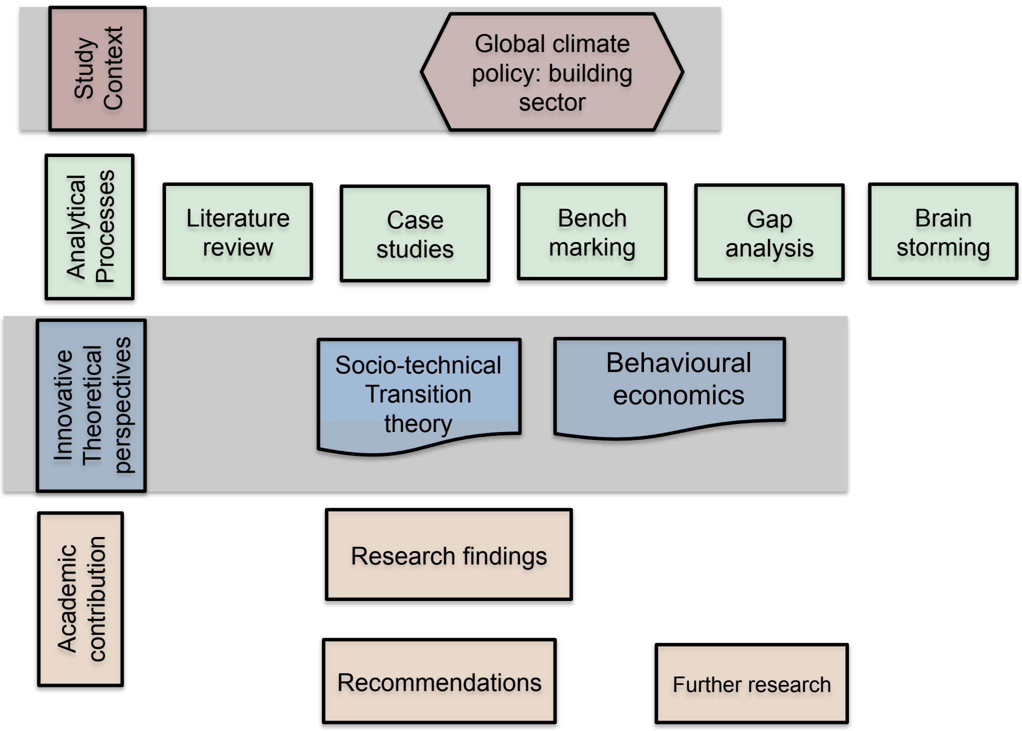

Figure 2 Overview of the tailored analytical approach developed for this research project

(Bickman, 2009) advises that there are three main categories applicable to the design of applied social research: descriptive, experimental and quasi-experimental. This project falls into the first category. Pertinently, Bickman also suggests that the development of applied social research design rarely follows a simple linear process. More typically the process involves the development of a hybrid design that effectively responds to the multiplicity of study questions, resource constraints, and project dynamics (Bickman, 2009). Such is the case with the bespoke analytical approach developed for this project (Figure 2).

1.4.3 Process

The outcomes from this PhD program are structured in a modular form as a series of individual manuscripts either published (Appendices B and C) or submitted to peer reviewed academic journals (Appendix A); in combination with peer-reviewed papers presented at local and international conferences (Appendices D, E, F). This body of academic scholarship is designed to provide policy makers with guidance concerning the strengths and weaknesses of regulatory interventions in the building sector as a preferred vehicle for expediting and accelerating low carbon building construction at both a national and a global scale.

This analysis of building regulatory methodologies is innovative in comparing the current regulatory approach, which tends to be narrowly focused on compliance at the design and construction stage by industry stakeholders, with alternatives that are more broadly focused in order to embrace operational building performance and end of life aspects. The research also more actively addresses consumer engagement issues (Appendix C). It is hoped that the analysis will be utilized by government agencies in examining the case for increasing the focus, stringency and effectiveness of current building energy standards; thereby leading directly to reduced carbon emissions from the built environment.

By drawing upon contemporary research in the field of Behavioural Economics this research also offers quite novel perspectives on the effectiveness of alternative policy interventions available to governments in this domain (Appendix C).

1.4.4 Research questions

The fundamental research question addressed by this PhD study is as follows:

> What is the role of building regulation as a policy instrument for the transition to a Low Carbon Built Environment?

Four subsidiary research questions have been articulated which support and elaborate on the primary question, in order to provide a structural framework for the PhD program. These questions are:

> Does regulatory intervention to improve building energy efficiency necessarily have a negative impact on housing affordability? (Appendix D)
>
> How effective are economic instruments compared with other potential government interventions, such as mandatory building standards, in maximizing the prospects for successful policy implementation? (Appendix A)
>
> How do Australian building energy standards measure up when benchmarked against world's best practice? (Appendix B)
>
> How does consumer choice operate in the property market when examined from the standpoint of Behavioural Economics? (Appendix C)

Responses to these questions were developed through reference to two significant conceptual bases.

Firstly, through an examination of the relevance of Socio-technical Transition Theory to this research. This conceptual foundation was examined in a paper published in the journal Energy and Buildings (Appendix B).

Secondly, a broad-based discussion of the genesis and application of the rationale of Behavioural Economics to building energy policy was used to answer Research Question 4. This analysis is the subject of a manuscript published in the international academic journal Buildings (Appendix C).

Figure 2 illustrates this analytical approach in structural terms. The diagram illustrates how the analysis progresses through four stages: from context setting to detailed analysis using a variety of *ad hoc* techniques; through the application of concepts drawn from Socio-technical Transition Theory and Behavioural Economics; on to the development of novel, academically significant research findings and conclusions.

2 Literature Review (incorporating Systematic Literature Review)

The literature review process undertaken in order to provide this doctoral thesis with a comprehensive underpinning grounded in the existing academic literature took two forms. A highly structured and formalized SLR was undertaken as described in Appendix G. Some eight hundred individual citations were initially collected through the SLR process; these were then consolidated through a further filtering and screening process in order to yield an operationally manageable cohort for subsequent detailed interrogation.

In addition to, and in parallel with the SLR, a narrative literature review process was also undertaken through a conventional deductive process. This *ad hoc* approach identified an additional twelve hundred citations in the course of developing the six individual manuscripts that constitute this Thesis by Publication. These citations are cited in the References Section for each individual manuscript. Sources cited specifically in this Exegesis are listed in the Exegesis Reference section. Citations produced from the two-pronged literature review process are listed in the Bibliography (chapter 9). In addition each appended paper has its own specific references annotated.

A function of the SLR discussed in Appendix G was to clarify the boundaries of current academic knowledge relating to the application of building energy codes as an instrument of climate change policy. A subsidiary outcome of the SLR is the identification and definition of gaps in this existing knowledge, gaps to potentially be addressed either by this thesis directly, or as referenced in the thesis' findings and conclusions.

2.1 Outcomes of SLR process

As explained in the Introduction, this analysis works from the premise that global climate policy is insufficiently cognizant of the significance of GHG emissions from the building sector. This premise is underpinned by the pioneering work of

McKinsey (McKinsey Company, 2009) as well as analysis conducted for UNEP by Urge-Vorsatz (United Nations Environment Program, 2007). At a more strategic level the Stern report on the economics of climate change (Stern, 2006) also acknowledges the importance of GHG emissions from the building sector. In a local, Australian, context the definitive analysis of the relative significance of buildings' emissions in the national GHG inventory has been undertaken by ASBEC (Australian Sustainable Built Environment Council, 2010). This question has also been addressed from a progressive industry perspective by the WBCSD.(WBCSD, 2009) Definitive policy analysis relating to climate change in the Australian context is attributable to the Garnaut reports for the Commonwealth Government (Garnaut, 2008, Garnaut, 2011, Garnaut, 2017).

Once the significance of sectoral GHG emissions is acknowledged, the consequent question must clearly be how to respond in a policy sense. What form should a sophisticated, fully informed building energy policy take? Here the work of the IPCC WG3 is pertinent to addressing climate change mitigation from a building sector perspective (Lucon O. and Liphoto, 2014). The UNEP report cited earlier also provides (United Nations Environment Program, 2007) an excellent summary of tools available to policy makers intent on reducing buildings' impact on global GHG emissions. Explicit and potentially transformative regulatory responses to building sector emissions have been promulgated by the EU (European Union, 2010, European Union, 2012, European Union, 2016).

A valuable source of information on the development and implementation of building energy policy is provided by the IEA (International Energy Agency, 2010, International Energy Agency, 2013a, International Energy Agency, 2013b, International Energy Agency, 2014); which is a Paris-based intergovernmental organization established under the umbrella of the OECD.

It is worth noting that the citations identified through this literature review process predominantly relate to the work of governmental and industry bodies rather than sources obtained from the academic literature. Indeed, this observation may reflect a lack of focus by academia on the policy level issues considered in this thesis.

Reports published by the Australian Greenhouse Office and related agencies such as the Department of Climate Change and Energy Efficiency have proven to be particularly pertinent to this study (AECOM, 2012) (Australian Greenhouse Office, 2000). That said, the work of Rosenow, Lorch, and Visscher (Rosenow, 2013, Rosenow et al., 2016c) (Visscher et al., 2014, Visscher et al., 2016b, Lorch, 2017) does counter observations about a lack of academic focus on building energy policy to some degree.

The effectiveness of building energy codes as an instrument of climate policy is a central pillar of this analysis. Studies undertaken in the US in relation to the operation of national codes in that country were found to be particularly pertinent (Nadel, 2013, Livingston, 2014). Energy efficiency provisions for Australia's National Construction Code (NCC) are examined in detail here in a case study that highlights both the benefits and potential shortcomings of a contemporary building regulation regime.

Administration of the NCC is the responsibility of the ABCB (Australian Building Codes Board, 2016), whose many freely available publications in turn are an important source of information on regulatory development process. Particularly, how the outcomes of formal regulatory impact assessment reports can be interpreted in a new light to make a case for widespread market failures in the property sector; from which one can infer that financially based interventions in this market are likely to be unsuccessful (Australian Building Codes Board, 2001a, Australian Building Codes Board, 2005, Australian Building Codes Board, 2009, Australian Building Codes Board, 2010, Australian Building Codes Board, 2011, Australian Building Codes Board, 2001b).

This area of the literature review unearthed many references, both local and international, that illustrate how building codes are intended to operate in theory; but that in practice such policy objectives are not being met for a variety of reasons. These include poor enforcement and also the behavior of the occupants of notionally energy efficient buildings (Meacham, 2010, Pitt & Sherry, 2014a, Pan and Garmston, 2012) (Levinson, 2016, Shergold and Weir, 2018, CSIRO, 2013, Harrington, 2017) (Deason, 2011) (Gram-Hanssen and Georg, 2018). The energy efficiency gap remains pertinent to this area of inquiry (Allcott and Greenstone, 2012, Jafarzadeh and Utne, 2014)

Discussion of the transformative effects of building energy regulations was developed from an initial exposition of the basis of socio-technical transition theory, where the works of leading academics in the field such as Geels (Geels, 2005) and Christensen (Christensen, 2004) were found to be pertinent. Other writers such as Dolfsma (Dolfsma and Seo, 2013) and Gann (Gann et al., 1998) provide evidence for making the case that building energy standards are potential catalysts for innovation in the sector. While Kuzemko provides a high level overview of the governance structures needed to facilitate the changes to energy supply systems, thereby facilitating a transition to sustainability (Kuzemko et al., 2016).

Benchmarking of the NCC against world's best practice in building codes, as an exemplar of socio-technical transformation in action, is very much beholden to bespoke analytical tools made available by the (Global Buildings Performance Network, 2014).

In developing a narrative around potential synergies between the discipline of Behavioural Economics and building energy policy formulation a first principles approach has been taken, drawing upon the work of founding academics in the field in the first instance. Here the seminal works of Kahneman and Tversky (Kahneman and Tversky, 1979, Kahneman et al., 1982, Kahneman and Tversky, 2000, Kahneman, 2003, Kahneman, 2011), Thaler (Thaler, 1980, Thaler, 2009, Thaler, 2016), Ariely (Ariely, 2008) and Schwartz (Schwartz, 2005) are of particular academic relevance. While Altman's (Altman, 2006) and Samson's (Samson., 2018) more generalized guidance texts on BE are also potentially useful.

One interesting outcome of the literature review process was the discovery of a substantial body of academic literature that both critiques and challenges the effectiveness of current building energy policy initiatives. The preceding discussion has already touched on documented evidence for the poor implementation of energy efficiency regulations, as one key policy instrument (Pitt & Sherry, 2014b). The issue of market failure and its implications for financially based policy initiatives such as carbon pricing was also discussed above (see Appendix E).

So it was something of a surprise to learn that the third plank of building energy policy, as represented by building performance certification and disclosure (International Energy Agency, 2010), was subject to rather scathing appraisal by Ben-Shahar (Ben-Shahar, 2014). Backhaus' review (Julia Backhaus) of the EU EPC Program is also telling, as are a number of complementary studies with a narrower, more specifically national focus in Germany, Sweden and Norway respectively (Amecke, 2012) (Hårsman et al., 2016) (Olaussen et al., 2017).

Shove is another leading scholar in the field of energy management, and behavioural aspects in particular, who takes a rather iconoclastic stance to the philosophical basis for current policy approaches (Shove, 2010, Shove, 2017, Shove et al., 2014).

Exploration of a presumptive nexus between BE and building energy policy leads one into academic literature dealing with notionally behavioural approaches to climate policy and, more pointedly, household energy consumption. Here the works of Allcott (Allcott, 2011, Allcott and Mullainathan, 2010, Allcott and Rogers, 2014), Baddeley (Baddeley, 2011, Baddeley, 2016) and Klotz (Klotz, 2011, Klotz, 2017, Shealy et al., 2016) stand out. As do contributions from Blasch (Blasch et al., 2019), Gowdy (Gowdy, 2008), McNamara and Grubb (McNamara and Grubb, 2011), and Pollitt (Pollitt and Shaorshadze, 2011) *inter alia*.

An interesting observation emerges when reviewing literature dealing particularly with the application of BE methodology and tools to management or optimization of consumer energy use in a residential setting. Which is that these studies are generally focused on matters related to appliance selection, and consumer energy consumption during building operation. Whereas the intention of this specific analysis is to apply a BE lens to decisions made by stakeholders in the course of building design, construction, operation, marketing and ultimate demolition. The latter represents a somewhat different and hopefully novel perspective.

A major constituent of this thesis is concerned with a critical examination of how the building/property market operates in practice; shortcomings in market operation; the effectiveness of price signals – *via* an ETS for example; and the economics of regulatory interventions. Here documentation by the ABCB of regulatory impact assessments, cited earlier, proved invaluable. As did a more general discussion of flaws in conventional economic approaches to market operation by Keen (Keen, 2011), and Quiggin (Quiggin, 2010). Grafton's dictionary of environment and economics (Grafton, 2012a) is an excellent basic reference work for developing analysis relating to notional relationships between economic, environmental and climate factors.

The SLR process brought out a number of thematic issues to be investigated further in the course of the research program. In order to facilitate further consideration these issues were consolidated pragmatically into the following categories:

- Policy formulation: regulatory development processes
- Market operation: consumer behaviour
- Technical analysis of building performance
- Building materials, products and services

In comparison with citations identified through the conventional narrative literature review process it is apparent that the first three of these categories overlap across both approaches; but the narrative approach did not highlight the last category – building materials, products and services. Which is unsurprising, nor of particular concern, because this area of the literature is not relevant to this research program.

3 Theory

3.1 Socio-technical transformation

Appendix B sets out an examination of policy interventions in the building sector from a fresh perspective, whether for GHG mitigation or other purposes. In this case the residential and commercial building industry is considered as a socio-technical system in order to evaluate and better understand the potential for government intervention to deliver defined policy outcomes. Here the analysis draws upon

extensive literature in the academic domain of transition theory (Christensen, 2004, Dolfsma and Seo, 2013, Gann et al., 1998, Geels and Schot, 2007, Lutzenhiser, 1994, Ruan et al., 2014).
Building policy makers must address two key objectives: firstly, identify a role for government policy interventions in the property sector to capture the economic benefits of high performance, energy efficient buildings; and secondly deploy policy instruments that are optimal for this task. By taking up a perspective that views the building industry as a socio-technical system (Geels, 2005) it is possible to draw upon contemporary concepts in transition theory and related disruptive innovation processes to seek answers to these questions. Geels' analysis is discussed in detail in Appendix B, in which the definition of transition theory and the basis for its application to building energy policy are elucidated.

An unambiguous case has been made for intervention in the building sector to be the focus of government energy policies that seek to reduce national GHG emissions in line with international treaty obligations (Appendices B and C). Australia's situation is noteworthy for the country's combination of high urbanization levels, high urban GHG emissions and high population growth levels. These are factors that give rise to exceptionally high levels of residential building construction. The salience of building energy policy as a key component and focus point for climate change response is thereby reinforced (Figure 3).

A selection of potent and efficient policy instruments for deployment by government when applying energy policy to the building sector is imperative. Typically, as shown by UNEP studies (United Nations Environment Program, 2007), such selection processes are bi-polar in that they utilize economic and environmental performance measures for decision-making. What the orthodox analytical approaches do confirm is that building energy codes are a particularly effective policy instrument in comparison with the other options available to government (Appendix A).

Appendix B breaks new ground by tapping into the extensive body of contemporary academic theory on socio-economic system transition in order to inform the process of energy policy formulation. It is shown that transition theory provides pertinent case studies of the role of government interventions - such as direct regulation through building energy codes - being deployed to effect the transition of socio-economic systems. This finding has immediate applicability to the important socio-economic system that the building sector represents in both developed and developing economies.

So the conclusion to be drawn from an examination of the building industry through the lens of transition theory is that government intervention in the form of regulation has great potential to effect socio-technical change. This finding supports the conclusions of more conventional economic and environmentally grounded analyses. The salience of building emissions in Australia's GHG inventory (George Wilkenfeld & Associates Pty Ltd., 2002) calls for a decisive policy response. Intervention through building energy regulations has a proven track record of effectiveness in the local context. In comparison with leading international jurisdictions Australia has been relatively slow to embrace the demonstrated benefits of building energy codes (detailed in Appendix D).

3.1.1 Transition and innovation: housing construction

As is the case in many developed economies, building activity levels in Australia are actually dominated by the residential sector. Using building approval numbers as an effective measure of sectoral activity, residential approvals make up 80% of the national total (Victorian Building Authority, 2016).

In order to analyze the potential for disruptive innovation potentially triggered by government regulatory intervention in the residential building sector a sound understanding of the behavioural, socio-technical and cultural characteristics of Australian residential builders is required.

The national residential building sector is dominated by a multitude of small construction firms (Dalton, 2013) with all the attendant and well documented behavioural characteristics of such small-to-medium-enterprises (SMEs). Barrett (Barrett, 2008) has studied the process of innovation in small construction firms observed through a series of case studies and has found that the innovation process is not uniform but tends to proceed in a discontinuous manner under the influence of external factors. Because the analysis here is concerned with the role of regulation as a vehicle for systemic transition of the building sector, it could be argued that recourse to regulatory intervention by government is in fact precisely the action that Barrett (Barrett, 2008) sees as triggering innovative change.

Barrett (Barrett, 2008) concludes that innovation in small construction firms is behavioural rather than rational in nature observing that small construction firms operate quite differently to large firms in relation to innovation processes. This observation has important implications for policy makers. The limited resources available to SMEs and their lean organizational structure pose a unique set of challenges to agencies seeking to engage firms effectively in transitional, innovative socio-technical change processes.

A detailed review of innovation processes at work in the Australian housing industry is provided in a report by the Australian Housing Industry Development Council (AHIDC) (Australian Housing Industry Development Council, 1993) that examines the industry from a broad perspective. The AHIDC notes that the housing industry culture is conservative and is marked by low levels of innovation and tardiness in adopting technologies that are being rapidly taken up in other sectors of the national economy.

The AHIDC report also observes that there are strong synergies between the research and development performed by an industry and its adoption of new technology. Generally speaking the Australian construction sector is identified as making the lowest investment in R&D of any key sector in the national economy [52]. Further, AHIDC identifies a number of industry characteristics that prevent innovation in a conclusion that echoes Barrett's findings (Barrett, 2008). These impediments include: pre-dominance of a large number of SMEs; lack of effective networks for dissemination and diffusion of technological innovations; production processes described as effectively being a cottage industry model; bespoke product design; and parochial localized markets largely protected from national or international competition. Information technology is seen as being the most likely prospect for disruptive change in the industry [52].

A more sanguine view of innovation in the housing industry is put forward by a study for the Australian Housing and Urban Research Institute (AHURI) (Dalton, 2013). This analysis identifies housing construction as a socio-technical process that shows evidence of process innovation in areas such as mobile telephony, use of onsite mechanical equipment and IT support. Importantly AHURI also concludes that sectoral innovation is driven by exogenous factors such as government regulation.

3.2 Behavioural approach to stakeholder engagement

The paper attached as Appendix C, Behavioural facilitation of a transition to energy efficient and low carbon residential buildings, has been published in the journal Buildings (Enker and Morrison, 2019). It describes an in-depth review of the role that the discipline of Behavioural Economics (BE) could make to building energy policy development and implementation.

The research process underpinning the research presented in this dissertation was set out earlier on Figure 2. The manner in which this process reaches its conclusion is explained in Figure 4; wherein questions related to the practical application of BE theory are seen to be addressed. The purpose of Figure 3 is to illustrate how the gap analysis technique may be applied to the examination of current building energy policy instruments. The potential influence of BE principles on policy development is also incorporated into the flow chart.

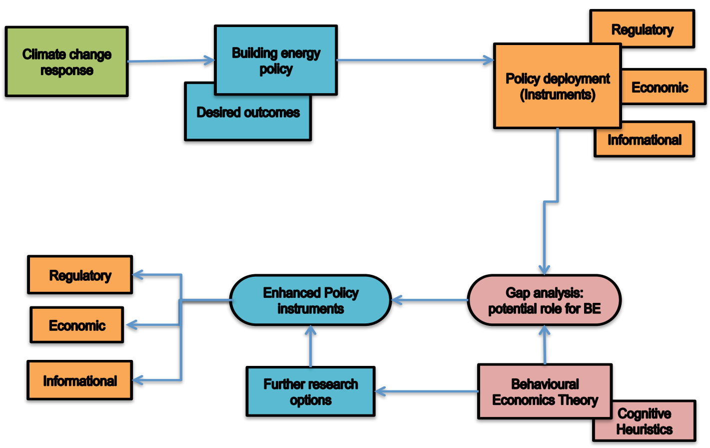

Figure 3 Analytical process for identifying the potential contribution of BE theory to building energy policy implementation

The analysis presented in Appendix C demonstrates how lessons learned from BE could make a significant contribution to the design and implementation of the policy instruments deployed by governments in order to accelerate transition to a low carbon built environment.

4 Research Methods

This research can be characterized as a hybrid in regard to the research methods utilized. The variety of research techniques and methods have been applied on an *ad hoc* basis determined by functional suitability as a means of addressing each of the identified research questions in turn (Figure 2).

By way of comparison, Elbaz and Zait (Elbaz and Zaiţ, 2016) were confronted with similar methodological problems in their investigation into the use of behavioural tools to reduce domestic electricity demand. In a manner similar to this thesis, the methodology adopted by Elbaz and Zait (Elbaz and Zaiţ, 2016) combined literature review with reference to secondary data sources that in turn led onto analysis and synthesis of findings.

4.1 Case study analysis

A case study analysis has been used to directly address one of the key research questions, as is the case in the Appendix D manuscript in which implementation of Victoria's 5 Star residential energy efficiency standard was analyzed in detail in order to answer a key research question. Other case studies have been synthesized from the academic literature to illustrate particular analytical hypotheses. For example, the effectiveness of consumer oriented information disclosure programs was reviewed through recourse to a case study of the EU program that is being rolled out under the aegis of the EU's EPBD (Appendix C).

4.2 Meta-analysis: detailed data review

In discussing the design of an applied social research project Bickman (Bickman, 2009) distinguishes five data sources (Bickman, 2009): self-reporting; extant databases; behavioural data; observational data; and documentary material. This project relies on data from the second and last of these categories.

Data available in the public domain from Australian government sources such as the Australian Building Codes Board (ABCB) and the Australian Bureau of Statistics have been analyzed and interpreted to either address specific research questions or to illustrate particular points being made in the wider context of the thesis research program. In Appendix E historical data available from a series of hitherto unconnected Regulatory Impact Statements published by the ABCB during the period 2004 – 2009 was consolidated to support the hypothesis being tested: that building energy standards actually provide indisputable economic benefits at both a consumer and societal level when assessed using conventional cost-benefit techniques.

4.3 Brainstorming

Opportunities to tap into the expertise and insights of academic and professional colleagues by means of brainstorming exercises were found to be particularly valuable. Brainstorming partners engaged in this way included: fellow postgraduate students at the Curtin University Sustainability Policy Institute (CUSP); former colleagues at the Victorian Building Authority; academics at other institutions, particularly members of the CRC LCL; and also engineering colleagues who form part of the professional network of the author. Specific elements of the PhD research program facilitated by this means included the regulatory case study presented in Appendix D and the critique of conventional economically based interventions in the property sector presented in Appendix E.

Experiential knowledge such as that derived from my own work experience at the Victorian Building Authority and that of my professional colleagues is described by Maxwell (Maxwell, 1998) as critical subjectivity. Maxwell argues that the explicit incorporation of personal experience is gaining much wider theoretical and philosophical support in the field of applied social research. Such experience and expertise can provide a rich source of insights, research hypotheses and validity checks (Maxwell, 1998).

4.4 Benchmarking

Recourse to a benchmarking process that references an accepted international standard was adopted as a means of establishing the relative status and characterization of Australia's building energy code relative to international best practice criteria articulated by the Global Building Performance Network (Global Buildings Performance Network, 2014) (Appendices B and F).

4.5 Gap analysis

This analytical technique was useful for identifying opportunities to utilize techniques accessible from the discipline of Behavioral Economics in order to reform and enhance current approaches to the implementation of building energy policy (per Appendix C).

4.6 Academic sources informing the research

The approach to this research has evolved and been progressively elaborated from an analysis of the role of building regulation as the catalyst for socio-technical transition within the building sector (Enker and Morrison, 2017). This analysis was the subject of a peer reviewed paper published in the journal Energy and Buildings (Appendix B).

An analysis by Kuzemko (Kuzemko et al., 2016) provides a pertinent overview of the factors that give effect to this socio-technical transition process. In Figure 4 Kuzmenko's approach has been adapted for application to this study.

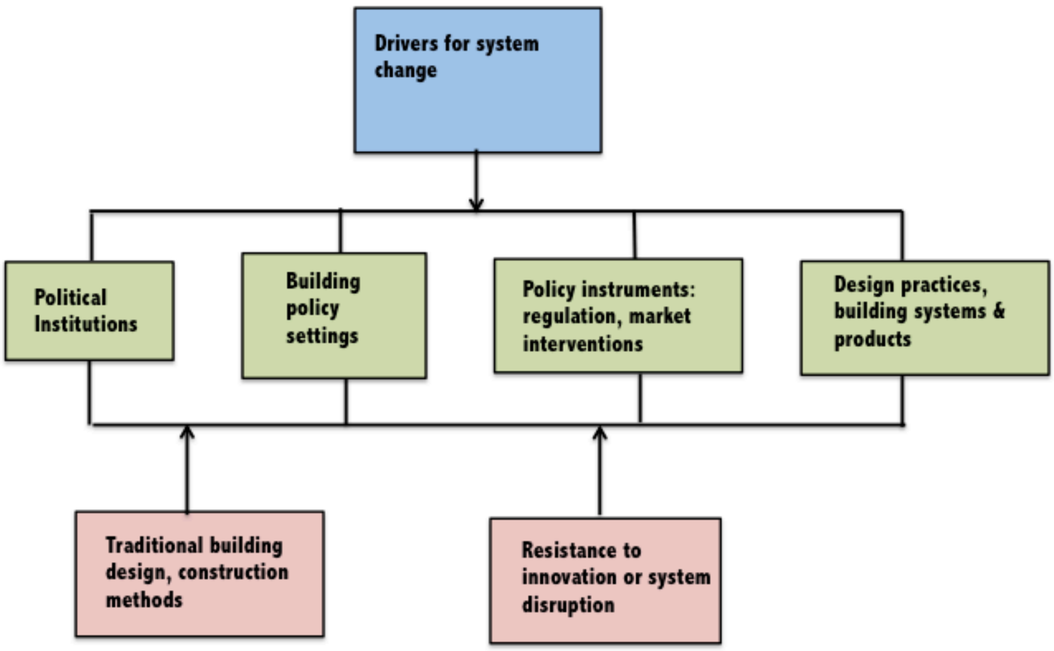

Figure 4 Socio-technical factors applying to a transition to sustainable building practice

As discussed in Appendix B systemic energy transitions depend on institutional settings and governing economic paradigms, with the development of building energy codes having taken different paths in Australia, USA and the rest of the EU (Levine, 2012). Australia's governing political paradigm has tended to a bias against regulatory intervention by government (Council of Australian Governments, 2010) (Christoff*, 2005) while the EU's political institutions facilitate a goal oriented approach by policy makers (European Union, 2012).

Dolfsma & Seo (Dolfsma and Seo, 2013) have developed a typology that is applicable to the role of government policies for influencing technological innovation. Under this paradigm technologies are seen to either develop in a cumulative fashion through incremental refinement of previous developments; or alternatively in a discrete, autonomous manner. By applying the Dolfsma typology (M. Evans, 2009, Dolfsma and Seo, 2013) to innovation in the building industry it can be seen that this process is cumulative in its development trajectory while being subject to high network effects due to the entrenched relationships between industry participants. Thus an appropriate role for government policies that seek to promote technological development in the building industry would be twofold: (a) to facilitate market liberalization; and (b) the setting of standards (Geels and Schot, 2007). Clearly building codes provide precisely such a manifestation of industry standard setting (Appendix A).

Additional dimensions to the underpinning theoretical framework are drawn from the work of Rosenow (Rosenow et al., 2016b) and that of Visscher (Visscher et al., 2016a). Rosenow's analysis broadens the conventional approach to assessing building energy policy beyond the typically single policy measures to the exploration of a more generic framework for assessing the effectiveness of a particular policy mix. Empirical analysis of building energy efficiency policies in fourteen EU countries was utilized by Rosenow to demonstrate application of this methodology.

The work of Visscher (Visscher et al., 2016a) in critically examining the basic governance regime operating on energy efficiency policy for buildings (in this case housing) is particularly pertinent to the issue of building energy code effectiveness. Visscher (Visscher et al., 2016a) argues that policy makers need a better understanding of, and improved engagement with, occupant practices and behaviour if ambitious energy efficiency goals enshrined in current policies such as the near zero carbon by 2020 program of the EU (European Union, 2016) are to be achieved in practice (also Appendix C).

5 Analysis and discussion

5.1 Pervasive market failure in the building sector

The issue of market operation in the building sector is canvassed in detail in Appendices A and D. A crucial point to make here is that market-based instruments are often a necessary but not wholly effective vehicle for policy intervention in situations where multiple modes of market failure operate (Grafton, 2012b). This proposition suggests that market-based instruments may be ineffective without support from additional policy intervention measures. Appendices A and D further explore this observation by demonstrating that the market for energy efficient buildings is bedeviled by diverse failure modes when viewed from an orthodox economic perspective. Table 1 provides a summary of these market failure modes.

Table 1: Building sector market failure mechanisms

	Market failure mode	Explanation and consequences
1	Split incentives	Project builders and developers typically have little incentive for long term investments as they don't have to pay buildings' operating energy costs, the burden then falls upon property owners or tenants
2	Information asymmetry	Consumers relative lack of knowledge and experience with the various benefits of energy efficiency puts them at a clear market disadvantage
3	Information failures	Agents' inability to readily obtain and comprehend information on the lifecycle costs and benefits of energy efficient buildings
4	Externalities	Market transactions affecting third parties are not incorporated into the cost of the transaction; carbon pollution being a classic example
5	Public goods	Goods such as attributes of environmental quality are available to all market agents without a direct charge and are undervalued

A significant inference follows from this finding: that the presumptive market for energy efficiency services in the building sector may be effectively non-functional in conventional economic terms. Restoring efficient market operation thus requires corrective intervention by government agencies responsible for building policy. Alternatively, building policy instruments should be selected on the basis that they are not overly reliant on market operation for successful deployment and delivery of policy outcomes.

Grafton (Grafton, 2012b) provides a comprehensive overview of the options available for the deployment of market-based mechanisms to address climate policy objectives such as those agreed under the Paris Accord. These actions typically manifest either as carbon taxes or ETS. Countries seeking cost-effective policies that embrace commitments made under the Kyoto Protocol have tended to favour ETS over carbon taxes (Grafton, 2012b) on the basis that the former provide certainty about the quantity of GHG abatement. By comparison taxes provide greater certainty about the costs of abatement.

Pertinently, the IPCC WG3 report points out that various barriers hinder the market-based uptake of cost-effective opportunities (Lucon O. and Liphoto, 2014). These barriers, which include split incentives fragmented markets and inadequate access to information or financing, can be overcome by policy interventions addressing all stages of the building and appliance lifecycles.

Mirroring the IPCC, the Stern report (Stern, 2006) on the economics of climate change had previously identified market flaws that impede action for climate change mitigation, particularly in relation to energy efficiency. Stern (Stern, 2006) goes on to break down policy responses aimed at overcoming these barriers into three broad categories: regulation, information and financing.

5.2 Regulation as an effective energy policy instrument

The preceding analysis suggests that simple translation of conventional economic instruments to building sector emissions policy is beset by fundamental weaknesses that are manifest in multiple market failures and thereby obstructing effective policy deployment. Consequently, governments are advised to consider non-economic, non-financial, policy instruments such as mandatory building standards and public information campaigns to effectively mitigate the rapidly escalating GHG emissions attributable to the building sector.

It has been shown that building energy codes have the potential to play the role of a major intervention in property markets by acting as a primary agent for GHG abatement within the framework of global climate policy (Appendix A Table 4).

The Australian case study demonstrates that mandatory building performance standards effected through the NCC will not only contribute to national climate policy objectives but also provide substantive economic benefits in terms of generally positive benefit/cost ratios and substantially positive outcomes in terms of net present value; as well as outcomes achieved in parallel with cost-effective GHG abatement, expressed as negative costs per unit CO_2.

Unfortunately, this potential is not being realized in Australia currently due to to effective operation of building energy codes. Such findings suggest that the potential of this regulatory device is likely to be constrained without corrective action by government at a policy level; these impediments are detailed in (Enker and Morrison, 2020) (Appendix A).

5.3 Corrective policy interventions

A number of corrective policy measures are proposed in order to close the identified gap between *ex post* building energy code performance and the *ex ante* expectations and assumptions built into energy efficiency policy settings. By adopting these policy measures building codes may be able to realize their potential for acting as prime instruments of global climate change policy implementation:

- Stronger focus on compliance and enforcement measures; for example as recommended in (Pitt & Sherry, 2014a)
- Introduction of comprehensive policy packages that support regulatory measures in a practical, integrated manner (Rosenow et al., 2016a); (Lorch, 2017)
- Strengthened, more effective governance regimes (Visscher et al., 2016b)
- Move to outcomes-based compliance verification as the next stage in progressive code development with linkages to transparent consumer feedback (Harrington, 2017); (Nadel, 2013)
- Draw upon the lessons from the field of Behavioural Economics to address issues around ex post building performance by raising consumer awareness of energy efficiency benefits (Frederiks et al., 2015); (Laskey, 2013); (Shove et al., 2014) (Appendix C)

5.4 Australia's NCC: case study

The Commonwealth of Australia standards for all aspects of building performance are enshrined in the country's NCC, which is centrally administered by the ABCB (ABCB). Under this hierarchy the NCC is given effect through the legislation of individual States and Territories while administrative arrangements for Code implementation and enforcement remain a state jurisdictional responsibility. Detailed technical provisions are articulated in referenced Australian Standards that underpin the NCC (Australian Building Codes Board, 2015).

Governance arrangements for Australia's NCC are set out on Figure 5. The role of the NCC is to provide uniform building and plumbing standards across Australia that relate to performance outcomes in key policy areas such as health, safety, and durability. Sustainability was also included as a high level goal for the Code in 2006 (Australian Building Codes Board, 2010). Consistent application of NCC provisions by individual administrations is strongly encouraged in the interests of national economic efficiency (Appendix A).

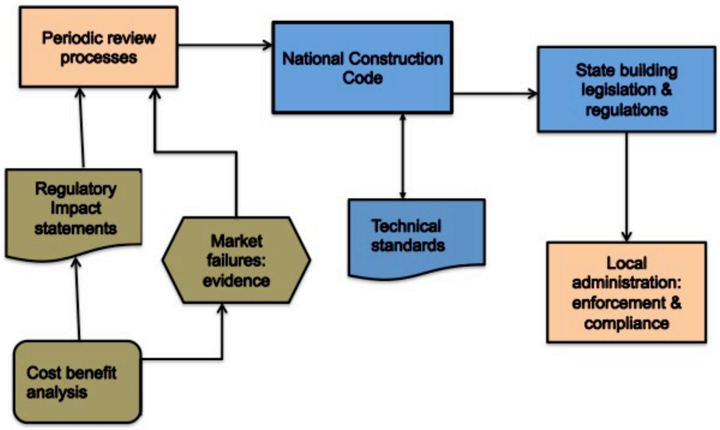

Figure 5 Australia's building regulation framework: the NCC sits at the apex of a hierarchy whose periodic reforms are subject to formalized economic review

Energy efficiency measures for buildings have a long history in Australia going back to the late 1970s when voluntary energy guidelines were first published by government and industry. Mandatory energy efficiency standards for residential buildings were first introduced by the State of Victoria, Australia in 1990 in local building regulations (Victorian Government, 1993). The progressive introduction of national energy efficiency provisions for all classes of buildings in the NCC did not commence until 2003 under a strategic program set out by the ABCB in its Directions Report (Australian Building Codes Board, 2001b) indicating that the process would take until 2004 to complete. In fact a rollout of energy measures for all building classes continued until 2006.

In 2009 a national policy decision was taken for the Council of Australian Governments to reform the initial tranche of NCC energy efficiency provisions for all building classes by ramping up stringency. Under national legislative requirements changes to the NCC that potentially impose an additional cost burden on the community, either at the business or consumer level, are subject to a transparent public consultation process underpinned by a formal Regulatory Impact Statement (RIS). The RIS makes the case for the proposed regulatory reform and justifies the planned measures, including their stringency by means of cost-benefit analysis (Australian Building Codes Board, 2001a).

A recent report by the IEA provides a useful template for considering the policy pathway for a review and potential overhaul of national building energy codes (International Energy Agency, 2013a). The IEA recommends that the process of improving energy within the buildings sector through the deployment of energy codes should include the four phases of quality management systems: plan, implement, monitor and evaluate.

Maintenance and on-going development of the NCC is the responsibility of the ABCB. In a recent document (Australian Building Codes Board, 2015) the Board outlines a series of planned reforms to the Code: making the NCC available free online; digitizing the NCC; moving to a three-year amendment cycle; and including quantified performance measures in the 2019 NCC amendment cycle.

5.4.1 NCC stringency: international context

In an exercise undertaken for the Australian Greenhouse Office (AGO) in 2005 the stringency of Australia's national residential energy standards was compared with those of leading jurisdictions in the northern hemisphere (Horne, 2005). In Appendix D international building energy standards were compared with the 5-Star regulatory requirements introduced nationally in Australia in NCC 2006. Appendix D, Table 2 uses the findings of the AGO review to illustrate the comparative stringency of US, Canadian and UK residential building code requirements expressed in terms of Australia's Nationwide House Energy Rating Scheme (NatHERS) rating scale.

It is evident from Table 2 that the stringency of Australia's energy code provisions lagged behind international best practice by almost 2 Stars on the NatHERS scale used in the NCC.

The stringency of Australia's residential energy efficiency provisions has only been reviewed once in the last decade, being raised from a 5-Star to a 6-Star level in NCC 2009. During the same period the UK building code began a planned transition to the 2016 zero carbon target for residential buildings; and the IECC building energy code widely adopted for residential buildings in the US was updated in 2006, 2009, and 2012 (Deason, 2011) (Appendix F).

Table 2: Comparison of NCC 5 Star energy efficiency provisions with international standards using the NatHERS scale, (Using public access software maintained by the Commonwealth Department of Science & Industry. The rating scale extends from 1–10 Stars.)

Australian location	Comparison location	Comparison location: energy rating requirement
Darwin, NT	Florida, USA	7 Stars
Brisbane, Queensland	Texas, USA	6 Stars
Perth, WA Sydney, NSW	Southern California, USA	7.5 Stars
Melbourne, Victoria	Northern California, USA	7.6 Stars
Hobart, Tasmania	United Kingdom: Canada	7.2 Stars
Average all climate zones		6.8 Stars

To date an equivalent exercise has not been undertaken to compare the stringency of Australian energy code provisions for commercial buildings against international standards. Nevertheless it is possible to make an observation about the potential opportunity for a stringency increase in NCC commercial building energy provisions using the criterion that stringency increases are viable to the point where the economic cost benefit ratio to society exceeds one. In the last review of these energy efficiency provisions (Australian Building Codes Board, 2009) this cost benefit ratio was assessed as 1.6:1 by the ABCB. This scenario suggests substantial scope for further reform along the same lines as the regular reviews of EU and US building energy codes during this last decade, which would deliver positive economic benefits to Australian society (Appendix F).

5.5 International best practice building energy codes

Founded in 2010, the GBPN is a broad-based international organization whose mission is to provide policy expertise and technical assistance to advance building energy performance (Global Buildings Performance Network, 2017). The GBPN supports development and refinement of building energy policies that aim to accelerate the uptake of net zero energy or positive energy buildings, as well as encouraging deep renovations to existing buildings. Examples of the work of the GBPN are available in numerous published reports consistent with its overall mission (Global Buildings Performance Network, 2014, Global Buildings Performance Network, 2013).

5.5.1 Technical Adequacy

The first stage in benchmarking a building energy code against international best practice is to focus on the technical sufficiency of the code in addressing pertinent building elements and performance attributes. To this end the work of Evans et al (M. Evans, 2009) in comparing building energy codes in the Asia Pacific Region is apposite. This study reveals that the development of a national building energy code in Australia in 2003 made this country a relatively late starter compared with other developed countries such as Japan (1979-80) and the USA (1975-77).

From a structural perspective the Australia national code is found to measure up well in comparison with building energy codes in Canada and the USA, since it is explicitly a performance-based code that allows cost-effective design trade-offs between individual building elements (Appendices A and F)

The NCC also benchmarks well against equivalent codes in Canada, Japan and the USA. This is because key building elements impacting on energy use are addressed through defined energy performance requirements: the building envelope; HVAC systems; service hot water; lighting; common services and renewable energy supply. The research of Evans et al (M. Evans, 2009) goes on to make a number of observations that are consistent with the earlier discussion in this paper and touch on the overarching question of the role of building codes as an instrument of government energy policy:
Building energy codes are a proven, cost-effective means of improving energy efficiency in new buildings (Appendices A and F).

A building's initial design is a strong determinant of lifetime energy consumption so design standards provide a strong leverage point. High building construction rates in regional countries such as China and India mean that the contribution of Asia-Pacific regional countries to global building space, energy consumption and GHG emissions, will be significant.

The US Building Energy Codes Program has delivered savings of $30-50 for every dollar spent on the program, saving over $1 billion in energy costs per year according to a review undertaken for the DoE by Livingston et al (Livingston, 2014). Regrettably no comparable review has been undertaken in Australia of the economic and environmental impacts of NCC energy efficiency provisions since their initial introduction in 2004 (Appendix F).

5.5.2 Structural Aspects of best practice building codes

In its 2013 report the GBPN (Global Buildings Performance Network, 2013) drew upon a large body of international energy policy experts and building officials to prepare a document designed to facilitate the development of ambitious building codes. With this objective in mind the report incorporates multi-criteria comparisons of international building codes and policies for new buildings. Fifteen criteria, grouped into five key themes, are identified as defining regulatory best practice. The GBPN benchmarking methodology is exceptional in providing a comprehensive, objective and systematic framework for benchmarking national building energy codes from an inherently structural perspective.

GBPN code assessment criteria are set out below in Table 3.

Table 3 GBPN Regulatory Best Practice Criteria

Assessment Criterion	Detailed elements for achieving best practice
Holistic	Performance based covers all energy uses includes renewables
Dynamic process	Zero energy target regular revision process encouragement beyond minimum levels
Implementation	Effective enforcement practitioner certification policy linkages
Technical elements	Building envelope building services renewable energy supply
Overall performance	Operational assessment primary energy use defined GHG emissions aggregated

Conceptually this framework offers a high level assessment of building energy code effectiveness in that it focuses on the policy settings, governance regime and operational structures within which the code operates, rather than on low level features such as the technical adequacy of code provisions.

5.5.3 Outcomes of the NCC benchmarking exercise

Mapping the NCC energy efficiency provisions (Australian Building Codes Board., 2011) and structure against GBPN criteria yields qualitative results that can potentially be extrapolated to other jurisdictions beyond the leading regulatory regimes in the EU and US (McDonald, 2013). Table 4 (drawn from Appendix B) sets out the results of benchmarking Australia's NCC against the GBPN *de facto* standard.

Table 4 Benchmarking the NCC against comprehensive GBPN criteria

Rating criterion	**Assessment of Australia's NCC**
Performance based approach	Code is explicitly performance based as a core element of its underlying rationale
Inclusion of all energy uses	Significant energy usages not included in performance assessments: viz. appliances, residential HVAC plant
Renewable energy sources included	NCC energy performance provisions do not include alternative or renewable energy supply options in core energy provisions
Zero energy target	No such visionary target has been articulated to date in building policy
Regular revision cycles	No revision cycles for almost a decade; timing of future revisions is uncertain
Performance beyond minimum levels	Code sets minimum compliance standards; exceptional performance outcomes are inherent in limited areas such as the national house energy rating scale
Effective enforcement	Recent analysis has highlighted systemic enforcement problems for which State building administrations are responsible
Performance certification	Certification at design stage is included in the residential provisions but post construction assessment is not required
Policy complementarity	Limited integration of regulatory policy with national energy policy initiatives, but not with climate policy
Building envelope addressed	NCC technical provisions deal comprehensively with the building envelope characteristics
Technical systems	Building services are dealt with but commissioning and operation are not addressed
Renewable energy systems	Limited recognition of renewable energy systems performance contribution
On-site energy	Service performance currently out of NCC scope
Aggregate building performance	Not currently assessed in the Australian building energy code

The aim of this benchmarking exercise has been to use the Australian situation as the exemplar of a process for identifying improvement opportunities in the way that building standards and related policies are developed and progressively upgraded over time.

Specific initiatives designed to address gaps between current regulatory practice in Australia and international best practice should include the following measures (Appendix A).

- Lock in periodic reviews of code energy provisions to address a development hiatus
- Articulate a visionary objective for the NCC in the same vein as the UK's zero carbon building objective and the near ZEH target of the EU (European Union, 2016)
- Consider the question of operational performance validation for new buildings as an element of the code along the lines of UK and US building policies
- Australia benefits from a technically sound and nationally consistent building energy code whose on-going development has unfortunately languished for almost a decade. Looking to best practice examples in Europe and the US provides an indication of the pathway which can make up for lost ground in confronting the twin challenges of climate change and energy productivity in the economically vital building sector. Government leadership in building energy policy is essential if the cities in which 80% of Australians live are to take on the challenge of a low carbon transition.

5.6 Energy efficiency regulation and housing affordability: challenging a fallacious premise

This is a topic that was addressed at length in a paper (Enker, 2015c) presented to the Architectural Science Association (ASA) Conference, Melbourne in December 2015 (Appendix D).

In an analysis of Victoria's 5 Star Energy Efficiency Standard for residential buildings the ASA paper found that it was in fact an effective regulation, according to criteria articulated therein. The government's dual policy objectives of firstly, improved residential energy efficiency and secondly, GHG abatement were achieved without evident detriment to housing affordability or residential housing market supply.

Further, analysis of Victoria's 5 Star Standard demonstrated that it was an unambiguously effective regulatory instrument (Victorian Building Commission, 2002b). This regulatory measure achieved government policy objectives for energy efficiency and GHG abatement without significant detriment to local housing affordability. Its introduction actually paved the way for subsequent reform of NCC energy provisions (Australian Building Codes Board, 2006).

Using the Victorian 5 Star Standard (Enker, 2015b) as a case study of residential energy regulation more broadly allowed a number of conclusions with important implications for the role and effectiveness of building regulation as an instrument of government energy policy to be reached:

- Research over the last decade suggests that government policy objectives for GHG abatement that led to regulatory intervention in 2002 by the State of Victoria were proven to have been met
- Formal regulatory impact assessment reports have tended to underestimate both the capacity for industry adaptation to new energy requirements and the rapidity of such adaptation (transition processes in action: Appendix D)
- Claims by the housing industry that mandatory energy efficiency requirements for new home construction would have a deleterious impact on

housing affordability are shown to have been ill-founded on the basis of the historical cost trajectory of energy efficiency costs

- Assertions of larger scale negative impacts on the local housing market were found to be lacking in substance,

5.7 Behavioural insights into current failures of building energy policy deployment

It is postulated in the Appendix C paper (Enker and Morrison, 2019) that effective implementation of building energy policy inevitably, fundamentally, depends on achieving behavioural change in salient stakeholder groups. This outcome requires persuasive engagement with property developers, contractors, lessees, builders, or individual consumers depending on the market sector targeted by the strategy in question. In the pivotal residential sector builders, consumers and building services providers are seen as the targeted stakeholders.

By working from a grounding in BE theory the study reported in Appendix C explains why decisions made by key actors in the property market actually differ markedly from the assumptions of a conventional, essentially economic perspective. Furthermore, a high degree of congruence between key elements of BE theory and the behavioural triggers that building energy policy seeks to influence is also established in this paper (Enker and Morrison, 2019).

In a series of case studies supported by evidence obtained through the literature review process the article critically examines operation of each chief category of building energy policy intervention. Its findings are both concerning and potentially iconoclastic, in that each area of policy intervention is shown to suffer from significant delivery flaws. It is postulated that these shortcomings can to some degree be attributed to the failure of policy makers to appreciate both the extent of behavioural change sought from targeted stakeholders, and also the need for potent, proven intervention instruments to actually bring about such behavioural change.

Examining these policy failures through the illuminating lens provided by BE can provide a range of useful insights:

- The reasons why compliance with energy efficiency requirements mandated in building regulations is significantly, perhaps fatally, compromised due to general indifference by both building project developers and consumers .
- The reasons why price-based interventions in the property market (such as through an ETS) will not actually trigger the anticipated rational response from consumers.
- The reasons why public information campaigns such as the EU EPC initiative fail to achieve a significant market impact or a price premium for superior certified performance because of weak and irrational consumer responses.

The BE rationale suggests that applying inferences to be drawn from an appreciation of the cognitive heuristics in play among these stakeholders could contribute to a marked improvement in the prospects for successful policy intervention, thereby delivering enduring behaviour change. But conversely, failure to heed the lessons of BE is likely to further jeopardize prospects for successful deployment of building policy initiatives.

BE has the potential to inform all stages of public policy development although its application by governments thus far is quite variable (Afif and Dalton, 2019). Many governments around the world have established Behavioural Insights Teams (BITs) whose role is to explore the use of BE in public policy. These teams' activities have tended to focus on policy areas such as consumer protection, finance, labour market reform, energy education and health services (OECD, 2017).

While there is a strong case for a focus on building energy efficiency in the context of global climate response (Stern, 2006) (McKinsey Company, 2009), this area of public policy has yet to be actively embraced by the proponents of BE or to be included in the work programs of BITs. As discussed earlier, application of BE to the domain of building energy policy has thus far been limited to issues of consumer appliance selection and energy conservation during residential building operation; rather than addressing the more fundamental question of building design and construction quality. Poor building design and construction inevitably places limitations on the potential for subsequent energy conservation during building operation.

6 Conclusions

This section of the Exegesis opens with a discussion of the research questions being addressed by the thesis.

6.1 What is the role of Regulation as a policy instrument for transitioning to a Low Carbon Built Environment and its efficacy?

Firstly, this research found that reform of the building sector must be a key component of global climate change policy for such policy to be truly effective (Appendix A).

Secondly, that building energy codes are a highly potent instrument of climate/energy policy with the capacity to trigger disruptive socio-technical transformation of the building sector (Appendix B).

Thirdly, that implementation of mandatory building energy standards potentially offers a wide range of environmental, economic, social and strategic benefits. With the caveat that effective implementation is contingent on establishing governance regimes that deal robustly with enforcement and compliance features (Appendix A).

Fourthly, it was established that financial instruments such as carbon taxes or ETS actually have limited impact on building sector GHG emissions (Appendices A & E).

A fifth finding is that public information and education campaigns also suffer from potential shortcomings that demand quite considered and potentially challenging policy design to ensure effective deployment (Appendix C).

Finally, that the discipline of Behavioural Economics has untapped potential for contributing to improved building policy implementation, particularly in the area of consumer and stakeholder engagement (Appendix C)

The following sections of the Exegesis explain how the four secondary research questions have been addressed by the thesis.

6.2 Does regulatory intervention to improve building energy efficiency necessarily have a negative impact on housing affordability?

This topic was the subject of a paper presented to the ASA Conference in Melbourne in December 2015 (Enker, 2015b). A copy of the paper is attached as Appendix D. This research question was addressed by using Victoria's Five Star Residential Energy Efficiency Standard as a case study.

The analysis found that the Standard was an effective regulation in that it achieved the State Government's dual policy objectives of enhanced sectoral energy efficiency in tandem with GHG abatement.

A number of additional conclusions concerning the role and effectiveness of building regulation as a government policy instrument were reached. Firstly, that formal regulatory impact assessment reports tended to underestimate both the capacity for industry adaptation to new energy requirements and the rapidity of such adaptation. Secondly, that claims by the housing industry that mandatory energy efficiency requirements for new home construction would have a deleterious impact on housing affordability were shown to be ill-founded on the basis of a historical construction cost trajectory. And finally, that no evidence was found to support industry claims of large scale negative impacts on the local housing market as a result of regulatory intervention.

6.3 How do Australian building energy standards measure up when benchmarked against World's Best Practice?

As discussed above in Section 5.5 the GPBN framework provides a first-rate functional template for benchmarking the NCC against global best practice standards. In this case the analysis found that Australia has been relatively slow to embrace the triple bottom line benefits of building energy codes in comparison with international leaders. However the fact that the Australian federation boasts a uniform national building energy code with quite close coordination in implementation processes between State and Territory administrations is an advantage compared with the EU and the United States of America.

Although energy efficiency provisions in the NCC compare quite well with best practice in a technical sense, guiding policy settings and code development processes underpinning the NCC are deficient in key areas (Appendix B).

A number of specific initiatives designed to address gaps between current regulatory practice in Australia and international best practice are proposed herein. Locking in periodic reviews of energy efficiency provisions in step with the triennial NCC amendment cycle is seen to be important. So are regular code reviews that include comprehensive performance monitoring and reporting of outcomes achieved along US lines. Using the US DoE approach as a basis for enhancing the level of resources provided by the Commonwealth in support of market transformation and industry cultural change is proposed.

There is a need to articulate a medium-long term visionary objective for the NCC in the same vein as the UK's zero carbon building objective and the EU's near ZEH target. Extending mandatory disclosure and EPC to other key building classes in addition to the office buildings currently addressed by the national Commercial Building Disclosure program should be considered. A concerted national approach should be instituted in order to address major flaws identified in the NCC compliance enforcement regime (Appendix F).

Consideration should be given to including operational performance validation for new buildings as an element of the Code along the lines of UK and US energy codes.

6.4 How does consumer choice operate in the property market when examined from the standpoint of Behavioural Economics?

Analysis presented in Appendix C demonstrated how BE theory and functional processes have a significant contribution to make in relation to implementation mechanisms for climate change response and building energy policy. The conclusions of this analysis were that:

- Strong complementarity exists between the key tenets of the BE discipline and the mechanics of building energy policy.
- Understanding the impact of cognitive heuristics on industry stakeholders' behaviour offers potentially significant insights into the design of market intervention policies.
- Policy implementation vehicles such as building energy codes, carbon pricing and consumer information campaigns suffer from significant delivery failures

whose underlying causes can be better diagnosed and corrected through the application of BE theory.

- The economic and environmental argument for market intervention using instruments such as building energy codes rests on assumptions of operational effectiveness, requiring high levels of regulatory compliance; without compliance such projected benefits are illusory.
- Behavioural insights not only hold out a promise of improved effectiveness for building policy delivery but also the threat of compromised program outcomes should the BE lessons fail to be learned.

Governments internationally are calling upon BE theory to improve the effectiveness of policy delivery in diverse areas such as consumer protection, education, public service delivery and labour market reform; these nascent initiatives are typically managed by specialized BITs. Application of BE theory to building energy policy has been focused largely on the mechanics of consumer engagement with energy markets; but the arguably more significant issue of building project delivery, from conception through design and construction to operation, has yet to be rigorously examined from a BE perspective – despite all the fresh insights that such an approach might provide. Clearly the next step for governments is to broaden the remit of their BITs in order to address building energy policy from a rigorous but open-minded BE perspective (Appendix C).

Four distinct research opportunities were identified in the Appendix C article to exploit the potential contribution of BE theory to building policy development.

The first of these is to better understand the drivers and influencers of consumer choice and rationality; which is to say the role and true potency of building performance disclosure.

Secondly, BE theory should be utilized to accelerate building industry learning processes that will entrench effective change management.

A third area for research is identification of international best practice approaches to building regulation in the context of demonstrably unfavourable behavioural responses by industry stakeholders.

Fourthly, understanding industry culture and operation of peak industry bodies and lobby groups as these relate to the effectiveness of policy implementation.

6.5 How effective are economic instruments compared with other potential government interventions such as mandatory building standards in maximizing the prospects for successful policy implementation?

Findings in relation to this question were dealt with in Section 5 of the Exegesis. Key findings on this topic were that market-based instruments may be ineffective without support from additional policy interventions measures (Appendix E). In addition, the market for energy efficient buildings and building services is bedeviled by diverse failure modes when viewed from an orthodox economic perspective (Appendix C). Restoring efficient market operation requires corrective intervention by government agencies responsible for building policy. Building energy policy instruments should be selected on the basis that they are not overly reliant on market operation for successful deployment.

7 Re-imagining the building/energy policy paradigm

It is appropriate to reflect on the implications of the findings of this dissertation, by posing the question: how to proceed from this point when further considering synergies between BE and Building Energy Policy? Or to put it another way, what might be the direction of further research as a consequence of this analysis and how might one tease out such considerations?

The following discussion sets out some of the author's preliminary thinking on these questions.

7.1 The pollution control and waste management hierarchy

Figure 6 sets out widely accepted principles applying to the control of point source pollution and management of industrial wastes that make an important contribution to the development of environmental policy at a generalized societal level (Victoria., 2018). This schematic developed by Victoria's Environment Protection Authority is a more sophisticated version of the hierarchy generally known as the 3 Rs of Sustainable Development (FIA). This construct is quite consistent with the Circular Economy model (Andersen, 2007) that was first articulated by Pearce in the early 1990s (Turner et al., 1994).

It is postulated that exploring the potential for translating and applying this hierarchy to the prioritization of policy options for reducing GHG emissions from the building sector may be a worthwhile endeavor. Doing this provides a credible basis for ranking the emission reduction options delivered through energy management reforms. To this end, one needs to imagine an analogous one-to-one relationship between the prioritization of waste management options with the aim of advancing sustainability in the industrial sector and the task of prioritizing energy management intervention options in the building.

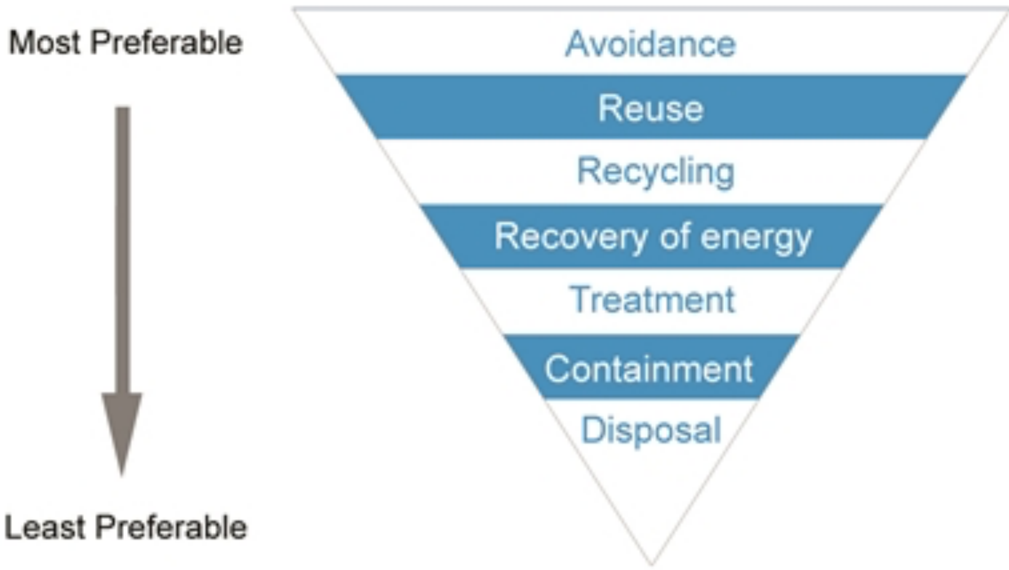

Figure 6 Waste and pollution management hierarchy

7.2 Implications for building energy policy

This notional correspondence between hierarchically ranked waste management/pollution control options and building energy management options can be articulated as follows (Table 5).

Table 5 Correspondence between hierarchical priorities for sustainable waste (or pollution) management and energy management

Priority ranking	Waste management imperative	Energy management imperative
1	Waste avoidance	Reduced energy consumption
2	Reuse, recycling, recovery of energy	Energy recovery *in situ*
3	Waste treatment	Modification of energy supply source (lower carbon intensity)
4	Waste containment	On-site renewable energy supply
5	Waste disposal	Market based carbon pollution offsets

Embracing this conceptual hierarchy moves the analysis forward to allow an important observation: that the energy policy intervention points in the building project development cycle which provide the most potent opportunities for reshaping building project outcomes - through the utilization of novel BE techniques such as nudging - will occur at the design (front end) stage of construction projects. Furthermore this model intervention hierarchy is also useful for answering questions related to the prioritization of GHG mitigation options on a trajectory that is directed towards achieving zero carbon building outcomes (Li et al., 2013).

For example, an opening question might be whether improving building fabric performance should be prioritized over the alternative of supplying power from alternative, low emission source can now be answered in the affirmative. Furthermore the question of whether operational (behavioural) factors impacting on building energy efficiency outcomes should be prioritized over building envelope performance considerations would now be answered in the negative (Sunikka-Blank and Galvin, 2012, Liu and Lin, 2016).

A third question is whether capital investment would be better directed to improving building fabric energy performance or alternatively to improving the performance of building plant and services? On this question the hierarchical model is effectively neutral since both options deliver front-end reductions in energy consumption - equivalent to waste avoidance in Table 4.

To better answer this question one needs to consider the relatively long life expectancy of the building envelope, in the order of many decades, and the difficulty of implementing significant upgrades during this period. Whereas building plant items such as water heaters last for a decade or so, at which time replacement with technologically superior systems is readily achievable.

A number of proposals for the practical application of BE principles to the residential property market can be extrapolated from the analysis presented in Appendix C by focusing specifically on pivotal project lifecycle stages (Figure 7).

One proposal could be mandating disclosure of House Energy Ratings for new homes to potential purchasers. It is noteworthy that while NCC energy efficiency provisions currently mandate a 6 Star minimum energy rating, there is no regulatory compulsion to actually disclose a building's design rating to home-buyers (Australian Building Codes Board, 2017). Which is to say, whether this is at or exceeds regulatory minimum standards.

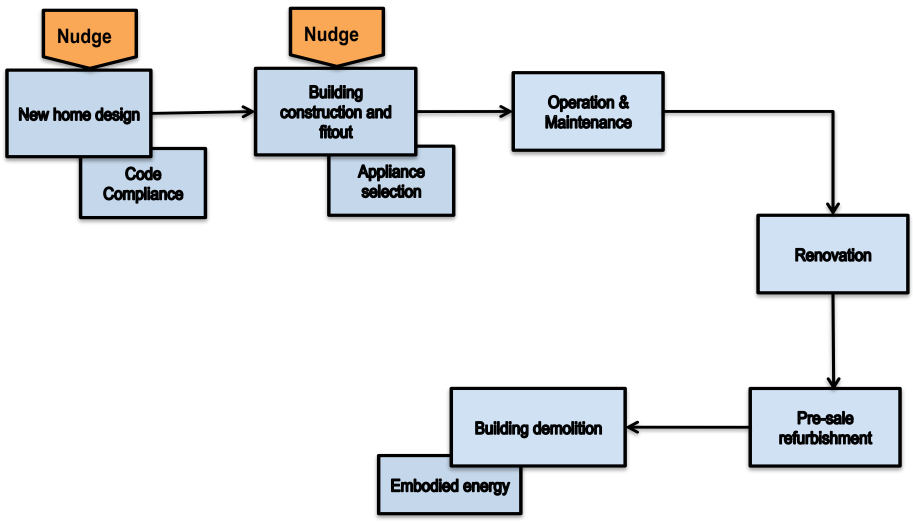

Figure 7 Headline decision points in the residential property development cycle for energy policy intervention

Another suggestion is using BE nudge techniques to better engage building industry professionals to commit to delivering high performing buildings that exceed code minimum requirements and are directed towards low carbon dwelling design by utilizing behavioural heuristics such as social norms (Thaler, 2009) (Samson., 2018).

A further initiative could be to more effectively engage with project managers to obtain higher levels of commitment to regulatory compliance through the exploitation of BE heuristics such as risk aversion, social norms and herd behaviour (Samson., 2018).

Providing consumers with exemplar blueprints of good design to simplify decision-making as is done with default superannuation options (Department of Climate Change & Energy Efficiency, 2014) is another possible policy innovation; sitting alongside with giving consumers access to benchmarking information on the relative performance and design of typical Australian project homes compared with best practice in the Northern Hemisphere (at appropriate nudge point: Figure 7). The discussion in Appendix F is also pertinent here.

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Appendix A

Energy Efficiency Journal article - **Enker, R.A**., Morrison, G.M, The potential contribution of building codes to climate change response policies for the built environment (Enker, R.A., Morrison, G.M. The potential contribution of building codes to climate change response policies for the built environment. *Energy Efficiency* (2020). https://doi.org/10.1007/s12053-020-09871-7). Publication 1.

Appendix B

Energy and Buildings Journal article - **Enker, R.A.**, Morrison, G.M, Analysis of the transition effects of building codes and regulations on the emergence of a low carbon residential building sector; Energy and Buildings, V156, December 2017, pp 40-50. Publication 2.

Appendix C

Buildings Journal article - **Enker, R.A.**, Morrison, G.M, Behavioural facilitation of a transition to energy efficient and low carbon residential buildings; Buildings 2019, 9, 226. Publication 3.

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Article

Behavioral Facilitation of a Transition to Energy Efficient and Low-Carbon Residential Buildings

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Abstract: Reducing carbon emissions from the building sector is an international policy priority, as a consequence of the Paris Climate Accord obligations. The challenge for policy makers is to identify and deploy effective policy instruments targeting this sector. Examining the mechanics of policy operation in the residential sector is particularly instructive, because of the high level of building activity, diverse stakeholders, and complex policy considerations—involving both consumers and industry stakeholders. Energy policy initiatives undertaken by the European Union provide pertinent case studies; as does the operation of Australia's national building code. The paper builds upon earlier research examining the application of socio-economic transition theory to the regulation of the building sector. Here, building policy options are examined from a behavioral economics perspective, where stakeholder actions in response to strategic initiatives are considered in socio-psychological terms. The application of behavioral economics principles to building policy has the potential to impact all of the stages of the building lifecycle, from design through construction to operation. The analysis reveals how decision-making by building industry stakeholders diverges substantially from the assumptions of conventional economics. Significant implications then arise for the framing of building sector climate and energy policies, because behavioral economics has the potential to both contribute to the critical re-appraisal of current policies, and also to provide innovative options for refining interventions at key stages in the building lifecycle.

Keywords: buildings; behavioral economics; climate change; greenhouse abatement; policy instruments; regulation

1. Introduction

Following the ratification of the Paris Climate Accord in December 2015 [1] governments worldwide have been deliberating on the most effective means of delivering individual commitments to mitigate national greenhouse gas (GHG) emissions. A significant body of research suggests that the building/property sector provides an unequalled opportunity for GHG abatement [2–5] compared with other economic sectors.

The contribution of the IPCC (Intergovernmental Panel on Climate Change) Working Group Three to the IPCC Fifth Assessment Report provides a comprehensive overview of both the contribution of buildings to global GHG emissions, and the benefits and costs of mitigation for this sector [6]. Thus, the challenge facing governments is to devise the most effective, economically efficient policy instruments for intervention in the property sector, in order to exploit its GHG abatement potential.

When considering the formulation of policies designed to improve buildings' energy efficiency to reduce lifecycle GHG emissions, a typical approach is to view buildings as technical systems whose design is to be optimized in engineering and architectural terms [3]. This perspective point is given full expression in the application of socio-technical transition theory [7] to the building production process. An appreciation of transition theory can also be utilized in order to better understand the effectiveness (or otherwise) of building energy efficiency regulations [8].

By way of contrast, this paper approaches the question of building energy policy instruments through the perspective offered by behavioral economics (BE) theory in order to provide a fresh perspective to assist policy makers, thus complementing the earlier analysis of transition theory. BE has been defined as a method of economic analysis that applies psychology into human decision-making in the economic domain [9]. Note that in this paper, no distinction is drawn between BE and its sister discipline behavioral science [10].

BE seeks to re-assess conventional economic assumptions about individual perceptions and notions of value, and personal preferences. Thus, BE challenges the conventional concept of homo economicus, in which humans are seen as consistently rational agents who are driven by narrow self-interest [11]. Through psychological experimentation, BE has generated theories about human decision making and identified a range of biases in the way people think and feel [9]. Rather than making choices after careful deliberation, consumers often make intuitive judgements based on information that may be either readily accessible to memory, or prominent in the contemporary milieu, as explained by Kahneman [12]. In a practical sense, the modern school of BE owes its underpinnings to the work of Kahneman and Tversky [13]. Thaler has also played a key role in formulating BE theory and its practical application to public policy [11].

Synergies between BE theory and the domain of public policy have already been explored to some extent in the literature (for example in [14–16]). This analytical trajectory also extends the exploration of potential contributions from BE theory to the development of environmental policy [17], and more specifically to climate/energy policy [18,19].

In regard to the application of BE principles to building energy performance and its supportive policy settings, the focus of academic reviews has tended to be on the facilitation of domestic energy conservation in a broad sense [20–22], rather than specifically on the intersection of stakeholder behavior with building design and operation per se. The objective of this paper is to address this gap in the academic literature by focusing on the application of BE to policy interventions that deal with building sector stakeholder behavior relating to decisions on building design, construction, and operation.

It is worth pointing out (even if notionally self-evident) the following:

- Building (energy) policy initiatives ultimately depend on their fulfillment and effective deployment on behavior change by property sector stakeholders;
- BE theory offers a rich body of evidence-based analysis that could be employed to enhance delivery mechanisms for these policy initiatives.

2. Study Methodology

The methodology for the research draws upon two complementary theoretical frameworks to examine the policy role of building energy regulations. These twin theoretical frameworks are socio-technical transition theory and behavioral economics. This paper is directed to examining potential synergies between behavioral economics and building energy policy. The methodology employed in the research project parallels the approach taken by Elbaz and Zait [23] in their investigation into the use of behavioral tools to mitigate domestic consumers' electricity consumption. This approach is based on combining a systematic literature review with detailed reference to secondary sources, then undertaking the consequent analysis and synthesis.

The paper opens by articulating the directly congruent relationship between global climate policy and building sector greenhouse gas (GHG) mitigation measures on the basis of information provided by a systematic literature review of the field. The next stage of the analysis is to review policy options—that is, alternative instruments—for the deployment of building energy policy that has developed as a consequence.

Next, the conceptual base and relevance of BE is discussed through of a review of the pertinent literature, in order to demonstrate how BE can be relevant to building policy formulation and implementation. This examination also indicates where gaps currently exist in the relevant research literature.

Case studies of building policy implementation are examined below (Section 5), as a vehicle for developing the analysis. This section of the paper also includes a critique of the current regulatory, economic, and informational approaches to building energy policy.

The paper concludes with a discussion on the analytical findings, leading to proposals for applying BE principles to building energy policy.

The paper aims to map out a fresh policy landscape arising out of an application of BE theory to the building sector. Recommendations are made for further studies to progress this evolving area of academic inquiry, together with proposals for the application of lessons from BE theory specifically to the residential property market.

3. Linking Climate Policy with Building Energy Policy

The concept of a policy trajectory that runs directly from global responses to climate change (enshrined in the 2015 Paris Climate Accord) [1] through measures to prioritize sectoral energy efficiency in national economies is particularly helpful in taking this analysis forward. This conceptual trajectory can then be extended to measures that specifically target the building sector for government intervention. By adopting this perspective, the role of building energy policy in meeting global climate change objectives is brought to the fore and is highlighted.

Moreover, this strategic hierarchy clearly indicates that a deliberate policy focus on building energy efficiency and low-carbon buildings is vital if national climate change policies are to be effective. A pertinent report by the International Energy Agency [24] confirms that judiciously implemented building energy codes have a key role to play in the deployment of national building energy policies. By drawing on the principles of socio-technical transition theory, it can also be shown that building codes have a substantial transformative impact on the customary behaviors and practices at play in the building industry [8].

A variety of analyses have been concerned with the various policy instruments available to governments seeking to mitigate GHG emissions from the building sector. A study conducted for the United Nations Environment Program (UNEP) by the Central European University provides a concise overview of such policy options [25]. Other studies have also sought to address energy efficiency options from a broader perspective, which addresses an aggregate policy mix rather than individual policy instruments [26].

For the purposes of this paper, the classification and categorization of policy instruments has been developed from a structure proposed by Rosenow [26], which is in turn based on article seven of the EU Energy Efficiency Directive [27].

A high-level review of the literature suggests that these policy instruments may be grouped into the following three broad categories for practical purposes, so as to facilitate further strategic analysis [26,28,29]:

1. Economic and financial interventions;
2. Regulatory approaches, including codes and standards;
3. Information provision, consumer engagement, and industry capacity building.

Therefore, the comprehensive EU classification has been divided into three principal categories suggested by the literature (Table 1). This classification is also broadly consistent with a structure proposed by the International Energy Agency (IEA) [29].

In an analysis directed at understanding policy principles related to the greening of household behavior generally, rather than simply driving energy efficiency, the Organization for Economic

Cooperation and Development (OECD) takes a similar approach to the categorization of policy instruments [30], identifying these as the following:

- Taxes, charges, and subsidies
- Direct regulation
- Information provision
- Provision of infrastructure (by governments).

Table 1. Categorization of building energy policy instruments.

EU Classification [29]	Analytical Classification
Carbon taxes	Economic/financial
Finance schemes and fiscal incentives (grants and loans)	Economic/financial
Tax rebates	Economic/financial
Regulations or voluntary agreements	Regulatory
Energy labeling schemes	Informational
Standards and norms	Regulatory
Training and education programs	Informational

By way of comparison, United States policy-makers at both national and state government levels have deployed a whole range of policy measures defined by this classification system [31].

4. Foundations of Behavioral Economics

4.1. Understanding Human Behaviour

BE seeks to challenge the way that classical economics deals with people's perceptions of value, choices, and preferences. BE suggests that the conventional model of homo economicus [11] is open to being challenged, in that people are not necessarily self-interested, benefit maximizing and cost minimizing individuals with stable preferences. In Kahneman's terms [13], a similar distinction is drawn between the rational econs who operate in the realm of classical economic theory, and the ostensibly irrational humans who inhabit the domain of BE.

Personal choices are often not made after careful deliberation [13], but can be rather impetuous, subject to the decision-making context, and supported by information that readily comes to mind. Kahneman makes the distinction between the intuitive, rapid, relatively effortless System 1 decision-making processes, and measured, deliberate System 2 thinking processes.

It is in the expedient System 1 area that the employment of heuristics by property market participants plays such an important role. A heuristic is defined as a mental shortcut or unconscious mental rule of thumb used by individuals to simplify decisions by substituting an easier question for a more difficult one [9,32]. Studies in the BE field suggest that people are actually conservative, resistant to change, risk averse, subject to distorted memory, and not particularly skilled in allocating economic cost and benefits to future events [11]. So, as consumers of goods and services in the free market, BE theory proposes that we are in effect predictably irrational [33]. This observation mirrors the conclusion reached by Blasch et al in a study on consumer responses to the display of appliance energy efficiency [34]—individuals with a higher level of investment literacy are more likely to undertake an exercise in economic optimization, rather than relying on a decision-making heuristic; such individuals are also more likely to identify and purchase cost-efficient appliances in the first instance.

The concepts derived from BE theory have significant implications for the development and implementation of government policy in areas as diverse as public finance, health management, and consumer protection. In fact, the potential policy repercussions of BE have given rise to an increasingly multidisciplinary approach to this discipline; that is, taking it beyond a narrow economic perspective [10], as also evidenced by the rise of the parallel discipline of behavioral science [10].

To date, BE has been applied to various areas of government policy, such as consumer protection, finance, labor market reform, energy policy education, and health services [35]. Recent evidence suggests that the previously limited application of BE principles to the built environment may now be changing [36]. Governments seeking to capitalize on the contribution that BE principles can make to enhanced policy delivery typically approach this task through the establishment of dedicated behavioral insight teams (BITs).

Major studies done recently by the World Bank [15] and the OECD [35] have catalogued these initiatives on a global scale. These studies have found that specialized public sector organizational units have been set up as arms of the central government in countries such as the United Kingdom, the United States, Australia, Canada, Denmark, France, Germany, Singapore, Peru, and the Netherlands in order test the application of BE principles to government policy development processes. Significantly, the World Bank and OECD reviews also found that projects being undertaken by BITs tended to be further experimental and investigatory in character; which reflects the relative immaturity of BE utilization as a policy instrument in global terms.

In the particular domain of energy policy that is the focus of this paper, the application of BE theory has been limited to areas such as the provision of consumption data to consumers, promoting the uptake of renewable energy, improving the transparency of energy contracts, and the roll-out of smart metering systems [35].

4.2. BE Principles: The Crucial Central Role of Heuristics

A recurrent and central theme of BE theory has been the development of a deeper understanding of the impacts of heuristics on consumer behavior [13]. According to BE theory, heuristics are mental shortcuts used to cope with difficult, rationally taxing questions by substituting simpler and more intuitive answers [10]. The overwhelming array of decisions facing a consumer buying a new home [37] provides a prime example of when heuristics typically come into play.

The approach taken in this paper to investigating the application of BE principles, to the modification of the behavior of stakeholders in the building sector is illustrated in Figure 1. Selected heuristics are used as a surrogate for BE theory in operation, then the impact of these heuristics is mapped against projected behaviors of building sector stakeholders during the course of market operation. The results of this mapping exercise are set out in Table 2.

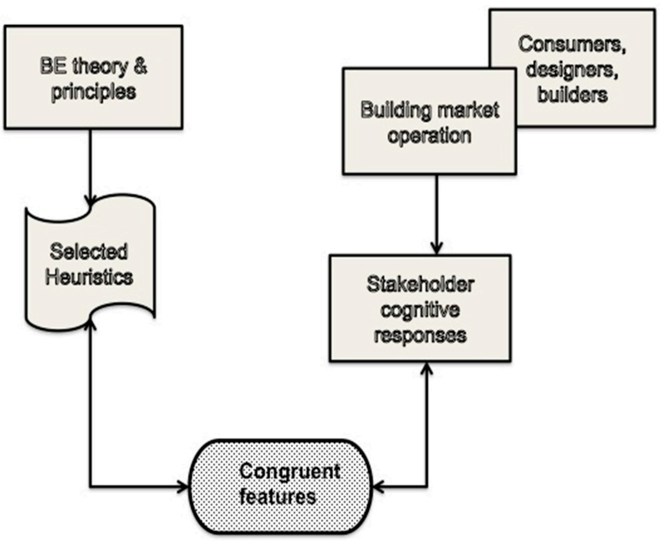

Figure 1. Approach to examining the impacts of behavioral heuristics on the cognitive processes employed by the building sector stakeholders, and the potential congruence between these features.

Table 2 sets out a selection of heuristics distilled from the much wider group that have been developed within the BE discipline. This subset has been chosen because of its relevance to the operation of the market for building products and services; it is deliberately intended to provide the reader with an initial grasp of the relevance of cognitive heuristics to consumer behavior and decision-making in relation to the goods and services available in the property market.

Table 2. Heuristics developed under BE theory: applicability to property market operation.

Heuristic	Description	Property Market Example
Anchoring	Initial exposure to a value serves as a reference point for subsequent decisions and choices	Setting pricing points for new consumer goods and capital investments, such as new homes
Availability	People make judgments about the likelihood of an event based on how easily an example comes to mind	Consumers rely on anecdotal advice from friends, family, and other non-expert sources for investment decisions
Bounded rationality	Bounded rationality challenges attributes of homo economicus; limited thinking capacity creates bounds [11]	Self-limited decision making by residential building purchasers (see also choice overload)
Choice overload	This phenomenon is a consequence of the excessive choices available to consumers	Excessive decisions facing home buyers for building features, appliances, and fit-out [38]
Cognitive bias	Systematic thinking errors and deviation from desirable and accepted norms	Also termed keeping up with the neighbors for major consumer purchases
Confirmation bias	People seek out or evaluate information in a way that fits with prior beliefs	Industry stakeholders are change averse, preferring traditional choices (also known as herd behavior)
Framing effect	Choices expressed to highlight positive (or negative) aspects of a decision, leading to changes in relative attractiveness	The marketing of consumer goods is carefully managed so as to promote positive features and gloss over negatives
Herd behaviour	People emulate others' decisions and do not make independent decisions; the collective irrationality of financial investors creates stock market bubbles	Conformity in product design and selection becomes a fashion statement, rather than objective decision-making
Present bias	People give stronger weight to payoffs closer to the present time; distant rewards have a relatively low perceived value	Investment in energy efficiency is simplistically based on upfront rather than lifecycle costs
Social norm	Signal appropriate behavior according to social group norms or expectations; social norms may differ from market exchange norms	Keeping up with the neighbors is an expression of such behavior; links to herd behavior and cognitive bias
Status quo bias	Preference for stasis through inaction or adherence to prior decisions; occurs for low transition costs but high-decision importance	Owners can be reluctant to upgrade poorly performing assets despite compelling economic evidence

It is evident from Table 2 that numerous "fast thinking" [12] cognitive heuristics are utilized by individuals confronted with important and complex decisions, such as those facing homebuyers or renovators. The pervasive influence of these heuristics lends weight to analyses suggesting that consumer behavior diverges significantly from the "rational actor" model favored by orthodox economics in relation to market operation in the property sector, for example [11,39].

5. Options for Market Intervention by Policy Makers

While in theory, governments have a range of policy instruments at their disposal (Table 1) for mitigating GHG emissions from residential buildings, all of these interventions ultimately have one critical feature in common, namely: they are all directed towards triggering behavior change by building sector participants. Thus, the effectiveness of these market interventions must be measured by the degree of behavior change achieved. Later case studies in the paper (Sections 5.1–5.3) explore this question in detail.

A review of the literature suggests that a number of studies have been undertaken to identify and ideally optimize the mix of market interventions deployed by policy makers. For example, Rosenow [26] reiterates the observation that energy efficiency measures are expected to play a key role for meeting European Union targets to reduce energy use and GHG emissions. Rosenow [26] developed a framework for assessing combinations of building energy policy interventions that, it is suggested, will be more effective than the single policy measures that are typically subjected to scrutiny.

Lorch [40] observes that the success of policy interventions to reduce GHG emissions from building stock have been met with limited success for a number of reasons, including—of particular relevance to this analysis—failure to address the social aspects of building design and operation, with an over-emphasis on technical solutions. It is in this area of the social dimensions of building policy that BE theory has a potentially powerful role to play.

In a report specifically addressing the Australian building policy setting, Harrington [41] suggests that the key elements of an optimal carbon and energy policy framework for the built environment should include, inter alia, the following: national emissions targets, effective carbon pricing, strong emphasis on compliance with energy performance regulations, encouraging over-compliance with the minimum building code requirements, and encouraging an enhanced carbon performance for existing building stock. It is in these latter three areas in particular that BE tools have a potentially powerful role to play.

5.1. Policy Lessons from BE Theory

The analysis now moves on to consider how BE theory might be utilized to offer insight into the behavior of designers and residential builders responding to the requirements of performance-based building codes.

Regulations seek to change the behavior of architects and building designers. Financial measures aim to elicit a rational behavioral response from property developers, owners, and investors. Information campaigns typically aim to modify consumer choice and decision-making practices. Therefore, BE can provide powerful insights into the effectiveness of such policy instruments. BE can help determine whether desired behavioral modifications are actually being achieved in practice, and if not, which changes to policy settings are called for as a remedy.

A summary of the key actors operating in the property market is set out in Table 3. Reference to the headline heuristics set out in Table 2 provides explanations as to why industry stakeholders may behave in an irrational manner [33], rather than conforming with or responding rationally to the opportunities for innovation and creativity offered by performance-based building codes. Table 3 further develops the basic BE heuristics set out (Table 2) earlier, by identifying their applicability to specific stakeholder groups active in the building sector/property market.

Table 3. Heuristics operating in the building sector defined in terms of affected stakeholder groups amenable to interventions based on BE principles.

	Sectoral Manifestation	Influenced Stakeholder Groups
Anchoring	Designers set energy performance levels at a regulatory minimum, thereby failing to explore alternatives with increased consumer benefits	Building designers and architects [42,43]
Availability	Consumer choices influenced by well-marketed project home designs that may lack innovation, together with informal word of mouth information	Consumers (also meaning homebuyers) [44]
Bounded rationality	Homebuyers face complex choices and multi-faceted decisions, and energy efficiency is a low priority in this context	Consumers and industry professionals [34,45,46]
Choice overload (decision fatigue)	Complexity of decisions facing consumers seems overwhelming, leading to status quo defaults	Consumers and service providers [15,37,38]
Social norm	The McMansion syndrome (1) emphasizes cosmetic building features over performance characteristics, using comparison with neighbors as an indicator of social or material success	Developers, consumers, and builders [18,19,47]
Status quo bias	Owners of existing buildings resist investment in building upgrades	Investors, consumers, and homeowners [43,46,47]
Temporal discounting	Payback benefits of investments in energy efficiency widely overlooked or ignored, with buyers focused largely on upfront capital costs rather than lifetime operating costs	Developers, investors, consumers, and builders [18,21,46,48]
Confirmation bias	Energy efficiency features discounted to consumers as excessively expensive by building practitioners on the basis of pre-conceived notions of value	Developers, consumers, builders, and service providers [49]
Framing effect	Product information is focused on superficial, tangible aesthetic elements rather than subtle factors, such as the benefits of high-performance dwellings	Developers and consumers [47–50]

Notes: (1) McMansion syndrome describes a consumer preference for purchasing excessively large houses, specifically in the new project home market segment. Citations provided in the table refer to articles dealing specifically with issues of energy policy, rather than property market operation more generally.

Moving on from this analytical step, one is then in a position to identify opportunities for targeted market interventions that are directed towards achieving defined energy policy objectives for the building sector. Linking synergistic aspects of BE theory with the operational objectives of building energy policy will enable the identification of opportunities to improve existing policy instruments. The operation of the heuristics set out in Table 3 in the building sector has evident implications for policy formulation and delivery, which warrant further study.

5.2. Building Codes, Regulations & Standards

The effectiveness of building regulations and appliance standards as policy instruments for reducing GHG emissions in both developed and developing economies has been demonstrated extensively in the literature available from academic [25] and industry sources [3]. Major international organizations have also examined the issue, reaching similar conclusions concerning the usefulness of building performance standards (codes) as a preferred instrument for government interventions, which aim to give effect to international commitments for GHG emission abatement [28,29,51]. The effectiveness of building codes as a vehicle for reducing GHG emissions through the promotion of energy-efficient design practices has also been demonstrated in a number of ex-post studies (such as [52–55].

Furthermore, there is a consensus that best practice building regulations should be performance-based rather than prescriptive in character [56,57]. Performance-based building codes have now been adopted in jurisdictions as diverse as Australia, Austria, Canada, China, Japan, the Netherlands, New Zealand, Norway, Singapore, Sweden, Spain, the United Kingdom, and the United States [58]. While these performance-based regulations focus specifically on energy efficiency outcomes rather than buildings' elemental features, their effective implementation is crucially dependent on a rational response to the mandated performance requirements by designers, architects, and engineers [59]. Gann [60] suggests that the benefits of flexible performance-based regulations are quite wide-ranging, providing firms with market incentive and institutional frameworks within which to innovate.

Case Study: Australia's Building Code

Australia's National Construction Code (NCC) has, from its inception in 1996, been structured as a performance-based building regulation [61]. Evidence obtained from ex-post studies of the NCC in operation [55] demonstrates that the effective implementation of mandatory performance-based building energy standards can deliver significant consumer benefits, in that the compliance costs can be reduced as a consequence of the industry learning processes [62] that effectively contribute to market transformation [8].

As building codes such as Australia's NCC are amended at regular intervals [63], such step changes offer an opportunity to analyze the operation of the socio-technical transition processes that these reforms trigger [8]. At this point, building designers have a choice between either re-specifying by making incremental changes to existing designs; or comprehensively re-designing their projects in order to take full advantage of the code performance requirements. The latter response is intrinsically rational, while the former is irrational, and exemplifies Kahneman's System 1 thinking in practice, when viewed from a BE perspective [12].

A study of the industry learning processes at work in the Australian building sector [62] suggests that industry sectors respond differently to the upgrading of building energy standards, as follows:

- The commercial sector—responsible for major developments comprising a relatively small proportion of aggregate market activity—has a positive response to energy-efficiency requirements, frequently exceeding the minimum compliance levels
- The residential volume builder sector—responsible for around half of new home building—design response typically includes a combination of design changes and re-specification, with the minimization of incremental cost as a key criterion
- Small residential builders—responsible for around 50% of local home building—typically respond with re-specification, an expensive compliance pathway for consumers. This conclusion is consistent with the degree of cultural conservatism and change aversion evident in this sector [64].

Research undertaken for the building regulatory agency in the State of Victoria, Australia, following the introduction of more stringent residential energy efficiency standards in 2006, sheds further light on the behavior of industry stakeholders [65]. An improvement, of some 25% in thermal efficiency, was observed during the implementation period for the new building energy standard. However, this improvement was shown predominantly as being attributable to increased building insulation levels (re-specification), rather than to more integrated design solutions that actually took advantage of the performance-based residential energy efficiency standard (redesign) [65]. A recent thorough analysis of the code-compliant home energy ratings by Moore [66] demonstrates that as-designed performance tends to cluster tightly around the stipulated regulatory minimum levels, rather than taking advantage of performance-based code objectives for truly optimum performance, from a consumer perspective. In effect, this situation represents a substantive market failure [56].

Another important constraint on the effectiveness of building codes in practice is substantive compliance with mandated energy performance requirements; as has been pointed out in the studies from the United Kingdom [57]. The Australian situation is possibly even worse than that of the United Kingdom, according to a recent review of compliance with NCC energy efficiency provisions conducted for the Government of South Australia [67]. This forensic study of code compliance concluded that the prevailing industry attitude was generally characterized by a disturbing combination of ignorance and apathy in relation to energy-efficiency provisions. Full compliance with energy performance requirements was the exception to the norm, consumer awareness of the energy efficiency objectives was low, and the prevailing attitude of industry stakeholders was that under-performance in the energy domain was unlikely to be detected or sanctioned by regulators (or homebuyers either). Thus, one can see that the potential effectiveness of building codes as an instrument of energy policy is likely to be compromised, unless their implementation is carefully managed, utilizing a perspective that draws on behavioral principles grounded in an appreciation of industry culture.

Returning to the property sector heuristics set out Table 3 illustrates how a BE perspective can provide insight into the effectiveness of regulatory interventions through a deeper understanding of the particular heuristics that are applicable to this regulatory case study, namely:

- Anchoring [42,43]
- Cognitive bias [48]
- Bounded rationality [34,43–45]
- Confirmation bias [49]
- Temporal discounting [18,21,45].

5.3. *Financial Instruments Utilized for Energy and Climate Policy Operation*

A summary of the available financial instruments is provided in the discussion paper prepared for the IEA [31], which sets these out as the following:

- Direct taxation of CO_2 emissions
- Emissions trading schemes (ETS)
- Taxes on process inputs or outputs (fuel or vehicle taxes)
- Subsidies for emission reductions.

In order to examine the potential congruence between BE theory and building energy policies, the case of ETS application will be investigated in some detail, because ETS represents a particularly significant and widely adopted element of national climate change policy in both developed and developing nations.

Case Study: ETS and Residential Buildings

A study for the UK Government [68] made the case for an ETS, asserting that setting a carbon price must be an essential foundation for climate-change policy. Another key public policy document in debates around climate change mitigation is the Fifth Report of the IPCC [69]. The IPCC confirms Stern's position [68], that carbon-pricing mechanisms including cap-and-trade schemes or carbon taxes have the potential to achieve cost-effective mitigation, provided that such schemes are supported by good policy design and governance regimes.

By making emitters such as companies and consumers bear the full environmental costs of their actions, they would be influenced to switch away from high-carbon goods and services, and invest in low-carbon alternatives. Such price signals operate by increasing the relative cost of carbon-intensive, energy-inefficient buildings, so stakeholders are encouraged to shift their focus to lower carbon alternatives. This crucial behavioral change in the decisions and market choices being made by businesses and consumers is the fundamental, inescapable objective of carbon-pricing policies. However, this objective is equally often overlooked in public policy debates.

Drawing on the analysis set out in Table 3, it can be seen that a BE perspective offers insight into the effectiveness of price-based market interventions through a deeper understanding of the behavioral heuristics that are applicable here, namely:

- Bounded rationality [34,43–45]
- Social norm (herd behaviour) [18,19,47]
- Temporal discounting [18,21,45].

The impact of these behavioral heuristics on the property market is to cause irrational behavior by consumers, which tends to undermine the financially rational responses to higher energy prices on which carbon-pricing market interventions are based [42].

This important observation implies that additional instruments may need to be deployed by governments in support of carbon pricing, if desired policy outcomes are to be achieved in the residential building sector [70,71].

5.4. Stakeholder Information Provision

According to an IEA analysis [31], policy initiatives that may be classified as information and voluntary approaches include the following:

- Public information campaigns
- Education and training, including industry capacity building
- Product certification and labeling
- Award programs.

Within this category, governments in many national and regional jurisdictions have placed considerable emphasis on policy instruments that utilize the performance rating and labeling of buildings as a vehicle for market intervention, with the aim of reducing GHG emissions from buildings. The rationale behind this intervention pathway assumes that performance disclosure will lead to changes in consumer behavior as a consequence of such information provision. Thus, it is assumed that consumers will respond by purchasing or renting buildings with superior performance ratings.

An extensive analysis on the benefits of energy performance certification (EPC) schemes for buildings, as well as best practice implementation processes, has been undertaken by the IEA [72]. EPC also offers additional benefits, such as increased public energy awareness, lower consumer costs, and improved building data collection, as an input to further policy development.

BE heuristics that potentially influence the operation of climate change and energy efficiency information provision policies include the following:

- Bounded rationality [34,43–45]
- Choice overload (decision fatigue) [15,37,38]
- Temporal discounting [18,21,45]
- Social norm (herd behavior) [18,19,47].

5.4.1. Case Study: European Union Building Certification Program

The European Union's Energy Performance of Buildings Directive (EPBD) [73] represents a major policy intervention in the building sector, which aims to deliver significant improvements in the energy efficiency of building stocks in all building sectors, for both new and existing buildings. The sweeping ambitions of the EPB program are encapsulated in its stated objective of delivering nearly zero energy buildings (NZEB) post 2020.

EPC is a key element of the EPBD. This EPC program is intended to be an instrument for market transformation by providing an information tool for market actors, such as building owners and occupiers; creating demand for building energy efficiency; influencing real-estate transactions; and offering recommendations for performance upgrades [66,74]. Because EPC is concerned with triggering behavior change in industry stakeholders through the provision of information, its operation can be examined through the lens of BE theory when evaluating program effectiveness.

High-level analyses of EU EPC program efficacy, such as Arcipowska [66] tend to focus on process control and quality assurance issues (certifier accreditation, centralized data collection, and legislative governance) rather than actual program outcomes measured against core policy objectives. However, Arcipowska [66] does recognize the need for an independent analysis of EPC program effectiveness. With this in mind, EPC reviews undertaken at a national level are illuminating.

In a study of ten national EPC programs, Backhaus et al. [75] found the impact of EPC's on home purchasing decisions to be low. Analyzing the Norwegian housing market, Olaussen [76] found no evidence that the labels have a substantive market impact or result in a price premium for superior certified performance. In a study of the Dutch residential property market, Murphy [77] concludes that the potential impact of EPC in driving efficiency improvement in existing buildings is problematic, unless complementary policy instruments are deployed to address multiple [78] barriers. In a Swedish study, Harsman [79] suggested that consumers are influenced more by information obtained from site visits than by EPC disclosure information; hence EPCs are not likely to stimulate market decisions in favor of energy efficiency or conservation. The German housing market has been investigated by Amecke [70], in order to assess the influence of EPCs on owner-occupied dwelling purchasers' decisions to incorporate energy efficiency into their purchasing decisions. This study concluded that energy certification actually had a limited influence on consumers.

Perhaps the most telling observation on the policy impact of current EPC programs in the EU comes from an extensive in-depth study by Backhaus, of 3000 homeowners in ten EU jurisdictions [71]. This analysis was based on a combination of in-depth interviews and a large-scale survey, which established that the EPC has a negligible impact on home-owner decision-making. These findings [71] have been attributed to a number of factors, namely: poor EPC availability, lack of awareness, and lack of understanding. These findings point to substantial flaws in consumers' behavioral responses to EPC disclosure information, in comparison to policy assumptions underlying the EPC program.

To sum up, the inadequacies in a key EU building policy initiative are attributed to unexpectedly weak and irrational consumer responses to EPC certificates. This outcome is one that a review of EPC through the lens of BE might well have anticipated (Table 3). Further consideration of the potential synergies between BE (heuristics) and the effective delivery of building energy policy measure is provided later in the paper (for example, Table 4).

5.4.2. Choice Overload: A Daunting Challenge Facing Homebuyers and Renovators

Purchasing or renovating the family home is a major strategic and financial decision that is undertaken relatively infrequently; hence, consumers do not have substantive personal experience to draw upon [37].

A general analysis of the negative effects of the excessive choice options available in modern consumer societies is also applicable to the housing purchase decision scenario. Schwarz [38] demonstrates how excessive consumer choice, rather than being beneficial, can frequently lead to unhappiness; disappointment; and, ultimately, even mental depression [33,38].

An experimental investigation by Malhotra [37] into how information overload affects consumer decision making for house purchasing found the following:

- The decision to buy a house normally entails substantial information seeking and processing;
- A house is a product that is used and understood by almost everybody;
- It is a complex product that is evaluated in terms of many salient attributes.

Two pertinent conclusions are set out in Malhotra's study, namely:

- Consumers struggle to make detailed comparisons of more than ten alternative choices, without experiencing cognitive dysfunctionality;
- Under decision overload conditions, consumers fail to make detailed comparisons of all alternatives, but adopt simplifying strategies (heuristics) to cope with the task of ranking options.

Another useful study examines the consumer choice dilemma in the case of purchasing a prefabricated house [80]. This study identifies no less than thirty parameters that must be taken into account by prospective homebuyers at a strategic decision-making level. When taken in conjunction with Malhotra's finding, that decision stress takes effect where choice alternatives reach ten or more [37], this result suggests that prospective home purchasers operate under a cognitive regime of considerable stress and significant dysfunctionality. So, consumers need active support to successfully navigate the daunting and complicated residential property market.

This area of consumer behavior is influenced by a number of the cognitive heuristics and biases articulated previously under BE theory (per Table 3), namely:

- Bounded rationality [34,43–45]
- Choice overload [15,37,38]
- Cognitive bias [48]
- Confirmation bias [49]
- Framing effect [47–50]
- Temporal discounting [18,21,46,48]
- Social norm (herd behaviour) [18,19,47].

5.5. Quantification of the Benefits of Residential Sector Intervention

It was explained in the Introduction that this article of necessity takes a qualitative approach to an examination of the contribution that BE might make to building energy policy and its subordinate regulatory instruments. Nevertheless, one can provide pertinent quantitative examples of the impact of effective policy implementation based on information available from the literature. Here, the example of Australian National Construction Code will be utilized in order to illustrate the potential effectiveness of BE-based enhancements to building energy codes.

An overview of the economic benefits of progressive reforms to Australian residential building energy standards over a decade, based on data publicly available from national regulatory impact assessment reports [9], suggests that the regulations have a benefit–cost ratio of up to 4.6:1, and deliver carbon abatement at a negative cost (cost saving) of AUD \$70/tonne-CO_2.

Further evidence for the benefits of building energy codes, this time in the United States context, is provided by Livingston [54], who determined that the net present value of cumulative energy and cost savings from the United States codes over the study period of 1992–2040 was \$230 billion. It is worth noting that—in the context of this article's central theme concerning the application of BE to improve the effectiveness of energy policy instruments—that Livingston makes a considered attempt to allow for non-compliance with building code provisions, to the extent of 25–30%, in estimating the economic benefits arising from US code implementation [54].

A recent report prepared for the Australian Sustainable Built Environment Council (ASBEC) [81] provides quantitative evidence on the energy consumption of high performance, energy efficient buildings in comparison with a conservative base case. ASBEC finds that base case energy consumption for a code-compliant apartment building in the Melbourne, Australia, climate zone would be 73 kwh/m^2; adopting an accelerated reform trajectory for the building code would bring forward a revised energy efficiency target of 57 kwh/m^2, corresponding to savings of some $300/year on the energy bill. By the same token, ASBEC reports that a base case annual energy consumption of 45.6 kwh/m^2 could be reduced to 30.5 kwh/m^2 through the accelerated deployment of more ambitious energy efficiency standards in the National Construction Code.

6. Discussion

It is unarguable that an effective response to the challenge of climate change and its contributory GHG emissions must include an explicit policy focus on the building sector [2–5,54]. To this end, a coherent response by governments calls for the deployment of diverse, complementary policy instruments [26,82,83].

The effective implementation of building energy policy ultimately depends on achieving an intended behavioral change by the respondent sectoral stakeholder group. These outcomes require engagement with property developers, contractors, lessees, builders, or individual consumers, depending on the market sector targeted by the policy measure in question. For example, in the residential sector, consumers and building service providers are seen to be the key target stakeholder groups.

This paper seeks to break new ground by examining residential building energy policy interventions using a BE approach, wherein the behavior of key stakeholders such as consumers, designers, and builders, is addressed from a socio-psychological perspective. Although BE theory is being applied to policy implementation in areas such as consumer protection, finance, and public health, its principles have yet to be applied to the key building sector in the core area of building performance (as energy efficiency). It is worth reflecting on the contribution of residential building performance, including services such as water heating, to total residential energy demand. According to a definitive study by the Australian Government [75], residential space conditioning and water heating accounts for over 60% of the total residential energy consumption, with the balance taken up by electrical appliances and cooking. So, policy interventions focused on improved building design and construction are particularly important for reducing residential energy consumption, as downstream interventions directed towards reducing demand during building operation will inevitably be constrained by structural factors.

Working from a grounding in BE theory, the paper explains how decisions made by building industry stakeholders differ substantially from those assumed by an orthodox (essentially economic) policy perspective. This divergence has significant implications for the framing of sectoral climate and energy policies. Thus, BE theory suggests that understanding and applying inferences drawn from an appreciation of the cognitive heuristics at play among stakeholders can contribute to a marked improvement in the prospects for successful policy intervention, to deliver sustained behavioral change. Conversely, failure to heed the lessons available from BE theory is likely to jeopardize prospects for successful policy deployment.

A high level of complementarity between key elements of BE theory—represented by cognitive heuristics—and the behavioral triggers that building energy policy seeks to influence (Table 2) has been demonstrated. So, it follows that lessons available from BE theory might make a substantial contribution to the development of the government policy instruments that are being deployed to accelerate the transition to an energy efficient, low-carbon residential building stock (see Table 4 below for examples).

In a series of case studies (Section 5), the operation of each major category of building energy policy intervention was examined in turn. This section of the paper clarifies and reinforces the strong relationship between the tenets of BE theory and the mechanics of building policy. More revealingly, each category of policy implementation is shown to suffer from significant flaws—deficiencies that might reasonably be attributed, at least prima facie, to a failure by policy makers to appreciate the implications of the behavioral changes expected from targeted stakeholder groups. The utilization of BE principles through the application of appropriate heuristics offers a powerful vehicle for addressing these identified policy shortcomings.

Reviewing these policy failures through a BE lens better explains the following:

- Why compliance with energy efficiency requirements mandated in building regulations may be fatally compromised as a result of indifference by both building project developers and consumers;
- Why price-based interventions in the property market (such as through an ETS) will not necessarily prompt a rational response from consumers;
- Why consumer information campaigns such as the EU EPC initiative fail to achieve a significant market impact, or a price premium for superior certified performance, because of weak and irrational consumer responses.

These findings are summarized in Table 4, together with selected references from the literature that could provide a platform for the development of more effective market interventions based on BE principles.

BE theory suggests that understanding and applying inferences to be drawn from an appreciation of the cognitive heuristics at play among industry stakeholders could contribute to a marked improvement in the success of policy interventions, delivering a sustained behavioral change. But failure to heed the lessons available from BE theory is likely to jeopardize prospects for successful building policy deployment.

Despite the strong case for a focus on energy efficient buildings in terms of a global climate response, this policy area has yet to be appreciated by government BITs. A recent OECD study [35] into the potential application of BE principles to energy policy development concluded that areas for exploring the application of behavioral insights should specifically focus on regulatory implementation and decision making by regulatory agencies.

In the domain of climate and energy policy, which is the focus of this paper, the application of BE theory has tended to address aspects of consumer engagement with energy markets, such as the provision of consumption data, energy contract provisions, smart metering systems, and barriers to the uptake of renewable energy. Although the planning, design, construction, and operation of building projects could reasonably be seen as the essential focus for building policy, these aspects have yet to addressed by behavioral insight teams and other governmental proponents of BE.

As explained earlier, although BE has the potential to inform all stages of public policy development, its application by governments, to date, has been quite variable [14]. Many governments around the world have established BITs whose role is to explore the use of BE in public policy, and advise government agencies on the value of BE and behavioral science. However, the worldwide application of BE to public policy is still limited—most efforts are seen as operating in the exploratory or pilot phases [14]. Numerous case studies do demonstrate the successful application of BE theory to public policy in areas such as consumer protection, education, energy, environment, health and safety, taxation, telecommunications, public service delivery, and labor market reform [35].

Expanding the methodology for this study takes the discussion on to Figure 2. Here, the relationships between the final stages of the analysis are re-examined in order to demonstrate how further research into the enhancement of building policy instruments using BE theory might now be developed as a consequence.

Table 4. Application of BE measures to correct shortcomings in market interventions, as demonstrated in preceding case studies.

Building Energy Policy Measure	Intended Success Measures	Substantive Outcomes (See Case Studies)	Behavioral Insights: Consideration of Applicable Heuristics and Corrective Interventions	Pertinent References
Carbon pricing—emissions trading schemes	Reductions in domestic energy consumption; market preference and higher valuation for low carbon, energy efficient buildings	Limited success in operation; ineffective in the property market [39]	Influence of social norms—try nudging Status quo bias correction needed Bounded rationality impedes policy delivery	Allcott 2010 [18]; Allcott 2011 [20]; Allcott 2014 [47]; Fredericks 2015 [21]; Baddeley 2011 [45]; Baddeley 2016 [46]; Blasch 2017 [34]; Lunn 2014 [15]; Yoeli 2017 [50]
Regulation through building energy codes	Code compliance; aspirational design objectives beyond code minima (performance-based code design)	Widespread non-compliance [57,67]; performance levels cluster tightly around code set point minima [56,65]	Anchoring around regulatory minimum performance standards Use social norms with performance transparency to encourage compliance Loss aversion influential if coupled with improved regulatory enforcement	Klotz 2010 [42]; Klotz 2011 [48]; Fredericks 2015 [21]; Moore et al. 2019 [57]
Energy performance certification	Market preference for higher rated buildings—reflected in their market value	Consumer indifference gives rise to ongoing market failure: energy efficiency gap persists	Anchoring, availability, and choice overload Bounded rationality and choice overload may be addressed through timely nudges Unhelpful framing needs correction: disclosure of operating costs not ratings Temporal discounting is a major impediment	Baddeley 2016 [46]; Baddeley 2011 [45]; McNamara 2011 [44]; Lunn 2014 [15]; Yoeli 2017 [50]; Blasch 2017 [34]; Shealy 2016 [51]; Allcott 2010 [18]; Fredericks 2015 [21]

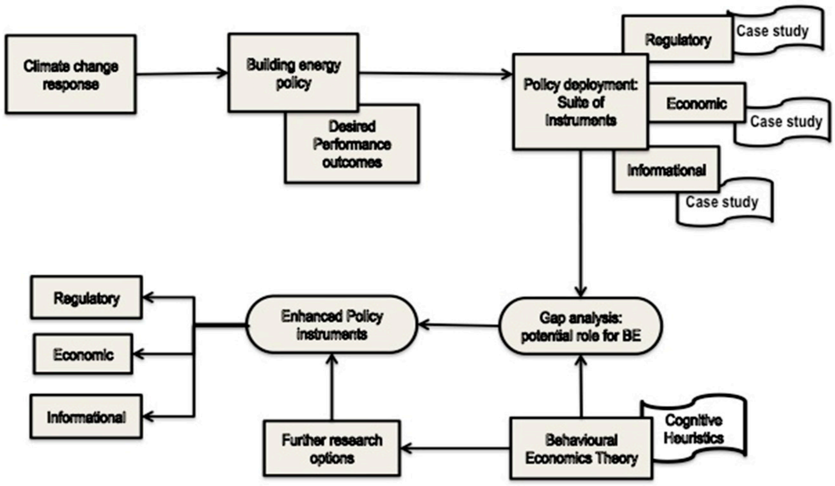

Figure 2. Overview of the key analytical elements at a concluding stage, illustrating the methodological process followed in the analysis; beginning from a review of policy settings, through to the discussion of policy deployment instructions, on to a gap analysis of the potential role for BE in building policy that then leads to findings on the enhancement of policy instruments.

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7. Conclusions

This study has not attempted to provide an exhaustive review of BE theory or the principles of climate response policy. Its scope is limited to highlighting potential areas of alignment between BE theory and those energy policy interventions that are focused, in particular, on the residential building sector. This approach facilitates the identification of opportunities for drawing on BE principles to enhance the effective operation of building energy policy instruments; that is to say, regulations, financial interventions, and information provision programs.

The study's headline conclusions may be summarized as follows:

- Strong complementarity exists between the key tenets of BE—as represented by cognitive heuristics—and the mechanics of building energy policy
- Understanding the impact of cognitive heuristics on industry stakeholders' behavior can provide important contributions to the improved design of market intervention policies
- Policy implementation vehicles such as building energy codes, carbon pricing, and consumer information campaigns suffer from significant delivery failures, whose underlying causes could be better diagnosed and corrected through the application of BE principles (via heuristics)
- The economic and environmental argument for market intervention using building energy codes rests on assumptions of operational effectiveness, and high levels of regulatory compliance; without compliance, such projected benefits are illusory
- Behavioral insights not only hold out a promise of improved effectiveness for building policy delivery, but also the threat of compromised program outcomes, should the BE lessons fail to be learned
- Governments worldwide are calling on BE theory to improve the effectiveness of policy delivery in diverse areas such as consumer protection, education, public service delivery, and labor market reform; these nascent initiatives are typically managed by specialized BITs
- Application of BE theory to (building energy) policy by government BITs has tended to focus on consumer engagement with energy markets; the equally important issue of building project delivery, from conception through, design and construction, to operation, has yet to be well examined from a BE perspective
- Clearly, the next step for governments is to broaden the remit of their BITs in order to address building energy policy from a rigorous and broad-based BE perspective.

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8. Further Research

One outcome of this analysis is that further research is shown to be valuable, if the contribution of BE to building energy/climate policy is to be successfully exploited, as follows:

- Understanding the drivers and influencers of consumer choice and rationality—the role and true potency of building performance disclosure
- Facilitating and accelerating industry learning processes to entrench effective change management, particularly in the residential building sector
- Identifying international best practice approaches to building regulation in the context of behavioral factors and influences
- Understanding industry culture and the operation of peak industry bodies, as these relate to policy support and delivery

By way of a concrete example, a number of suggestions for the practical application of BE principles to the residential property market can be deduced from the analysis (see Table 4).

First, is to recourse to BE nudging techniques to persuade building industry professionals into committing to the delivery of high performing buildings that actually exceed code minima and aim at achieving zero carbon performance levels. A nudge is defined as a non-regulatory intervention that alters the choice architecture without effecting economic incentives [9,84]. In the same vein, one could envisage the use of targeted heuristics to engage consumers in a collaborative journey directed towards the delivery of low carbon homes with performance levels comparable with the Passivhaus standard, for example [85].

A second approach might be to address widely recognized building code compliance and enforcement problems [56,57,64,65,67] by employing lessons from BE to properly understand, and then redirect, the response of industry stakeholders to meeting regulatory obligations. Here, the heuristics of social norms and loss aversion are likely to be applicable.

A third proposal might be to provide consumers with representative blueprints of good design to simplify decision-making and address the problem of choice overload (Table 2). This approach mirrors the strategies being developed by BITs in a number of jurisdictions to simplify financial decision-making, by providing consumers with default choices. The State Government of Victoria, Australia, recently introduced a relevant initiative. Recognizing that complex and poor-value electricity supply contracts were disadvantaging consumers, the State Government decided introduce a simplified, government mandated default power supply offering. This initiative also links directly to the issue of choice overload; it is expected to save individual electricity customers up to $2000/year.

Interestingly, the design blueprint approach was implemented in the State of Victoria over sixty years ago. With the support of one of the country's leading architects and a local newspaper, the Small Home Service, it offered local homebuyers an inexpensive package of architect plans, working drawings, and construction specifications. Recently, Australia's national government has made archetypal designs for sustainable, energy efficient homes available freely to the public through a national communications program known as Your Home [86].

It is noteworthy here that Kruzner's analysis draws attention specifically to the need for policy interventions to deliver the consumer benefits flowing from passive solar residential designs [87].

In a study on the influence of cost-reflective electricity pricing, Hobman [22] sought to apply BE principles to the identification of opportunities for enhancing customer response by a cross-section of the population. This paper offers transferable insights that could also be applied to the investigation of linkages between BE, and building energy policy and regulation. Hobman [22] examined a series of salient heuristics (mirroring those presented in Table 3) in order to demonstrate how these behavioral biases act as barriers to the responses to cost-reflective pricing by consumers that were intended by policy makers. Similar behavioral barriers exist in the case of the effective operation of building energy standards; a comprehensive review undertaken for the Australian government clearly demonstrates shortcomings of precisely this type [67].

that were intended by policy makers. Similar behavioral barriers exist in the case of the effective operation of building energy standards; a comprehensive review undertaken for the Australian government clearly demonstrates shortcomings of precisely this type [67].

Finally, it is worth reflecting on the fact that the residential property market is a prime opportunity for the application of BE principles to building energy policy. This is the case, because the residential property purchase and ownership lifecycle includes a series of key decision points that provide potential intervention opportunities to facilitate behavior change, using tools such as nudging [9,49].

These potential nudge points (highlighted on Figure 3) represent opportunities to alter the architecture of consumer choice at key decision points, by employing non-regulatory BE techniques that do not effect underlying project economics. It is at these points in the building lifecycle that heuristics come into play for industry stakeholders. Therefore, it is also these points that provide optimal intervention opportunities for policy makers making use of BE instruments, such as nudges. This strategy is illustrated in Figure 3, which mirrors findings by Yoeli [49], that interventions directed at modifying consumer choice architecture are most effective if focused on transition points in building lifecycle decision-making by consumers.

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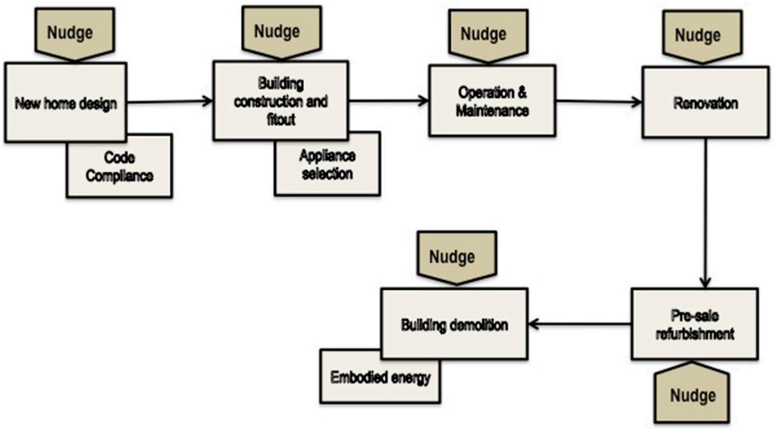

Figure 3. Key decision points in the residual building ownership lifecycle that present opportunities for the application of BE change management tools, such as nudging, in order to more effectively achieve desired policy outcomes.

Author Contributions: conceptualization, R.A.E.; methodology, R.A.E. and G.M.M.; investigation, R.A.E.; resources, R.A.E.; writing—original draft preparation, R.A.E.; writing—review and editing, R.A.E. and G.M.M.; visualization, R.A.E.; supervision, G.M.M.; project administration, R.A.E.; funding acquisition, R.A.E.

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Appendix D

ASA 2015 conference paper - **Enker, R.A**., Reframing housing regulation: delivering performance improvement in conjunction with affordability; Conference Proceedings: Living and Learning: Research for a Better Built Environment 2015, pp 403-412. Publication 4

Reframing housing regulation: delivering performance improvement together with affordability
ASA Submission # 210

Abstract:

In developed economies a significant proportion of greenhouse gas emissions result from energy demand in the building sector. Many countries have recognized the need to mandate building energy performance standards as a key element of a national energy or climate change policy. The Commonwealth of Australia included energy efficiency provisions in the national Building Code early last decade. This initiative has however not been without controversy or resistance from certain industry stakeholders. Typically such opposition is predicated on the assumption that more stringent energy efficiency requirements, particularly in the residential sector, would detrimentally impact on housing affordability. The State of Victoria introduced significantly more stringent residential energy efficiency requirements [entitled the *5 Star Standard*] in 2004. This study of the new standard investigates its effectiveness as an instrument of energy policy, testing the assumption that more stringent regulatory requirements are at odds with housing affordability. The analysis concludes that the 5 Star Standard has delivered significant greenhouse abatement; and encouraged industry innovation in a way that embodies regulatory best practice; while at the same time not compromising housing affordability for consumers or impacting negatively on the local housing market.

Keywords: Regulation; energy; housing; affordability.

Introduction

A substantial body of research exists to demonstrate the significant role that improved building performance should play in reducing global greenhouse gas emissions (Ürge-Vorsatz and Novikova, 2008) ,particularly in developed countries where most people live in urban settings. In Australia almost a quarter of greenhouse gas emissions result from energy demand in the building sector (Centre for International Economics, 2007). It has also been demonstrated that the building sector provides potentially the most cost-effective economic sector for greenhouse gas abatement (McKinsey Company, 2008).

But how should government's act to mine this golden seam of abatement opportunities? The role of regulation as an effective policy instrument for government has been addressed in a report for the UN Environment Program (United Nations Environment Program, 2007). In examining the potential for mitigating greenhouse gas emissions from energy use in the world's buildings Urge-Vorsatz et al suggest that appliance standards and building codes are particularly cost-effective. Analysis of trends in energy use and CO2 emissions in the Swedish building sector by Nassen & Holmborg (Nässén and Holmberg, 2005) found that stagnation in energy efficiency levels since the nineties should be addressed by policy interventions that included, as a priority, regulations aimed at improving the technical performance of buildings. Nassen & Holmborg also asserted somewhat controversially that regulations designed to affect building occupant behaviour should also be considered by government policy makers – citing Denmark and Germany as successful examples of such initiatives.

Gann (Gann et al., 1998) draws upon analysis of the UK building regulations to discuss the impact of building regulations as both constraints and drivers for innovation in housing design. In tracking the development of energy efficiency provisions in Swiss building codes Groesser (Groesser, 2014) points out that performance levels set in building codes for both new construction and refurbishments are a "powerful lever for reducing greenhouse gas emissions.

The Netherlands uses a range of policy tools to support the energy performance of its buildings (Adshead., 2011):

- energy labeling, covenants, and thermal performance standards for existing buildings
- mandatory energy performance standards and covenants for new buildings

In an Australian context the nation's Ministerial Council on Energy (Australian Building Codes Board, 2006) decided that ramping up energy efficiency standards in the national building code should be a cornerstone of the National Framework for Energy Efficiency [Energy Efficiency and Greenhouse Working Group, 2003 #1277] which defined the future direction of Australia's energy efficiency policy and programs.

The role of building standards as one element of a strategic policy framework for transitioning to a low carbon economy is recognized in the UN Economic Commission for Europe's *Action Plan for Energy Efficient Housing in the UNECE Region* (United Nations Economic Commission for Europe, 2011). The Action Plan is constructed around three key elements: (1) governance and finance; (G20 Group) energy performance standards and technological development; (3) access to affordable of energy efficient housing. Within policy area (G20 Group) improving energy efficiency in newly built and existing homes is effected by high regulatory standards among a range of other complementary measures.

In an Australian context the basis for regulatory intervention is defined in the national Building Code as being to **"***enable the achievement of nationally consistent, minimum necessary standards of relevant safety (including structural safety and safety from fire), health, amenity and sustainability objectives efficiently* (Australian Building Codes Board., 2011)

While pressures for reform of building regulations may be constant, so are the reactions of vested interests to such reforms. In a recent a report produced for the C40 Climate Leadership Group former New York Mayor Michael Bloomberg recommended that government strategy needs to include a way forward that should include deep building energy efficiency standards for new buildings and building energy retrofits for existing buildings (Bloomberg. M. R., 2014) However around the world there are often strong reactions from building industry and social housing organizations about the impact of such changes on affordability of housing. For example Groesser (Groesser, 2014) discusses the resistance of "incumbent agents" to innovative energy efficient housing introduced in response to regulatory interventions by the Swiss government; and (refs).

This paper examines an Australian case study that investigates building regulation for energy efficiency and greenhouse gas mitigation reduction and how effective they have been at inducing positive change. Its focus is on the role and effectiveness of building energy regulations as a policy instrument. Lutzenhiser points out in his study of barriers to energy efficiency in the United States housing industry (Lutzenhiser, 1994) that a range of sociological, technological and economic factors provide such barriers. Lutzenhiser goes on to observe that markets for energy efficiency often fail because the economically rational behaviour required for effective market operation is effected to a significant degree by cultural and institutional factors.

The State of Victoria, Australia was the first national jurisdiction to introduce energy efficiency regulations for buildings, back in 1991. Then in 2002, as part of a comprehensive Greenhouse Strategy for the state, Victoria dramatically ramped up its residential energy efficiency standards to a level defined as 5 Stars within the framework of Australia's *Nationwide House Energy Rating Scheme.*

This initiative was very controversial at the time. Housing industry bodies in particular were vociferous in their opposition, claiming that this regulation would not only impact negatively on the cost of new homes – housing affordability – but also damage the residential building market in the state as a whole. When Victoria's initiative was subsequently emulated in the Building Code of

Australia through adoption nationally of 5 then 6 Star residential energy efficiency standards industry opposition based on alleged threat to housing affordability continued unabated.

Following implementation of the BCA 6 Star requirements a series of nationwide analyses have been conducted to assess the effectiveness of these regulatory outcomes from a high level policy perspective. By drawing upon formal, public regulatory impact assessments and other available data it is possible to map the trajectory of the true cost impost of mandatory energy efficient standards for residential buildings.

A decade after its implementation Victoria's 5 Star Residential Standard provides a useful and very pertinent Case Study for the purposes of such analysis as extensive data is available on actual and projected implementation cost. The analysis also includes discussion of the important role of industry learning and skills development in *effectively responding* to more stringent regulatory requirements.

2 THE REGULATORY CONTEXT

2.1 Australia's Building Code: the *National Construction Code*

Australia has had a national building code since 1996. In 2010 the *Building Code of Australia* [BCA] was transformed into a *National Construction Code* [NCC] through incorporation of the *Plumbing Code of Australia*. The BCA now comprises Volumes 1 and 2 of the NCC.

Under the Australia Constitution legal responsibility for the built environment is vested in the eight States & Territories, each of which has its own individual regulatory regime to address land planning and building control matters. Further, the NCC is only given legal force in each State and Territory by being referenced in the relevant legislation of that administration. In the case of Victoria this reference to the NCC is made in the State's uniform Building Regulations (State of Victoria, 2006).

The fundamental role of the NCC is to set uniform construction standards across Australia for all building classes that are based on building performance outcomes in key areas such as health, safety, durability. Since 2006 these goals have also included explicit reference to *Sustainability,* viz*:*

> *The goal of the BCA is to enable the achievement of nationally consistent, minimum necessary standards of relevant safety (including structural safety and safety from fire), health, amenity and sustainability objectives efficiently.* (Australian Building Codes Board, 2011a).

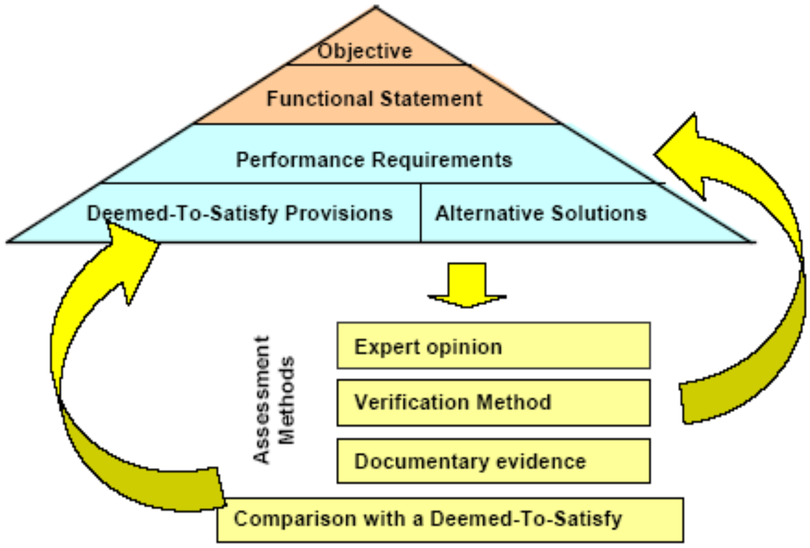
The rationale for the NCC is to set the minimum acceptable standards for building performance at the design stage in its defined areas of applicability. Compliance with the Code is determined by building certifiers and surveyors at a building's design stage by establishing whether *performance objectives* prescribed in the Code have been met. The Code is quite flexible, deliberately providing a range of compliance pathways in order to encourage innovative, cost-effective design solutions.

In the case of residential buildings the NCC prescribes the Performance Requirement for energy efficiency with which building solutions must comply in these terms:
"A building must have, to the degree necessary, a level of thermal performance to facilitate the efficient use of energy for artificial heating and cooling …."

The functional structure and operational basis of the Code is illustrated in Figure 1.

The Code also specifies that *new dwellings* and major construction work on *existing* residential buildings must achieve an energy efficiency performance level of 6 Stars as measured by Australia's Nationwide House Energy Rating Scheme. Figure 1 sets out a conceptual perspective on operation of the NCC compliance process in relation to defined performance objectives.

Figure 1: BCA: a Performance Based Code



2.2 Australia's Nationwide House Energy Rating Scheme: the important contribution of energy ratings to national building regulations

Australia's Nationwide House Energy Rating Scheme [NatHERS] provides a nationally consistent framework for assessing the thermal performance of residential buildings (Department of Industry, 2014). The scheme provides for both *certification* of compliant House Energy Rating software and *accreditation* of suitably trained Thermal Performance Assessors.

The building design's star rating is calculated using software accredited for this purpose under the Scheme. Compliant software package simulate the performance of buildings in service by taking into account climatic and other factors about the physical characteristics of the building envelope, its location and occupancy levels. The rating scale ranges from a minimum of 1 Star to a maximum rating of 10 Stars. A 10 Star design theoretically would require no external energy inputs for heating or cooling.

Quite deliberately the House Energy Rating methodology only assesses energy used for heating and cooling of Australian residential buildings. Other residential energy consuming systems or services such as appliances, water heating and cooking are currently excluded from the rating scale.

In a strategic sense the NatHERS structure has a threefold function:

- providing a regulatory tool referenced in the NCC
- facilitating improvements in performance-based design of residential buildings
- providing consumers with a simple basis for comparing the energy efficiency of alternative building designs for both new homes and home alteration projects

Victoria's Residential Energy Efficiency Regulations

In 1991 the State of Victoria, Australia introduced energy efficiency requirements for residential buildings. It was the first Australian jurisdiction to do so. These insulation regulations were subject to a regulatory impact assessment which was focused around a public consultation document that set the costs and benefit of the new regulations (Department of Planning & Urban Growth, 1990). The prescriptive insulation regulations aimed to deliver new buildings with the equivalent of a 3 Star energy rating on the NatHERS scale.

Interestingly Victorian government policy at the time suggested an intention to ramp up these energy efficiency requirements to the 5 Star level in 1993. Whereas in reality this reform took another decade to implement.

Estimates for additional cost to homeowners of implementing the 1991 insulation regulations for the typical new $160m^3$ home being constructed at the time ranged from $1400-$2000. It was anticipated that the resulting improvement in thermal performance would reduce heat losses by 40%, saving the average homeowner around $300 on annual energy bills; and reducing greenhouse emissions from gas heating systems by 2-3 tonnes of CO_2 per annum. .

In 2000 in an extensive study sponsored by the Australian Greenhouse Office (Australian Greenhouse Office, 2000) concluded that the Victorian insulation regulations had raised the performance of new homes to a level of approximately 2 Stars on the Nationwide House Energy Rating scale. While this was a positive outcome it did not fully achieve the 3 Star policy objective defined for the regulations in 1991.

Thus in 2001 the Victorian Government decided to reform the decade-old insulation regulations as a key element of a formal Greenhouse Strategy that was to be progressively implemented from 2002. The Victorian Greenhouse Strategy (Department of Natural Resources and Environment, 2002) focused on reducing greenhouse gas emissions in key sectors of the state's economy such as transport, buildings, and manufacturing.

In its commitment to implementing the 5 Star energy efficiency standard for new homes the Victorian Government justified the regulation with the policy statement that:

> *"Energy use in homes is responsible for around 16% of Victoria's total greenhouse gas emissions ….. residential heating and cooling account for 50% of the energy consumed each year in the average Victorian home"*

A new performance based residential energy efficiency standard was announced by the Victorian State Government which made use of house energy rating software to assess compliance (Minister for Planning, 2002). In effect stringency was significantly ramped up from a nominal 2 Star to a 5 Star energy rating level on the NatHERS assessment scale; which translated to a 40% reduction in permissible energy usage for heating and cooling under the Building Code.

Victorian legislation that major regulatory reforms such as building energy standards must be preceded by a transparent public consultation process underpinned by a *Regulatory Impact Statement* that incorporates economic analysis of costs and benefits. The Victorian Building Commission published a comprehensive public consultation document (Victorian Building Commission, 2002) whose cost benefit analysis was then formally endorsed by the Victorian State Cabinet.

This *Regulatory Information Bulletin* advised that the proposed 5 Star Standard would deliver a range of significant economic, environmental and social benefits to the citizens of Victoria:

- Addition of $570M to the Gross State Product
- Creation of up to 1100 new jobs
- Annual energy savings by consumers growing to $124M - within the 20 year time horizon of the study

- Greenhouse gas abatement of 8Mt CO_2 over twenty years

The regulatory document also estimated that the additional cost of redesigning and re-specifying a typical new home to comply with the Standard would be in the order of *$1100 - $3300* [2002 dollars]. Which represented an increase of 0.7% - 1.9% in the cost of the average new home at that time.

2.2 REGULATORY PUSHBACK

During the subsequent period of public consultation following release of the 5 Star *Regulatory Information Bulletin* by the Building Commission the housing industry undertook a protracted political lobbying campaign opposing the planned regulatory reform.

Industry criticism was founded on the assertion that these mandatory energy efficiency requirements for new homes would cause excessive increases in the cost of construction with deleterious impacts on *housing affordability*. It was also alleged that price sensitive first homebuyers would be particularly hard hit by such an unwarranted cost impost.

For example, the position of peak housing industry group the Housing Industry Association [HIA] was outlined in a contemporary newspaper article (Angela O'Connor, 2002):

> *The Housing Industry Association's Victorian executive director, John Gaffney, is fighting to delay the rules, arguing they are too much, too soon and impose undue burdens on builders. He says the standard should not be mandatory until 2005 or 2006, and claims it could cost up to $10,000 per house to implement, which could cut out a significant section of the population from home ownership. The added cost on a basic $150,000 house would be about $8000 - enough to cut 4000 to 5000 prospective buyers out of home ownership, he said.*

Thus that the HIA was asserting that a cost increase of *over 5%* could be attributed to the 5 Star requirements when applied to entry-level homes in the market. The HIA CEO further claimed that (Kate Jones (a))):

> *Energy efficiency for homes now is at about a two-star rating and by jumping up to a five-star rating, many home deals will fall over. He said that the new measures would dampen the property market, predicting that up to 10 per cent of buyers would have difficulty purchasing.*

Further evidence for the housing industry's trenchant opposition to Victoria's new housing energy efficiency standards may be derived from public submissions to the Building Commission's *Regulatory Information Bulletin* (Victorian Building Commission, 2002) which included statements such as:

- Costs to consumers – builders estimate added costs at up to $10,000 per dwelling, as opposed to the $3,300 average in the RIB [MBAV Nov 2002];
- One size fits all approach – not all homes or building sites are the same leading to dramatic [cost] increases for some consumers [MBAV Nov 2002]
- HIA recommends that the government reconside their analysis of the 5 Star energy rating on the basis that, amongst other matters, the analysis is fundamentally flawed [HIA Nov 2002]
- HIA contends that the cost increase for housing to reach 5 Star energy efficiency using FirstRate [software] as outlined in the RIB is understated [HIA Nov 2002]

2.3 Regulatory Effectivness: Proposed Criteria

The following criteria are now proposed as appropriate for evaluating the effectiveness of the 5 Star Standard from a policy perspective:

1) Did the standard represent *good regulatory practice*?
2) To what extent have Government *policy objectives* been met?

3) How valid were claims of *excessive compliance costs* and consequent impacts on the price of new homes?

4) Were industry concerns about significant *damage to the new home market* well founded from an evidence-based perspective?

2.3.1 Good Regulatory Practice

In its *Victorian Guide to Regulation* (Department of Treasury and Finance, 2011) the Victorian Treasury notes that factors to be considered in good regulatory design should include, inter alia (op cit Table 3.1):

- *Clear articulation of the nature and extent of the problem being addressed*
- *Prior quantification of the costs and benefits of the proposed regulatory measures*
- *Performance-based approach in preference to prescriptive compliance requirements*
- *Effective, but not unduly burdensome enforcement regime*

In replacing outdated and prescriptive insulation regulations with the performance based 5 Star Standard, enacted through the Building Code of Administered and administered through the robust, well established Victorian building control regime (Victorian Government, 1993), following a transparent regulatory impact assessment process (Victorian Building Commission, 2002) the Government's market intervention would appear to demonstrably address these criteria .

2.3.2 Government Policy Objectives

The Victorian Government's policy objectives for 5 Star were discussed earlier in the context of the State's formal *Greenhouse Strategy* (Department of Natural Resources and Environment, 2002). A primary policy deliverable in this context is would certainly have to be [cost-effective] greenhouse emissions abatement. For which the desired outcome was articulated out in an article in the Building Commission's *Inform* publication (Victorian Building Commission, 2003) which advise that:

> *In its first year, 5 Star will cut greenhouse gas emissions by 40,000 tonne, and save over $6 million on household energy bills. Over the next 5 years, the 5 Star standard is expected to reduce greenhouse gas emissions by 600,000 tonnes*

This projection actually underestimate the regulation's benefits as they were based on assumptions that turned out to be conservative in practice:

- A significantly higher rate of new home construction than originally assumed
- Extension of 5 Star Standard home renovations in 2008
- Mandatory installation of solar water heaters subsequently included in the standard

Based on updated historical data for housing starts (Australian Bureau of Statistics, 2010) the author's calculations suggests that the regulation will deliver aggregate greenhouse abatement to the levels set out in Table 1.

Table 1: Aggregate greenhouse gas abatement attributable to the 5 Star Standard

Year	Cumulative abatement 5 Star building fabric	Cumulative abatement solar water heating	Aggregate abatement	Nominal policy target
2009	0.8 Mt CO_2	0.18 Mt CO_2	0.98 Mt CO_2	0.6 Mt CO_2

2014	3.0 Mt CO_2	0.4 Mt CO_2	3.4 Mt CO_2	NA
2024	11.4 Mt CO_2	0.8 Mt CO_2	12.3 Mt CO_2	7.6 Mt CO_2

Meaning that Government's key policy objective as articulated in its Greenhouse Strategy (Department of Natural Resources and Environment, 2002) was demonstrably being achieved.

Subsequently national residential energy efficiency provisions were introduced in the BCA at a nominal 4 Star stringency in 2003. In 2006 the stringency of BCA provisions was increased to 5 Stars following Victoria's lead. A further step up to the 6 Star minimum performance level was included in the BCA 2010 Amendment. These measures were formally adopted in Victoria in 2011.

Once again major building industry bodies questioned the case for introducing the BCA 6 Star provisions on the basis of allegedly negative impacts on housing affordability; particularly in the sensitive first home market segment.

2.4 REGULATORY COMPLIANCE COSTS

All national residential energy efficiency provisions are subject to formal Regulatory Impact Assessment and Cost Benefit Analyses [RIS] prior to their introduction in the Building Code of Australia. Thus analyses undertaken at a national level for progressive increase in the stringency of BCA energy efficiency requirements to the 4 then 5 Star performance levels provide an important source for quantifying compliance costs.

In addition a number of publically available independent studies have now been undertaken since full regulatory implementation of the 5 Star residential energy efficiency standard in Victoria in 2004. These studies also allow the incremental cost of mandated energy efficient requirements to be tracked with a degree of confidence over the last decade as stringency was progressively increased.

In this way not only can the evidence for actual building costs in practice be compared with government projections in support of proposed regulatory measures, but also with industry assertions that such costs would be so excessive as to threaten housing affordability for consumers, and the related prosperity of the housing industry itself.

Table 2 summarizes this historical cost data as collected from the range of sources now available, in order to define the trajectory of compliance costs.

TABLE 2 5 STAR COST TRAJECTORY: A HISTORICAL PERSPECTIVE

YEAR	SOURCE DOCUMENT	5 STAR COST INCREMENT	Context for cost increment	Percentage house price rise [base cost where available]
2002	BC Regulatory Information Bulletin (2002)	$1100 - $3300	Base case Vic housing stock	0.7 – 1.9% [160 - 170k]

2003	ABCB RIS 2003	(a) $2100 - $3400	Stringency increase: 2-4 Stars	NA [Melbourne climate zone]
2006	ABCB RIS 2006	(b) $124 - 2600	Stringency increase: 4-5 Stars	NA [Melbourne climate zone]
2005	Cost Report for Building Commission	$1500	Base case Vic stock pre 5 Star Standard	0.4% [$230,000] [nine volume builders]
2005	VCEC 2005	$250 - $30,000		2 - 3% [$200,000]
2013	CSIRO 5 STAR STUDY	$5000 cost **reduction** on base	Detailed costs based on industry guide	NA [design outcome]

References
1. (Victorian Building Commission, 2002)
2. (Australian Building Codes Board, 2002)
3. (Australian Building Codes Board, 2011b)
4. (Victorian Government, 2005)
5. (Victorian Competition & Efficiency Commission, 2005)
6. (CSIRO, 2013)

It is evident from Table 1 that the original estimate for the incremental cost of complying with the 5 Star Standard was not only accurate, but probably conservative. Moreover, industry claims at the time of excessive compliance costs are not supported by this evidence.

A clear trend has emerged over time for compliance costs to quite rapidly diminish in magnitude. To the point where the most recent and sophisticated studies demonstrate that well-considered design changes can actually deliver highly energy efficient passive solar homes at a *reduced* base cost. This encouraging scenario sits comfortably with the fundamental tenet of Australia's Building Code: *setting performance based standards* to encourage an industry response that takes the form of innovation in both design and provision of building products and services.

2.4 THE ROLE OF INDUSTRY LEARNING

A significant 2012 study undertaken by a leading international consultancy for the national Department of Climate Change and Energy Efficiency examined the role of "industry learning" in responding to energy efficiency standards mandated through the Building Code (AECOM., 2012).

This AECOM study concluded that different sectors of the building industry responded in markedly different ways to energy efficiency improvement opportunities - whether voluntary or mandated; viz:

- the commercial sector had a very positive response often going beyond regulatory requirements
- volume home builders were not pro-active in embracing energy efficiency opportunities, but were able to rapidly adopt cost effective design changes in response to mandatory standards
- small residential builders were risk averse, only introducing energy performance improvements when compelled by regulation
- in particular small residential builders typically responded to regulatory requirements through the expensive pathway of increasing building specifications – rather than the more cost-effective, economically rational approach of design change

A key finding of the AECOM study was that the "traditional approach to estimating the cost impact of energy efficiency standards is likely to overestimate costs" by failing to account for industry learning and assuming an unreasonably expensive compliance pathway. The corollary of this finding is that many cost-benefit analyses undertaken by Governments at both state and national levels as the cornerstone of requisite Regulatory Impact Statement processes tend to *overestimate* the cost of satisfying new, more stringent building energy standards.

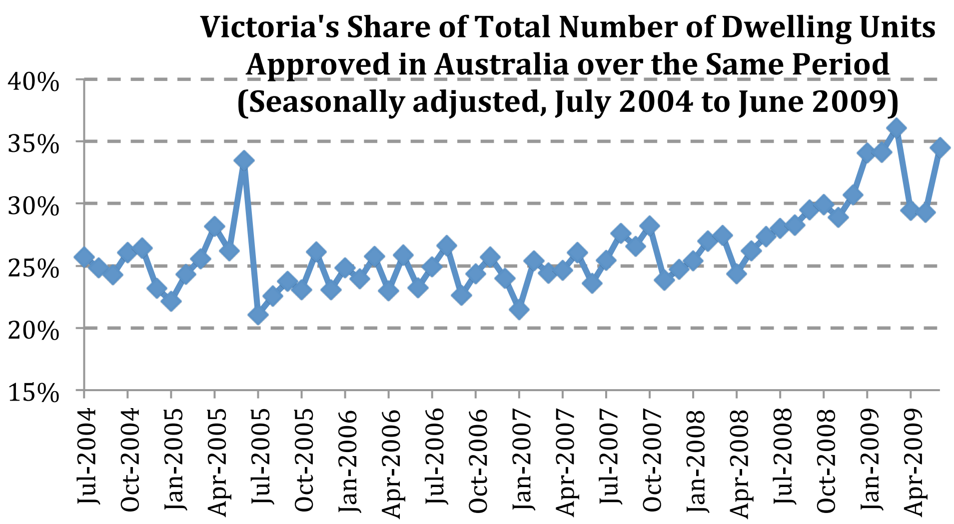
These finding suggests that further research is warranted into both the dynamics of industry responses to energy regulation [for example, in terms of building industry culture] and the basis of economic projections of the costs and benefits of compliance. In order to more effectively develop and implement new building standards through vehicles such as Australia's national Building Code.

2.5 Market Impacts: evident in practice?

The preceding discussion made reference to predictions by senior housing industry representatives that the new energy regulations would have dire consequences for the local housing market. It is certainly worthwhile examining these predictions with the benefit of hindsight so that we can now "learn the lessons of history" for future policy making.

Figure 2 illustrates the level residential building approvals in Victoria for the five-year period immediately following regulatory implementation of the 5 Star Standard on 1 July 2004. As a point of reference the performance of Victoria's residential housing market is compared with the national market as a whole.

Figure 2



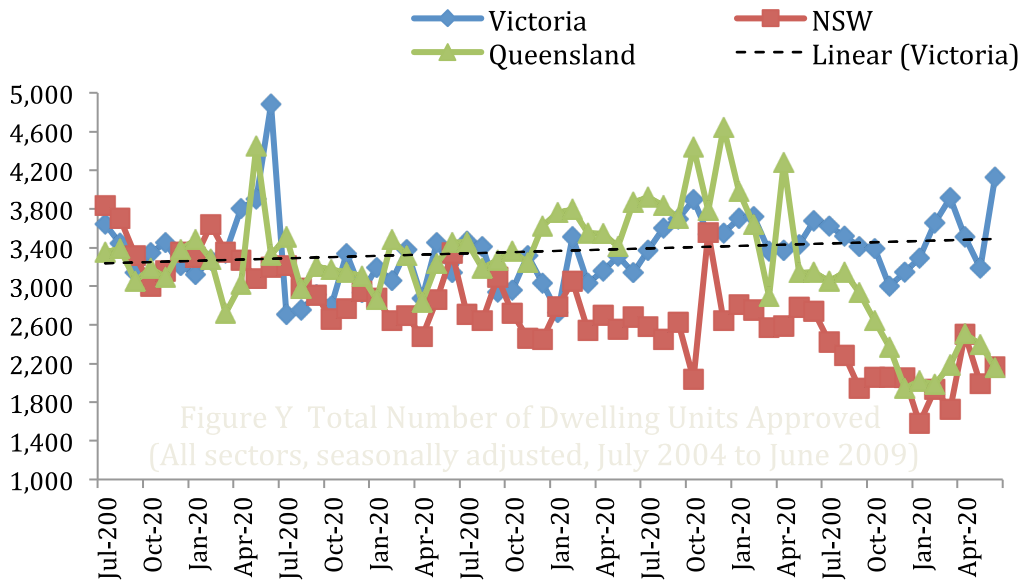
Apart from a slight dip in 2005/2006 the proportion of residential building activity taking place in Victoria during the 5 years following introduction of the 5 Star Standard hovers around the 25% level. With indications of a healthy up-kick in 2008/2009.

During the period in question the State of Victoria's population remained steady at just below 25% of the national population (Australian bureau of Statistics, 2014). So it would not be unreasonable to suggest that the level of residential building activity during the period in question is roughly commensurate with the State's share of national economic activity. Which does imply that the

Victorian building market at that time was generally performing in line with normal, healthy activity levels.

Performance of Victoria's housing market is compared with the two other most populous Australian states in Figure 3 during the implementation period for the 5 Star Standard. Building activity levels are susceptible to a wide range of external factors: such as national interest rate settings; immigration levels; industry capacity; and consumer sentiment. So one cannot say with complete confidence that either a positive or negative feedback relationship exists between the new energy regulation enacted in 2004 and the local housing market in the absence of more sophisticated statistical analyses.

Figure 3 Total dwelling approvals in major Australian states: 2004 - 2009



2.6 Independent review of the 5 Star Standard

The Victorian Competition and Efficiency Commission (VCEC) is an independent statutory body reporting to the State Treasurer whose mandate encompasses:

- *reviewing regulatory impact statements and advising on the economic impact of significant new legislation*
- *undertaking inquiries into matters referred to it by the Victorian Government*

In 2005 the VCEC was directed by the Government to undertake a comprehensive review of the state's housing regulations. This review included an investigation of the recently enacted 5 Star Energy Efficiency Standard.

In its subsequent report (Victorian Competition & Efficiency Commission, 2005) the VCEC made relatively minor criticism of the 5 Star regulation, finding that:

> *"Victoria's energy efficiency regulation (embodied in the 5 Star scheme) could be improved to better deliver at least cost against its*
> *objectives, including in the future as technology changes. Some improvements that should be considered are: implementation of the 5 Star scheme be more clearly related to the Victorian Government's energy efficiency objectives ……the scheme should incorporate more flexibility through the accreditation and use of more contemporary software "*

However the VCEC report made no specific reference to allegations of an excessive regulatory burden arising from the additional cost of constructing new homes to comply with the 5 Star regulation.

The Commission did examined regulatory compliance costs based on information provided by a limited sample of new homebuilders. It reported that that these were estimated to range from $250 to $30,000 (Victorian Competition & Efficiency Commission, 2005).

Notably a number of builders and designers in the sample set reported compliance costs in the range $10,000 - $20,000. This anomaly was explored in more detail earlier in this paper under "Industry Learning".

In its formal response to the findings of the VCEC inquiry the state government stated that:
"The Victorian Government regards the 5 Star scheme as an important initiative towards achievement of its energy efficiency objectives. Consumers already have considerable flexibility in meeting their obligation. Nevertheless the Government is actively pursuing progress in these areas …."

3 CONCLUSIONS:

The paper has analyzed the 5 Star Energy Efficiency Standard for Victorian residential buildings and shown that it was indeed an "effective regulation". It achieved the government's policy objective of energy efficiency and greenhouse gas abatement without significant detriment to housing affordability. Furthermore its introduction has paved the way for subsequent progressive reform along the same lines. Thus the effectiveness of the regulation is in line with other global understandings of how to implement change through regulation.

In detail this review of residential energy efficiency regulation using Victoria's 5 Star Standard as a case study has reached a number of conclusions concerning the role, effectiveness and possible unintended consequences of building regulation as a government policy instrument in driving the transition to a low carbon built environment.

These conclusions are summarized as follows:

1. On the evidence now to hand as a result of research over the last decade the government policy objectives for greenhouse gas abatement that led to regulatory intervention in 2002 were shown to have been met or even exceeded

2. The regulatory process itself would seem to demonstrate good regulatory practice when assessed against objective criteria

3. Cost benefit analyses of the projected regulatory cost imposts by government have tended to overestimate the magnitude of these impacts, while underestimating the wide ranging benefits

4. Formal regulatory impact assessment reports tended to underestimate both the capacity for the building industry to adapt to the new energy efficiency requirements and the relatively rapidity of such adaptation

5. Significantly, vehement claims by the housing industry that mandatory energy efficiency requirements for new home construction would have a deleterious impact on *housing affordability* are shown to have been unfounded on the basis of available evidence for the historical cost trajectory of energy efficiency costs

6. Nor was there found to be evidence of larger scale impacts on the performance of local

housing market as a whole; again contradicting expressed industry concerns at the time the regulations were introduced

4 FURTHER RESEARCH

This study has pointed up the need for and value of further research in a number of related areas in order to better inform future government policy initiatives in the area of energy efficient, low carbon [residential] buildings, for example:

- Benchmarking international best practice approaches to building regulation against local policy settings
- Examining industry learning processes in more detail
- Examining the process of consumer choice and its relationship with economically rational behaviour
- Coming to grips with the building industry culture and the interaction between peak industry lobby groups and government policy makers

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Appendix E

CESB 2016 - Central Europe Towards Sustainable Building: Innovations for Sustainable Future 2016: **Enker, R.A**., Building energy policy: why dollars don't always make sense; Conference Proceedings, CESB 2016, Prague, Czech Republic, pp 1366-1373. Publication 5

ENERGY POLICY FOR BUILDINGS: WHY ECONOMIC INTERVENTIONS MAY BE INEFFECTIVE

Abstract

A significant body of research confirms the major contribution that improved building performance can make to national energy and greenhouse abatement policies. The challenge facing governments is how best to realize the potential of energy efficient buildings. This paper reviews the effectiveness of economic instruments for building energy policy compared with alternative interventions such as building regulation and information campaigns. The approach taken to building policy by Lord Stern in his seminal climate change report is a cornerstone of this analysis, as is national policy development in Australia as this provided the foundation for this country's controversial carbon-pricing regime. Regulatory reforms to the Australian Building Code over a decade provide economic analysis to support a historical review of the environmental economics discipline. Formal building code development processes are interrogated to establish the strengths and weaknesses of market based approaches to building energy policy. Study findings confirm that conventional economic interventions are likely to be ineffective as a vehicle for reducing greenhouse gas emissions from the building sector despite the significant potential benefits available therein.

Keywords: building regulation, energy efficiency, greenhouse abatement, policy instruments

Introduction

A landmark report by the OECD (9) identified the building sector's significant contribution to energy consumption and greenhouse gas emissions in developed economies. Energy use in the building sector was estimated at 25–40% of the total in OECD member countries. Subsequent analysis by the McKinsey Company (8) concluded that the building sector offers excellent prospects for greenhouse gas abatement in developed economies. Improving the energy efficiency of buildings can deliver abatement at a *negative* economy-wide cost per tonne of CO_2. Which contrasts with significant cost burdens in other economic sectors such as centralized power generation and distribution. Analysis conducted for the International Panel on Climate Change [IPCC] by the Central European University (16) found that a reduction of almost 30% in building sector emissions could be achieved cost-effectively by 2020.

The paper analyses the comparative effectiveness of using economic instruments by governments in order to mitigate greenhouse emissions from the building sector. The analysis works from first-principle reflection on the principles of environmental economics; through consideration of market based intervention options; thence to referencing specific evidence-based reporting of market failures in the building sector in the Australian policy setting.

Principles of Environmental Economics

Defining the problem

The United States' National Environmental Protection Act 1969 was a milestone in environmental policy development. Policy makers were grappling with the best mechanisms for achieving environmental quality objectives being articulated in legislation. Intense and on-going debates began between advocates of "command and control" policies, which rely on statutory mechanisms to enforce prescribed outcomes, and policy analysts who favoured notionally more flexible "market based" policy measures. Application of economic levers to environmental policies provided many alternatives for policy implementation, ranging from waste charges through pollution levies to pollution control subsidies.

The early focus of environmental policy was essentially local, dealing with industrial waste discharges to regional air sheds; watersheds and freshwater or marine water bodies. Diffuse pollution at a regional or global level had not yet reached the policy agenda. New challenges arose in the 1980s with growing awareness of the significance of global environmental issues such as the ozone hole and greenhouse effect. These concerns culminated in signing of the UN Framework Convention on Climate Change at the 1992 Rio de Janeiro Earth Summit. The objective of this treaty is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system" (13). The 1997 Kyoto Protocol links to the 1992 Convention; the Protocol emphasizes use of market-based instruments to reduce global greenhouse gas emissions.

Economic tools for environmental protection

David Pearce's early work on Environmental Economics (10) provided a strong conceptual basis for addressing environmental problems using economic instruments. When analysing pollution control methods Pearce discusses the choice between environmental regulations and economic instruments and also, with remarkable prescience, raises the issue of "Pigouvian" taxes. These taxes represent a public policy response to the external, societal costs of pollution by levying charges on pollution generators.

Grafton (5) provides a comprehensive overview of the role to be played by market-based economic instruments in relation to climate change policy. In structure these options include either carbon taxes or emissions trading schemes [ETS]. The latter in turn can either have a cap-and-trade or a baseline-and-credit structure[1]. According to Grafton countries seeking cost-effective policies that embrace the rationale underpinning the Kyoto Protocol have tended to favour emissions trading over carbon taxes. This is because an ETS provides certainty about the *quantity* of greenhouse gas abatement. Compared with a tax, which provides greater certainty about the *cost* of abatement. Grafton explains that market-based instruments "are often a necessary but not sufficient [policy] measure when more than one market

[1] Cap-and-trade scheme: ETS scheme where limits are set on total emissions from specific sources to define permit levels
Baseline-and-credit scheme: form of ETS where desired emission levels are used to credit reductions relative to the baseline

failure exists". The market for energy efficient buildings will be shown to suffer from a range of substantive market failures in later sections of this paper.

The Stern Report

Lord Nicholas Stern's report to the British Government in 2006 (12) represents a historic milestone in both climate policy and the application of economic analysis to a global environmental problem. Stern recommended strong and early action to stabilize emissions asserting that "policy to reduce emissions should be based on … carbon pricing, technology policy, and removal of barriers to behavioural change".

Lord Stern's conclusions concerning energy efficiency

Part IV of Lord Stern's report recognizes the need for climate change policies that go beyond simply pricing emissions and supporting technology development. Stern observes that "even if these measures are taken, barriers and market imperfections may still inhibit action, *particularly on energy efficiency*" [emphasis added]. Stern argues that such "market imperfections" represent obstacles to the uptake of prudent mitigation options and diminish the uptake of technological innovations for energy efficiency. Although the Garnaut Report, Australia's key climate policy setting document (4) recommended an ETS as the policy cornerstone, the report also recognized the need for a suite of *complementary measures* to be adopted to address numerous identified market failures that obstruct uptake of energy efficiency opportunities in the building, transport and industry sectors.

Energy policy for buildings: instruments and options

Governments generally have a range of options available once a decision has been made to focus national greenhouse abatement policy on the built environment:

- *Economic measures* utilizing either positive or negative financial incentives
- *Direct regulation* by setting performance standards through building codes or similar instruments
- *Public information campaigns*, both targeted and broad-brush
- *Developing industry capacity* to facilitate market transformation

Research conducted for the United Nations Environment program (14) in an "Assessment of Instruments for Reducing Greenhouse Gas Emissions from Buildings" compares the effectiveness of the policy instruments available to governments to mitigate greenhouse gas emissions from the built environment. The study assessed the potential effectiveness and efficiency of policy instruments including building codes and appliance standards. Appliance standards and building codes were found to be "high" in effectiveness; although the efficiency of building codes was limited by lack of incentives to exceed minimum compliance standards. Economic instruments such as carbon taxes were judged to be "low" in both efficiency and effectiveness.

Further evidence for the transformative role of building codes on building performance is to be found in a report for the International Energy Agency (7) which observed that "buildings are characterized by a life expectancy of many decades … while planning for energy efficiency at the design stage is relatively simple and cost effective, subsequent improvements in service may be problematic or simply impractical".

Economic basis of Australian building regulations

In the Commonwealth of Australia standards for all aspects of building performance are enshrined in the National Construction Code [NCC]. A rigorous institutionalized process operates in Australia for managing building code reforms. Government guidelines require changes to the NCC that might impose an additional cost burden on the community to be subject to detailed regulatory impact assessment including economic analysis (3). A key principle is that government intervention is justified only in situations of *demonstrated market failure.* Regulatory development processes are underpinned by a public document known as a Regulatory Impact Statement [RIS] that comprehensively addresses alternative policy options, considering both regulatory and non-regulatory approaches.

For to the NCC the RIS document is required to justify proposed measures by means of a cost-benefit analysis methodology detailed by the Australian Building Codes Board (G20 Group), the national body responsible for administering the Code. In the course of developing Australia's building energy standards over the last decade a series of RIS reports have been prepared for the national government. These reports not only demonstrate the benefits of energy efficiency standards enacted through the building code but also provide a source of independently verified evidence on the strengths and weaknesses of alternative energy efficiency policy instruments, whether fundamentally regulatory or economic in nature.

Eight individual RIS documents have been examined for the purposes of this paper; their findings are detailed in Table 1. Since each RIS must make a credible case for regulatory intervention by demonstrating the lack of effectiveness of alternative policy measures the document provides powerful insights into the relative merits of alternative policy vehicles for reducing building sector emissions. The finding that emerges from examination of these RIS reports is that conventional economic measures are ineffective in reducing buildings' emissions when compared with regulation of building performance through mandatory setting of energy performance standards. On evidence presented in the RIS reports the futility of pursuing economic policies lies in the fact that the building sector is characterized by numerous market failures that impede uptake of energy efficient building practices but are not amenable to correction through economic means.

Market failures in the building sector: the evidence

Table 1 confirms that widespread incidence of market failure in the building sector has been identified through Australia's formal regulatory impact assessment processes:

1. *Public goods* available to all without a direct charge and are consequently undervalued
2. *Externalities:* market transactions affecting third parties are not incorporated into the cost of the transaction; carbon pollution being a classic example

3. *Information failures:* inability to readily obtain and comprehend information on the lifecycle costs and benefits of energy efficient buildings
4. *Split incentives:* project builders and developers typically have little investment incentive as they don't have to pay buildings' operating energy costs, whose burden falls upon property owners or tenants
5. *Information asymmetry:* homebuyers' relative lack of knowledge and experience with the various benefits of energy efficiency puts them at a clear market disadvantage

Table 1 *Australian Regulatory Impact Statements for Building Code energy efficiency measures*

Report title and [reference]	Date	Identified market failure mechanisms	Economic benefits
Regulatory Information Bulletin: residential buildings [Victoria]	9/2002	• Public goods Natural monopolies • Information failures	NPV[2] $570M
Energy measures: BCA Volume 2 [RIS2002/04]	12/2002	• Policy options only include regulation by definition	NPV $485M
Proposal to Amend the BCA: Energy Efficiency for Residential Buildings other than Housing	2/2004	• Externalities not factored into market decisions • Aggregation of private decisions not socially optimal	BCR[3] 1.66:1
Energy Efficiency for BCA Class 5-9 Buildings [RIS 2005-01]	3/2005	• Externalities not accounted • Split incentives • Inadequate market information	BCR 4.6:1
Proposal to amend BCA to increase energy efficiency requirements for housing [RIS 2005-02]	4/2005	• National energy policy measures complement BCA mandatory standards	BCR 1.53:1
Proposal to amend BCA to increase energy efficiency for housing [RIS 2006-01]]	3/2006	• Consumers don't pay full cost of energy production • Market complexities obstruct rational decision-making	BCR 1.27:1 abatement cost -3.6c/kg CO_2
Revised Energy Efficiency Requirements for Residential Buildings [RIS 2009-06]	09/2009	• Inelastic Energy demand: not responsive to market signals • Market barriers not addressed by carbon price	BCR 0.88 NPV -$259M
Revised Energy Efficiency Requirements for Commercial Buildings [RIS 2009-07]	12/09	• Split incentives • Capital constraints • Excessive transaction costs	BCR 1.6:1 abatement cost -70c/kg CO_2

The benefits of regulation

Cost-benefit ratios in Table 1 are quoted in government RIS reports where conventional economic techniques were used to compare capitalized building costs for improved design performance nation-wide in Australian with

2 NPV – net present value
3 BCR – benefit/cost ratio

anticipated benefits of fuel savings from energy efficiency. Rather than attempt to a problematic conversion of historical costs to current dollar values taking inflation into account, Benefit Cost Ratios have been used to compare the results of economic analyses undertaken during the review period 2002-2009.

Detailed analysis of the RIS reports as outlined in Table 1 also yields information on the potential economic benefits resulting from mandatory building energy standards including greenhouse abatement cost savings of up to $70/tonne CO_2 and generally positive benefit: cost ratios ranging from 1.27:1 as high as 4.6:1. To put these abatement costs into perspective, the McKinsey Company has estimated costs in $/tonne CO_2 of a wide range of potential global emission reduction strategies (17).

Economic principles

It is beyond the scope of this paper to critique the principles of neo-classical economic theory that provide the foundation for application of market-based economic instruments to environmental problems such as climate change. Still, the reader's attention is drawn to a growing body of literature that does address this issue. For example in the works of Keen (6), Quiggin (11), Ormerod (18) and Davies (19). Key doctrines used in the application of market economics to the climate change problem are discussed in the following sections. Denniss' recent critique (21) is also pertinent to this analysis.

Climate change economics: are these actually blunt, ineffective instruments?

Market approach: general principles

Free trade in the market is assumed to determine efficient allocation of environmental goods. However as Grafton (5) points out, achieving economically efficient resource allocation, meaning effective market operation, is contingent upon both *well defined property rights* and prices that *include all externalities*. Which is a rather improbable state of affairs according to critiques of market economics by Davies (19) and Denniss (21).

The Coase Theorem

Ronald Coase's influential "Theory of Social Cost" states that assignment of a property right can be used to internalize an externality - as in the case of emission trading schemes. The critical caveat on application of Coase Theorem to climate change policy is that it holds true *only under quite idealized circumstances* (5) such that:

- Market actors do not behave strategically;
- Transaction costs are zero; and
- Information is perfectly accessible to market participants

Pigouvian tax

The work of economist AC Pigou (G20 Group) provides the conceptual basis for the design of taxes applied to emissions or pollution designed to internalize environmental externalities. An emissions trading scheme is the archetypal example of a Pigouvian tax. Such a scheme is has been subject to criticism, including reservations expressed by Pigou himself, since it requires policy makers to possess market information that may be unobtainable in practice as Denniss (21) points out.

Case study: Australia's experience with climate change policy

In hindsight, Australia's troubled experience with climate change policy provides a useful case study illustrating the general issues being canvassed in this paper.

Policy foundations

Climate change policy in Australia was the outcome of analysis undertaken for the Australian Government in Professor Garnaut's Review (4), which found that climate change was expected to have a "severe and costly impact on agriculture, infrastructure, biodiversity and ecosystems in Australia"; however "these impacts would be significantly reduced with ambitious global mitigation". Garnaut concluded that "a well designed emissions trading scheme has important advantages over other forms of policy intervention"; and that "the role of complementary measure is to lower the cost of meeting emissions reduction trajectories, as well as correcting market failures".

Policy implementation

Because Professor Garnaut examined policy options through an economic lens it is unsurprising that his recommendations favour the use of economic instruments by recommending introduction of an ETS. Nevertheless explicit reference was made in this report to the value of *complementary measures* to support the proposed carbon pricing mechanism. By adopting Garnaut's recommendations to introduce an ETS in 2012 the national Labour Government caused a storm of political controversy and spawned political opposition that contributed to its subsequent loss of office. In 2014 incumbent Liberal Government repealed the ETS, ending the nation's brief experiment with carbon price based climate policy.

Despite Australia's dramatic experience with climate policy one might well ask whether the abortive ETS would actually have had a significant moderating influence on emissions from the building sector in the long run? Evidence presented in this paper suggests not.

Conclusions

The importance of greenhouse gas emissions from the building sector demands prompt, effective response from national governments; which have a range of potential policy responses. Application of economic instruments to environmental protection has a history of success in addressing both point source and diffuse pollution. However analysis provided herein suggests that simple translation of conventional economic instruments to building sector emissions policy is beset by fundamental weaknesses that inhibit effective deployment.

Lord Stern's advice that market imperfections are relevant to energy efficiency initiatives has been applied to examination of the Australian building code regime to demonstrate that the building sector is beset by pervasive *market failures*. Established failure modes include split incentives, non-costing of externalities, lack of consumer information and excessive transaction costs. Many assumptions underpinning the application of economic instruments such as carbon pricing are open to challenge in that they rely on questionable models of idealized market behaviour embodied in doctrines such as the *Coase Theorem* and *Pigouvian* taxation models.

The Australian case study further demonstrates that building performance standards contained in the National Construction Code will not only deliver national climate policy objectives but also provide substantive economic benefits [positive benefit: cost ratios and Net Present Values] together with cost-effective abatement outcomes in terms of negative cost/kg CO_2.

These findings imply that governments would do well to deploy non-economic policy instruments such as mandatory building codes in order to address the rapidly escalating greenhouse gas emissions attributable to the global building sector (16).

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Appendix F

Sustainable Engineering Society of Australia 2015 Conference: Enker, R.A., The evolution of building energy standards in Australia: a journey interrupted? Conference Proceedings, Adelaide, Australia, September 2015 (unpublished).

The Evolution of Australia's Building Energy Code: A Journey Interrupted?

ABSTRACT

Extensive analysis over the last decade has demonstrated that in developed economies such as Australia energy use in buildings is one of the most significant contributors to the nation's aggregate greenhouse gas emissions. But what is even more significant and possibly yet to be fully appreciated by policy makers is that reducing greenhouse gas emissions from the building sector provides a range of social and economic benefits in addition to anticipated environmental benefits. In fact greenhouse abatement from buildings can actually be delivered at a negative cost/tonne $CO_{2.}$ Compared with significant societal cost burdens arising from alternative abatement strategies such as carbon capture and storage.

International policy responses to this realization have been evolving and growing in sophistication over the last decade. Options for government intervention in the building market broadly encompass: regulation; financial incentives or penalties; consumer information campaigns and industry capacity building.

All of these policy measures have been adopted in Australia with varying degrees of success and effectiveness.

This paper focuses specifically on the continuing evolution of building energy efficiency standards in the Commonwealth of Australia. By following the trajectory of energy efficiency provisions in the national Building Code, and examining the current status of this area of government energy policy in the context of other initiatives such as the Federal Government's Direct Action Program.

Most importantly the paper benchmarks Australia's building energy code against international best practice policy frameworks in European and North American jurisdictions. This analysis takes into account key factors such as regulatory stringency, policy implementation processes and enforcement measures, in order to sketch out a roadmap for the future building code that is suited to the needs of an emerging Low Carbon Economy.

Introduction

Extensive policy analysis over the last decade has demonstrated that in developed economies such as Australia energy use in buildings is one of the most significant contributors to the nation's aggregate greenhouse gas emissions. However, more significant and yet to be fully appreciated by policy makers is that reducing greenhouse gas emissions from the building sector provides a range of social and economic benefits in addition to anticipated environmental benefits. Greenhouse abatement from buildings can actually be delivered at a negative cost/tonne CO2. Compared with significant societal cost burdens arising from alternative abatement strategies such as carbon capture and storage. This paper focuses specifically on the continuing evolution of building energy efficiency standards in the Commonwealth of Australia. This is achieved through following the development of energy efficiency provisions in the national Building Code, then moving on to an examination of this area of government energy policy in the context of other initiatives such as the Federal Government's Direct Action Program.

Background

As early as 2003 the Organization for Economic Cooperation and Development [OECD] (Organization for Economic Cooperation & Development, 2003) drew attention to the fact that the building sector not only contributes significantly to GDP and employment in developed economies but also contributes significantly to energy consumption and greenhouse gas emissions in these countries. Energy use in the building sector was estimated at 25–40% of the total in OECD economies. In the Australian setting which is subject to detailed analysis in this paper, a more recent estimate of greenhouse gas emissions from residential and commercial buildings is that these comprise 23% of the national total (Centre for International Economics, 2007).

A key attribute of building sector emissions has been identified in ground breaking analysis undertaken by the McKinsey Company (McKinsey Company, 2009). Subsequently this analysis was updated locally (Climateworks, 2013). The key findings of these analyses were twofold. Firstly, that the building sector offers potentially the best possible prospect of all for greenhouse gas abatement. Secondly, that improving the energy efficiency of buildings using conventional and proven technologies could actually deliver greenhouse abatement at a *negative* economy-wide cost per tonne of CO_2. In contrast to a significant cost *burden* arising from abatement in other areas such as the power generation sector for example.

The World Business Council for Sustainable Development [WBCSD] succinctly puts the case for reform of the building sector (World Business Council for Sustainable Development, 2009):

> *Buildings worldwide account for a surprisingly high 40% of global energy consumption, and the resulting carbon footprint, significantly exceeding those of all transportation combined. Large and attractive opportunities exist to reduce buildings' energy use at lower costs and higher returns than other sectors.*

Global estimates of the potential for carbon dioxide mitigation from the world's buildings were calculated in a detailed analysis conducted for the IPCC by the Central European University (Ürge-Vorsatz and Novikova, 2008). This analysis found that a reduction of almost 30% could be achieved cost-effectively by 2020. The Ürge-Vorsatz study also reinforced the message that the building sector has the largest potential for abatement among all sectors reported by the IPCC.

Turning specifically to Australia, analysis of the national economy by CIE for the Australian Sustainable Built Environment Council (Centre for International Economics, 2007) translated such potential abatement gains into explicit economic terms. CIE's projections suggest that:

- *The building sector as a whole could reduce its share of GHG emissions by 30-35 per cent whilst accommodating growth in the overall number of buildings by 2050.*
- *This can be achieved by using today's technology to significantly reduce the energy needed by residential and commercial buildings to perform the same services.*
- *Energy efficiency gains delivered by the building sector can reduce the costs of GHG abatement for all sectors by nearly 14 per cent by 2050.*

So the key policy questions become: what role is there for government policy intervention in the property market in order to facilitate these *potential* economic and environmental gains; and which *policy instruments* should government choose to employ for the task?

The work of Ürge-Vorsatz et al at the Central European University also extended into an appraisal of policy instruments (ürge-Vorsatz et al., 2007) in analysis which was incorporated into a definitive report by the UN Environment Program (United Nations Environment Program, 2007). The UNEP report examined a range of regulatory instruments including building codes and appliance standards. Australian policy makers have employed both these approaches. Commenting on the importance of building codes in improving energy efficiency, UNEP highlighted two potential limitations to their effectiveness: difficulties with compliance and enforcement; and application only to new buildings.

Further evidence for the transformative role of building codes in relation to buildings' energy performance is to be found in a report by the International Energy Agency (Laustsen, 2008). The IEA report noted that buildings are characterized by a life expectancy of many decades; where refurbishment to substantially improve performance may only occur at long intervals; and that while planning for energy efficiency at the *design stage* is relatively simple and cost effective, subsequent improvements in service may be problematic or simply impractical.

Hence "energy efficiency requirements in building codes or standards are therefore among the most important single measures of buildings' energy efficiency" (Laustsen, 2008).

The same conclusion is reached in a report published by the European Climate Foundation (Chalmers, 2014) in which findings from the Fifth Assessment Report of the IPCC are analyzed in terms of their implications for buildings. In concluding that energy demand from buildings could be cut by 50% by 2050 Chalmers notes that well designed and implemented building codes and appliance standards are among the most effective emission reduction instruments.

Developing Australia's Building Energy Code

In the Commonwealth of Australia standards for all aspects of building performance are enshrined in the National Construction Code [NCC]; which was formerly known as the Building Code of Australia [BCA].

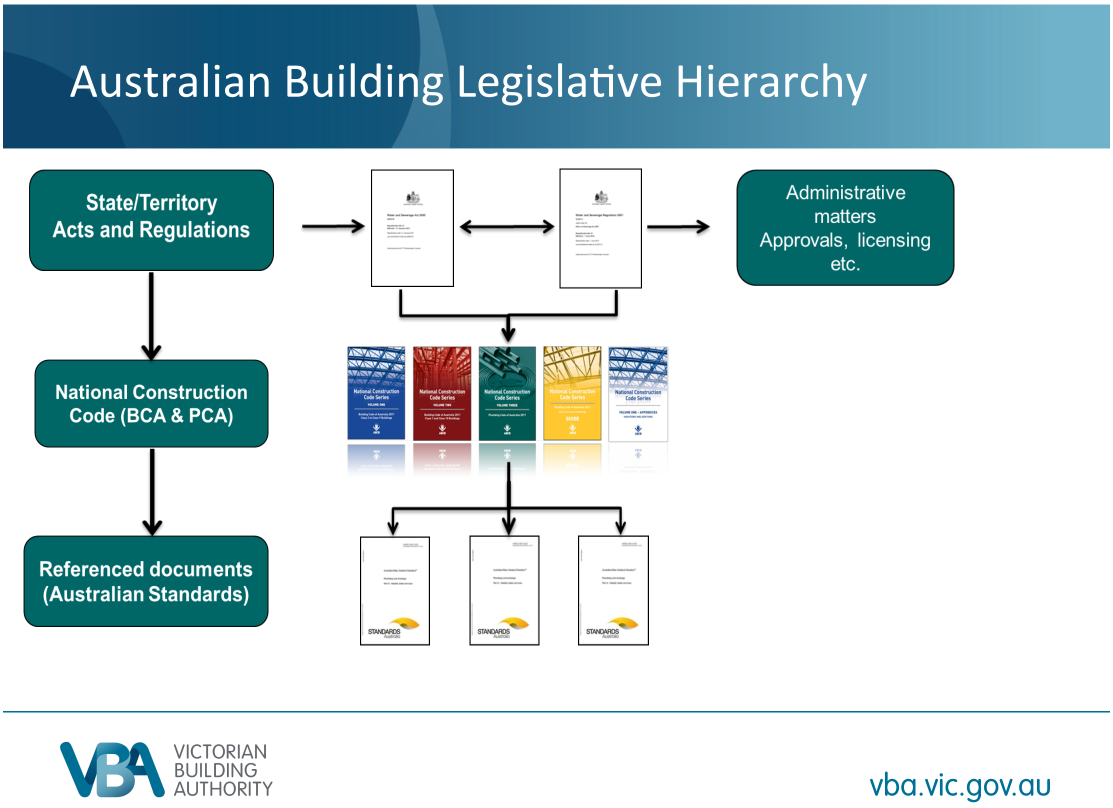
The structure of Australia's legislative regime for building regulation is illustrated diagrammatically in Figure 1. Under this hierarchy the NCC is given effect through the legislation of individual State and Territory jurisdictions; while administrative arrangements for Code implementation remain a state jurisdictional responsibility. The NCC in turn receives detailed technical support from a series of referenced Australian Standards.

The essential role of the NCC is to set uniform building and plumbing standards across Australia that relate to performance outcomes in key policy areas such as health, safety, durability; as well as sustainability since 2006.

Energy efficiency measures for buildings have a long history in Australia (Australian Greenhouse Office, 2000), going back to the late 1970s when voluntary energy guidelines were first published by government and industry. Mandatory energy efficiency standards for residential buildings were first introduced by the State of Victoria in 1990 through its local building regulations (Victorian Government, 1993).

Progressive introduction of *national* energy efficiency provisions for all classes of buildings in the BCA did not commence until 2003 under a strategic program set out by the Australian Building Codes Board in its *Directions Report* (Australian Building Codes Board, 2001) indicating that the work would take until 2004. In fact this progressive roll-out took until 2006 to implement.

Figure 1 Australia's building legislation



In 2009 a policy decision was taken by the Building Ministers Forum, peak national building policy setting body reporting to the Council of Australian Governments, to reform the initial tranche of NCC energy efficiency provisions for all building classes by ramping up stringency. Under national legislative requirements, changes to the NCC that potentially impose an additional cost burden on the community at either at the business or consumer level are subject to a transparent public consultation process underpinned by a formal Regulatory Impact Statement [RIS]. The RIS makes the case for the proposed regulatory reform and justifies the planned measures, including their stringency, by means of a prescribed cost-benefit analysis methodology (Australian Building Codes Board, 2011).

Although inclusion of energy efficiency measures in the national building code was explicitly supported from the outset by national energy policy such introduction encountered a measure of controversy and resistance from sectors of the building industry. These objections to both the introduction of BCA energy efficiency provisions in 2003/4 and their progressive reform in 2006 and 2009 were particularly intense in the residential building sector. Such resistance reached its zenith during the 2009 public RIS process and even included significant media coverage at the time (Andrew Brasier, 2010 #143).

Industry critics asserted that more stringent building energy requirements would add significantly to the initial cost of new homes, impacting on their affordability for consumers, thereby adversely effecting the whole residential building sector. This argument was seen to be particularly applicable to the price-sensitive first-home buyers' market segment.

THE STATE OF PLAY

Now that a decade has elapsed since the introduction of the initial NCC/BCA energy efficiency provisions it is timely to review their current status and future direction as a policy instrument for Government. A review is also timely in view of the current public policy debate in Australia concerning the Commonwealth Government's responses to the challenge of climate change.

A recent influential report by the International Energy Agency provides a useful template for considering the "policy pathway" for a review and even potential overhaul of the national building energy code (International Energy Agency, 2013).

The IEA recommends that "the pathway to improving energy within the buildings sector through the deployment energy codes" should include the four phases which are familiar to the exponents of quality management systems: plan, implement, monitor and evaluate. In effect this paper is concerned with the "evaluation" phase of the standard *Plan-Do-Check-Act* cycle familiar to exponents of Quality Management Systems. Of course undertaking such evaluation is contingent upon the availability of relevant monitoring data concerning implementation and effectiveness of Australia's national building energy code.

According to the current work program of the Australian Building Codes Board (Australian Building Codes Board, 2015a) in relation to the reform of energy efficiency provisions in the Code is primarily concerned with maintenance issues rather than active regulatory reform or potential increases in stringency. Board activities on energy efficiency include tasks such as: monitoring development of the National Strategy for Energy Efficiency; maintaining the relationship with Administrator of the Nationwide House Energy Rating Scheme; and participating in the National Energy Efficient Building Project - of which more discussion follows below.

The rather passive nature of these activities is not indicative of a current appetite for regulatory reform. In a recent document "The Next Installment in Building Regulatory Reform" (Australian Building Codes Board, 2015b) the Board refers to a series of planned and unquestionably worthwhile reforms such as: making the NCC available free online; digitizing the NCC; moving to a three-year amendment cycle; and including *Quantified Performance Measures* in the 2019 NCC Amendment cycle. However this planned reform program includes *no commitment* to reviewing or revising the current suite of energy efficiency provisions in the national Building Code.

Because the NCC amendment cycle will move from an annual to a triennial basis from 2016 the first opportunity to reform the existing energy efficiency provisions would arise in NCC 2019. Even then prior completion of necessary regulatory impact analyses would be problematic. Meaning that reform of energy efficiency could be delayed until NCC 2022. A rather unfortunate scenario given that the last tranche of NCC energy efficiency reforms were approved in 2009.

The case for applying greater urgency and energy to developing and promptly implementing NCC energy efficiency reforms will be developed below.

INTERNATIONAL BEST PRACTICE: EXEMPLARS

In order to put Australia's building energy code into an international context it is necessary to examine contemporary regulatory developments in the European Union and the United States.

The European Union

The European Union [EU] comprises 28 member states that are party to the founding treaties of the union and thereby subject to the obligations of membership. Constituent states of the EU must adhere to its binding laws in exchange for representation within the common legislative and judicial institutions. Like the Commonwealth of Australia the EU embraces a wide range of climate zones from the Finnish arctic in the north to the Mediterranean climate of Greece, Malta and Cyprus at its southern perimeter.

Regulation of buildings' energy efficiency is based on EU Directives that member states are bound to implement. The governing document is the Energy Performance of Buildings Directive, [EPBD - Directive 220/91/EC], introduced in 2002 and revised in 2010. The EPBD sets performance levels for new and for existing buildings undergoing major renovations.

Crucially the 2010 revision of the EPBD requires that all new buildings constructed after 2020 must by "nearly zero energy buildings" [nZEB]. This is a challenging, visionary and ambitious objective. A number of individual EU jurisdictions also commit to regular, frequent code revision processes (Levine, 2012). The UK has acted to move ahead of the EPBD target with its "zero carbon homes" policy. Introduction of the *Code for Sustainable Homes* in 2006 included a commitment that from 2016 all new UK homes would be zero carbon. In 2008 the UK government announced its intention that new non-residential buildings would also be zero carbon from 2019 (Designing Buildings Limited, 2015).

The European situation is not dissimilar to Australia in regard to the actual enforcement of building standards. Just as in the European Union, where compliance rates vary significantly between members countries and data is lacking (Levine, 2012), so it is that in the Australian Commonwealth enforcement is the responsibility of individual State and Territory building administrations – with varying levels of success. Accurate data on compliance rates appears to be lacking in the EU as is also the case in Australia.

Levine et al point out that setting the stringency of building performance standards is a matter for individual EU Member States and varies widely with no simple method for comparison or standardization. In this regard the consistent application of performance requirements in the NCC gives Australia a clear advantage.

The challenge of enforcing ambitious building energy standards is articulated by Pan & Garmston in their review of England's Building Regulations Part L (Pan and Garmston, 2012). According to Pan the low compliance rates discovered in this review call into question the UK Government's policy objective for new build homes to be zero carbon by 2016.

Like other regulatory instruments internationally Australia's building energy code sets *minimum* building performance levels. In relation not only to energy efficiency but also other regulated building performance attributes. So a key policy challenge becomes: how to encourage building designs that exceed minimum regulatory standards where this is a societally desirable outcome? Otherwise there is a risk that design standards in practice will tightly cluster around, or frequently just above, the prescribed minimum regulatory level. One vehicle for encouraging developers to exceed minimum standards exists in the EU in the form of voluntary standards for constructing or renovating buildings to high energy performance levels. Both the *PassivHaus* [GDR] and *Minergie* [Fra] building certification frameworks provide such voluntary design benchmarks for energy efficiency that go beyond regulatory compliance levels.

Development and publication of Energy Performance Certificates is another crucial requirement of the EPBD designed to *complement* energy efficiency requirements of the Directive at the design stage by providing transparent market information on in-service building performance. The certificates display a buildings' energy performance relative to its peer group. Display is mandatory at construction, sale or rental of residential and commercial buildings. The intention being to promote the factoring of energy efficiency characteristics into decisions being made by building owners, tenants and purchasers at various stages of building's life cycle (ADENE, 2012 #1308).

In this context the Global Building Performance Network finds that the:

> *EPBD remains perhaps the most ambitious, transformative and influential policy worldwide that addresses energy use in buildings* (Levine, 2012)

In 2012 the EU adopted a further Energy Efficiency Directive (European Union, 2012 #1309) that requires member nations to establish long term strategies for mobilizing investment in the *renovation* of public and private building stocks.

The United States

US states began implementing building energy codes as far back as the early 1970s. Under the US federal structure individual states have autonomy to develop, adopt and implement building codes. Local jurisdictions, generally at state level but also at municipal level, typically adopt either the American Society of Heating Refrigeration and Air-Conditioning Engineers [ASHRAE] code or that developed by the International Conservation Council, the International Energy Conservation Code [IECC]. These codes go through regular and relatively frequent review cycles that ensure compatibility with current developments in building technology, with the result that "the codes become tools for market transformation" (Levine, 2012). While it is true that most US states have adopted a version of either national model code, some do lag years behind (Deason, 2011).

To facilitate progress by individual states the federal Department of Energy [DOE] provides resources for code development and incentives to encourage adoption of contemporary versions of the model codes. A wide range of support services is provided by the DOE in support of code uptake by individual states, leading ultimately to market transformation. These services include technical support to regulators for code adoption processes; resources available to industry stakeholders for compliance improvement; compliance software tools and training materials (Livingston, 2014).

Most states typically choose to set stringency levels based on recent versions of the ASHRAE and IECC models. While California provides a noteable example of national leadership. The state has adopted a mandatory energy code that is 12% more stringent than the IECC. Stringency levels vary according to climate zones; and a variety of compliance pathways are available.

The United States has had limited experience with voluntary building energy labeling schemes and does not mandate building certification in the same way as the EU does through its EPBD scheme. Mandatory schemes have tended to be enacted at a state and municipal level (Levine, 2012) rather than through a concerted national push.

The Building Energy Codes Program [BECP] maintained by the DOE provides a central information resource and clearing-house for the building energy code implementation process at a local level. Where the BECP stands out is in its deliberate, periodic assessment of program effectiveness. For example the analysis by Livingston et al (Livingston, 2014) not only assessed the historical impact of US building energy codes over the period 1992-2012 but also projected ongoing code impacts out to 2040. An assessment such as this provides policy makers with a useful tool. The report's findings also make a strong base for ongoing reform of US building energy codes by providing evidence of outcomes achieved in terms of energy and cost savings. But not greenhouse gas abatement one should point out.

The US market also stands out for the wide range of financial incentive programs to support adoption of the building energy codes. Which is not surprising given a national focus on market based policy instruments. While detailed investigation of this area of energy policy is beyond the scope of this paper reference is made to a useful overview by the Alliance to Save Energy (Alliance Commission on National Energy Efficiency Policy, 2013) which discusses the operation of energy efficiency investment support mechanism in both public and private sectors. These varied mechanisms include utility programs, energy services performance contracting, energy efficient mortgages, state and municipal loan programs.

The Question of Stringency: How high to Set the Bar?

In a landmark benchmarking exercise undertaken for the Australian Greenhouse office in 2005 the stringency of Australia's national residential energy standards was compared with those of leading jurisdictions in the northern hemisphere (Horne, 2005). Table 1 draws upon the findings of this review to illustrate the comparative stringency of US, Canadian and UK residential building code requirements - expressed using the Australian NatHERS rating scale[1]. International building energy standards are compared with the 5 Star regulatory requirements introduced nationally in Australia in NCC 2006.

[1] NatHERS is the Nationwide House Energy Scheme for rating residential building energy efficiency, maintained by the Dept. of Science & Industry; the rating scale extends from 1 – 10 Stars

Table 1 Comparative stringency: NCC 5 Star requirements compared with selected US, UK, Canadian codes using the NatHERS scale (Horne, 2005)

Australian Location	**Comparison location**	**Benchmark rating (sample mean)**	**NCC 2006 Star rating**
Darwin	Florida	7	5
Brisbane	Texas	6	5
Perth Sydney	California (Bakersfield)	7.5	5
Melbourne	California (San Francisco)	7.6	5
Hobart	UK Canada	7.2	5
Average all climate zones		*6.8*	*5*

It is evident from Table 1 that the stringency of Australian building energy code provisions lagged well behind international best practice as far back as 2006. By an average of almost 2 Stars on the local NatHERS rating scale.

Since the 2005 AGO study the stringency of Australia's residential energy efficiency provisions has been raised from the 5 Star to a 6 Star stringency level [in NCC 2009], equivalent to a 24% stringency increase in the Melbourne climate zone. During the same period the UK building code began transitioning to the 2016 zero carbon target for residential buildings; and the IECC building energy code that is widely adopted for residential buildings in the US was regularly updated in 2006, 2009, and 2012 (Deason, 2011).

To this time a stringency benchmarking exercise has not been undertaken to compare Australian building energy code provisions for *commercial* buildings with international best practice. However it is possible to make an observation about the potential opportunity for stringency increase in NCC commercial building energy provisions. Based on the criterion that stringency increases are viable to the point where the economic cost benefit ratio exceeds unity.

In the last review of these energy efficiency provisions (Australian Building Codes Board, 2009) the cost benefit ratio was assessed as 1.6:1 by ABCB consultant the Centre for International Economics. Suggesting a degree of latitude for further reform the along same lines as the regular reviews of EU and US building energy codes during the same period.

Australia's National Building Energy Efficiency Project: a Crucial Critique

The report of the Australia's National Building Energy Efficiency Project [NEEBP] (Pitt & Sherry, 2014) is arguably the first *comprehensive* review of the NCC energy efficiency provisions since their initial implementation in 2003. Although an earlier evaluation of the 5 Star energy efficiency provisions (CSIRO, 2013) was a step in this direction, it was intentionally focus narrowly on the residential sector. The NEEBP report produced findings that received wide media coverage and stakeholder interest. It was seen by some commentators (Johnson, 2015 #1310) as a damning critique of Australia's building energy code; but is a somewhat parochial evaluation in comparison with the international benchmarking exercise on which this paper is grounded.

Pitt & Sherry's review included almost fifty separate recommendations, covering areas ranging from government leadership and policy setting; through regulatory development and implementation; to industry culture and capabilities; on to consumer awareness issues. Considerable evidence, admittedly anecdotal in character, was gathered about systemic shortcomings in the national energy regulatory regime applying to buildings.

It is possible to distill these recommendations into four thematic strands:

- *National policy leadership*: stronger role for Building Ministers; mandatory performance disclosure introduced; as-built compliance verification
- *Increasing regulatory effectiveness*: strengthened enforcement; addressing non-conforming building materials; linking compliance to as-built performance
- *Industry capacity building*: guidance materials; register of conforming products; mandatory accreditation of industry professionals
- *Cultural transformation*: raised awareness of the benefits of energy efficiency within both industry and the wider community

While narrower in scope than the internationally accepted framework to be used as a reference for this benchmarking exercise, the NEEBP review does nevertheless make a crucial contribution to the exercise in terms of mapping the current regulatory landscape for Australia's building energy code.

As such it points up significant shortcomings in the local regulatory regime. At all levels from national policy setting to on-ground implementation.

BENCHMARKING BEST PRACTICE IN BUILDING ENERGY CODES

Technical Adequacy

As a the first stage in benchmarking Australia's building energy code against international best practice attention will be focused on the technical sufficiency of the NCC when addressing pertinent building elements and performance attributes.

To this end the work of Evans et al in comparing building energy codes in the Asia Pacific Region is apposite (M. Evans, 2009). Evans' study reveals that development of a national building energy code in Australia in 2003 made this country a relatively late starter compared with other developed countries such as Japan [1979-80] and the USA [1975-77].

From a structural perspective the NCC is found to measure up well in comparison with building energy codes in Canada and the USA. Because it is explicitly a performance-based code which allows cost-effective design trade-offs between individual building elements.

In its technical sweep the NCC also benchmarks well against equivalent codes in Canada, Japan and the USA. Since key building elements impacting on energy use are addressed through defined energy performance requirements, viz: the building envelope; HVAC systems; service hot water; lighting; common services and renewable energy supply.

Evans' work makes a number of observations that are consistent with the earlier discussion in this paper:

- *Building energy codes are a proven and cost-effective means of improving energy efficiency in new buildings (International Energy Agency, 2007)*
- *A building's initial design is a strong determinant of lifetime energy consumption so design standards provide a strong leverage point*
- *High building construction rates in regional countries such as China and India mean that the contribution of Asia-Pacific regional countries to global building space, thus also energy consumption and greenhouse gas emissions, will be highly significant*
- *It is estimated that the US Department of Energy's Building Energy Codes Program has delivered savings of $30-50 for every dollar spent on the program, thus saving over $1billion in energy costs in a year*

Structural Aspects

Founded in 2010 the Global Buildings Performance Network [GBPN] is an international organization whose mission is to provide policy expertise and technical assistance to advance building energy performance. It operates from a central office in Paris, has partner organizations in Brussels, Washington D.C. and Delhi, and a regional office in Beijing.

In its 2013 report (McDonald, 2013) the GBPN drew upon a large body of international energy policy experts and building officials to prepare a document consistent with the Network's aim of facilitating the development of "ambitious building codes". With this aim in mind the report incorporates multi-criteria comparisons of international building codes and policies for new buildings. Fifteen criteria, grouped into five key themes, are identified in order to define regulatory best practice. Table 2 sets out the benchmarking themes and structure developed by GBPN.

Conceptually this framework is very much a “macro-level” assessment of building energy code effectiveness in that it focuses on the policy settings, governance regime and operational structures within which the code operates; rather than on “micro level” aspects such as the technical adequacy of code provisions themselves.

Table 2 Best Practice Themes and Criteria (McDonald, 2013)

Theme 1: Holistic	**Theme 2: Dynamic process**	**Theme 3: Implementation**	**Theme 4: Technical Requirements**	**Theme 5: Overall performance**
Performance based	Zero energy target	Effective enforcement	Building envelope	On-site operational assessment
Includes all energy uses	Continual revision cycles	Certification	Building services & systems	Aggregate primary energy use
Includes renewables	Beyond minimum levels	Policy complementarity	Renewable energy systems	Aggregate greenhouse emissions

Measuring Australia's Building Energy Code against Best Practice Criteria defined by the Global Building Performance Network

1 **Performance based approach**
The NCC is explicitly a performance based building code as an integral element of its regulatory doctrine

2 **Inclusion of all energy uses**
Some forms of energy usage in buildings are not yet included in performance assessment, particularly in the residential sector

3 **Renewable energy sources included**
NCC energy performance provisions do not include alternative or renewable energy supply options in its core energy efficiency provisions

4 **Zero energy target**
No such visionary target has been articulated to date

5 **Continual revision cycles**
Periodic revision cycles have not been defined recently; timing of future revisions remains uncertain

6 **Performance beyond minimum levels**
The Code sets minimum compliance standards; however exceptional performance outcomes are inherent in some areas such as house energy ratings

7 **Effective enforcement**
Recent analysis has highlighted systemic enforcement problems for which State building administrations are held to be responsible [see S4 below]

8 **Certification of Performance**
Performance certification is inherent in the residential provisions but not explicitly sanctioned or encouraged by the Code

9 **Policy complementarity**
Limited integration of regulatory policy with complementary building energy policy initiatives exists at either state or federal levels

10 **Building envelope**
NCC technical provisions deal comprehensively with the building envelope characteristics

11 **Technical systems**
In general building services are dealt with well, particularly in the commercial sector; though commissioning and operation are not really addressed for either residential or commercial buildings

12 **Renewable energy systems**
Performance requirements for active renewable system are not incorporated

13 **On-site operational energy assessment**

Building performance in service is currently out of scope

14 **Aggregate building performance: primary energy & emissions**

Not assessed in the Code

THE POLICY CONTEXT

What of the role Australia's building energy code as an instrument of energy/climate change policy? Can building standards play a more effective role in a national policy setting where government has an explicit commitment to red tape reduction?

The Australian Government's current response to climate change is focused on its Direct Action Policy; which in turn has the Emission Reduction Fund as its centre-piece. In its current incarnation the Direct Action Policy makes no explicit reference to potential role of buildings and the built environment generally in reducing Australia's growing greenhouse gas emissions. Even the latest national emission projections (Department of the Environment, 2015 #1307) fail to disaggregate sectorial emissions data to highlight the role of buildings.

However an earlier document produced by the Coalition Parties while in opposition does offer some encouragement from the policy perspective in that it recognizes the contribution of the built environment to national greenhouse emissions. This policy paper (Liberal Party of Australia, 2010) states that:

Reducing CO_2 emissions presents many opportunities for industry, households and government to take action on sustainable living and energy efficiency. We can, for example, embed sustainability principles in our homes, commercial buildings and workplaces…… [p19]

In 2014 Australia hosted the G20 summit whose outcomes included the *G20 Energy Efficiency Action Plan,* which sets out a framework for voluntary cooperation between G20 member states on energy efficiency. Among its stated priorities for "accelerating existing international work" is a key area devoted to Buildings: sharing international best practices in performance codes, and building ratings and disclosure. Performance codes are described in the Plan as the "workhorses" of building energy efficiency, with acknowledged benefits including reduced lifecycle costs and improved occupant health outcomes.

The Australian Government's recently published "Guide to Regulation" (Australia, 2014) sets out regulatory reform principles that are consistent with its red tape reduction doctrine. The principles for policy makers set out therein emphasize the need for regulation to only be imposed when it can be shown to offer an overall net benefit. Regulatory Impact Statements must be undertaken early in the policy development process the Guide stresses.

Since these principles are consistent with regulatory development processes routinely undertaken to support and validate amendments to Australia's national building code they should not be seen as an obstacle to prosecuting further reforms of energy efficiency provisions in the NCC as a matter of priority.

DISCUSSION: BENCHMARKING OUTCOMES

This paper has benchmarked Australia's building energy code against the yardstick of international best practice by drawing upon policy approaches taken in the European Union and the United States. Doing so has highlighted a range of opportunities for reform the NCC in order to fully capitalize on the potential of Australia's building energy code as an instrument of national energy and climate change policy. Taking full advantage of these opportunities will require top down leadership from government together with active engagement from all three tiers of government.

In Table 3 energy code assessment criteria defined by GBPN are used to *qualitatively* rate Australia's building energy code against best practice.

Table 3: Assessment Matrix – after (McDonald, 2013) **p30**

Theme 1: Holistic approach	**Theme 2: Dynamic process**	**Theme 3: Implementation**	**Theme 4: Technical requirements**	**Theme 5: Overall Performance**
Performance based	Zero energy target	Effective enforcement	Building envelope	Operational assessment
Includes all energy uses	Continual revision cycles	Certification	Building services & systems	Aggregate primary energy use
Includes renewables	Beyond minimum levels	Wider policy complementarity	Renewable energy systems	Aggregate greenhouse emissions

Legend

Code	Assessment	Rating
	Satisfactory	>6/10
	Marginal	4/10 – 5/10
	Poor	<3/10

1. Holistic approach

Australia's National Construction Code rated quite well in terms of its technical basis, scope and elemental focus; being an explicitly performance based code also counts in its favour.

2. Dynamic process

Lack of a visionary strategic objective to compare with Europe's "near zero energy by 2020", together with a revision cycle that appears to have effectively stalled since 2009 are seen as major weaknesses.

3. **Implementation**

Effective enforcement and compliance levels are shortcomings that our own NCC shares with European codes; nevertheless that this area urgently requires concerted attention by Australia's building administrators was highlighted in unequivocal terms by the Pitt & Sherry report (Pitt & Sherry, 2014).

4. **Technical requirements**

The Australian code rates well in this aspect; apart from a lack of overt recognition of alternative & renewable energy systems.

5. **Overall Performance**

Best practice regulation is moving towards integrated assessment of operational building performance. This is an area of demonstrable weakness in Australia's building energy code, relying as it does on enforcement at the point of construction completion. Without stronger checks on actual building performance post-construction there is a real risk that desired policy outcomes will fail to be achieved in practice.

CONCLUSIONS & RECOMMENDATIONS

KEY POINTS

- Salience of building emissions requires policy response
- Regulatory intervention through BECs has proven track record and demonstrated success record – for example in assessment by US DoE
- Australia has been relatively slow to embrace the TBL opportunities offered by BEC – no comprehensive national stds enacted till 2006
- Energy efficiency provisions in the NCC compare quite well with IBP in a technical sense
- The fact that the Australian federation boasts a uniform national building energy code with quite close coordination in implementation processes between State & Territory administrations is also a comparative advantage
- However the policy settings and high level development processes underpinning the NCC have been found to be deficient in key areas when compared with IBP

From the preceding discussion in this paper a number of specific initiatives focused on addressing the identified gaps between current regulatory practice in Australia and international best practice may be deduced. These are seen to be:

1. Recognition that emissions from the building sector demand a strong policy response; and that
2. Building energy codes have a demonstrated record of achievement
3. Lock in periodic reviews of energy provisions in step with the triennial NCC amendment cycle to address the code development hiatus since 2009
4. Energy code reviews should include comprehensive performance monitoring and reporting of outcomes achieved along US lines; reported initially to Building Ministers by the ABCB then to the wider public
5. Look to the example of the US DOE as a basis for enhancing the level of resources provided by the Commonwealth, in support of market transformation and cultural change in the building industry through the Department of Science and Resources
6. Articulate a medium-long term visionary objective for the NCC in the same vein as the United Kingdom's "zero carbon building" objective

7. Extend mandatory disclosure and energy performance certification to other important building classes in addition to the office buildings currently addressed by the Commercial Building Disclosure program
8. Institute a national approach involving the ABCB in concert with State & Territory administrations to address major flaws identified in the NCC compliance enforcement regime
9. As part of its long term strategy for NCC development the ABCB should consider the question of operational performance validation for new buildings as an element of the Code, along the lines of UK and US codes

RELATED WORK/further research

Industry *learning* in more detail

Consumer *choice* & rationality

Industry *culture* and the operation of peak industry lobby bodies

International best practice approaches to building regulation

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Appendix G

Literature review: The role of building regulation as a policy instrument for the transition to a low carbon built environment.

The role of building regulation as a policy instrument for transition to a low carbon built environment:

Systematic Literature Review

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ABSTRACT

Ratification of the Paris Climate Agreement has significant implications for international climate change policies. A substantial body of literature addresses the question of prioritizing global greenhouse gas emission reduction efforts by identifying those sectors of national economies where climate response actions will be most effective. Effectiveness criteria must be holistic, including not only economic but also environmental and societal performance measures. These strategic analyses typically point to the building sector as a prime focus for the deployment of greenhouse emission reduction strategies. So a challenge for policy makers becomes identification and implementation of the most effective policy instruments for reforming the energy efficiency of the building sector to achieve the identified sectoral abatement potential. Prospective policy instruments include regulatory, financial and informational market interventions or combinations thereof. This Systematic Literature Review (SLR) intends to provide a platform for a PhD research project whose subject is analysis of the role of building regulation as a policy instrument for driving transition to a low carbon built environment. Currently regulation is frequently seen as an impediment to improving building performance rather than a potential driving agent for transformation of building stock to reduce its substantial carbon footprint. Findings of this literature review and its parent PhD study will be relevant to agencies involved in the development and implementation of international building codes by providing a basis for evaluating both the relative effectiveness and stringency of local regulatory regimes.

Keywords: climate change, buildings, energy efficiency, public policy, regulation, greenhouse gases.

1 Introduction

• 1.1. A greenhouse gas emissions policy hierarchy applying to the building sector

The concept of a nexus between climate change response and building energy policy is well developed. For example, one key analysis defined cost curves for GHG mitigation options applicable to both the global and Australian economies (McKinsey Company, 2008). It is clear from analyses such as that of McKinsey that the most cost-effective mitigation strategies are associated with improving the energy efficiency of buildings, their associated services and fittings. A study undertaken for the Australian Sustainable Built Environment Council (ASBEC) (Australian Sustainable Built Environment Council, 2010) concluded that improved building performance could not only make a significant contribution to national GHG emissions abatement objectives but would deliver substantial material benefits for the whole national economy. Research commissioned by WBCSD provides further evidence for such a nexus (World Business Council for Sustainable Development, 2009).

In considering policy supporting the mitigation of GHG emissions from the building sector, Urge-Vorsatz (ürge-Vorsatz, Koeppel, & Mirasgedis, 2007) highlights the effectiveness of regulation relative to other policy interventions. Thus the Urge-Vorsatz analysis (ürge-Vorsatz et al., 2007) lays the groundwork for the proposition that regulatory intervention should be a preferred policy instrument for government aiming to reduce emissions from the building sector.

Studies by the International Energy Agency (IEA) (International Energy Agency. & Organisation for Economic Co-operation and Development., 2008) show that energy efficiency has the potential to be the greatest contributor to global emission reductions by 2050. The Agency argues that policy to reduce emissions should be based on three elements: carbon pricing, technology policy, and removal of barriers to behavioural change; and also that the removal of barriers to behavioural change is essential for encouraging the take-up of opportunities for energy efficiency. The challenge for policy makers is therefore to identify the precise form of government intervention that will be most effective in achieving the vital transition to a low-carbon building sector.

• 1.2 Building energy codes as a policy instrument

Building codes have a well-established historical role in delivering socially desirable outcomes such as protecting human health, enhancing fire safety and improving building durability. Extending the role of building regulation into the realm energy efficiency and sustainability more broadly is a relatively recent development (Laustsen, 2008).

In order to be relevant and innovative in a contemporary sense the analysis of building regulatory methodologies needs to compare the current regulatory approach, focused on compliance at the design and construction stage, with alternatives also focused on operational building performance.

These findings are expected to be of use by government agencies in order to examine the case for strengthening the focus, stringency and effectiveness of current building energy standards with the ultimate objective of delivering reduced carbon emissions from buildings.

For example Australia's National Construction Code (NCC) operates within a formal administrative structure that provides uniform technical building performance standards in this nation of 24 million citizens; local building designers most cope with diverse climatic settings ranging from the equatorial tropics to arid desert regions and high altitude mountain regions (Figure 1). The Australian experience provides a useful case study because of the country's high per capita emissions; its significant levels of urbanization; and high rates of population increase population growth that lead to rapid growth of the local building sector and its greenhouse gas emissions.

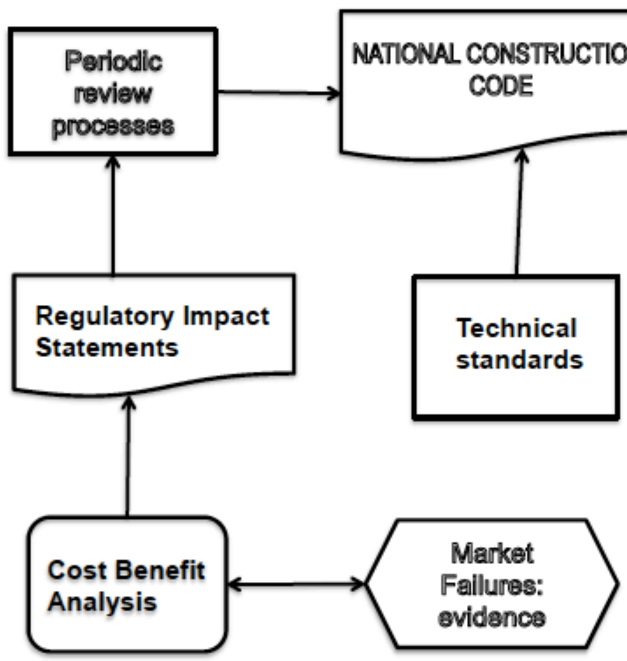

Figure 1 NCC administrative regime

Australia's National Construction Code (NCC) has from its inception in 1996 been set up as an overtly performance-based regulation (Australian Building Codes Board, 2017). Evidence obtained from ex-post studies of the NCC in operation (CSIRO, 2013) suggests that effective implementation of mandatory performance-based building energy standards can deliver significant consumer benefits in that compliance costs can be reduced as a consequence of the industry learning processes

(AECOM, 2012) that effectively contribute to property market transformation processes (R. A. Enker, Morrison, G.M., 2017a).

1.3 Identified research needs

The objectives of this Systematic Literature Review (SLR) include identifying and aggregating various reports, programs, and regulations by government agencies, across national and regional governments, whose purpose is to influence consumer, industry and market behaviour. These influences should consequently also hasten the adoption of low carbon techniques for building design & construction. Thus the SLR aims to provide a broad overview of such efforts in the course of identifying the literature dealing with relevant strategies, mechanisms, and tools.

Another research gap to be addressed involves an investigation of processes and outcomes associated with the benchmarking of national building energy codes against world's best practice. The point of this exercise is to provide jurisdictional policy makers with a means of progressively reforming their respective local building codes. Such reform processes need to pay particular attention to the role of in situ construction quality, its impact on achieving *ex ante* design outcomes, and the influence of building operational characteristics on aspirational policy outcomes.

Historically the development of building energy policy has been approached by either viewing the building as a technically engineered system, or alternatively from a social practice perspective that focuses on owner and occupant behaviour. In the former case examining building energy standards through the lens of socio-technical transition theory has potential value in providing a superior understanding of the effectiveness, or shortcomings, of regulation as a policy instrument.

There would also appear to be value in exploring policy options from the novel perspective of behavioural economics theory since this discipline addresses stakeholder behaviour from a sociological and psychological base that sits outside more conventional diagnoses.

These innovative approaches to an examination of the role of building regulation as a policy instrument for transition to a low carbon built environment is at the very core of this PhD project. Figure 2 illustrates these conceptual pathways by broadly mapping out the methodology of the PhD research program.

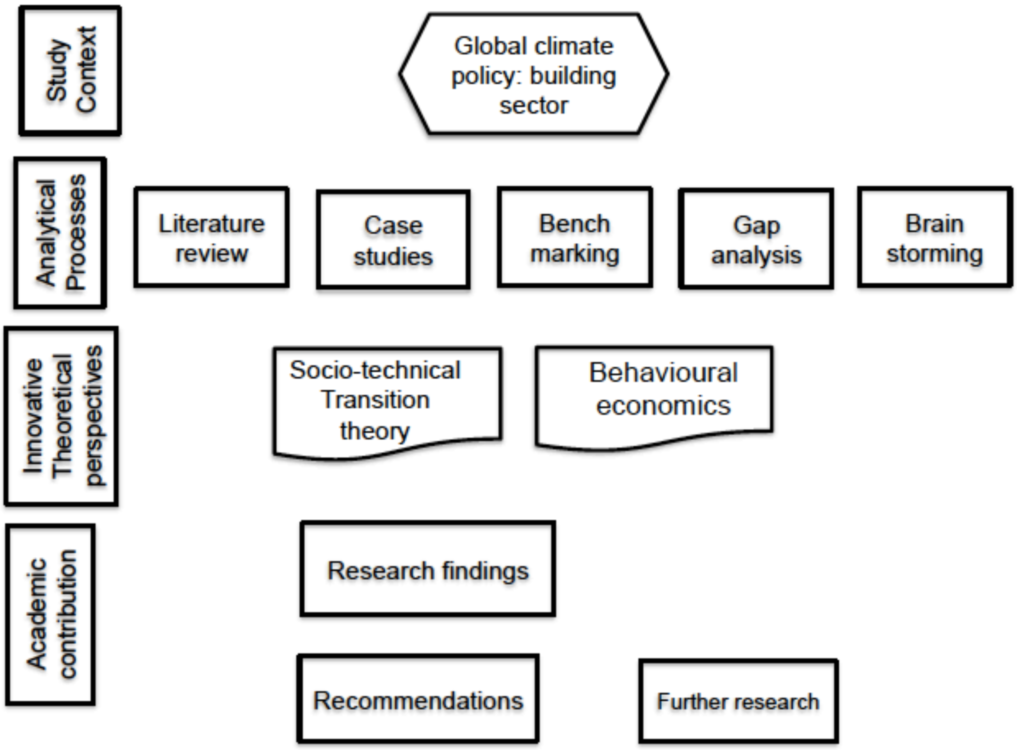

Figure 2 Key elements of PhD program methodology

2 SLR process

As a starting point this SLR draws upon the work of Fink (Fink, 1998) in outlining a generalized approach to the conduct of a research literature review. While useful in its general discussion of an approach to analyzing the large body of literature that is pertinent to a research work such as this, Fink's outline does now appear to be a little dated in its discussion of online electronic search options.

A particular problem encountered in developing the SLR is that much of the SLR methodology outlined in the literature (Fink, 1998) (Petticrew, 2005) has its roots in scientific disciplines such as medicine, social research and psychology wherein the need for systemization was first identified. A SLR in a field such as medicine is likely to be concerned with evaluating a series of quantitative studies in terms of the validity of their data collection. However this PhD research project is essentially qualitative in character. So the process of aggregating, screening, and verifying the relevance of individual studies thrown up by the online search process must be structured accordingly; that is to say, effectively tailored to this study in a bespoke manner. This approach necessarily divergence from the more conventional methods outlined by Fink, Pettigrew et al.

With these considerations in mind the work of Okoli (Okoli & Schabram, 2010) was found to be particularly useful despite its primary emphasis on conducting systematic literature reviews in the field of Information Systems research. The guide provided in Okoli's paper (p9) has been utilized to develop the following methodology for this SLR, while still taking account of the qualitative character of the research for which this SLR has been undertaken (see Figure 3).

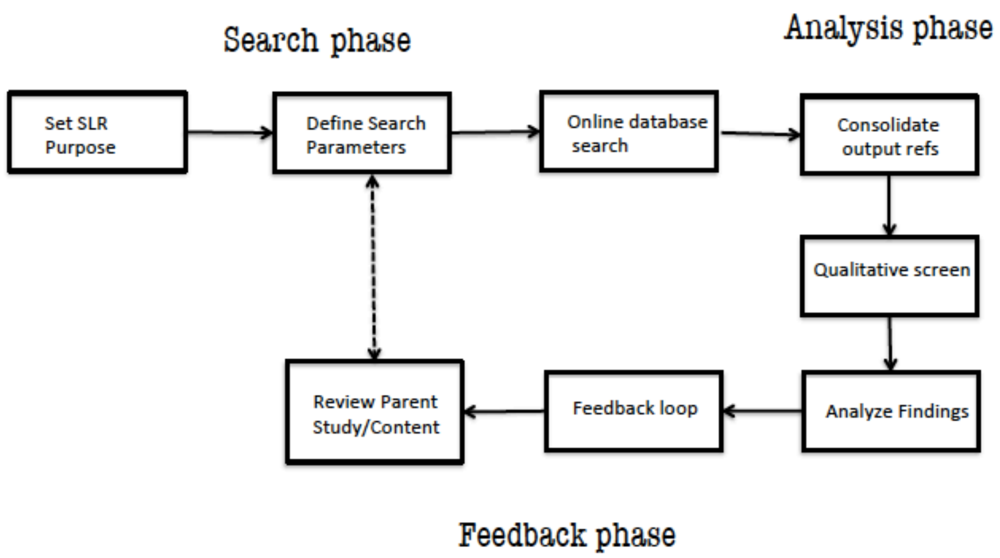

Figure 3 SLR process map

The flowchart set out on Figure 3 will now be used as a conceptual framework for a detailed explanation of the SLR methodology .

2.1 SLR purpose

The purpose of this SLR is to provide a solid intellectual and conceptual foundation for a research project that examines "the role of building regulation as a policy instrument for the transition to a low carbon built environment".

As its point of departure the SLR has been realized through a structured search of selected online databases.

2.2 Definition of search parameters

Definition of the selected online database search parameters drew in part upon the work of Rosenow et al in their paper "Energy Efficiency and the Policy Mix" (Rosenow, Fawcett, Eyre, & Oikonomou, 2016) whose analysis is pitched at similar policy level to this study. Additional input was derived from the important paper prepared for the United Nations Environment Program by the Central European University (United Nations Environment Program, 2007).

The following search parameters were selected by drawing upon these two sources:

- Buildings
- Regulation

- Public policy
- Energy efficiency
- Greenhouse gases

The selected temporal range for the searches was: 1990 – 2017. This range is seen to be both a sufficiently extensive, and a practically manageable time window.

2.3 Online Database Search

The following databases were selected for search purposes on the basis of their breadth of coverage and functionality; for example the ability to readily export references into EndNote (further discussed in S3.4 below).

- *Web of Science*
- *Proquest*
- *Scopus*

Categories of publications to be searched included: journal articles, conference proceedings, government reports from organizations such as UNEP and IEA, dissertations and theses.

2.4 Consolidating search outputs

Conducting the online searches using parameters defined above in S2.2 and the databases set out in S2.3 yielded a total of 836 individual references distributed as follows:

- Web of Science – 418 citations
- Scopus - 289 citations
- Proquest - 129 citations

Each of these databases provides for subsequent analysis of search results. Typical analytical parameters used for this process are: publication date, source, subject area, and authorship. See Figures 4 and 5 for these results, as obtained specifically from the Scopus search process.

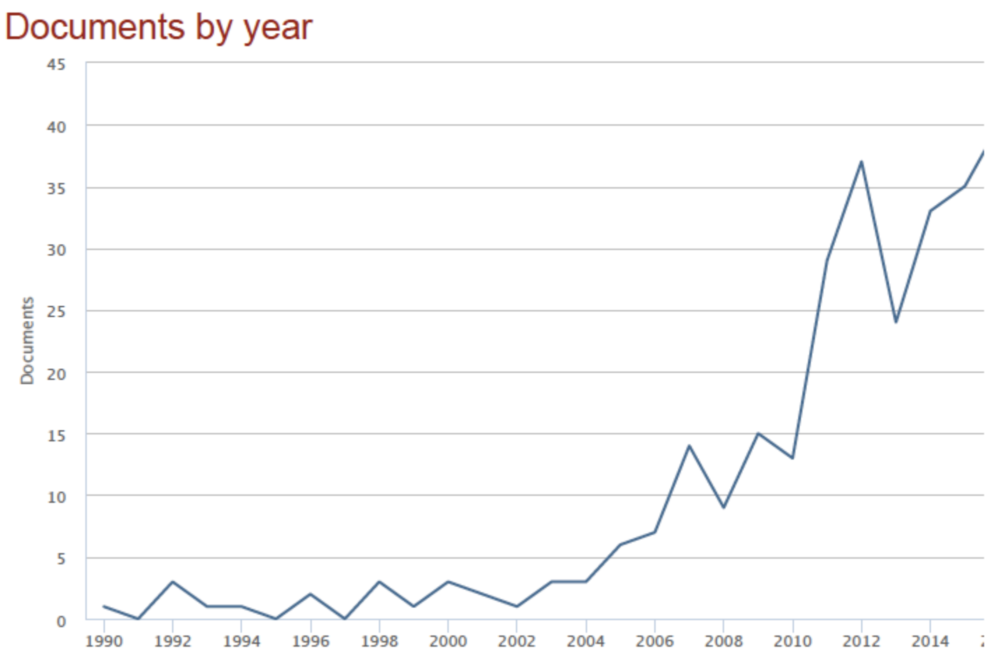

Figure 4 Scopus search analysis by publication date

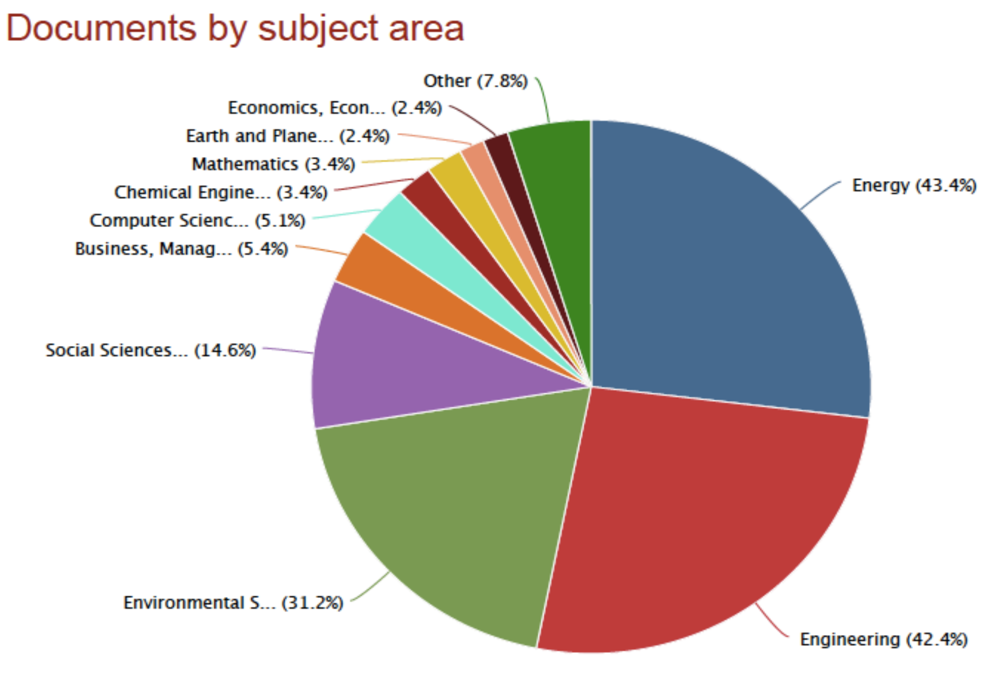

Figure 5 Scopus analysis by subject area

For the purposes of further examination of these results in the SLR a breakdown of searched citations according to thematic subject areas is now posited as being functionally beneficial. Subject areas common to the three search databases (Web of Science, Scopus and Proquest) could thus be grouped under the following headings:

1. Energy/fuels
2. Engineering
3. Construction
4. Environmental science/sustainability
5. Business
6. Economics
7. Public policy

It is reasonable to infer that these subject areas have been selected by the search engine developers because of their general applicability to literature in the field; however they do not necessarily have particular applicability to this SLR.

• 2.5 Filtering and screening search outputs

The next step in the SLR was to consolidate all the identified references such that those that were determined to be of particular prominence were highlighted and extracted for subsequent detailed analysis. This step was implemented by comparing results of the three individual database searches to identify reference that appeared (ie were duplicated) in more than one database.

In order achieve this form of A⇔B⇔C reconciliation all the search results were firstly exported to the EndNote citation management software. Then each database was assigned to an EndNote Group. These three EndNote Groups were aggregated into a Group Set linked to the SLR. Next the EndNote File Duplicate function was employed to identify references appearing repeatedly within this SLR Group Set. Next, duplicate citations were outputted to discrete EndNote Group for further screening and analysis.

By this means some 72 salient (ie duplicated) references were identified using this EndNote filtering process.

• 2.5 Qualitative & Chronological Screening

Through detailed review of their abstracts, each of the 72 consolidated references was qualitatively examined to establish its potential and direct relevance to the core themes of the parent PhD research project.

While each of the original online search databases has its own unique system or lexicon for classifying citations according to their subject areas (as discussed earlier) it is proposed that the classification system set out in Table 1 explicitly well suited to this SLR. This classification is also quite compatible with the parent PhD research project.

For comparison purposes the 72 consolidated references are now subjected to a similar analysis to that which was illustrated earlier in Figs 2 and 3; but with the distinction that the subject areas used have been reset to those addressed in Table 1 for the purposes of improving the utility of the SLR.

Table 1: Tailored screening classifications

	Subject area classification
1	Policy formulation: regulatory development
2	Technical analysis: building performance
3	Building materials, components, services
4	Market performance: consumer behaviour

Moving on from Table 1, analyses of the results of this enhanced screening process are presented graphically in Figs 6 and 7.

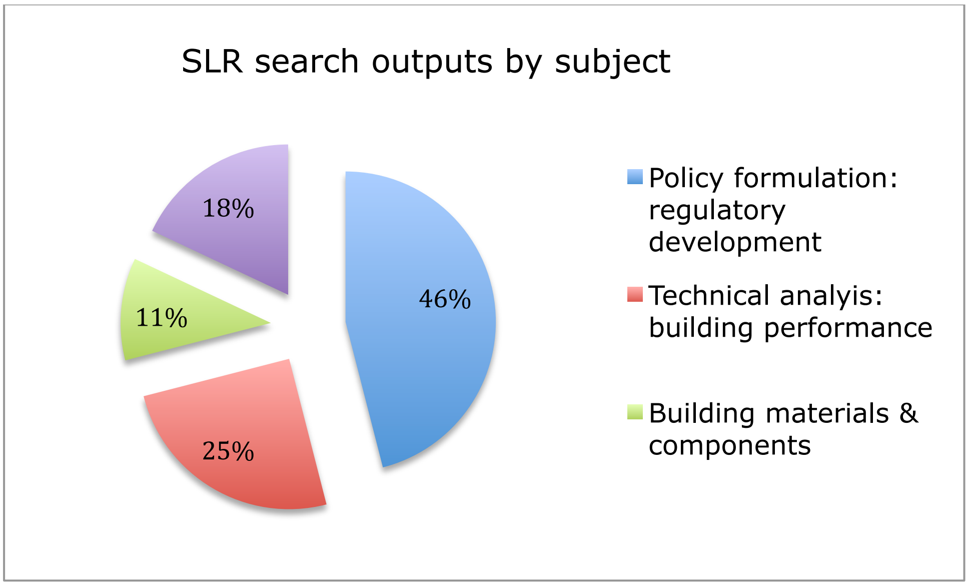

Figure 6 Classification of SLR search results

Figure 6 suggests that ordering (in effect prioritizing) the 72 key citations according to the frequency with which each of these subjects was addressed results in the following ranking:

1. Policy formulation
2. Building performance (technical)
3. Market performance: consumer behaviour
4. Materials & components

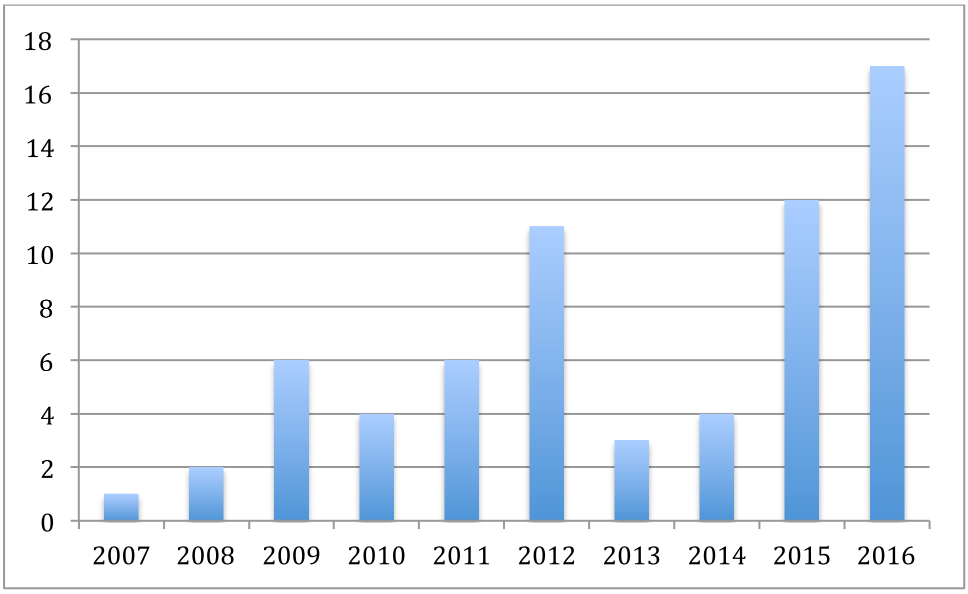

Figure 7 Publication dates for SLR search citations

It is apparent from Figure 7 that the frequency of pertinent publications has steadily increased during the second half of this decade after a temporary trough in the early years.

The preceding qualitative screening process also yielded some dozen valuable and pertinent citations that the conventional literature review process being undertaken in parallel with the SLR in the course of the parent PhD project had not uncovered; specifically these were: (Clinch & Healy, 2000b); (Crawford, Bartak, Stephan, & Jensen, 2016b); (Drummond & Ekins, 2016); (Guerra-Santin & Itard, 2012a); (Levinson, 2016a); (Li & Shui, 2015); (Shapiro, 2016); (Shiel, 2009); (Stephan & Crawford, 2016); (Sunikka-Blank & Iwafune, 2011a; Tambach, Hasselaar, & Itard, 2010b); (Visscher, Majcen, & Itard, 2014); (Visscher, Meijer, Majcen, & Itard, 2016b).

• 2.7 Review of key citations

The next section of the SLR provides detailed analysis of the salient citations brought out through the focused search process described above. This step aims to integrate these specific citations into the overarching PhD research program. Because of its methodological structure this SLR has a built-in quality control loop, essentially in form of a conventional *Plan-Do-Check-Act* cycle. As has been illustrated on the process map provided in Figure 3.

Some 300 citations have already been identified and examined through a conventional literature review process undertaken in the course of drafting the individual manuscripts that will aggregate into this PhD by Publication. The content of these documents is being incorporated into each of the individual papers as appropriate on an ad hoc basis. The following analysis also summarizes outcomes of the non-systematic literature review process being undertaken in parallel with the SLR.

3 Overview of PhD research program

The Research Question being addressed in this PhD study is: "What is the role of regulation as a policy instrument for the transition to a low carbon built environment?".

A series of subordinate investigations have also been identified to support the central Research Question; thus providing a framing structure for the PhD study. These subordinate questions are:

1. Does regulatory intervention to improve building energy efficiency necessarily have a negative impact on housing affordability?
2. How effective are economic instruments compared with other potential government interventions, such as mandatory building standards, in maximizing the prospects for successful policy implementation?
3. How do Australian building energy standards measure up when benchmarked against World's Best Practice?
4. How does consumer choice operate in the property market when examined from the perspective of Behavioural Economics?

The current status of addressing these research questions in the course of the overall PhD program (see Figure 2) is discussed in the following sections of the paper.

• 3.1 Building energy regulation: implications for housing affordability

This topic was addressed in a paper presented to the Architectural Science Association Conference in December 2015 (R. A. Enker, 2015).

This analysis of Victoria's 5 Star Energy Efficiency Standard for residential buildings concluded that it was an effective regulation in the sense that government policy objectives relating to energy efficiency and greenhouse gas abatement were achieved in practice without significant detriment to housing affordability.

A number of additional conclusions concerning the role and effectiveness of building regulation as a government policy instrument were also reached.

Research over the last decade suggests that government policy objectives for greenhouse gas abatement that led to regulatory intervention by the State Government of Victoria in 2002 were met in practice. Furthermore, widely publicized and vociferous claims by local housing industry lobby groups that mandatory energy efficiency requirements for new home construction would have a deleterious impact on housing affordability were shown to have been ill-founded. In fact no large-scale impacts on the local housing market were evidenced by the literature.

In addition the formal regulatory impact assessment reports mandated by Australian regulatory development processes tended to underestimate both the capacity for industry adaptation to new energy requirements and the pace of such adaptation.

3.2 Relative effectiveness of economic instruments in comparison of building sector regulation

This research question was the subject of a paper presented to the CESB2016 Conference, Prague, June 2016 (R. Enker, 2016).

The analysis found that, while application of economic instruments to environmental protection has a history of success in addressing point source and diffuse pollution, simple translation of conventional economic instruments to building sector emissions policy is beset by fundamental weaknesses that inhibit effective deployment. Furthermore, many assumptions underpinning the application of economic instruments such as carbon pricing are open to challenge in that they rely on questionable models of idealized market behaviour embodied in doctrines such as the Coase Theorem and Pigouvian taxation models.

This Australian case study demonstrated that building performance standards embedded the National Construction Code would not only deliver national climate policy objectives but also provide substantive economic benefits together with cost-effective abatement outcomes in terms of negative cost/kg CO_2.

3.3 Benchmarking Australia's national building energy standards; application of Transition Theory (see Fig 2)

This issue was initially addressed in a paper presented to the national conference of Australia's Sustainable Engineering Society in 2015 (R. Enker, 2015). The comparative analysis technique was further developed and refined in a manuscript published in the journal "Energy and Buildings", which framed the NCC benchmarking process within the wider context of government's role in triggering a socio-technical transition process in the building sector (R. A. Enker & Morrison, 2017).

These studies concluded that Australia had been relatively slow to embrace the triple bottom line benefits of building energy codes in comparison with international leaders. However the fact that the Australian federation boasts a uniform national building energy code with quite close coordination in implementation processes between State & Territory administrations is an advantage compared with the EU and the United States of America. Although energy efficiency provisions in the NCC compare quite well with best practice in a technical sense, guiding policy settings and code development processes underpinning the NCC have are deficient in key areas.

Initiatives designed to address gaps between current regulatory practice in Australia and international best practice were proposed in order to address these gaps. As a starting point, periodic reviews of energy provisions should be undertaken in step with the triennial NCC amendment cycle; and regular code reviews to include comprehensive performance monitoring and reporting of outcomes achieved along US lines (Levinson, 2016b).

There is a need to articulate a medium to long term visionary objective for the NCC in the same vein as the UK's "zero carbon building" objective (Department of Communities and Local Government, 2014) and the EUs' "near ZEH" target (European Union, 2012).

Evolution of building energy efficiency standards through the Australian National Construction Code was also scrutinized by benchmarking the building energy code against international best practice in (Enker, 2017 #5628). This paper examines application of socio-technical transition theory to the building sector with Australian energy policy as a case study. The relatively high level of local building construction offers significant opportunities for market transition with appropriate policy settings so this national case has international implications. Government intervention in the building sector through direct regulation is shown to have substantial potential to effect this transition.

Nevertheless, such intervention has proven to be politically controversial in Australia. The paper provides two contributions to research in the domain of building energy policy. Firstly by making the connection between transition theory and the role of building energy codes; and secondly by demonstrating the practical application and utility of a structured building code benchmarking process.

3.4 Consumer choice in the property market: lessons from Behavioural Economics (see Fig 2)

This manuscript is under development for publication in the academic journal "Buildings". The central proposition developed in the paper is that the enhancement of building energy efficiency has typically been approached by viewing the building either as a technical system or from a social practice perspective focusing on owner/occupant behaviour.

Policy makers face a significant challenge in identifying effective policy instruments targeting GHG emissions from the building sector. Understanding the mechanics of building policy in the residential sub-sector is particularly instructive because of the high level of building activity, diverse stakeholders, and complex policy considerations involving both consumers and industry professionals. The Australian experience provides a national case study where high urbanization levels and population growth rates have promoted rapid growth in building sector greenhouse emissions.

As its point of difference this paper examines policy options through the lens of behavioural economics theory wherein stakeholder behaviour is addressed from a socio-psychological perspective; as opposed to a conventional economic or technocratic perspective. Such analysis reveals that decision-making of building sector stakeholders diverges substantially from a normative economic perspective. Significant implications arise for the framing of sectoral climate and energy policies; while behavioural economics can contribute to strategic re-appraisal of policy effectiveness by providing additional options for the progressive refinement of instruments for policy intervention at key decision points in the building lifecycle.

4 Discussion: outcomes of the SLR process

Thematic issues arising from the 72 research documents paper yielded by the consolidated SLR process outlined earlier were grouped into the four salient subject areas identified earlier (Table 1) for further consideration in the course of the parent PhD research program. These issues are now discussed in some detail.

• 4.1 Policy formulation: regulatory development

Tambach concludes that complementary instruments such as more stringent enforcement measures are needed to ensure that the Dutch building control regime applicable to the upgrading of existing housing stock meets policy objectives (Tambach, Hasselaar, & Itard, 2010a).

In the Japanese setting it was observed that a previous policy preference for the employment of market based instruments rather over regulatory intervention will not deliver continued energy savings unless supplemented by mandatory thermal regulations (Sunikka-Blank & Iwafune, 2011b). In direct contrast to the Japanese scenario, Li observed that China's approach to building energy efficiency has actually shifted from a purely mandatory approach to also supporting voluntary green building initiatives (Li & Shui, 2015).

Crawford's analysis of Australian building energy standards proposed that the NCC should account for embodied energy in addition to its current focus on buildings' operational energy consumption because of the former's significant share of life cycle energy demand; this postulate gives rise to a call for an emphasis on design strategies that also take account of embodied energy (Crawford, Bartak, Stephan, & Jensen, 2016a).

In a study with quite wide implications for questions of building energy code effectiveness as an instrument of climate/energy policy, Levinson found that energy savings from Californian energy codes fell short of predictions made when these regulations were enacted (Levinson, 2016b)

• 4.2 Market performance: consumer behaviour

Clinch suggests that failure of the Irish market for domestic energy efficiency should be addressed by a mix of measures including grants and State-led consumer information campaigns (Clinch & Healy, 2000a).

In a study of EU building sector energy initiatives Visscher found that improved governance - including better engagement with occupant behaviours - is needed if EU's espoused policy objectives for creating energy-neutral building stock are to be achieved in practice (Visscher, Meijer, Majcen, & Itard, 2016a).

In the same vein Shiel makes the general point that, because human behaviour is a significant contributor to building GHG emissions, strategic engagement of stakeholders is vital for success in minimization of emissions from (existing) buildings (Shiel, 2009).

The important matter of stakeholders' behavioural responses to building energy regulations is further developed by Guerra-Santin (Guerra-Santin & Itard, 2012b) who assert that simply tightening energy performance standards is likely to be ineffective without: (a) also changing occupant behaviour and (b) addressing construction quality issues linked to industry culture.

• 4.3 Technical analysis: building performance issues

A study of Irish housing stock found the case for energy efficiency measures to be categorical; thermal retrofit measures in the detached housing stock had the potential to make a significant contribution to Ireland's residential carbon abatement projections with the greatest savings result from improving the performance efficiency of pre-1979 stock (Ahern, Griffiths, & O'Flaherty, 2013). Representative archetypes of Irish houses were used to estimate the performance during retrofitting, operation, maintenance and disassembly phases of selected scenarios; the aim being to provide policy makers with a holistic view of life cycle performance for existing dwellings (Famuyibo, Duffy, & Strachan, 2013).

An insight into the energy performance of residential and tertiary sector buildings in Spain through analysis of energy performance certificates issued for existing buildings by the Catalan Institute of Energy generated data useful for prioritizing energy conservation efforts according to building type, climate zone and specific end-use (Gangolells, Casals, Forcada, Macarulla, & Cuerva, 2016).

Shiel's paper, cited earlier (Shiel, 2009), provided examples of building refurbishments, government policies and stakeholder behaviour for the purpose of evaluating successful market intervention strategies. Shiel's assertion that buildings' operational is found to be a significant contributor to global GHG emissions is pertinent when read in the context of Crawford's argument that more emphasis should be given to embodied energy in building codes (Crawford et al., 2016a).

• 4.4 Building materials, components & services

EU energy policies have led to specific measures for the building envelope, use of efficient HVAC technologies and the integration of renewable energy systems. Anastaselos et al studied radiative heating systems by applying an integrated assessment model to evaluate interventions the behaviour of the buildings' envelope, in a Life Cycle Analysis that accounted for energy, economic and environmental performance, and thermal comfort (Anastaselos, Theodoridou, Papadopoulos, & Hegger, 2011).

Building industry researchers have been devising methods of optimizing envelope thermal insulation levels, whilst simultaneously employing materials characterized by low environmental impacts. Baccilieri's contribution to this research area was to assess the insulation features of totally natural and biocompatible materials (Baccilieri et al., 2016).

Standard techniques of engineering economics have been shown to be either inappropriate or misapplied in assessing the performance of the market for energy efficiency. In this context Koomey et al examined the engineering and economic characteristics of standard and energy-efficient magnetic ballasts for fluorescent lighting. The analysis found solid empirical evidence to support skepticism about: (a) the effectiveness of the market mechanism in promoting cost-effective energy efficiency improvements; and (b) the benefits of regulation to counteract this shortcoming (Koomey, Sanstad, & Shown, 1996).

EU policies promoting buildings' energy performance differ from the Chilean Thermal Regulation in that the latter does not consider heat losses by air infiltration. In this context Ossio reviewed a series of of 14 European national standards countries with the aim of deriving lessons for development of the Chilean Thermal Regulation (Ossio, De Herde, & Veas, 2012).

5 Conclusions

This Systematic Literature Review provides a comprehensive academic basis for the PhD project being undertaken as part of a wider program under the aegis of the Cooperative Research Centre for Low Carbon Living. The PhD study aims to articulate the role of building regulation as a policy instrument for driving transition to a low carbon built environment.

Through its structured and rigorous approach to the literature search process the SLR has succeeded in identifying a pertinent references that had not been discovered previously in the course of conventional but less structured search processes.

Thematic topics identified in the course of the SLR filtering and distillation process (per Figure 6) are shown to be broadly consistent with the five subsidiary research questions (Section 3.0) underpinning the primary PhD question: "What is the role of building regulation as a policy instrument for transition to a low carbon built environment?".

Moreover the SLR process has allowed the two relatively untapped areas of academic theory - Transition Theory and Behavioural Economics - that are being incorporated into this PhD program (Fig 2) to be tested for their potential contribution to the body of academic literature on building energy policy. It is apparent from the SLR findings that neither Transition Theory nor Behavioural Economics have to date been applied to the evaluation of such policy formulation. Therefore the approach proposed for this PhD program does have merit insofar as its potential for providing a substantive and novel enhancement of the academic literature in the domain of climate, energy and buildings policy development and implementation.

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Reframing housing regulation: delivering performance improvement in conjunction with affordability

Abstract: In developed economies a significant proportion of greenhouse gas emissions result from energy demand in the building sector. Many countries have recognized the need to mandate building energy performance standards as a key element of a national energy or climate change policy. The Commonwealth of Australia included energy efficiency provisions in the national Building Code early last decade. This initiative has not been without controversy or resistance from industry stakeholders. Typically such opposition is predicated on the assumption that more stringent energy efficiency requirements, particularly in the residential sector, would detrimentally impact on the affordability of new housing. The State of Victoria introduced significantly more stringent residential energy efficiency requirements [entitled the *5 Star Standard*] in 2004. This study of the new standard investigates its effectiveness as an instrument of energy policy, testing the assumption that more stringent regulatory requirements are at odds with affordability. The analysis concludes that the 5 Star Standard has delivered significant greenhouse abatement; and encouraged industry innovation in a way that embodies regulatory best practice; while not compromising consumer affordability or impacting negatively on the local housing market overall.

Keywords: Regulation; energy; housing; affordability

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Appendix 2

The Evolution of Building Energy Standards in Australia: A Journey Interrupted?

Abstract:

In developed economies such as Australia, energy use in buildings is one of the most significant contributors to aggregate greenhouse gas emissions. Of even more significance is the fact that reducing greenhouse gas emissions from the building sector provides a range of social and economic benefits in addition to anticipated environmental benefits. Greenhouse abatement from buildings can potentially be delivered at a negative cost/tonne CO2, compared with significant economic burdens arising from alternative abatement strategies such as carbon capture and storage. International policy responses to this realization have been evolving and growing in sophistication over the last decade. Options for government interventions in the building market encompass: direct regulation through building codes and mandatory standards; financial incentives or penalties; consumer information campaigns and industry capacity building. All of these policy measures have been adopted in Australia with varying degrees of success and effectiveness. This paper focuses specifically on the evolution of building energy standards in Australia by following the trajectory of energy efficiency provisions in the National Construction Code. Then the paper moves on to examine the current status and future directions of this key energy policy area. The paper benchmarks Australia's building energy code against international best practice policy frameworks in European and North American jurisdictions in a critique that identifies improvement opportunities for aspects such as policy implementation, regulatory stringency and enforcement capabilities. The roadmap for a future building code suited to the needs of the emerging Low Carbon Economy is sketched out together with the compatibility of enhanced regulatory intervention with national energy policy initiatives such as the Commonwealth Government's greenhouse emissions Direct Action Program.

Keywords: building regulation, building design, built environment, energy efficiency, energy policy, greenhouse gas abatement.

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Energy Policy For Buildings: Why Economic Interventions May Be Ineffective

Abstract
A significant body of research now confirms the major contribution that improved building performance can make to national energy and greenhouse abatement policies. The challenge facing governments is how best to capitalize on the unrealized potential of energy efficient buildings. This paper reviews the effectiveness of economic instruments for building energy policy compared with alternative interventions such as building regulation and information campaigns. The approach taken to building policy by Lord Stern in his seminal climate change report is a cornerstone of this analysis, as is national policy development in Australia as this provided the foundation for this country's controversial carbon-pricing regime. Regulatory reforms to the Australian Building Code over a decade provide economic analysis to support a historical review of the environmental economics discipline. Formal building code development processes are interrogated to establish the strengths and weaknesses of market based approaches to building energy policy. Study findings confirm that conventional economic interventions are likely to be ineffective as a vehicle for reducing greenhouse gas emissions from the building sector despite the significant potential benefits available therein.

Keywords: building regulation, energy efficiency, greenhouse abatement, policy instruments

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Appendix H

From: **Robert Enker** robert.enker@postgrad.curtin.edu.au
Subject: Fw: [Buildings] Manuscript ID: buildings-577643; doi: 10.3390/buildings9110226. Paper has been published.
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