ENERGY TRANSITION IN THE INDIAN BUILDING SECTOR

"Assessing Net Zero Energy Building's niche' development"

MANSI JAIN

University of Twente, the Netherlands

ENERGY TRANSITION IN THE INDIAN BUILDING SECTOR

- ASSESSING NET ZERO ENERGY BUILDINGS' NICHE DEVELOPMENT

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Table of Contents

List of Tables

List of Figures

Abbreviations

ADA	Ajmer Development Authority
AMC	Ajmer Municipal Corporation
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AVVNL	Ajmer Vidyut Vitran Nigam limited
BCA	Building Construction Authority
BEE	Bureau of Energy Efficiency
BREEF	Building Retrofit Energy Efficiency Financing
BRICS	Brazil, Russia, India, China, and South Africa
CII	Confederation of Indian Industry
CIT	Contextual Interaction Theory
CPUC	California Public Utilities Commission
CPWD	Central Public Works Department
CTA	Constructive Technology Assessment;
ECBC	Energy Conservation Building Codes
ECO	Energy Conservation and Commercialization
EERMC	Energy Efficiency and Renewable Energy Management Centre
EIST	Environmental Innovations and Societal Transitions
EPBD	Energy Performance of Buildings
EPI	Energy Performance Index
FAR	Floor Area Ratio
GAT	Governance Assessment Tool
GBIC	Green Building Innovation Cluster
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoI	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment
HRIDAY	Heritage City Development and Augmentation Yojana
HVAC	heating, ventilation and air conditioning
IGBC	Indian Green Building Council
IMCSD	Inter-Ministerial Committee on Sustainable Development

IS	Innovation System
IST	International Sustainability Transitions
LEED	Leadership in Energy and Environmental Design
NAPCC	National Action Plan on Climate Change
NBC	National Building Code
NEEAP	National Energy Efficiency Action Plans
NHB	National Housing Bank
NMEEE	National Mission for Enhanced Energy Efficiency
NMSH	National Mission on Sustainable Habitat
NZEBs	Net Zero Energy Buildings
MEP	Mechanical, Electrical and Plumbing
MLP	Multi-Level Perspective;
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest and Climate Change
MoUD	Ministry of Urban Development
OECD	Organization for Economic Co-operation and Development
PACE-D TA	Partnership to Accelerate Clean Energy – Technical Assistance
SDA	State Designated Agency
SNA	State Nodal Agency
SNM	Strategic Niche Management
SIS	Sectoral Innovation Systems
SSIAf	Sectoral Systems Innovation Assessment framework
TIS	Technological Innovation Systems
TER	The Energy and Resource Institute
TM	Transition Management
ULB's	Urban Local Bodies
USAID	The United States Agency for International Development
USGBC	US Green Building Council
UHBVN	Uttar Haryana Bijli Vitran Nigam Ltd
WBP	Whole Building Performance Method

Chapter 1: Introduction

1.1 Research background

As countries develop and living standards improve, demand for energy grows rapidly. For instance, in nations experiencing fast-paced economic growth, the share of population demanding improved housing—which requires more energy to construct and operate—often increases (Vedala, et al., 2012). Across the world, the built environment accounts for the largest proportion (approximately 40%) of energy consumption (mostly from fossil fuels) and is considered the major contributor of greenhouse gas emissions among all other economic sectors (Olivier, Janssens, & Jeroen, 2012).

Much of the world's increase in energy demand occurs among the developing non-OECD nations[1], where strong economic growth and expanding population leads to an increase in energy use (IEA, 2013). In these nations, consumption of energy in buildings is expected to grow by 2.1% annually from 2012 to 2040, which comprises nearly three times the growth rate of OECD nations (IEA, 2013). The five most emerging national economies namely Brazil, Russia, India, China, and South Africa (BRICS)[2] also promise massive growth and an increased demand for new buildings due to their stable economic growth, increasing population, and high pace of urbanization.

Among the BRICS nations, India is the second most populous country in the world, with over 1.2 billion people (17% of world's population) (GoI, 2011), and grows at the rate of 1.28% per year (Bank, 2014). According to International Monetary Fund (2016) India's economic growth is expected to accelerate to 7.2% in 2017-18 and 7.7% in 2018-19 fiscal years. McKinsey Global Institute (2010) projected that urban population in India could soar to 590 million people by 2030 (which comprises nearly 40% of the country's total population). It is estimated that cities in India will contribute to 70% of the GDP of the country by 2030 (Sankhe, et al., 2010). Thus far, economic growth has been accompanied by an increase in energy needs as an input to sustained economic development. India's existing energy structure is heavily dependent on fossil fuels, primarily driven by coal and imported oil- which is a concern for the government for the long-term energy security of the country (Jana & Malladi, 2015). According to BP energy

[1] outside the Organization for Economic Cooperation and Development

[2] **BRICS** is the acronym for an association of five major emerging national economies: **Brazil, Russia, India, China, and South Africa**. (The BRICS idea was first conceived in 2001 by Goldman Sachs as part of an economic modelling exercise to forecast global economic trends over the next half century; the acronym BRICS was first used in 2001 by Goldman Sachs in their Global Economics Paper No. 66, "The World Needs Better Economic BRICS".)

outlook (2017), India's energy consumption is set to grow 4.2% a year till 2035, faster than that of all major economies in the world (ET Bureau, 2017). As a result the country remains import dependent despite increase in production, henceforth increasing the burden on existing energy infrastructures (NRDC & ASCI, 2012).However, with increased attention given to renewable energy production through government policies and other interventions, RE has witnessed an increase in share of production and is expected to overtake oil as the second largest source, increasing from 4% in 2016 to 14% in 2035 as oil drops from 10% in 2017 to 3% by 2035 (ET Bureau, 2017).

With stable economy and urbanization, demand for new buildings is expected to rise in cities in India. It is estimated that 70% of the buildings for 2030 are yet to be constructed (Vedala, et al., 2012). Buildings account for up to 40% of the total energy consumption in India. Commercial and residential real estate combined will account for more than 2,000 TWH of energy consumption by 2030 (which will be more than double of the figure in 2012) (Akhaury, 2016). India's growth could easily see an increase in building energy consumption and CO_2 emissions of around 700% by 2050 if corrective measures are not taken (Sankhe, et al., 2010). Currently, India has an energy deficit of around 12% which is likely to increase with the government's electrification drive in rural areas (Akhaury, 2016). The current energy infrastructure is poor and incapable of coping with this exponential increase in energy demand. This situation calls for a system change which focuses on increasing energy efficiency alongside addressing other features such as improving the energy infrastructure in the country (Vedala, et al., 2012).

For these reasons, it is imperative for the Indian building sector that projected energy growth is managed in a feasible and a more sustainable manner. To cope with this, ambitious efforts are required to introduce state-of-the-art policies and environmental regulations to push the demand for low energy buildings targeting introduction and diffusion of new sustainable technologies, energy efficiency in building design so that the potential energy savings are not missed (IEA, 2013). Hence, there seems to be an urgent need to design and implement policy instruments, and governance arrangements that influence key systemic conditions to overcome

barriers that are essential in the transition of the building sector towards low energy or low carbon energy systems, and towards near zero energy goals.

1.2 Problem statement

Green buildings[3] in India account for less than 5% of the current building stock in the country (Analytics, 2016). However, in recent years, energy efficient and green buildings have seen an increased uptake. According to the Smart Market Report (2016), by 2018 the green building industry in India will have increased by 20 per cent, which is largely due to environmental regulations and demand for healthier neighbourhoods (Analytics, 2016). According to the findings of the report the country secured a third position in 2016 in the US Green Building Council (USGBC) annual rankings of top 10 countries for LEED[4], a green building rating system. India has 15.90 million gross square meters (GSM) of LEED-certified space and an additional 89.28 million cumulative GSM of LEED-certified and registered space (Analytics, 2016). India is also among the top 10 countries outside the United States making progress in sustainable building design, construction and operations. Despite this, green building uptake also meets with several challenges such as lack of public awareness, lack of public incentives, high perceived upfront costs, and lack of market demand to name but a few (Analytics, 2016).

Green buildings with the highest energy efficiency level are now being projected as 'near' or 'net zero energy buildings' (NZEB) in the western world. They use renewable energy for energy production. NZEBs are buildings with an extremely low energy demand, and in which the remaining energy demand is met by on site renewable energy. Torcellini, *et al.* (2006), define NZEB as: *"a residential or commercial building with greatly reduced energy needs through efficiency gains in such a way that the balance of energy needs can be supplied with renewable technologies."* This concept has currently gained attention across the world by research communities, early adopters of construction innovations, policy makers as well as green building rating systems (such as LEED), setting ambitious targets to transform the building sector by adopting low, near or net zero energy building goals. Such buildings offer a

[3] Green building is the practice of increasing the efficiency with which resources that are used such as energy, water, materials and waste. This is ideally achieved through better siting, design, construction, operation and maintenance as well as in retrofits. i.e. through the complete building life cycle

[4] LEED-certified buildings save energy and water, helping residents and businesses to make savings. Such spaces reduce carbon emissions and create a healthier environment for residents, workers and the larger community.

promising solution to deal with future energy challenges and have limited environmental impact. Hence, large scale uptake of NZEBs in the Indian building sector may provide a long term sustainable solution to the unprecedented demand for energy in the coming years. To make this happen, it is required that NZEBs are to be tested, up scaled, and diffused. This requires the development of the right public-sector interventions, as well as private sector innovations.

Radical transformation and structural change is necessary to govern the innovation towards this relatively new concept in India's building sector. In general (socio-technical) transition implies changes in structure, user practice, regulations, networks, infrastructure, culture and technology (Loorbach & Rotmans, 2005). A transformation from the status quo (of conventional building design and construction) is sure to face with huge resistance (Loorbach D. A., 2007). This especially applies to pursuing ambitious NZEB goals.

Geels (2002) advocates the complete replacement of an entire (embedded) socio-technical system (which may contain conventional building practices). This can only be achieved via the niche development and breakthrough of radical innovations, and gradual breakdown of current regime structures. However, it is typically considered as a complex and a difficult process. To achieve this, a major systemic transformation is required to fundamentally change the way in which buildings are designed, constructed, operated and refurbished throughout their lifecycles to develop them as low energy or zero energy buildings. However, this is easier said than done, as despite the efforts toward sustainable solutions for buildings, mainstreaming of energy efficiency in the building sector still meets with many challenges worldwide including in India (WEC, 2013).

At the same time –coupled with high growth - India faces many structural problems emerging alongside a general situation of socio-economic stress; i.e., resource shortages, institutional weakness and a general inability to deal with key issues (Ofori, 2002). Current government policies based on traditional and outdated approaches are insufficient in solving these problems. They mostly produce a sub-optimal level of solutions (Loorbach D. A., 2007). Major revisions are required at the development process, restructuring of institutions and societal functions to stabilize new innovations and technologies in society. The seriousness and magnitude of problems make it clear that extra efforts are needed, and that solutions along

existing pathways do not offer enough perspectives (Olivier, Janssens, & Jeroen, 2012). Thus far, research into sustainability transitions is mostly restricted to the global West. However, there has been little attention on research into sustainable transition in emerging economies like India, and particularly in economic sectors like the building sector.

Theoretical frameworks such as Strategic Niche Management (SNM; Hoogma *et al*., 2002; Raven 2005) and Sectoral Innovation Systems (SIS; Malerba, 2004; Geels, 2004; Faber and Hoppe 2013) provide insight into how to foster technological and social change, and at the same time initiate sustainable transitions. SNM is an analytical tool designed to facilitate the introduction and diffusion of new sustainable technologies through societal experiments (Schot & Geels, 2008). SNM supports development of radical innovations and focuses on early adoption of new technologies which will be instrumental in the wider diffusion of NZEBs in India. SNM also concerns with how governments can foster introduction of these technologies, initially through experiments within protected niches (Kemp, Loorbach, & Rotmans , 2007). Similarly, another approach based on an innovation perspective highlights studies on 'sustainable innovations' taking a specific technology as a starting point (Malerba F. , 2002).

The SIS perspective provides understanding of the learning and innovation process specific to an economic sector (e.g., the building sector). It supports analysis of technological change, nature and dynamics of innovation (Malerba F. , 2004). Radical innovations are necessary towards wider diffusion of NZEBs in the building sector. It is well argued that to understand innovation activities at the niche level it is also important to understand sector level innovations by using a conceptual SIS perspective (Weber & Hoogma, 1998).

Governments and governance systems play a special role as a facilitator in stimulating innovation and supporting or obstructing the wider diffusion and adoption of new sustainable technologies. The Governance assessment tool (GAT; Bressers *et al*., 2013) can be used to assess the existing quality of a governance context. GAT can provide us with a vision towards current and possible future pathways for the governance context. This can be helpful to assess the introduction and innovation diffusion of NZEBs in the Indian building sector, as well as future policy programs for sustainable innovations. The thesis also attempts to compare the integrated assessment framework of SNM and SIS with GAT to further the understanding and analytical

approach to assess niche developments and deepen our understanding of innovation and diffusion of sustainable technologies in a given sector.

For these reasons, the aim of this research project is to explore these theoretical frameworks further, and to examine their use for assessing the status of niche formation of NZEBs in India. The study will further focus on developing an integrated assessment framework for assessing the NZEB niche development in India based on the combination of SNM and SIS theoretical frameworks alongside using GAT.

1.3 Research objectives

The aim of this doctoral study is to understand the niche formation process of NZEBs and its potential contribution to the sustainable transitions of the Indian building sector. The study focuses on assessing the status of NZEB niche formation and development using appropriate theoretical frameworks, especially SNM, SIS and the GAT.

The study has three primary objectives. Firstly, to develop an integrated assessment framework using appropriate theoretical approaches to assess niche formation as well as innovations for NZEBs in the building sector. Secondly, to assess the status of the NZEB niche in India by evaluating demonstration projects by using the integrated framework. Thirdly, to assess the governance context for NZEB niche formation in two selected cities in India, namely New Delhi and Ajmer.

Further to this, the study also attempts to draw a comparative assessment of sustainable innovations between the building sectors in India and Singapore. The study assesses the applicability of using the same theoretical frameworks in distinct settings such as the building sector in Singapore.

1.4 Research questions

Based on the main research objectives, the doctoral thesis attempts to answer the following research question.

What are the supportive and restrictive conditions for Net zero energy buildings (NZEBs) niche development in the building sector in India?

The main research question is sub-divided into a set of initially four sub-research questions each using an appropriate theoretical framework and most suitable research method resulting in answering the main research question. Following is the set of sub-research questions:

1.41 Sub-questions

1. What integrated assessment framework suits best to assess NZEB niche development in India?

2 What does the SSIA framework tell about NZEB niche formation in India?

3 What is the state of governance in New Delhi regarding NZEB niche formation?

4 What is the state of governance in Ajmer regarding NZEB niche formation?

5 What does SSIAf tell about green buildings innovation in Singapore when compared to the building sector in India?

In addition, sectoral innovations are also explored for the building sector in Singapore using integrated framework in sub-question 1. The study will further a comparative assessment of the nature of building sector in two discrete and heterogeneous settings. This is considered as a novel approach in which SSIAf is explored under the backdrop of both a developing and developed country context

1.5 Thesis outline

This doctoral study is structured based on the publications (mostly refereed journal articles and conference papers) that were delivered during this study. Each chapter is primarily answering one of the sub-research questions 1 -5, and hence supporting the answering of the main research question. This is achieved by conducting a set of case studies using appropriate theoretical frameworks and research method (see figure 1 and 2). The study begins with introducing the research background in this ***Chapter 1*** along with identifying the problem statement, key research objectives, the main research question and its sub-questions.

Chapter 2 presents an overview of NZEBs with their scientific and practical definitions, state of the art in academic literature, the status of green buildings in India, and existing green rating systems.

Chapter 3 focuses on the theoretical frameworks of SNM, SIS and GAT to explore the conceptual basis and development of an appropriate assessment framework to answer the main research question. The theoretical frameworks which are best suited to answer this were selected and redeveloped as the integrated frameworks to suit the context of the study. This chapter answers the sub-research question 1 where the study identifies the appropriate theoretical framework to assess the status of NZEB niche formation in India. Findings of this chapter were presented at a *Netherlands Institute of Governments (NIG)* conference in September 2014, at Delft University of Technology, in Delft, the Netherlands.

Chapter 4 comprises the presentation of the first case study designed to assess the status of NZEB niche formation in India by evaluating seven demonstration projects (either completed or on-going) using the assessment framework developed in chapter 3. This chapter answers the sub-research question 2, what does this framework tell about NZEB niche formation in India? This chapter is based on an article published in the refereed journal of *Environmental Innovations and Societal Transitions (EIST)*, published in November; 2016. The journal is dedicated to research in sustainability transitions.

Chapter 5, the second case study, is designed to assess the state of governance for NZEB uptake in the regional setting of New Delhi. This case study uses the GAT to evaluate the state of governance along with drawing insights from SNM. This chapter answers the sub-research question 3, what is the state of governance in New Delhi regarding NZEB niche formation? This chapter is based on an article that was published in the refereed journal, *Energies* in August, 2017.

Chapter 6, the third case study is designed to assess the state of governance for NZEB in another selected region of India, namely Ajmer. This case study also uses GAT for assessing the governance context in Ajmer along with drawing insights from SNM. The findings of this article were presented at an international conference, *International Sustainability Transitions (IST*) at the Wuppertal Institute of Climate and Energy, Germany in August 2016.

In ***Chapter 7,*** the results of the study are compared with a case study on transition in the Singapore building sector, using a similar theoretical framework (i.e. SSIAf and GAT). The comparisons are drawn to broaden the scope of this study and understand the applicability of theoretical frameworks in a different country with distinct contextual settings for the building sector. The chapter has been submitted as an independent research article to *Journal of Cleaner Production for publication.*

Chapter 8 presents the results and conclusions of the doctoral study, which brings all the cases studies together to assess the holistic outcome of the doctoral thesis answering the main research question. This is done by drawing insights from chapters 3-7. The results of each of the sub-studies will contribute to answering of the main research question. The synthesis will be the culmination of all the sub-studies, providing a holistic picture about the phenomenon under research (NZEB niche development in India). Further to the analysis, the study sets the conclusions.

Some conceptual backgrounds are repeated in chapters which demand re-introduction of theoretical frameworks before presenting the case study. The results of each of the mentioned studies prepare ground work for subsequent studies. All in all, the studies contribute to answering the primary research question.

Figure 1 and 2 below, presents the graphical representation of the flow of this thesis.

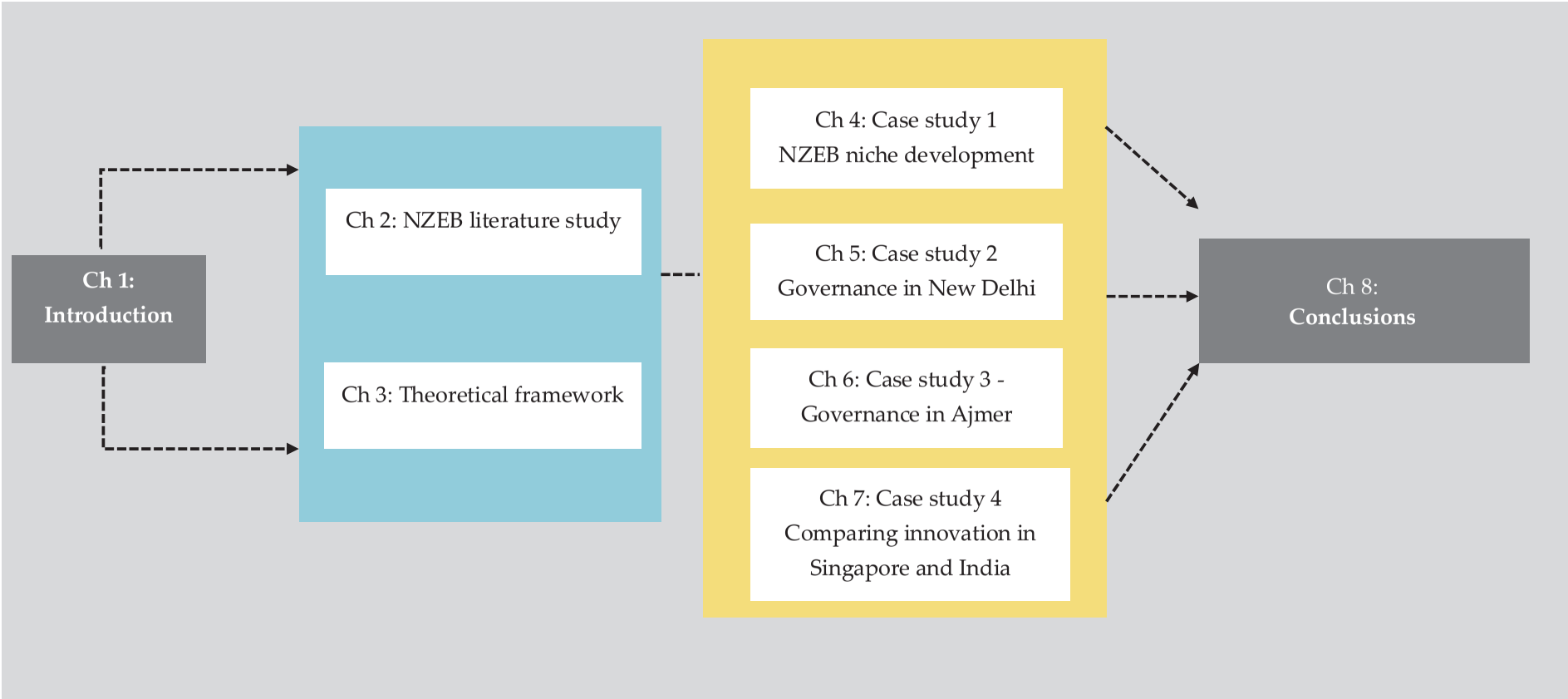

Figure 1 : Thesis outline

Figure 2 : Research approach

Chapter 2:
Net zero energy buildings - an overview

2.1 The building sector in India – an overview

The construction sector in India is expected to generate a huge demand for buildings. Currently, this sector contributes 7.74 percent to the Indian GDP (20161-17) (Planning Commission, 2017) and is the second largest employing economic sector in the country after agriculture (TERI & Bank, 2014). Spatial areas used for buildings (i.e. land area covered by constructed buildings) in India are speculated to increase five-fold from 1,858 million sqm in 2005 to over 9,292 million sqm in 2030 (TERI & Bank, 2014). By 2050, it is projected that India will see an unprecedented escalation of floor area of around 400% (Urge-Vorsatz, et al., 2012).

The Indian building sector consists predominately of the residential and the commercial sector. Nearly, 700 - 900 million sqm of commercial and residential space is projected to be built each year until 2030, which is similar to building the city of Chicago (Sankhe, et al., 2010). Figure 3 presents future trends of the building sector in India (differentiated per type of building) (Vedala, et al., 2012). The numbers of buildings are expected to increase rapidly for all types of building. Most growth, however, is expected for residential buildings followed by the commercial sector.

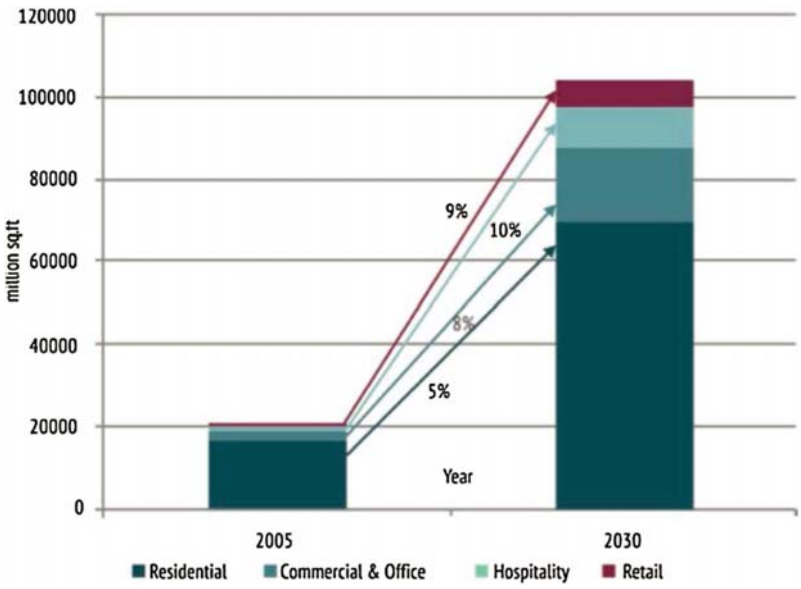

Figure 3 : Future trends in growth of buildings in India per type of building (Vedala, et al., 2012)

Considering the scale of growth, it is imperative for the building sector to manage its projected growth in a feasible and a sustainable manner as buildings consume huge amounts of energy and contribute to GHG emissions causing adverse environmental impact.

A striking increase in energy demand will be difficult to manage due to existing resource constraints and heavy dependence on fossil fuels for energy generation in India. Unconventional or clean energy solutions need to be explored to manage the dramatic impact of energy consumption on the growing building sector in India (Shnapp & Laustsen, 2013).

Most recently in India, increased efforts to advance energy efficiency in buildings have been incorporated in various policies such as Energy Conservation Building Codes (ECBC) for commercial buildings. Additionally, the government seeks to explore unconventional energy resources and a big push to a wide uptake of solar energy (through government programs such as National Solar Mission, development of solar parks and so-called 'Ultra mega solar power projects') (Jana & Malladi, 2015). Key policy interventions which can further a sustainable energy transition, include promoting appropriately regulated competitive energy markets, appropriate pricing and efficient resource allocation, efficiency improvements and associated governance reforms (Jana & Malladi, 2015).

The Government of India (GoI) is committed to a low carbon energy transition, while simultaneously aiming to meet all the developmental challenges that the country faces. Following the 2015 International Paris Agreement on Climate Change, India has pledged to reduce emissions intensity of 33-35% by 2030 as compared to 2005 level. India has also set a target to transition to non-fossil fuel-based energy for 40% of its cumulative electricity generation capacity by 2030 (Ramji, et al., 2016).

2.1.1 Buildings and energy use

Buildings are large consumers of energy throughout their life cycles; i.e. from design, construction, operation, maintenance, to retrofits and demolition (NHB & KFW, 2014). Energy consumed by buildings predominantly concerns electricity and fuel use for cooking. Electricity in buildings is used to provide a variety of services such as thermal comfort (space heating and cooling), lighting, and water heating and electrical appliances. Figure 4 presents seasonal differences in energy demand for New Delhi, India (Manisha, Gaba, & Srivastava, 2007). During the summer months, air-conditioners and refrigerators each account for about 28% of total monthly electricity consumption, while lighting accounts for about 9 % of annual electricity consumption. In the winter, major electricity users are refrigerators (44%), water heating (e.g. "geyser", type 18%), and lighting (14%) (Manisha, Gaba, & Srivastava, 2007).

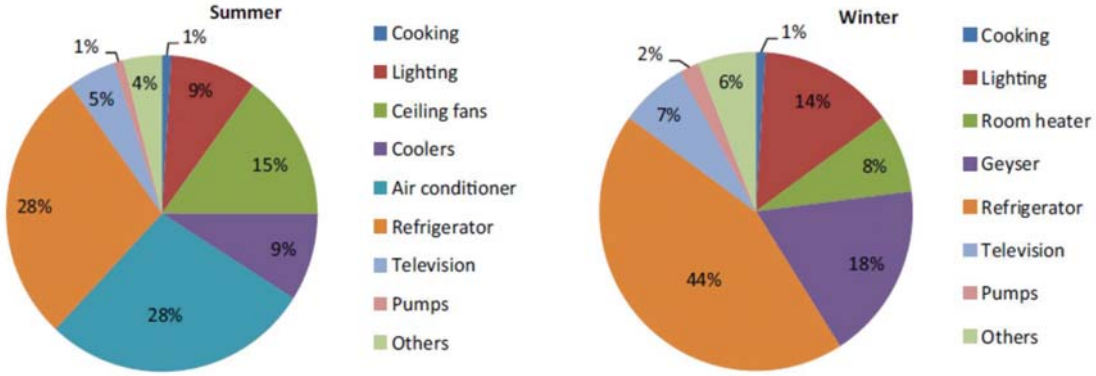

Figure 4 : Share –electricity use (by appliance) in New Delhi, India (Manisha, Gaba, & Srivastava, 2007)[5]

The share of energy use in buildings in the total energy use increases with improved standards of living. In India, building energy use has seen an increase from 14% in the 1970s to nearly 33% of total primary energy use in 2004–2005, with a near-consistent 8% rise in annual energy demand in residential and commercial sectors (Urge-Vorsatz *et al.*, 2010; Rawal *et al.*, 2012). The residential sector accounted for about 22% of total electricity consumption, and the commercial sector accounts for 8% (see Figure 5) (CEA, 2014-15)

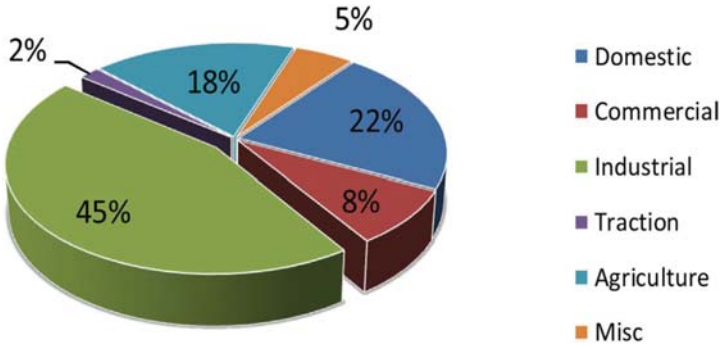

Figure 5 : Total final energy consumption by sector 2014 Source: (CEA, 2014-15)

2.1.2 Impacts of energy use by buildings

Buildings are the largest single contributor to global GHG emissions; accounting for around one third of the global final energy use and 30 per cent of global energy-related carbon emissions (Urge-Vorsatz, et al., 2012). Confronted by climate change, countries across the world are searching for effective ways to reduce GHG emissions from buildings. India's growth is estimated to easily see an increase in building energy consumption and CO_2 emissions of around 700% by 2050 if left unchecked (Shnapp & Laustsen, 2013). Such growth in the energy

[5] Other: washing machine, computers and iron

consumption by buildings will likely have a large negative impact on the environment. In such a situation, without a transformational change to low carbon buildings, energy consumption will increase to levels that are unsustainable and threatening India's energy security alongside detrimental effects to the environment. Increased energy efficiency in the building sector and utilization of renewable energy are very important to contain the rising energy demand and dependence on the electricity grid without jeopardizing the growth of the Indian economy, and the climate change commitments made by the GoI (Shnapp & Laustsen, 2013).

Notwithstanding the expected rise in energy consumption, the Indian building sector has a great potential for significant energy savings. According to a study, the savings potential is more than five times larger than the energy used by buildings in India today (NHB & KFW, 2014). Improving the energy performance of new as well as existing buildings can have a major role in managing energy, GHG emissions in the building sector, and securing its future energy needs. To meet this, ambitious efforts are required to introduce state-of-the-art policies and sustainable technologies to India so that the potential energy savings are not missed (IEA, 2013).

Energy efficient buildings, green buildings and high performing buildings such as NZEBs have the potential to provide long term solutions to the challenging situation regarding future energy demand. India has gradually started to introduce energy efficiency solutions in its building sector with several tools and strategies, and by supporting green building market growth in India with prevalent green building certification tools. If this is to be successful, these efforts must be improved or scaled to realize the potential for energy savings in proportion to the exponential rise in the building sector in India. Therefore, it is imperative that India's building sector is supported by strong policies and packages that include multiple facets of development and scaling of energy efficiency and integration of renewable technologies in both new and existing buildings (NHB & KFW, 2014).

2.2 Programs towards energy efficient buildings in India

In 2001, the Energy Conservation Act was introduced by the GoI to emphasize the national priority on energy efficiency in all sectors. Under the provisions of the Act, the Bureau of Energy Efficiency (BEE) was established in 2002 (BEE, 2015). The BEE is mandated to reduce the energy intensity of the Indian economy by actively working with stakeholders to accelerate the adoption of energy efficiency measures. One of the first initiatives of BEE was to prepare an Energy

Conservation Action Plan, which was released in August 2002. In June 2008, India released the first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate change mitigation and adaptation. The plan identified eight major national missions including a National Mission for Enhanced Energy Efficiency (NMEEE) (Ramesh & Khan, 2013). Over the past decade, the Ministry of New and Renewable Energy (MNRE), the Ministry of Environment and Forests (MoEF), the Ministry of Power (MoP) and the ministry of Urban Development (MoUD) have introduced sustainability components with overarching policy objectives to promote energy conservation in buildings (Vasudevan, Cherail, Bhatia, & Jayaram, 2011).

2.2.1 Energy conservation building code

BEE as a national agency has been introduces and monitors energy efficiencies of buildings and appliances in India. For mainstreaming the energy efficiency in the building sector, the BEE introduced the ECBC in May 2007. This is applicable to both new buildings and those undergoing major renovation. The ECBC applies to buildings or building complexes with a connected load of 100 kW or greater, or a contract demand of 120 kVA or more. Currently, the ECBC is in a voluntary implementation phase and the compliance percentage is forecasted to increase gradually from 10% until 2013 to 35% in 2015 and 65% by 2017 (BEEP, 2015). ECBC has been amended in twenty states of India out of which ten states have also notified its implementation (USAID, 2016). Currently, the ECBC provides both requisite and prescriptive requirements for five building components, namely: (a) building envelope, (b) heating, ventilation and air conditioning (HVAC), (c) service water heating and pumping (d) lighting, and (e) electrical power. For compliance with ECBC, projects can either adopt the 'prescriptive method[6]' or the 'whole building performance method (WBP)'[7]. The trade-off method is available only for the building envelope category (BEEP, 2015).

[6] Prescriptive Method: A building complies with the Code using the Prescriptive Method if it meets the prescribed minimum (or maximum) values for envelope components, comfort systems and controls, and lighting and controls, in addition to meeting all the mandatory requirements.

[7] Whole building performance method: A building complies with the Code using the Whole Building Performance (WBP) Method when the estimated annual energy use of the Proposed Design is less than that of the Baseline Design, even though it may not comply with the specific provisions of the prescriptive requirements. The mandatory requirements shall be met when using the WBP Method.

Under the 12th five-year plan (2012-17)[8], one of the priority areas for BEE is to update the existing ECBC in response to technological development, market changes, and the energy demand and supply scenario in the country. The United States Agency for International Development (USAID) - Partnership to Accelerate Clean Energy – Technical Assistance (PACE-D TA) program is provided support to BEE on this initiative. An ECBC technical update document was launched in June 2017 after it had been reviewed by the BEE and had been recommended by core working group committees (USAID, 2016).

2.2.2 BEE star rating for buildings

The BEE introduced the Star labeling programme for existing commercial buildings, which provides labels to the buildings based on their actual energy performance. This was done to create demand in the market for energy efficient buildings. The BEE Star labeling is applicable to buildings with the connected load of 100 kW or more or a contract demand of 120 kVA or more. One to five stars are awarded to the buildings based on their specific energy use with the five-star label recognized as indicating the most efficient building. A standardized format of data collection of actual energy consumption of the building was developed to collect information pertaining to the building built-up and floor area, conditioned and non-conditioned areas, type of building, hours of operation of building in a day, climatic zone, and other information related to facility (BEE, 2015). The star rating is based on actual energy performance of the buildings expressed as an Energy Performance Index (EPI) measured in terms of annual electricity consumption per unit of built up area (expressed in kWh/m^2/yr.). Currently, this rating is applicable to office buildings, business process outsourcing buildings, and shopping malls. In the future, the BEE would like to extend the star labeling to hotels and hospitals (BEEP, 2015).

2.2.3 Green building rating systems

In recent years, India has emerged as one of the world's top destination for green buildings and has implemented several rating schemes, which opens up a wide range of opportunities for innovation in construction, architecture and engineering design, building materials and as well as in technology (Ramesh & Khan, 2013). Green building can be viewed as the practice of increasing the efficiency with which resources are used such as energy, water, materials and

[8] From 1947 to 2017, the Indian economy was premised on the concept of planning. This was carried through the **Five-Year Plans**, developed, executed, and monitored by the Planning Commission (1951 - 2014) and the NITI Aayog (2014 - 2017). From 2012-17 is the 12th five year plan in operation.

waste during construction as well as operation phase. This is ideally achieved through improved site planning, design, construction, operation and maintenance as well as in retrofits, i.e. through 'greening' complete building life cycles. Green buildings aim to optimize the use of energy by incorporating various design strategies, new energy efficient construction materials and equipment, operation and maintenance resulting in reduced energy loads compared to the conventional building design (Mamta, 2015). Working on green buildings is largely a multi-stakeholder endeavor in which architects, engineers, builders, material manufactures as well as occupants work to make a green building (Ramesh & Khan, 2013).

There are three voluntary rating systems applicable for building design in India. These are:

- Indian Green Building Council (IGBC)/ LEED –India,
- Leadership in Energy and Environmental Design (LEED) USGBC, and
- Green Rating for Integrated Habitat Assessment (GRIHA).

The concept of green building landed in India in the late 1990s focusing on having a minimal environmental impact. In India, the green buildings movement was accepted and integrated by the Confederation of Indian Industry (CII) in the early 2000s. They formed the Indian Green Building Council (IGBC) which is actively involved in promoting the green building concept in India. Leadership in Energy and Environmental Design (LEED)-India is associated with the internationally known LEED (USGBC) program, which was administered in India by the IGBC until 2016. LEED India (IGBC) was launched in 2003 and since then has grown exponentially (ReportBuyer, 2016). Currently IGBC and LEED operate as separate rating systems. IGBC promotes a whole-building approach to sustainability by recognizing performance in key areas such as: sustainable site planning, water efficiency, energy efficiency, and renewable energy, conservation of materials and resources, and indoor air quality. This has created a large network of smaller stakeholders which includes the construction industry comprising corporate, government & local agencies, architects, project developers, builders, product manufacturers and most interestingly green building consultants whose profession was almost unheard of two decades ago. Since then the green building movement in India gained a strong impetus (ReportBuyer, 2016).

In the meanwhile, the MNRE and the Energy and Resource Institute (TERI) developed the GRIHA. This indigenous green building standard is similar to the LEED system in recognizing development that meets certain environmental and sustainable development practices (Smith R. M., 2015). It is a design evaluation system for green building and is intended for all kinds of buildings across every climatic zone in India (Ramesh & Khan, 2013). Until 2017, there were more than 4500 green building projects in India with about 4.17 Billion square feet built-up area which is only second after the USA in terms of built area as well as in number of projects. But the current stock of green buildings in India is only 5% of the total buildings (both new and existing) in the country. This shows the massive market potential of green buildings in India (ReportBuyer, 2016).

India's National Housing Bank (NHB) – India's state-owned housing financial institution has projected that India's real estate sector is set to surpass US$ 150 Billion industry by 2020, building on initiatives such as "Smart City mission" and "Housing for All by 2022" (ReportBuyer, 2016). According to the building industry estimates, for the new buildings, India's green building market is projected to be in the range of US$ 3-40 Billion (ReportBuyer, 2016).

Table 1 presents key national policies and guidelines that recommend energy efficiency in buildings under various ministries

Table 1: Chronological listing of key policies and codes, Source: (Vasudevan, Cherail, Bhatia, & Jayaram, 2011)

Policy/ Code	Year	Ministry	Status	Energy conservation guidance
National Building Code(NBC)	1970 Revised 2005 Revised 2012	MoUD	Model Code (Building bye-law)	• No mandatory energy perfromance standrd • Building materials • Construction technologies • Building and plumbing services
Energy Conservation Building Code(ECBC)	2007 Amended 2010 Revised 2017	MoP BEE	Currently voluntary	• Minimum perfromance standards for building envelops • Roof and windows • Lighting system

				• Air conditioning system • Electrical distribution system • Water heating and pumping system
Integrated Energy Policy (IEP)	2008	Planning Commission	Policy guidance	• Design and construction • HVAC • Lighting • Household appliances
Environment Clearance Notification – Environmental Impact Assessment (EIA)	Manual on norms and standards for Environmental clearance of large construction projects,2007	MoEF	Environmental clearance is mandatory for large construction projects with built-up area if 20,000-150,000sq.m. The manual provides recommendations for energy conservation	• Low energy design concepts • Energy effieicnt techniques and technologies • Solar passive techniques
National Mission on Sustainable Habitat (NMSH)	Approved in 2010	MoUD	Policy guidance document	• Sustainable habitat standards • Energy perfromance of buidlings • Structural safety • Energy effieicnt construction

2.3 Net zero energy buildings: conceptualization

The worldwide CO_2 emission mitigation efforts, the growing energy resource shortage, dependence on fossil fuels, and the fact that buildings are responsible for a large share of the world's primary energy use drives research towards new building concepts, in particular NZEBs. This concept has received increasing attention in recent years, since growing numbers of stakeholders globally are attempting to reduce the energy consumption, operating costs and embracing targets to diminish energy footprints from their buildings stocks. The latest and perhaps the most ambitious of these efforts relates to the development and evolvement of NZEBs.

NZEBs are commonly understood as highly energy efficient buildings which use, over the course of a year, renewable energy technology to produce as much energy as they consume. Torcellini, et al. (2006), defines NZEB as - *"a residential or a commercial building with greatly reduced*

energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies." Most commonly demonstrated examples illustrate the path of optimizing energy use, taking a "reduce, then produce" approach: driving down the building's energy demand as far as possible, then filling the remainder with renewable power generated on the property or purchased on the market (Marszal & Heiselberg, 2009).

However, a lack of common understanding and ambiguity over the definition of NZEBs has become noticeable since this concept can be described in wide range of terms and expressions. Torcellini et al. (2006) indicate that the definition of NZEB can be framed in several ways, depending on the project goals, intentions of the investor, concern about climate change or finally the energy costs, thus making NZEB a complex concept. The term is used commercially without a sound academic understanding. As such, countries are enacting policies and national targets based on the concept without having a clear definition in place. In the recast of the EU Directive on Energy Performance of Buildings (EPBD) it is specified that by the end of 2020 all new buildings shall be "nearly zero energy buildings" (EPBD Recast , 2010). For the Building Technologies Program of the US Department of Energy (DOE), the strategic goal is to achieve "*marketable zero energy homes in 2020 and commercial zero energy buildings in 2025"* (US DOE , 2008).

Research reveals that NZEB is not a very new concept; though; literature on NZEBs goes back to the late 1970s and the early 1980s. The reviewed literature has indicated that there is wide diversity among NZEB definitions. Esbensen and Korsgaard (1977) describes an experimental NZEB house in Denmark including only heating demand *"With energy conservation arrangements, such as high-insulated constructions, heat recovery equipment's and a solar heating system, the Zero Energy House is dimensioned to be self-sufficient in space heating and hot-water supply during normal climatic conditions in Denmark."* Followed by Gilijamse (1995) describing NZEB as; *"A house in which no fossil fuels are consumed, and the annual electricity consumption equals annual electricity production. Unlike the autarkic situation, the electricity grid acts as a virtual buffer with annually balanced delivers and returns"*. Later Iqbal (2003), elaborated NZEBs as; *"Zero energy home is the term used for a home that optimally combines commercially available renewable energy technology with the state of the art energy efficiency construction techniques. In a zero-energy home no fossil fuels are consumed, and its annual electricity consumption equals annual electricity production. A zero-energy home may or may not be grid connected"*. As stated, many approaches to NZEB have been

documented and published in articles in the past few decades, in which phrases such as 'a zero-energy house', 'a neutral energy autonomous house' or 'an energy-independent house' were used.

Additionally, the published academic literature and documented demonstration projects have highlighted that the path of achieving the 'zero energy' goal is affected significantly by the specific NZEB definition that has been adopted. Torcellini *et al*. (2006), proposed four different definitions based on various approaches to NZEB*(i) site ZEB, (ii) source ZEB, (iii) cost ZEB and (iv)emissions ZEB.*

- **Site ZEB**: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
- **Source ZEB** A source ZEB produces at least as much energy as it uses in year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
- **Cost ZEB:** In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid or feeds into the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- **Emissions ZEB**: A net-zero emissions building produces at least as much emissions-free renewable energy than it uses from emissions-producing energy sources.

Following this, the proposed definitions were further discussed in various publications. Kilkis (2007) defines a NZEB as; "*a building, which has a total annual sum of zero energy transfer across the building-district boundary in a district energy system, during all electric and any other transfer that is taking place in a certain period of time*". At the same time Mertz, *et al*. (2007) and Laustsen (2008) distinguish two approaches towards the NZEB: zero energy and zero emission (CO_2 neutral) building. In the definition for zero energy building the authors stress that the house generates the same amount of energy as it consumes. Furthermore, in a zero emission or a carbon neutral home is a complex concept, in which no CO_2 is emitted to the atmosphere due to the operation of the buildings. In addition, the home could generate all its energy on-site like

a net-zero energy home. The review has shown that NZEB is a complex concept but still poorly understood conceptually.

Developing a NZEB definition applicable for all cases is not a simple task as it is clouded by a variety of complex approaches. These approaches have created a list of main topics, which should be considered, when developing a new NZEB definition (Marszal & Heiselberg, 2010). In many publications (Torcellini *et.al*. 2006; Laustsen 2008; Marszal and Heisenberg 2009), authors present the wide variety of zero-energy working definitions and highlight the significance of these definitions in the framework of final design and actual performance. Strategies towards NZEB should reflect the climate, the building standard and energy system as well as the associated (future) energy grid infrastructure (Hermelink, et al., 2013). Therefore, the NZEB approach in a country can differ depending on the climate, the resources for (green) electricity in the grid, the heating and cooling grid infrastructures (Hermelink, et al., 2013).

Marszal & Heiselberg (2010) focus on the review of the most relevant existing definitions for NZEBs and various approaches towards possible calculation methodologies (e.g. the metric of the balance, the balancing period, the type of energy use included in the balance, the type of energy balance, the accepted renewable energy supply options, the used primary energy, the connection to the grid and unique features like requirements for energy efficiency, indoor climate or the building–grid interaction). The authors present and discuss possible answers to the above-mentioned issues in order to facilitate the development of a consistent NZEB definition and a robust energy calculation methodology.

2.3.1 Efforts toward NZEB concept in India

Thus far, the building's sector energy-efficiency related policy framework in India addresses and recognizes reductions in energy-use (see table 1). It recognizes the need for developing a long-term strategy for meeting energy demands of buildings primarily through increasing energy efficiency levels and the use of renewable resources. This concerns new buildings; which mean that most of the potential energy savings could come through the construction of novel, extremely energy efficient buildings or NZEBs. This means that all new constructed buildings must have much higher levels of energy performance to achieve this potential.

The GoI showed interest towards developing a long-term roadmap for NZEBs through bilateral project agreements between the BEE and the USAID. The Energy Conservation and Commercialization (ECO) was implemented in three phases in which the NZEB concept was introduced in ECO III (the ECO III project worked towards identification and development of a collaboration framework between the US DOE National Research Laboratories, U.S. academic institutes and research centers, and the CEPT University in India (PACE-R)) during phase II (2006-12). The USAID PACE-D TA program phase three 2012-17, collaborated with BEE (Ministry of Power) for a technical update of the ECBC as per market changes and technological advancement (towards super ECBC buildings) ready to integrate RE goals and a vision for NZEB. Next, a set of following key initiatives have been undertaken in India to spur NZEB market uptake: (i) NZEB portal and industry alliance, (ii) NZEB demonstration projects, (iii) Net Zero certification.

NZEB portal and industry alliance

The Ministry of Power and USAID launched India's first integrated web portal designed to promote and mainstream NZEBs in India in May 2017. The portal provides complete information about NZEBs– those that generate as much energy as they use – as well as how to achieve near-zero energy status using efficient lighting and equipment, integration of renewable energy technologies and best practice design strategies. In addition, the portal hosts the Indian NZEB Alliance, an industry-wide body setup to drive the Indian construction market towards the uptake of highly energy-efficient buildings (GoI, 2017). These efforts were largely initiated via afore mentioned agreements through international partnerships and government efforts.

NZEB demonstration projects

Recently, few NZEB demonstration projects have been built by both private and public-sector stakeholders. These projects were constructed with the aim to showcase how NZEBs are designed, constructed and operated using new methods and technologies. One such example is Indira Paryavaran Bhawan, the new office building for Ministry of Environment, Forest and Climate Change (MoEFCC) which embarks on a radical change from a conventional building design and claims to be the first net zero energy building in India. The project team has paid special attention to strategies for reducing energy demand by providing adequate natural light, shading, landscaping to reduce the ambient temperature, and energy efficient active building

systems. Several energy conservation measures were adopted to reduce the energy loads of the building. The remaining demand was met by producing energy from on-site installed high efficiency solar panels to achieve net zero criteria. Indira Paryavaran Bhawan uses 70% less energy compared to a conventional building. The project adopted green building concepts including conservation and optimization of water by recycling waste water from the site. Currently, it is India's highest green rated building. The project has received both GRIHA 5 Star and LEED Platinum certificate ratings. Moreover, the building constructed in the project has already won awards such as the Adarsh/GRIHA of MNRE for exemplary demonstration of Integration of Renewable Energy Technologies (USAID, 2017).

In addition, the USAID PACE –D TA program also supported NZEB pilot projects in India providing technical assistance namely to Nalanda University in Bihar and public office building - Uttar Haryana Bijli Vitran Nigam Ltd (UHBVN), Haryana. In a similar vein, few other demonstration projects (see chapter 4) are working towards the ambitious target of achieving a Net Zero Status.

Net zero certification

IGBC has announced to launch a net zero energy certification by mid-2017. IGBC also plans to promote demonstration NZEBs to prove their business case and is likely to work closely with the GoI to mainstream NZEBs in the country. This certification program by IGBC is designed to achieve the World Green Building Council's vision of reducing GHG emissions from buildings to zero by converting new and existing global building stock into net zero energy buildings (USAID, 2017).

2.3.2 Efforts for NZEB uptake in developed countries

While NZEB is seen as a new concept in a developing country such as India, many developed nations have experimented, exhibited and endorsed the concept of NZEB as a doable and practical solution to long term energy challenges in the building sector. Innovation and socio-technological transformations have been showcased in building sectors in several countries by implementation of government policies and other instruments supporting the uptake of the NZEB concept. These ambitious targets show that the countries are making serious efforts to transform their building sector towards low energy, low carbon and sustainable building stock.

Following is the host of efforts and initiatives taken by several developed countries regarding the uptake of NZEBs in their respective countries.

European Union

The NZEB goals of all member states of the European Union (EU) are governed by the Directive on Energy Performance of Buildings or EPBD. EPBD is an instrument for enhancing the building regulations on energy performance of the building stock in the EU member states which binds EU member states to ensure that all newly constructed buildings must have a nearly zero-energy performance by 2020 and all public buildings must be nearly zero energy by 2018. EPBD was first issued in 2002 (EPBD, 2002/91/EC) and then in 2010 (2010/31/EC) with amendments (Bürger, 2013). EPBD binds all the member states to amend relevant national laws to achieve the goals set by the Directive (Bürger, 2013)

Concentrated Action EPBD was launched in 2015 by the EU to support member countries in amending their national laws to achieve the goals set by the EPBD. MS have sets its own interim and final targets, and a host of strategies to accomplish these targets. Member states are also required to draw up national plans reporting on their plans for increasing the number of NZEBs, the definition of NZEB, policies and measures to stimulate the transformation of buildings that are to be refurbished and meet NZEB standards, and to undertake interim steps towards NZEB market uptake of Article 13(4) (USAID, 2017). Table 2 presents overview of European legislation addressing the building sector.

Table 2 : Overview of European legislation addressing the building sector (Bürger, 2013)

EU Legislation	Brief
Renewable Energy Directive (RED,2009/28/EC)	Makes it mandatory for MS to set up sector specific targets for renewable heating and cooling. The policies must be applicable to new buildings and existing buildings with planned major renovations. Progress is tracked through National Renewable Energy Action Plans (NREAPs)
Energy Service Directive (ESD, 2006/32/EC)	The ESD requires Member States to adopt an overall national indicative energy saving target of 9% until 2016 and to periodically report the progress and measures undertaken through NEEAPs. The main energy saving targets for the Member States are represented in the ESD. The ESD includes measures to improve energy services and energy efficiency
Energy Efficiency	The EED makes it mandatory for MS to establish a long-term strategy for

Directive (EED, 2012/27/EU)	mobilizing investment in the renovation of the national stock of residential and commercial buildings, both public and private. The member states establish energy efficiency obligation schemes for energy suppliers of grid operators (commonly known as White Certificate Schemes) or alternative measures with equivalent effect aiming at providing efficiency measures that achieve energy savings of 1.5% per year in average.
Eco design Directive (2005/32/EC) and its recast (2009/125/EC)	This directive sets minimum efficiency standards for energy related technologies and materials used in the building sector (e.g. boilers, hot water generators, pumps, and ventilation)
Energy Labeling Directive (1992/75/EWG) and its recast (2010/30/EU)	The directive requires MS to establish labeling schemes for energy related technologies and materials. It includes many technologies used in the building sector.
Outreach	The European Commission has set up an online information portal, BUILD UP, to support EU member states in implementing the directive. Building sector professionals are the primary target audience for this portal.

Germany

In Germany a well-established instrument portfolio for construction of new buildings and refurbishment of existing buildings exists. The main policy instruments are:

- The energy efficiency requirements defined in the building code;
- Low-interest loans and a repayment bonus for energy efficient refurbishment and new buildings depending on the energy standard achieved;
- Investment grants (existing buildings) and use obligation (new buildings) for the implementation of RES-H; and
- A variety of instruments for information and motivation as well as supply side measures.

The building codes have been adjusted (with progressive norms) five times over the past 35 years and energy demand reduction for space heating and domestic hot water has reduced from 300 to almost 65 kWh /m² (Schimschar *et al.*, 2011). The most recent update was in October 2009, when the new German building code (energy saving ordinance – EnEV 2009) became effective. To comply with the requirements of the European Commission, all newly constructed buildings must have a nearly zero-energy performance by 2021. Interim targets are:

- Reduction in the heat requirement of the building stock by 20% by 2020

- Reduction in the primary energy requirement by 80% by 2050,
- Aim to achieve an almost climate-neutral building stock by 2050

Table 3 presents overview of German legislation addressing the building sector.

Table 3: Overview of German legislation addressing the building sector ((Bürger, 2013)

German legislation	Brief
Energy Saving Ordinance (EnEV)	EnEV set minimum requirements for the energy-related quality of the building shell and the system technology for both new and renovations of existing residential and non-residential buildings. These requirements are updated to enhance their stringency.
Renewable Energies Heating Act	The Act mandates use of renewable energy sources to provide heating and cooling in both residential and non-residential buildings, whether new or existing. The government supports the act through capital grants for smaller systems and low interest loans or redemption grants for larger systems
Act on the Promotion of Renewable Thermal Energy (EEWärmeG)	EEWärmeG imposes the use of renewable energies, including solar heating systems and heat pumps, in the construction of new buildings (so-called obligation to use)
PassReg Project	The Passive House Regions with Renewable Regions (PassReg) project aims to promote implementation of NZEBs across 11 EU countries. An informational brochure that summarizes examples of NZEBs, approaches for municipalities to implement NZEBs through Passiv Haus Standard program.

United Kingdom

The UK government has committed itself to a challenging CO_2 emissions reduction target for 2050. The UK's target for all new homes to meet the Zero Carbon Standard from 2016 comes in advance of the EPBD target for all new buildings in the EU to be 'Nearly Zero-Energy Buildings' from 2020 (Zero Carbon Hub , 2014).

The country employs prescriptive energy efficiency requirements for buildings since 1976. In 2005, following the implementation of the 2002 EPBD, the first performance-based code was introduced. The 2010 code and related national policies have been further strengthened to reflect the provisions of the EPBD recast. In 2007 the national government's policy for all new homes to be zero carbon standards from 2016 was implemented primarily through the progressive tightening of Building Regulations. Phased introduction of zero carbon standards has already

begun (England); standards based on cost-effectiveness, currently cost benefit analysis and standards are executed. Table 4 presents overview of UK legislation addressing the building sector.

	Table 4: Overview of UK legislation addressing the building sector ((Bürger, 2013), (USAID, 2017)
UK Legislation	**Brief**
Zero Carbon Buildings Policy	The UK is committed to ensuring that new homes are zero carbon from 2016. From 2016 for homes and 2019 for non-domestic buildings, all new buildings in England will be required to be built to a zero-carbon standard. The policy and standard has continued to undergo revisions since 2007 to protect economic and technical viability and ensure these requirements remain achievable.
Building regulations Part L	Part L of the Building Regulations sets minimum standards for energy efficiency in new and existing buildings (it applies to new building work in England and Wales; Scotland and Northern Ireland have separate regulations). The current regulations came into effect in April 2014.
Code for Sustainable Homes (2007)	The code for sustainable homes is the national standard for the sustainable design and construction of new homes. It aims to reduce carbon emissions and promote higher standards of sustainable design above the current minimum standards set out by the building regulations.
Zero Carbon Hub	Zero Carbon Hub is a government/industry partnership body which gathers evidence and recommends appropriate requirements for on-home carbon reductions. Based on recently submitted findings of the Hub, on-home carbon reductions between 44% and 60%, dependent on house type are called for, compared to 2006 Building Regulations.
2nd National Energy Efficiency Action Plan (NEEAP)	The UK's 2nd Energy Efficiency Action Plan (NEEAP) brought together in one document all the then current and planned policies and measures the government and the Devolved Administrations have in place to improve energy efficiency. This updated the previous EEAP of 2007 and fulfilled the UK's obligation under the Energy End-Use Efficiency and Energy Services Directive (ESD) to report on progress towards an overall national indicative energy savings target of 9% by 2016. It was superseded by the 2014 Energy Efficiency Action Plan under the EU Energy Efficiency Directive.
National Renewable Energy Action Plan (NREAP) -2010	In the NREAP, various targets were set for UK to be achieved by 2020. These include: • 15% share of energy generated from renewable sources in gross final energy consumption • 12% of heat consumption met by renewable sources; • 31% of electricity demand met by electricity generated from renewable energy sources • 10% of energy demand met by renewable energy sources (Measures : Renewables Obligation (RO); System of feed-in tariffs Introduction of Renewable Heat Incentive (RHI)

USA –The state of California

California's NZEB strategies are one of its "Big Bold Energy Efficiency Strategies" to achieve long term energy efficiency through market transformation. The NZEB policy vision, authored by California Public Utilities Commission (CPUC), the leading implementing body for NZEB policies in the state, specifies ultra-high energy efficiency as vital in achieving net zero energy goals. Clean energy production and demand response is also to be encouraged to realize net zero energy buildings (USAID, 2017).

In 2007, the CPUC adopted the approach that all new residential buildings in California will be Energy Zero by 2020, and all new commercial buildings will be energy zero by 2030 (*2007 Integrated Energy Policy Report*). This commitment has been reiterated by the *California Long Term Energy Efficiency Strategic Plan* in 2008. The *2013 Integrated Energy Policy* laid out the steps and renewable options for achieving the NZEB goals.

Near (2009-2011), mid-term (2012-2015) and long term (2015-2020) milestones have been framed for timely implementation of the NZEB policy goals and to map progress toward the overarching objectives (USAID, 2017). California has developed separate milestones for residential and commercial buildings. By 2020, all new residential construction in California is set to become 'net zero energy'. By 2030, all new commercial construction and 50% of existing commercial buildings in the state will also be net zero energy. Distinct zero energy targets are set for federal buildings. By 2015, 15% of existing federal buildings will conform to new energy efficiency standards and 100% of all new federal buildings will be zero net energy by 2030. California has adopted a combination of pull and push market transformation strategies for NZEB goals:

- To catalyse improvement in energy efficient building technologies and practices by defining aggressive interim mandatory energy efficiency goals for buildings.
- The "Path to Zero" campaign to create demand for high energy efficiency buildings by marketing campaigns, financial incentives and information dissemination on zero energy and low energy technologies and design practices.

- Advancement in stringency of California energy codes (Title 24) - at each triennial update cycle, "beyond code" voluntary requirements of the preceding version are adopted as the mandatory requirement for the updated code.
- Green building ordinances adopted by the largest cities of California for large commercial buildings.
- To encourage local leadership initiatives for information dissemination on NZEB practices.
- Innovative financing programs have been set up, in part through private sector funding.

2.4 Existing challenges and barriers to NZEB market development in developed countries

To realize the potential benefits of NZEBs in India, it is necessary to first overcome existing barriers such as technical barriers, economic barriers, lack of capacity, or lack of awareness in the country. It is evident from efforts made in developed nations for NZEB that both market conditions and right policy interventions are needed for successful integration of NZEBs. In addition to those who have embarked on their own efforts to look at low energy buildings, there are several other stakeholders that need to be encouraged to join the drive and initiate transition. Based on findings of the ZEBRA2020 project in Europe and PassREg project in Europe and North America, there are host of barriers and challenges which have been brought to light which hamper or pre-empt the wide scale uptake of NZEB in these nations. The ZEBRA2020 and PassREg projects have undertaken studies to identify major barriers for market development of NZEBs:

2.4.1 ZEBRA2020 project:

ZEBRA2020 aims at creating an observatory for NZEBs based on market studies and various data tools and thereby generate data and evidence for policy evaluation and optimization. European legislation (EPBD) makes NZEBs a legally binding standard by 2020. Therefore, the key objective of ZEBRA2020 is to monitor the market uptake of NZEBs across Europe and provide data as well as recommendations on how to reach the NZEB standard. ZEBRA2020 covers seventeen European countries and about 89% of the European building stock and population. Thus, it is actively contributing to meeting the ambitious target of 100% share of NZEBs for new buildings from 2020 and a substantial increase of deep NZEB renovations

(ZEBRA2020, 2016). The project identified a set of barriers which were observed as common among the participating European countries (ZEBRA2020, 2016):

- A need for more knowledge on energy efficient projects as well as positive examples to feed into decisions for energy efficiency projects;
- Poor end user awareness on how they are using energy in residential buildings;
- Policy, regulation and standards are not established and are still developing across several countries;
- A need to understand what low energy building means in legislation for the actual building process;
- Investment cost are perceived as too high;
- There is a long payback period (of 15-20 years) and residents do not stay long enough in a house to benefit from this payback period;
- There are very little financial instruments available in the EU that are aimed directly and exclusively at supporting NZEBs;
- Lack of knowledge and interest of energy efficiency among residents and building owners, often due to lack of awareness combined with challenges and architectural and cultural values.
- Existing building structure and technical systems limit the choice of technical solutions possible for NZEB renovations.

Findings from the market study and policy evaluation study in ZEBRA2020 show that there is still a long way to go in establishing official national NZEB level for buildings, although most countries have recently revised existing rules, regulations and guidelines, and facilitated means enabling highly energy conservative buildings in accordance with the EPBD. Determined differences in the structure of national and regional management, attitudes and economic structures are all factors found to have both negative and positive effects on the progress and implementation of NZEBs in the different countries. The study suggests that many countries are poorly prepared for implementing NZEBs by 2020 and that there is a need for increased knowledge on new technology on all levels in the building industry along with economic incentives, building of pilot examples to follow, and utilizing the advantages that NZEBs bring (ZEBRA2020, 2016).

2.4.2 PassREg project

The PassREg project investigated front runner regions which have successfully implemented Nearly Zero Energy concepts using Passive House supplied as much as possible by renewable energies as the foundation. The lessons learned, and the solutions applied in these regions serve as a basis for adaptation and implementation in other regions across Europe. The project, co-funded by the EU within the framework of the IEE and with participating regions from ten European countries thus supports the implementation of the EPBD, recast 2010 and makes an important contribution to the achievement of the EU's efficiency goals for 2020 (PassREg, 2015). The project identified and highlighted the important barriers for the uptake of the NZEB concept in developed nations in EUROPE and North America (PassREg, 2015). Some of these are listed below in Table 5.

Table 5: Identified barriers for uptake of the NZEB Concept in Europe and America (PassREg, 2015)

Regulation and political agenda
• Lack of political will, motivation for transition • Lack of clear direction, vision, targets & insight in progress towards vision and target • Lack of stakeholder consensus • Lack of knowledge with policymakers and public servants
Business case and financing
• Risks and benefits accrue to different parties (split incentive) • Improved energy performance and non-energy benefits not recognized in appraisal process • Incremental cost due primarily to (in order of importance, most common ranking) • Cost of energy/carbon too low
Capacity
• Lack of interest, motivation to embrace PH/NZEB by end users • Unfamiliarity of suppliers with PH/NZEB • Resistance of suppliers/builders to change the local building tradition • Lack of awareness and familiarity for design professionals • Difficulty in finding trained traders and subcontractors • Design-build projects lack integration; integrated design still niche, not the norm
Knowledge
• Insufficient knowledge base • Inaccessibility of knowledge base • Lack of trained personnel
Applied products
• Lack of suitable variety and competitive market for high performance products (whether

manufactured in NA or imported) • Imported products do not have North American certification required by codes • Testing procedures for locally manufactured products not trusted for PH
Public and builder awareness of passive design and benefits
• Misconceptions on and lack of awareness of benefits of PH by policy makers, civil servants consumers and suppliers • Lack of demonstration projects showcasing range of building types in various regions • PH perceived as a brand; brand issues • Costs and lack of appropriate manpower to execute strategies on PR, marketing and communication
Quality Assurance
• Lack of experts capable of doing quality assurance • Lack of infrastructure to perform quality assurance • Value of certification beyond the first 2-3 projects does not justify the cost / time investment • Insufficient delivered quality Improper use and maintenance of PH/NZEB

The regions involved in PassREg discovered that no single barrier or solution is enough to make the transition towards PH/NZEB with RES. The transition depends on a complex of factors, which all have to be addressed properly for an upward spiral to be created. This observation is consistent with scientific evidence on transitions. This means that any region aspiring to make the transition a success has to plan and execute a diverse range of actions on several different playing fields (PassREg, 2015).

2.5 Conclusions

From the literature it is recognized that multitude of NZEB approaches exist. It is evident that the concept is well understood however, a consistent definition, which is internationally agreed upon, is missing. Although adoption of a consistent approach to NZEB largely depends on the purpose and political targets that lay behind the promotion of NZEB in a country (EPBD Recast , 2010). Important aspects for achieving NZEB goals are the criteria on energy efficiency and energy supply. While the pathway to building a NZEB is given by the balance of the two actions – energy efficiency and energy supply – experience from many already existing NZEBs underlines the priority of energy efficiency as the path to success (Voss & Musall , 2011). In many publications devoted to NZEB, similar pathways to achieve NZEB goals can be noticed. Firstly, the reduction of energy demand using energy efficient technologies and afterwards utilization of renewable energy sources (RES) to supply the remaining energy demand. A

minimum of energy efficiency requirements may be enforced in a NZEB definition. Finally, it is argued that only a measured rating would enable the verification of claimed NZEBs, the effectiveness and robustness of the design solutions, and finally the actual attainment of energy policy goals (Sartori, et al., 2010). Therefore, a measurement and verification (M&V) process is required and its completeness and complexity will be dependent on the options selected for the definition of criteria.

As complexity surrounding the NZEB term has been addressed actively in the research community, an increasing number of demonstration projects have also highlighted that NZEB can be seen as a feasible endeavor with lessons learnt communicated to a wider set of stakeholders. However, a paradigm shift is needed to mainstream NZEBs in the buildings sector, which is sure to face abundant challenges. National and international policymakers who wish to support the broad diffusion of net and near zero energy buildings will need to determine what kind of regulatory framework is most appropriate, especially in a country like India. In the meanwhile, market structures – both for public markets and in private-sector settings – are likely to require significant adjustments for net zero energy buildings to achieve scaling. Energy efficiency and renewable energy service providers may not be able to deliver the kind of integrated (or bundled) efficiency and renewable energy needed to achieve NZEBs cost-effectively. It will also be necessary to address uncertainties around performance measurement and certification, lack of available financing instruments, insufficient information, missing economic incentives, and a range of other issues of NZEBs are to move into the mainstream building market.

In light of the existing barriers which inhibit potential energy savings from buildings, a single instrument will be insufficient in bringing about the desired result in stimulating the NZEB concept widely in Indian building sector. Therefore, it is challenging to have a 'set' or 'mix' of instruments that cope with wide variety of barriers currently preventing NZEBs to flourish. In fact, a bundle of instruments is required to properly address the most relevant barriers at the same time, which would be necessary to intensify uptake of NZEB concept. In other words, a target-specific policy package will be the most appropriate approach to address incremental energy reductions from the building sector (Laustsen, 2008). In addition, from policy approaches adopted in developed countries across the world, a combination of policies (both RE and EE) is

proposed in various countries to exhibit techno-economically feasible NZEBs from their building stocks (Bürger, 2013). Like for example, the EU's Energy Efficiency Directive (EED) which since 2008 has required MS to describe co-ordinated packages of policies in their National Energy Efficiency Action Plans (NEEAP). Similarly, market transformation of domestic appliances in several developed countries has been achieved through a combination of minimum standards, energy labels, incentives for the most efficient equipment, and an effective communication campaign for end-users (Boza- Kiss, Moles, & Ürge-Vorsatz, 2013). It is fairer to state that certain (NZEB) niche markets have been formed. However, this is still far away from achieving system-wide market transformation.

Chapter 3:
Theoretical framework

3.1 Introduction

To analyze the socio-technical transformation of the building sector in India towards NZEBs, various theoretical frameworks were explored. In this doctoral study theoretical body on transitions and innovations, most particularly Strategic Niche Management (SNM) and innovation theory of Sector Innovations Systems (SIS) are emphasized. To further understanding to assess the developments and deepen our understanding of innovation and diffusion of sustainable technologies in a given sector, an integrated approach is followed. In addition to the SNM and SIS theories, theory on governance is also explored. In this perspective, the Governance Assessment Tool (GAT) was identified as an important theoretical framework to uncover restrictive and supportive conditions in a particular governance context vis-à-vis sustainable innovation like NZEBs.

In doing so, this chapter focuses on introducing the main theoretical insights which provide us with an analytical approach that can help answering sub-research question 1.1 ***What integrated assessment framework suits best to assess NZEB niche development in India?*** The integrated framework can be viewed as a theoretical concept bridging the literatures between the academic sustainable transitions and governance traditions. This results as a starting point for developing a research design for further empirical case studies addressing NZEB innovations in the Indian building sector.

Following the presentation of the integrated assessment framework in this chapter, the latter will be used in chapters 4-7 as the conceptual basis for reflective empirical analysis of separate case studies. Hence, some of the theoretical concepts are repeated in those chapters.

3.1.1 Strategic niche management for NZEB's: a theoretical approach

SNM can be defined as an analytical approach designed to facilitate introduction and diffusion of radically new sustainable technologies through societal experiments (Caniëls & Romijin, 2007). Established, commonly used technologies in society are mostly embedded into socio- technological 'regimes'[9], and offer substantial barriers to the introduction and diffusion of new sustainable technologies. Despite perceived high environmental and social benefits, these

[9] The socio-technical regime from the 'deep structure' that accounts for the stability of an existing socio-technical system. It refers to the semi – coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems (Kemp & Schot, Regime shifts to sustainablilty through processes of niche formation: the approach of strategic niche management, 1998).

technologies often fail to enter markets and do not become part of mainstream practices (i.e. a 'regime'). Smith & Raven (2011) and Kemp *et al*. (1998) state that introduction of sustainable technologies fails for various reasons including technology, government policies, regulatory framework, demand and production, cultural and societal reasons, and infrastructure. The concept of SNM was introduced by the end of 1990's as a theoretical framework and a policy tool to manage technological innovations and to facilitate introduction of sustainable technologies. SNM promotes interactive learning processes by moving away from the traditional concept of 'technology push' and addresses lack of diffusion of sustainable technologies in society (Schot *et al*, 1994; Kemp *et al*., 1998; Weber *et al*., 1999; Hoogma *et al*., 2002).

The focus on learning is an important aspect of SNM. Hoogma *et al*. (2002) claim that an interactive learning process is instrumental for fostering long term institutional and societal change. The concept highlights creating societal experiments for innovative stakeholders to collaborate, exchange information, knowledge and experiences. SNM terminology defines these *experiments*[10] as, "unique socio-technical laboratories for learning about the problems, shortcomings and barriers a new technology face" (Hoogma, 2000). Kemp & Schot (1998, p 64) define SNM as, "the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the rate of application of the new technology".

Niche development and its protection from regime forces

The SNM concept advocates development of protected spaces called "niches" for certain applications of the technology. This is done through the setting up of experimental settings which provide a conducive environment for actors to learn about the design, user needs, cultural and political acceptability and other aspects (Schot & Rip, 1997). A niche can be made up of one or more 'experiments' with new technologies (Raven, 2005). The formation of a niche develops an early foundation for diffusion and up scaling of innovations.

Academic literature and niche development mostly uses historical cases in Western European countries for its empirical basis. Attention to developing countries seems to be less prominent. In

[10] Weber et al. (1999) define an experimental project as the first step towards the development of a niche, and they see a niche as consisting of multiple more or less tightly coupled experimental local projects,

the case of NZEB integrated technology it can be stated that many Western countries have demonstrated NZEBs and hence, fostering NZEB niche development, to exhibit integration of energy efficiency and renewable energy technologies and reducing the energy demand of the building stock. BRICS[11] nations-, notably India, have joined the drive with NZEB demonstration projects. In addition, these projects play a key role in highlighting the technical and economic feasibility of the concept. However, NZEB niche development in India is in its formative stage, and it can be stated that NZEBs have not yet developed into a (relatively) 'mature' niche. To further stimulate innovation and diffusion of NZEBs, demonstration projects need to be managed appropriately to support niche formation. The SNM framework can be used to analyze these demonstration projects and understand the early adoption and diffusion of NZEB technologies for wider societal acceptance.

For niches to survive, experiments are developed under special protected conditions to support the gradual diffusion of a given new technology in real world conditions and become economically and technologically competitive. A niche is thus able to exist because of some form of "protection"– a set of conditions which provide a socio-technical "space" to test "configurations that might work" (Hoogma *et al*., 2002; Kemp and Schot, 1998). The role of niches is defined as, "a protective space for initiating path breaking innovations" (Smith & Raven, 2011). In these spaces, various stakeholders can participate in the innovation process without being subjected to immediate market pressure. Kemp & Schot (1998) define two forms of protection, namely 'technology' and 'market' protection. Technology protection may include government sponsorship, subsidies or tax exemptions, R&D commitment by firms, or a company's decision to accept higher costs or to fund a demonstration project (Hoogma, 2000; Kemp & Schot, 1998; Weber *et al*., 1999). Alternatively, market protection comes from user preferences, where the advantages of the technology outweigh the disadvantages only for specific users or in limited locations (Kemp & Schot, 1998). Once the new technology is sufficiently established after its initial phase of diffusion, and can survive on its own, the protection can be subsequently removed (Lovell, 2007).

[11] Brazil, Russia, India, China and South Africa - BRICS

The Niche formation process

Many SNM scholars explain the success or failure of a niche by analyzing interaction between the three main niche processes, namely *shaping of expectations, building social networks, and the learning process*.

a) *Shaping of expectations:* Promises and expectations of a new technology are important in a niche development processes to attract attention; mainly to clarify what the benefits of the niche will be (in our case the benefits of NZEB technology). Thus, interested actors - including firms, users, policymakers, entrepreneurs and other relevant stakeholders - participate in niche development processes based on hopeful expectations (Raven, 2005). These expectations are important in the early development of a new technology to pave the way for social embedding and for the wider learning process, particularly when its advantages are not clear. According to Raven (2005) the process of shaping expectations is good when: a) an increasing number of participants share the same expectations (expectations are converging into a shared vision); and b) the expectations are increasingly based on tangible results from niche experiments.

b) *Social network formation*: Developing a niche may require new actors to get together and make new social networks emerge and provide the necessary resources (like money, people, and expertise). Mourik & Raven (2006) state that social networks are considered good when: a) the network is broad (including firms, users, policy makers, scientists, and other relevant actors from the science and technology domains, the policy domain, the social domain and including both regime actors and regime outsiders); and b) when alignment within the network is facilitated through regular interactions between the actors. Governments can play a leading role to create such networks and articulate a vision of where a sector or society should be heading.

c) *Learning Process:* An interactive learning process is key to the SNM approach and is considered important for successful innovation. According to Raven (2005),” Learning should improve the alignment between the socio-technical configurations of an experiment”. A good learning process is: a) broad – focusing not only on techno-economic optimization, but also on alignment between the technical (e.g. technical design, infrastructure) and the social (e.g. user preferences, regulation and cultural meaning) –; and b) reflexive – there is attention for questioning underlying assumptions such as social values, and the willingness to change course

if the innovation does not turn out to match these assumptions. Hoogma (2002) identifies five aspects that learning should be about: technical development and infrastructure; the user context (i.e. user characteristics and consumer needs); societal and environmental impacts; industrial development, and government policy and regulatory frameworks.

SNM and the role of government

SNM is predominantly a multi-actor approach, with the government's role instrumental in facilitating wider transitions. SNM is one of the theoretical frameworks proposed to illustrate how governments can achieve significant, widespread technology change within well-established socio-technical systems[12] (Kemp and Schot, 1994; Schot and Hoogma, 1994; Kemp and Schot, 1998; Rip and Kemp, 1998; Smith, 2006; Weber and Hoogma, 1998). To stimulate a broader shift towards sustainable development an integral combination of technological progress and system-wide social-institutional transformation is needed. Economic sectors are said to become more sustainable with governments using the SNM model to catalyze fundamental system wide change (Lovell, 2007). A socio-technical system is, however, slow to change. This is often due to technological lock-in[13] (Schot and Hoogma, 1994; Unruh, 2002) and path dependency' (Phillimore, 2001). However, governments can play a defining role to transform the existing system by facilitating the process of niche formation and setting up a set of successive experiments, or by implementing policy instruments that support niche development, e.g. subsidy schemes, regulatory exemptions, or programs that include pilot projects.

In multi-actor process other innovative stakeholders, including NGOs, citizens' groups, private companies, industrial organizations or independent individuals, and knowledge institutions such as universities, are in the position to initiate and run niche projects. According to Schot and Hoogma (1994) niches may fail even when governments take the full responsibility. However, governments are still seen as the main actor involved in the management of niches and can facilitate diffusion of innovations. This can be done by supporting up scaling of successful experiments, through sponsorship or macro-policies (like changes in the regulatory

[12]Socio-technical systems consist of a cluster of elements, including technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and supply networks (Malerba F. , Sectoral Systems of Innovation, 2004)

[13] Technological Lock-in: where agents continue to employ an existing technology even though potentially more productive technologies can be found (Kemp & Schot, Regime shifts to sustainablilty through processes of niche formation: the approach of strategic niche management, 1998)

framework and the use of fiscal incentives). For demonstration projects to realize their full potential, they should be linked to long term strategies for structural change involving policy makers. After the initial stages of niche development, the SNM process usually expands to include policies for diffusion, and for exploring structural change through system innovation (Hoogma, 2000).

Theoretically speaking the mainstreaming NZEBs in the Indian building sector would require a SNM approach. This would be required to analyze the past developments (of on-going and completed NZEB demonstration projects) and evaluate the status of the NZEB niche in the country. The SNM framework can be used by researchers as a research framework to address the factors and conditions which determine whether the NZEBs niche will be a success or a failure in the country. Although, in spite of many promising aspects of SNM, it has not yet succeeded in linking theory with action and provides limited concrete 'management principles'. Theoretical concepts of SNM can be used to design an assessment tool for niche development policies. SNM is so far been used as an ex-post analysis to inform policy makers about options for future sustainability policies. Very few evidence, or cases have been documented with ex-ante analysis (Hoogma *et al*, 2002; Kemp & Schot, 2008).

3.1.2 Sectoral innovation systems – an innovation perspective

Innovation is considered a key condition to foster structural change. Interactive and learning processes among a wide variety of actors are necessary for innovation, thus making it more of a collective process (Edquist, 2005). An innovation system can be seen in networks of organizations, people and institutions within which the creation, diffusion and commercial exploitation of new technologies and other types of knowledge takes place (Malerba F. , 2004). The very concept of Sectoral Innovation Systems (SIS) has been developed to capture and understand the relations between producers, users, institutions and governments (Lundvall, 1992; Edquist, 2005). It is argued that the rate and type of innovation greatly differ across different sectors, which is mainly dependent on the characteristics of the economic sector to which it belongs. Sectors differ along several dimensions related to technology, production, innovation and demand. They also differ in the type and degree of change (Malerba F. , 2002).

A sector is defined as a set of activities which are unified by some related product groups (e.g. buildings) for a given or emerging demand, which share some basic knowledge (Malerba F.

, 2005). A sectoral system of innovation (and production) is composed of a set of agents carrying out market and non-market interactions for the creation, production and sale of sectoral products (Malerba F. , 2004). Similarly, innovation in the building sector can be defined by interactions between the main stakeholders involved in the process of design, construction, operation and renovation of buildings. The SIS gives a specific meaning to the concept of the 'structure' of a sector, which relates to the links and relationships among agents, knowledge, products and technologies (Beerepoot, 2007). In the sectoral system of innovation, the term structure is also referred to as 'networks' (Malerba F. , 2005). The SIS literature emphasizes on how the characteristics of a sector determine the scope of innovation within that sector (Beerepoot & Beerepoot, 2007). This innovation framework helps in understanding the agents and their interactions, learning and innovation process specific to a particular economic sector (Beerepoot, 2007).

Building blocks of the sectoral innovation system framework

The SIS framework can be described as the collective emergent outcome of the co-evolutionary interactions between the core building blocks of a sectoral innovation system (Malerba, 2002, 2004, 2007). These core building blocks are composed of: *knowledge and technology, actor and networks, and institutions*. In line with Malerba's key concept, Geels (2004) adds that the SIS approach needs more attention to the *demand* side. He mentions that most attention is mainly directed towards the study of development of knowledge and suggests that it should also address the diffusion and application of technology and its impact on society (Geels F. , 2004). Faber and Hoppe (2013) elaborated the SIS framework and used it to assess sustainable energy transitions in the Dutch construction sector. They define building blocks of the Dutch built environment sector under four core dimensions: *knowledge and technology, actors and networks, institutions and market demand (as a fourth building block)* (see figure 6).

a) *Knowledge and technology*: Any sector could be characterized by a specific knowledge base, technologies and inputs. The main characteristics of the knowledge base are the nature of knowledge (generic vs. specific, complex vs. simple, tacit vs. codified, independent vs. systemic) and the means of knowledge dissemination (Faber & Hoppe, 2012). Technologies are generally developed in a specific socio-technical context made up of tacit and explicit knowledge, sunk costs, learning conditions, complementarities and interdependencies (Dosi, 1982; Nelson and

Winter, 1982; Malerba and Orsenigo, 1997). Knowledge and technology places the issue of sectoral boundaries at the center of analysis (Malerba F. , 2004).

b) *Actors and networks:* Interactive processes are of key importance to innovation. Therefore, actors and networks are a major driving force towards sectoral change. Any sectoral system analysis, therefore, involves an overview of the main agents in the sector, including their interactions and formal as well as informal networks. Agents include individuals as well as organisations, which interact through processes of communication, exchange, cooperation, competition and command (Malerba F. , 2004). Agents are characterized by specific learning processes, competencies, beliefs, goals, organizational structures and behaviors (Faber & Hoppe, 2012). Faber and Hoppe (2013) differentiate agents as primary agents and secondary agents. Primary agents are those (key) actors who perform core innovative activities, experiments and capacity building. Secondary agents account for the supporting measures that, for example, have to do with knowledge diffusion, provision of financial support, formulation and implementation of regulations, and (legal) counselling. Connections such as relationships, collaborations, resource exchange or social ties between the actors can be described as a network of formal and informal relations and interactions (Faber & Hoppe, 2012).

c) *Institutions*: Institutions include various formal and non-formal rules, such as values, routines, common habits, established practices, laws and standards, which all shape cognitions and actions of agents, as well as the interactions between agents (Malerba, 1999, 2004). Formal regulations refer to 'the formal rules of the game', including rules, laws, monitoring and sanctioning. Informal institutions describe the rules that provide legitimacy to individual practices by reference to values, responsibilities, obligations, shared conceptions or common beliefs (Scott, 1995). Faber & Hoppe (2013) suggest that informal institutional dimensions may be influenced by shared visions and patterns of thinking. Shared visions can give rise to shaping of expectations, which is considered a primary process of niche formation of a new technology based on strategic niche management (Schot & Geels, 2008).

d) *Market demand*: Demand stems from private preferences of end consumers mostly revealed by actual consumer choices. However, various scholars in evolutionary economic approaches claim

that the variety of preferences for both consumers and producers stems from asymmetry in information or skills, constraints in opportunity, or heterogeneity of intrinsic motivations (Malerba F. , 2005). A large diversity of preferences gives rise to market fragmentation and, hence, increase the opportunity for radically new technologies to enter the niche market. Such niches could be stabilised by the experimental users themselves or by governmental support to allow environmental technologies to mature in protected niche markets, a notion that has been recognised in the policy concept of strategic niche management (SNM) (Schot & Geels, 2008).

Many studies emphasize that government (or policy-making and implementation of policies by public bodies) ought to play an important role in innovation systems and that government regulation should provide an incentive for innovation. The most common reason for government intervention is market failure in achieving socially desirable objectives (Beerepoot & Beerepoot, 2007)

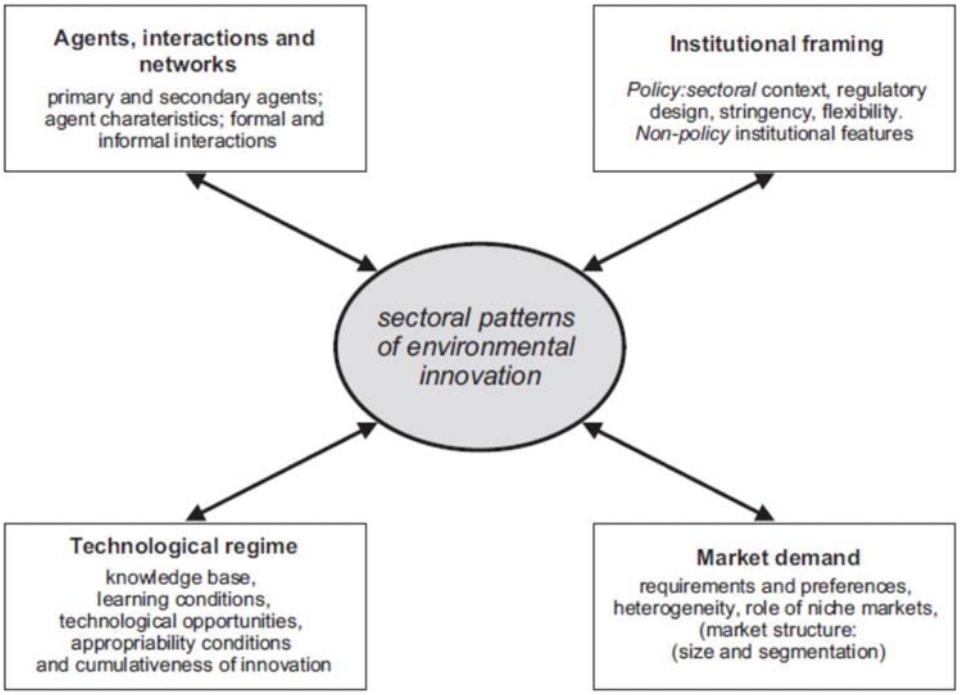

Figure 6: Dimensions of sectoral patterns of environmental innovations (Faber & Hoppe, 2012)

Innovation and the role of governments

Many studies emphasize that government (or policy-making and implementation of policies by public bodies) ought to play an important role in innovation systems and that government regulation should provide an incentive for innovation. The most common reason

for government intervention is market failure in achieving socially desirable objectives (Beerepoot & Beerepoot, 2007)

Governments can support and facilitate innovation in various ways. This can be done through various support schemes (e.g. funding public research institutes, or R&D subsidies) or government regulation (i.e. legal norms and standards). Traditional innovation policies have been designed to provide public resources for R&D and increase the incentives for firms to innovate, typical examples concern tax breaks for R&D, innovation subsidies and patents (Edquist, 2005). However, in the modern context, government innovation policies also need to deal with system imperfections (Smith, 2006) The SIS approach provides a good starting point for understanding what stakeholders are involved and how effective public policies are, as innovation policy should be sensitive to sectoral distinctions (Beerepoot & Beerepoot, 2007). It can be considered a useful analytical concept to study scale adoption and diffusion of NZEBs, for it requires innovation of new sustainable technologies. For this study (i.e. a focus on one particular sector – building sector for NZEBs), the SIS is the most convenient framework for analysis.

3.2 Integrated assessment framework for NZEB niche development

3.2.1 Comparing SNM and SIS

The theoretical frameworks of SNM and SIS share many commonalities. Although both frameworks were largely developed independently, as SNM derives from transition theory (in particular the Multi-Level Perspective (Geels F. , 2004) and SIS from the innovation systems paradigm, both have roots in evolutionary economics. The two frameworks explain innovation phenomena based on common conceptual grounds (Markard & Truffer, 2008). As observed in the previous sections, it is evident that both frameworks highlight and focus on the importance of *actor networks* for successful innovation and diffusion processes.

In the SNM framework, social network formation takes place where new networks emerge during the early niche formation process, whereas in SIS, interaction of existing regime actors is highlighted as the key determinant for long term transformation and successful innovations. In addition, actor networks in both frameworks simultaneously influence the niche development process and sector level innovations. New social networks from the SNM approach provide one

or more platforms for shared visions and the shaping of expectations of where innovations and economic sectors are heading. Thus, the niche formation process provides insights for prospective innovation dynamics both at the niche and the sector level. Shared visions and expectations also influence informal institutions (in the SIS framework) at the sector level, such as values, habits, routines, responsibilities, shared conceptions, and sometimes may also resist niche formation processes. Similarly, the learning process of the SNM approach highlights the aspects of technology development and user context, both complementing the two important building blocks of the SIS framework, in particular knowledge, technology, and market demand. In both SNM and SIS they relate to the concept of transformational change due to stimulating improved co-evolutionary alignment between technical and social aspects.

Despite vivid clarity in commonalities there are subtle differences between the two frameworks. Mild differences are found at the level of aggregation. In SNM, niches have a low level of aggregation of actors largely due to the development of innovation networks and attention towards single technology. Therefore, the efforts by actor networks at the niche level are typically devoted to fostering niche development of one single innovation (a technology that is said to have the potential to radically upset and replace an existing regime). In comparison, in the SIS framework the level of aggregation can be mapped from medium to high due to many actors from both the niche and regime being part of the innovation process. However, we assume that there is much more interaction between niche- and regime actors in SIS than in the case of SNM.

In addition, the SNM framework focuses on radical innovations whereas the SIS framework does not specifically make any distinction between radical and incremental innovations (Meleen & Farla, 2013). Considering the wider sectoral context, SIS studies tend to stress on (socio-technical) regimes. Moreover, it is inclined towards incremental rather than to radical innovations. In recent SIS frameworks, the role of end users and market demand (creation of market demand for innovations) has received considerable attention, and therefore has been included as a (one of the) building block(s) in the SIS framework (Faber & Hoppe, 2012). However, in the SNM approach such attention is highlighted to a lower extent, and only as part of the learning process, where user context and user preferences are briefly discussed.

However, special consideration toward the market demand aspect has not received enough attention (Jain, Hoppe, & Bressers, 2014).

The SIS (or Technological Innovation System) and SNM frameworks represent different perspectives on how processes of innovation and socio-technical transformations develop (Markard & Truffer, 2008). Considering the commonalities and differences between the two frameworks, there is a need to further understanding on how they can complement and compensate each other's limitations. For this reason, we have attempted to develop an integrated framework to bridge the gap between the two frameworks in innovation and transition literature. This integration will further support the development of an assessment framework for assessing the status quo of a given (radical) niche development within a sectoral innovation system (i.e. NZEBs in domestic construction sectors).

The integrated assessment framework might offer benefits which might reach beyond their respective limitations. Thus, integration of the frameworks should provide us with a new analytical approach to study niche development processes and further understanding in the innovation and diffusion processes of technologies within economic sectors (hence, a sectoral part of the regime level). In the integrated framework, we develop independent components which help as building blocks to understand or assess sectoral niche development processes. The building blocks are: *shaping of expectations, actor networks, institutions, learning process and market demand.* They form the core building theoretical blocks to analyze the transformative processes of economic sectors. Conceptually speaking, the framework addresses developments in both the niche and sectoral regime level.

The five components are mutually exclusive, but there are evident relations between them. When using the framework for assessing development and diffusion of sectoral innovations the five components will independently be used for assessing innovations and the growth of a new niche, but they are likely to show interdependencies; the one influencing the other (e.g. an actor network shaping expectation concerning a potential innovation that has the potential to upset a socio-technical regime). We envisage the use of the framework to assess empirical cases (in this doctoral study this is the NZEBs in the Indian buildings sector). This allows for assessing a case per theoretical component, but also helps to identify potential mutual dependencies between the components. We expect that these components jointly influence the niche development, and

potentially upset and replace existing sectoral socio-technical regimes. The integrated framework forms the basis of our research. This framework forms the basis for development of an Integrated Sectoral System Innovation Assessment Framework (SSIAf). Figure 7 presents a graphical overview of the Integrated Sectoral System Innovation Framework (SSIf). Table 6 presents an overview of the key theoretical components of the assessment framework. For each component (or cluster of components) the key conceptual items are presented.

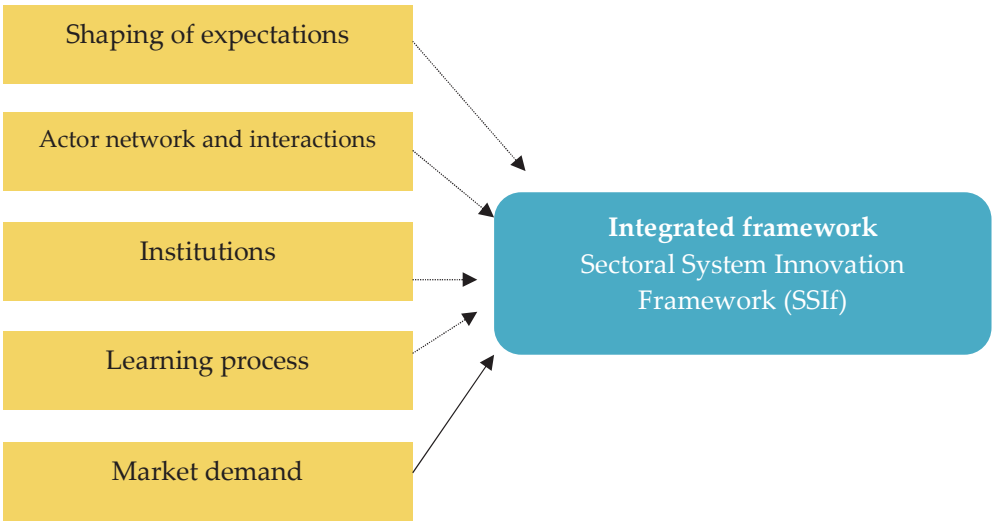

Figure 7: The Integrated Sectoral System Innovation Framework (SSIf)

Table 6: Integrated assessment framework (Sectoral System Innovation Framework-SSIf)

Framework	Description
Shaping of expectations	a. Shared visions (converging into shared visions for niche development). b. Expectations held by regime actors (how do they see market development?). c. Expectations based on tangible results from niche experiments.
Actor networks and interactions	a. Size of the sectoral actor network (including both primary agents and secondary agents, and both regime insiders and regime outsiders). b. Formal and informal interactions.
Institutions	a. Formal institutions (e.g., rules, laws, regulations, monitoring). b. Informal institutions (e.g., values, responsibilities, obligations).
Learning process	a. Broad learning (e.g., technology and knowledge, techno-economic optimization, technical and social alignment, knowledge dissemination). b. Reflexive, self-governance (with flexibility to change course).
Market demand	a. Requirements and preferences. b. Heterogeneity. c. The role of niche markets. d. Market structure, size and segmentation.

3.2.2 A comprehensive policy oriented 'failure' framework for transformative change

In the previous section, we combined the strengths of the two independent frameworks of SNM and SIS, into one integrated framework that forms the basis of a new assessment framework of niche development in economic sectors. In addition, both concepts could also serve as foundations for policies aiming to evoke radical transformative change. Weber & Rohracher (2012) combined the insights from innovation system and transition theory to develop a comprehensive 'failure' framework to legitimize innovation policies intervention for transformative change without 'unifying 'these approaches. This extended framework of failures allows for a policy–oriented integration of innovation systems with the complementary transition theory concepts. The 'failure' framework supports the idea of market failures (Arrow, 1962) and system failures (Woolthuis, Lankhuizen, & Gilsing, 2005) which legitimize current innovation polices, alongside addressing the lack of strategic and transformative operation of these polices in terms of additional failures that innovation polices should also address (Weber & Rohracher, 2012) .

We discuss system failures to understand innovation-oriented policies that aim to innovate economic sectors. System failure can be categorized into four types of failures (Woolthuis, Lankhuizen, & Gilsing, 2005):

- *Infrastructure failure*, i.e. lack of existing physical and knowledge infrastructures needed to enable innovation activities along with low return on investments for private investors.
- *Institutional failure*, for which hard and soft failures are distinguished. The former refers to formal institutional mechanisms that hinder innovation (e.g. regulations, standards, legislation), whereas the latter relates to matters of political and socioeconomic cultures, social norms and values.
- *Interaction or network failure*, for which weak and strong failures are identified. Strong network failure arises when interactions are too dense to allow for novel insights or inspirations to emerge. Weak interaction failure exists when there is too limited exchange with third parties, thus inhibiting interactive learning and ultimately innovation.
- *Capabilities failure,* which refers to the absence of the necessary capabilities to adapt to new and changing circumstances and (technological) opportunities. Capabilities failure also

captures the systemic problem of path-dependency of firms due to their inability to absorb new knowledge.

From the perspective of transformative change, well established system failures arguments are still valid to justify policy intervention, but they are too restrictive and leave out several important instances of failure (Weber & Rohracher, 2012). Alongside system failures Weber & Rohracher (2012) introduced four additional types of failures to broaden the analytical scope and further the understanding of transitions. The following transformational failures attempt to adopt the requirements for goal oriented transformative change.

- *Directionality failure* highlights a lack of shared vision regarding the direction of transformation process, inability of collective coordination of distributed agents involved in shaping systemic change, insufficient regulation or standards to guide and consolidate the direction of change, and a lack of targeted funding for research, development and demonstration projects and infrastructures to establish corridors of acceptable development paths.
- *Demand articulation failure* concerns insufficient spaces for anticipating and learning about user needs to enable the uptake of innovations by users, the absence of orienting and stimulating signals from public demand, and a lack of demand-articulating competencies.
- *Policy coordination failure* concerns a lack of multi-level policy coordination across different systemic levels, a lack of horizontal coordination between research, technology and innovation policies on the one hand and sectoral policies (e.g. transport, energy, and agriculture) on the other, a lack of vertical coordination between ministries and implementing agencies leads to a deviation between strategic intentions and operational implementation of policies; no coherence between public policies and private sector institutions, and no temporal coordination resulting in mismatches related to the timing of interventions by different actors.
- *Reflexivity failure* concerns insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance, a lack of distributed reflexive arrangements to connect different discursive spheres, to provide spaces for experimentation and learning, and no adaptive policy portfolios to keep options open and deal with uncertainty.

The comprehensive 'failure' framework expresses the importance of innovation policies and helps to extend the innovation system framework to make it more robust in changing policy environments. The proposed framework also offers advantages to transition theory by connecting them to prevailing models for legitimizing policy interventions. Governments play an important role in the policy making and implementation process. Therefore, we consider incorporation of conceptual notions from Weber and Rohracher 'failure' framework (2012) in our integrated assessment framework as instrumental in understanding and assessing the role of government and policy in niche development processes and sectoral innovation systems.

Weber & Rohracher (2012) claim that the framework needs to be tested in practice as a support instrument for policy development and suggest consolidating the theoretical underpinnings of the framework. Therefore, we assume that integration of transition theory and innovation systems approach would be needed. To do this we attempt to consolidate the 'failure' framework of Weber & Rohracher (2012) in our integrated assessment framework (SSIf) (see table 7). This will broaden the scope of this framework by not only preparing it to assess a given niche's status quo, but also making it useful to provide insights for policy strategies based on Weber and Rohracher 'failure 'framework (which was also developed to assist policy makers).

Table 7: Comparing the integrated sectoral system innovation assessment framework with Weber and Rohracher Failure Framework (2012)

Components	Assessment criteria	Failure framework
Shaping of expectations	a. Niche actors sharing the same expectations (converging into shared visions). b. Expectations of regime actors. c. Expectations are based on tangible results from transition experiments.	Directionality failure
Actor networks and interactionsns	a. The network is broad (primary agents and secondary agents). b. Formal and informal interactions.	Interaction or network failure
Institutions	a. Formal institutions (e.g., rules, laws, regulations, monitoring). b. Informal institutions (e.g., values, responsibilities, obligations).	Institutional failure Policy coordination failure Infrastructure failure
Learning process	a. Broad learning (e.g., technology and knowledge, techno-economic optimization, technical and social alignment, knowledge dissemination).	Capabilities failure

	b. Reflexive self-governance (flexibility to change course).	Reflexivity failure
Market demand	a. Requirements and preferences. b. Heterogeneity. c. Role of niche markets. d. Market structure, size and segmentation.	Demand articulation failure

3.3 Governance

The concept of "governance" is widely used, both in practice and in policy science literature, with a great variety of meanings (Rhodes, 1996; Bressers and Kuks, 2003, Pierre and Peters, 2000; Milward and Provan, 1999). Several authors have defined governance. The term generally refers to the way in which collective impacts are produced in a social system. Stone (1989) conceptualizes governance as, "creating the capacity to act" by bringing together the resources required to accomplish the collective ends of society. In the early 1990s, the term 'governance' or 'new governance 'arrived as a conceptual alternative for traditional top-down modes for the ways in which society was governed. Wamsley (1990) defines governance as the use of authority in providing systemic steering and direction, and stands for 'choosing, prioritizing, directing and steering'. In addition, Rhodes (1997) refers governance to self-organizing, inter-organizational networks'. Later Lynn *et al*. (1999) defined governance as "a regime of laws, administrative rules, judicial rulings, and practices that constrain, prescribe and enable governmental activity".

Milward and Provan (1999) conceptualized 'governance' as creating the conditions for ordered rules and collective action, often including agents in the private and non-profit sectors, as well as within the public sector. In this perspective the essence of governance is its focus on governing mechanism - grants, contracts, and agreements – that do not rest solely on the authority and sanctions of governments. In combining insights from scholarly work on governance (Bressers & Kuks, 2003) define governance in terms of the combination of the relevant multiplicity of responsibilities and resources, instrumental strategies, goals, actor-networks and scales. As a context, governance, to some degree, restricts and enables actions and interactions in a certain part of society (Bressers, et al., 2013). For example, the organizational, legal, financial and political aspects of a supportive context encourage the application of technical solutions as well as collaborative management does.

3.3.1 Governance assessment tool

The GAT was developed as a descriptive model to assess the quality of governance in a specific context. The basis for the tool was a collection of insights on governance as developed by Bressers and Kuks (2003, 2004), and has a background in the Contextual Interaction Theory (CIT) (Bressers & Kuks, 2004). CIT is an elaboration of more than 30 years' scholarly work on policy implementation theory and is designed to explain policy implementation processes and outcomes and helps to understand the governance of a certain part of society (De Boer *et al.*, 2013). The GAT helps to assess and identify the strong and weak points in the governance context when it comes to enabling and supporting collaborative and adaptive management in practice. The tool predominantly draws attention to understanding of existing situations that can obstruct policies and projects under complex and dynamic conditions (Boer & Bressers, 2011). Thus, it is of interest to us to incorporate the assessment tool into niche development process to deepen our understanding of transitions and innovations of niche developments while taking the complex governance context into account.

The dimensions of the Governance assessment tool

The GAT introduces five aspects of governance. It can be seen as a conceptual 'check list' to describe all relevant aspects of the governance context. Table 8 provides an overview of the governance dimensions that together describe a governance structure by developing further elaborative questions. This context influences the motivations, cognitions and resources of the stakeholders (as described in CIT) (Boer & Bressers, 2011). In GAT governance is no longer considered an extension to public policies. Moreover, policies are no longer assumed to be developed by one central actor only (nor are only one target group assumed). Interactions between different actors and networks at multiple levels contribute to developing policies (Boer & Bressers, 2011). However, actors have diverse perspectives, ambitions; strategies, instruments, resources and responsibilities. Hence, the five developed dimensions of governance are useful to assess the governance context regarding a particular aspect. Figure 8, presents the five interrelated dimensions of governance that are central to GAT.

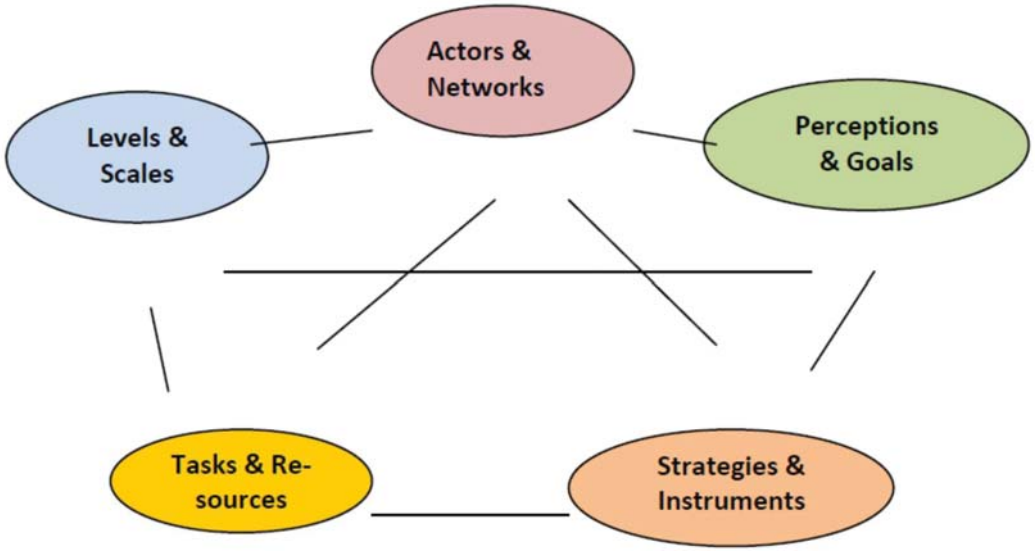

Figure 8: Five interrelated dimensions of governance (Bressers et al., 2013)

Table 8 : The five dimensions of governance (Bressers et al., 2013)

Levels and scales (not necessarily administrative levels)	Governance assumes a general multi-level character of all other dimensions.
Actors and networks	Governance assumes the multi-actor character of the relevant network(s).
Problem perspectives and goal ambitions	Governance assumes the multi-faceted character of the problems and ambitions.
Resources and organization (tasks and responsibilities) of implementation	Governance assumes the complex multi-resource basis for implementation.
Strategies and instruments	Governance assumes the multi-instrumental character of the strategies of the actors involved

The five dimensions provide a clear overview of the governance context (or contents of a governance regime in a certain area with certain issues) (see table 8). To understand how a governance context enables or restricts actions and interactions, the model was complemented with four quality criteria: *extent, coherence, flexibility and intensity* (Boer & Bressers, 2011). The governance dimensions and qualities together form the core of GAT. According the Bressers *et al.* (2013) these qualities can be generally understood through posing of the following four questions:

- Extent: Are all relevant aspects for the sector or project that is focused on taken into account?

- Coherence: Are the elements of the dimensions of governance reinforcing rather than contradicting each other?
- Flexibility: Are multiple roads to the goals, depending on opportunities and threats as they arise, permitted and/or supported?
- Intensity: How strongly do the elements of the governance context urge and support changes in the status quo or in current developments?

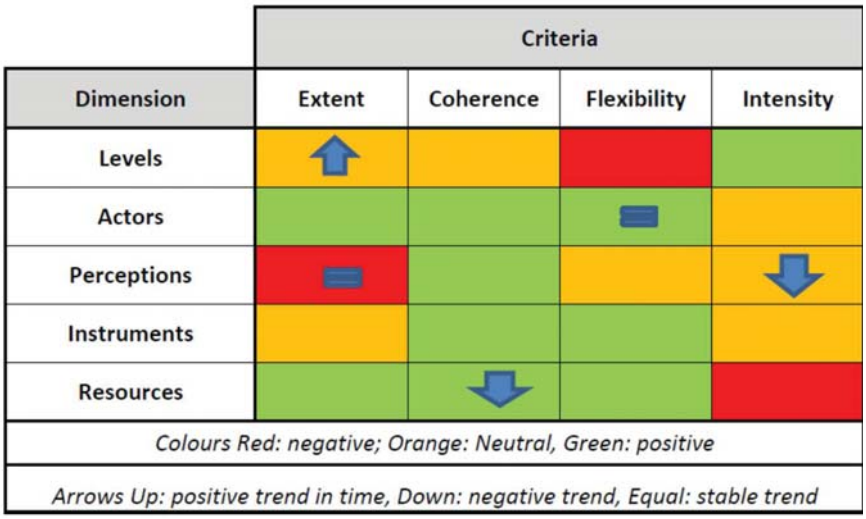

Figure 9 : Example of visualization of governance context diagnosis in score card adapted from De Boer et al, 2013

These dimensions and related questions can be used to follow up the first descriptive step and enable a more in-depth picture of the governance setting. Figure 9, represents the 'score card' that is used to asses existing governance settings where the arrows going up show that the present situation is changing positively or will change in the foreseeable future; whereas the arrows going down represent the present situation is changing negatively or will not improve in the foreseeable future. The stable '=' sign means that the status quo or business as usual remains as it is, and no change is expected in the foreseeable future (Bressers *et al.*, 2013).

The GAT and NZEB niche development

The GAT provides us with a vision towards current and possible future pathways for governance context. This can be helpful to reflect upon, assess or evaluate (like any other policy) the introduction and innovation diffusion of NZEBs in Indian building sector. Using GAT for an assessment will provide insights to the current governance context of NZEB demonstration

projects and NZEB niche development in India at large. The assessment can highlight the challenges in the governance regime which might obstruct or slow down the introduction and diffusion of NZEB in a new niche, but may also help to identify potential drivers to spur NZEB niche development as well as the innovations. In addition, the results can be used to make a holistic ex-ante evaluation of how the governance context can influence collaborative management of the NZEB niche development process.

Thus, it will be interesting to use GAT to understand and assess the governance context in the building sector in India vis-a-vis NZEB niche development. It will also be of theoretical interest to use the GAT in a way that allows for assessment of niche development of sustainable innovations (like NZEBs). This is rather novel since the beginning of this doctoral thesis GAT was not used thus far to assess developments and diffusion of sustainable innovations in the built environment, nor in the topical field of energy. However, recently few publications have emerged which use GAT in energy (Jain, Hoppe, & Bressers, 2017). The challenge to use GAT in this way, however, urges us to rethink how to incorporate key theoretical notions of SNM and SIS. In the next section we will further explore integration of GAT with these two frameworks.

Comparing the integrated assessment framework with GAT

The integrated SSIAf provides us with an analytical approach to assess niche developments and further understanding of innovation and diffusion of sustainable technologies in a given economic sector. Simultaneously, GAT helps us to advance understanding of the quality of governance in a given context (e.g., governance of NZEB niche developments in the Indian building sector, or governance of water systems in the Dutch Twente region), or identification of barriers to implementation of a given policy. Combining insights from the two concepts allows for broadening the scope and furthering the understanding of long term sustainable transitions, sectoral innovations, implementation of transition–oriented policies, and assessment of the role and state of 'governance' in niche development processes in sectoral systems.

In both the SSIAf and GAT assessment frameworks, *actors and their networks* are highlighted as important drivers for innovations and for assessing the governance context in which innovations evolve. Therefore, we believe that evaluating and assessing actors (and actor-networks) interactions forms a critical part of integrated assessment framework. As social interaction processes in multi-actor arenas are mostly driven by actors involved, these

interactions form a central stage in the theoretical basis that is key to the integrated assessment framework. Thus, the interaction process is considered as an ultimate driver for niche development, sustainability transitions and innovation. In this sense we believe actor-networks be the key units of analysis in SSIAf, because they form the key social configuration in which other important drivers for SSIAf occur, such as *shaping of expectations, perceptions and goals, informal and formal institutions, market demand and ultimately structural driver that influences learning processes*.

Although learning processes, as mentioned in SSIAf do not specifically reflect any direct complementary to GAT, there might be reasons to think there is. Learning can be viewed as resulting from actor interactions (e.g. sharing knowledge or experience, diffusion of beliefs, facing problems and jointly solving them) and therefore can be seen as an implicit component of GAT. It is also of key importance to understand that actor interactions will lead to wider social learning as elaborated by Reed *et al.* (2006) stating that social learning can occur through actor interactions, which may lead to changes at the individual level and may sometime go beyond the individual level (Kruijf, Bressers, & Augustijn, 2014). Thus, social learning can be implied as a process facilitated by creating interactive settings in which actors can share and reflect upon different perspectives, experiences and types of knowledge (Schusler, Decker, & Pfeffer, 2003).

Moreover, from a policy–oriented perspective one learns that policy change often results from policy–oriented learning (due to new cognitive and scientific insights, or external macro events hat prompt policymakers to adapt policy strategies to new circumstances and hence 'force' learning upon actors or learning from discursive conflicts that follow different advocacy coalitions fighting each other in decision-making arenas (Sabatier, 1988). De Boer and Bressers (2011) elaborate that as projects are extended over a considerable period this may provide windows of opportunity for wider technical and social learning resulting from the dynamics in the variation of specific actors (with specific actor characteristics), may cause changes in the setting of the interactions. The confluence of the key building blocks of GAT result in or can be seen as a process of interaction resulting in a learning process which can be explored further as technical and knowledge development, infrastructure, techno-economic optimization, technical and social alignment (user context), environmental impact and

reflexivity as elaborated in the integrated SSIAf (notably when niche experiments are viewed as multi-actor arenas, like a project setting).

Figure 10 shows, *perceptions and goals* (of where the niches are headed) which is a key aspect of governance in GAT, shows similarities to *shaping of expectations* (converging towards shared visions) and *informal institutions* (values, responsibilities and shared visions) from the SSIAf all resulting from actors and coalitions. *Formal institutions* from the SSIAf integrated assessment which include rules, laws, regulations, policies and instruments may involve multiple levels of administration, coinciding with the governance aspect of *levels and scale, and strategies and instruments*. The market demand on the other hand may show influences from the strategies and instruments targeting end users (market demand as a policy strategy and potential end users as key target group of a policy) and from the learning process that elaborate the user context. Figure 10 presents the comparisons we made between GAT and SSIAf.

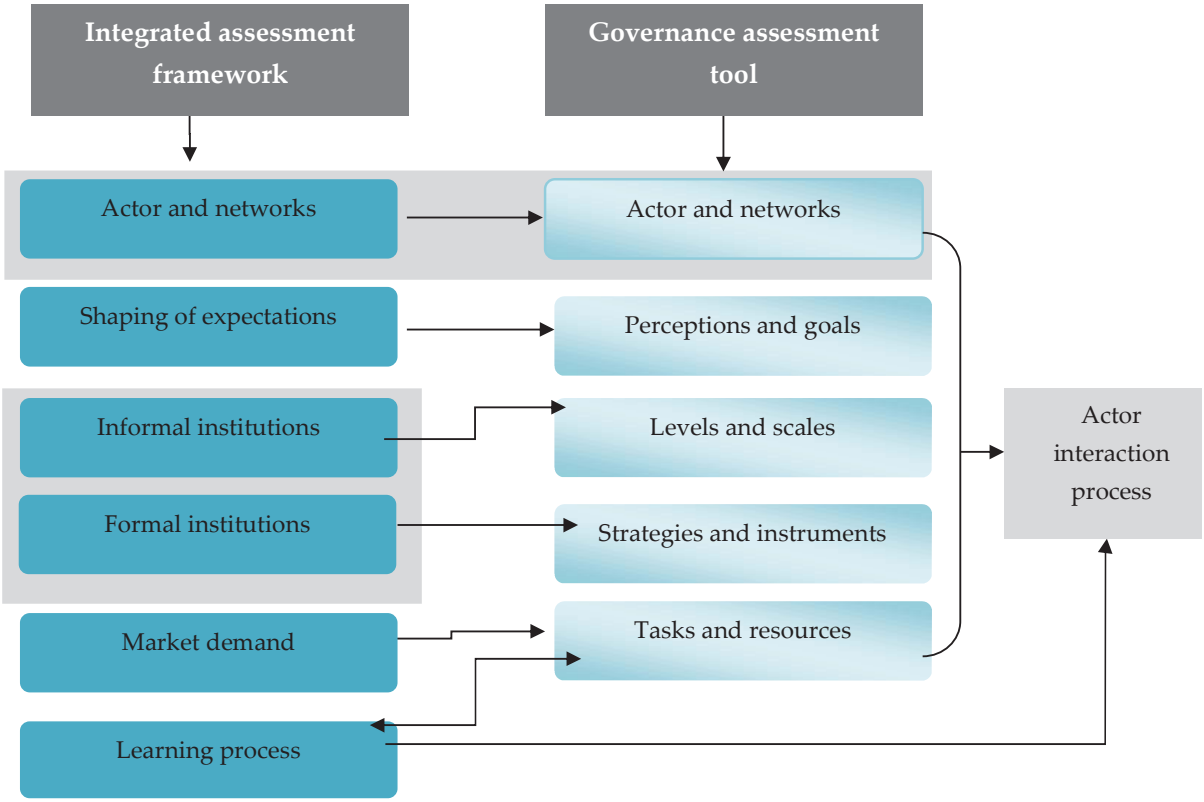

Figure 10 : Comparison of the GAT with the SSIAf.

Furthermore, the four quality criterions mentioned in GAT can be used to assess or evaluate niche development processes with respect to the five building blocks of the SSIAf integrated

assessment framework. For example, actor interactions, expectations, market demand, institutions and learning process can all be evaluated using the four quality criteria to understand the overlap with the GAT framework. However, the validity can be further elaborated based on the future empirical research.

3.4 Conclusions

In this chapter an integrated assessment framework was developed to assess niche development in energy innovations, in particular NZEBs in the Indian building sector. In doing so, we looked at two theoretical frameworks relevant to system innovations (SNM and SIS) and identified complementary aspects in these frameworks for assessing the innovation and diffusion of sustainable technologies. Next, we tried to develop an integrated assessment framework by combining those two frameworks. We called this the "Sectoral System Integrated Assessment Framework (SSIAf), which should be an analytical framework to assess niche development in a given economic sector. Because of the importance of 'governance' in sustainable system innovations, we addressed how governance was influential in to niche development and the formation of sectoral innovation systems. This led us to compare this to SSIAf. We judged that more attention to governance was needed and we looked at the GAT, to look for possibilities for incorporation of governance aspects in SSIAf. The integrated framework which resulted from this process will serve as a theoretical and analytical basis for future empirical research, starting with assessment of NZEBs niche development in India.

In summary, this chapter contributes to both transition studies-related theory and governance-related theory by developing an integrated assessment framework towards innovation and diffusion of sustainable technologies combining insights from both of the disciplinary fields.

Chapter 4:
Analyzing sectoral niche formation: the case of net-zero energy buildings in India

Mansi Jain, Thomas Hoppe & Hans Bressers (2017):
Analyzing sectoral niche formation: The case of net-zero energy buildings in India.
Environmental Innovations and Societal Transitions 25 (2017) 47-63

Abstract

Large scale development of Net Zero Energy Buildings (NZEBs) is seen as a potential solution to deal with future energy challenges in the building sector. This article aims to assess the current status of NZEB development in India by using an integrated framework named Sectoral System Innovation Assessment framework (SSIAf). The article addresses the research question: "'What does the SSIA framework tell about NZEB niche formation in India?"The SSIAf is developed using insights from the theoretical frameworks of Strategic Niche Management (SNM) and Sectoral Innovation Systems (SIS) with five key components: shaping of expectations, social network formation, institutions, learning process and market demand. A case study research design was used to analyze seven NZEB demonstration projects in India. The results show that the NZEB innovation niche has yet to develop into a mature niche, and is growing only slowly.

Keywords: Net zero energy building, Energy transition, Niche development, Strategic niche development, Sectoral innovation system

4.1 Introduction

Both in construction and in operation, buildings consume vast amounts of energy. This energy is mainly derived from fossil fuels (UNEP-SBCI, 2009). This poses a major challenge since these conventional sources of energy are limited and cause serious environmental damage including greenhouse gas (GHG) emissions. A transition towards low energy, low carbon and energy efficient buildings has gained much attention in recent decades but has seen mixed success (IEA, 2013). Many developed countries are currently preparing to transform their building sector (both new and existing) by deploying more Net Zero Energy Buildings (NZEBs)[14] (EU-Commission, 2013). NZEBs are buildings that are self-sufficient in meeting their energy needs, first by reducing energy demand and then by using on-site renewable energy sources to meet the remaining needs (Hermelink et al., 2013). Torcellini *et al.* (2006) define NZEB as "a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies."

The large-scale uptake of NZEBs is expected to enable many countries to reduce their energy and carbon footprints and move towards using renewable sources of energy for their building sector (Iqbal, 2004). To achieve this, policies and innovative approaches are being developed and implemented (Jain, Hoppe, & Bressers, 2014). As such, governmental actors are one of the main facilitators of the introduction and diffusion of new sustainable technologies. In addition, actors from both the public and private sectors are expected to participate in creating an enabling environment for this socio-technical transformation (Schot & Geels, 2008). The large-scale adoption of NZEBs is not straightforward as building-sector stakeholders still view it as a complex concept, to an extent because it can be described in a wide range of terms and expressions without a standardized holistic approach. Its definition can vary depending on the project goals, the intentions of the investor, concerns about climate change and energy costs (Marszal & Heiselberg, 2009).

Many developed countries have demonstrated the NZEB concept as a practical option. They are now in the process of expanding the niche towards wider adoption through societal

[14] Net Zero Energy Buildings is also interchangeably termed as Near-Zero Energy Buildings. (Boermans et.al., 2011)[

acceptance (Voss & Musall , 2011). In doing so, governments have also set ambitious targets to decarbonize their building sector (for example, the European Union (EU) Directive on Energy Performance of Buildings (EPBD) specifies that, by the end of 2020, all new buildings should be "Net Zero Energy Buildings" (EPBD Recast , 2010). However, ambitious targets and innovative approaches are missing in most developing countries where sustainable transitions are still needed (Lachman, 2013). A good example is India in which only a handful of NZEB demonstration buildings have been constructed in recent years.

In India, the building sector is growing rapidly, with an estimate that 70% of the 2030 building stock had yet to be constructed (NRDC & ASCI, 2012). In terms of energy consumption, this poses a large challenge as buildings are responsible for nearly 33% of India's total energy consumption, which is mostly derived from fossil fuels (NRDC & ASCI, 2012). A growing population, stable economic growth and rapid urbanization further increase the challenge of meeting the growing energy demand (Ofori, 2002). From this perspective, buildings which meet their energy demand through self-generation can become a favourable solution to deal with the energy challenges (demand–supply shortage, energy security, fossil fuel dependence) facing the country, especially in growing urban settings. To achieve this, a major systemic transformation will be required to fundamentally change the way in which buildings are designed, constructed, operated and refurbished throughout their life. This will be a formidable task since, despite efforts towards sustainable building solutions; the mainstreaming of energy efficiency in the building sector in India still encounters substantial economic, technical and implementation challenges (WEC, 2013). In recent years, a few NZEB demonstration projects have gained attention, showing early signs of the formation of a new niche. These NZEBs will require radical transformations or structural change on the societal scale once they are able to demonstrate the benefits. Such socio-technical transitions imply changes in structure, user practice, regulations, networks, infrastructure, culture and new technologies (Loorbach & Rotmans, 2005).

Theoretical frameworks such as Strategic Niche Management (SNM: Kemp *et al.*, 1998; Hoogma, 2002; Raven, 2005; Schot & Geels, 2008) and Sectoral Innovation Systems (SIS: Malerba, 2004; Geels, 2004; Faber & Hoppe, 2013) provide insight into fostering technological and social change to initiate sustainable innovations at the niche and sector levels respectively.

SNM is an analytical framework designed to facilitate and study the introduction and diffusion of new sustainable technologies through societal experiments (Schot & Geels, 2008). It is also argued that, to understand innovation activities at the niche level, it is also important to understand sector-level innovations through a lens that highlights sectoral innovation systems (Weber & Hoogma, 1998). The latter is a more holistic approach than focusing on a single technological niche and provides a more comprehensive understanding of learning and innovation processes that are specific to a given industrial sector. In this paper, a new heuristic tool is proposed that combines insights from the conceptual SNM framework and SIS framework: The *Sectoral Systems Innovation Assessment* framework (SSIAf) and can be used to analyse the innovation system surrounding a given technological niche in a given economic sector (the conceptual details are addressed in Section 2).

The aim of this paper is to assess the status of NZEB niche innovation in India. The main research question is: *"What does the SSIA framework tell about NZEB niche formation in India?"* The question will be answered by assessing NZEB demonstration projects in India. In this, SSIAf is used as the primary theoretical framework to assess the niche formation process at the sectoral level.

The paper is structured as follows. Section 4.2- 4.4 presents the theoretical underpinnings of SSIAf with origins in SNM and SIS. Next, Section 4.5 addresses the research design and methodology adopted in this study. Section 4.6 presents the results which then, in Section 4.7, are discussed and positioned in on-going academic debates. Finally, the main conclusions are presented in Section 4.8.

4.2 Background to the sectoral system innovation assessment framework

This article uses an assessment framework (SSIAf) that draws on insights from two distinct theoretical frameworks (and the research traditions they stem from): (i) Strategic Niche Management (SNM) and (ii) Sectoral Innovation Systems (SIS). Before presenting the SSIAf, the main conceptual notions of SNM and SIS will be presented, as well as their shortcomings and previous conceptual endeavours to combine insights from the two frameworks. Finally, based on these insights the SSIAf will be presented as an integrated framework that allows for analysing niche formation in a particular given economic sector.

4.2.1 Strategic niche management

The concept of SNM was introduced by the late 1990s as a theoretical framework and a policy tool to manage technological innovations and to facilitate the market introduction of sustainable technologies (Schot & Geels, 2008). The theoretical background of SNM draws on insights from constructivist science and technology studies (such as the Constructive Technology Assessment; CTA) and evolutionary economics as developed by Nelson and Winter (1982) and Dosi (1982). SNM refers to the process of deliberately managing niche formation processes through real-life experiments. In a society, established, commonly used technologies are generally embedded in societal structures that provide substantial barriers to the introduction and diffusion of new sustainable technologies. The introduction of sustainable technologies often fails for reasons linked to technology, government policy and regulatory frameworks, demand and production, culture and society, and infrastructure (Kemp & Schot, 1998).

SNM advocates for radical innovation through socio-technical experiments in which various stakeholders successfully collaborate and exchange information, knowledge and experience (Caniëls & Romijn, 2008). This involves several actors within the dominant sectoral regime making it a multi-actor approach. It sees governments (as one of the participating actors or stakeholders) as instrumental in facilitating wider transitions (Schot *et al.*, 1999; Rip & Kemp, 1998; Weber *et al.*, 1993). This can be achieved by setting up a set of successive experiments or by policy instruments (proposed by governments) that support niche development (e.g., subsidy schemes, regulatory exemptions, or pilot projects). SNM scholars explain the success or failure of a niche by analysing the interactions between the three main niche processes: (i) *shaping of expectations, (ii) building social networks* and, *(iii) learning processes* (Mourik & Raven, 2006; Caniëls & Romijn, 2008; Schot & Geels, 2008).

However, some scholars have critisized SNM claiming that it is difficult to assess whether SNM actually works (e.g., (Lachman, 2013)). SNM conveys the idea that a transition can be accomplished through the execution of appropriate management such that transitioning is largely viewed as a managerial task. This view does not align with the concept of a complex society, one that cannot be managed like a business firm (Shove & Walker, 2007). Criticisms of related theory (in particular the Multi Level Perspective; MLP) also applies to SNM because

SNM builds on these theories (Lachman, 2013). These approaches are considered to be heavily "flavoured" by the context in which they were conceived, and therefore as potentially less suitable for other contexts. This is a limitation in that most MLP and SNM related studies were conducted in developed countries, and only a few in developing countries. For this reason, calls have been made for more research on approaches to transitions in non-OECD and developing countries who are arguably "more in need of sustainable transitions" (Avelino & Rotmans, 2011).

When building on early transition-based policy concepts, such as SNM, there is a need to improve the understanding of the politics and policies of sustainable transitions. On the conceptual level, issues of power and politics were initially somewhat neglected (Meadowcroft, 2009; Shove &Walker, 2007) but have garnered more attention in recent years (e.g. Avelino & Rotmans, 2011; Grin *et al.*, 2010). In a similar vein, agency and power through the strategic interplay of different types of actors, including demand-side actors, civil society and grassroots movements, were considered as under-researched (Markard *et al.*, 2012; Shove & Walker, 2007; Seyfang & Hexaltine, 2012; Seyfang & Smith, 2007). In particular, the MLP has long been criticized for underplaying the role of agency in transition studies (Smith , Stirling , & Berkhout, 2005).

4.2.2 Sectoral innovation systems

An innovation system is a network of organizations, people and institutions within which the creation, diffusion and commercial exploitation of new technologies takes place (Malerba F. , 2004). The Innovation Systems literature, and in particular the Sectoral Innovation Systems (SIS) literature, emphasizes how the characteristics of an economic sector determine the scope of innovation within it (Beerepoot & Beerepoot, 2007). Within SIS, the core building blocks are: *knowledge and technology, actor and networks* and *institutions* (Malerba, 2002, 2004, 2007). Faber and Hoppe (2013) elaborated on the SIS framework and used it to assess sustainable energy transitions in the Dutch construction sector. In their view, SIS contain building blocks in four core dimensions: *(i) knowledge and technology, (ii) actors and networks, (iii) institutions* and *(iv) market demand creation* (adding the last one to Malerba's initial set of building blocks).

Although the Innovation System (IS) literature offers many benefits, it also suffers from various limitations. The focus is somewhat on the functioning of systems and element weaknesses rather than system change itself. Moreover, there is little attention given to reasons behind these weaknesses. The IS approaches tend to over-emphasize large actors such as industry, institutes and firms. There is a bias towards producers and suppliers and a tendency to neglect smaller actors such as citizen-led grassroots movements (Shove & Walker, 2007). Moreover, the IS approach neglects the demand side of markets. According to Geels (2004), most attention in IS studies are directed towards the study of the development of knowledge and that there is a need to also emphasizing the diffusion and application of technology and its impact on society.

Typically, IS approaches measure and assess innovation system performance at the level of the system and sub-systems. An indicator commonly used to measure the overall performance of a system is the diffusion of the innovation under study (Bergek & Jacobsson, 2003; Bergek *et al*., 2015). However, innovation diffusion was also used implicitly as the main indicator of system performance (with less attention paid to other theoretically relevant indicators). One of the key areas identified for further refinement and alignment in IS approaches is performance assessment (e.g., defining indicators for different types of systems and different IS sub-functions (Markard & Truffer, 2008). To an extent for this reason, the IS approach/perspective has been critisized for being "inwardly oriented" by not paying sufficient attention to the system's environment (Markard & Truffer, 2008).

4.3 Integration of concepts from the SNM and IS traditions in the literature

Several attempts have been made to integrate insights from the Innovation System and Transition theoretical frameworks, notably frameworks that have been established by Markard and Truffer (2008), Meelen and Farla (2013), and Weber and Rohracher (2012). We will address them shortly.

Markard and Truffer (2008) reviewed both theoretical concepts and explored commonalities and differences. They acknowledged that Techonological Innovation Systems (TIS) and MLP are closely related concepts in studying far-reaching technological changes. Based on the results of this comparison Markard and Truffer developed a combined approach. It provides certain

benefits: (i) it more explicitly considers innovation processes at the micro-level of organizations; (ii) it takes into account mutual interdependencies between actors and institutions; (iii) it provides consistent performance comparisons; and (iv) it facilitates systematic identification and assessment of the broad range of TIS factors that influence innovation processes. The authors went on to present a path towards a framework that combines the strengths of the two approaches to allow a better understanding of radical innovation processes and socio-technical transformations. Ideas were formulated to embed technological innovation systems that can contain one or more niches.

Meelen and Farla (2013) made a plea to combine the TIS framework with MLP to better capture the relationship between technology evolution and sectoral change. They combine insights from the two theoretical frameworks to develop an integrated framework that can be used to analyse sustainable innovation policy. In the framework, the multilevel view from the Transition Management (TM) / SNM approach has been integrated with the functions approach of the (T)IS literature. This integrated policy framework shows that specific policy goals and measures can be found at specific points in an intervention related to the interfaces between landscape, regime, IS and niches. The integrated framework suggests that the stimulation of (T) IS only makes sense when this is closely aligned with landscape and regime developments (Meelen & Farla, 2013).

Another attempt at a conceptual integration between the IS and SNM/MLP traditions is the "sustainable transitions failures framework" by Weber and Rohracher (2012). Insights from transition studies (MLP/SNM) are used in a policy framework that is based on the IS approach and the notion of 'failures' (factors that prevent sustainable innovations). This framework draws on a combination of market failures, structural system failures and transformational system failures (Weber & Rohracher, 2012). The focus of related research is often unsustainable value change, and sustainability issues such as climate change. Empirical research has shown that the framework is useful, but that it is difficult to address the comprehensive set of failures, and that many are intertwined. In addition, although designed as a 'policy framework', the failures framework neglects valuable conceptual insights that are available from the policy studies discipline (Hoppe, et al., 2016).

Although the afore mentioned merger frameworks as presented by Markard and Truffer (2008), Weber and Rohracher (2012), and Meelen and Farla (2013) offer clear benefits over solely using SNM/MLP or (T) IS theoretical approaches their benefits should also be viewed from perspectives of those who will be using it for research. For instance, the failures framework (Weber & Rohracher, 2012) problematizes a large set of barriers that prevent sustainable transitions from happening, which can serve as barriers to which policy makers can design interventions to overcome them. However, we consider this framework to be very comprehensive, time consuming to apply in empirical research, and pre-emphasizes barriers instead of having a more integrated view that also address (enabling conditions to) niche formation, which includes strategies and interventions to overcome the observed barriers.

In a similar vein, the framework by Meelen and Farla (2013) addresses issues that are of special interest to policy makers and does not go much beyond this scope. For these reasons we feel it is necessary to develop a theoretical framework that involves and integrates key insights from SNM and SIS, but copes with the problematic issues of the afore mentioned merger frameworks; i.e., by not only focusing on barriers and problems, by going beyond having a myopic (prescriptive) policy-oriented vision, and by avoiding to construct a framework that is too complex and comprehensive to apply to case study research of (sustainable, sectoral) niche formation.

In sum, we feel that a theoretical framework should be developed that is able to: (i) analyze the status quo of a given sectoral niche formation and (ii) analyze the historical development of this given sectoral niche formation process. Moreover, the framework should acknowledge most of the benefits offered by the integrative framework by Markard and Truffer (2008), including systematic identification and assessment of the broad range of (T) IS factors that influence innovation processes. The proposed SSIA framework presented in the following sub-section is designed to empirically assess sectoral niche formation. It should allow for a better understanding of niche innovation process within a given sectoral domain.

4.4. Integrated assessment framework to analyse sectoral niche formation

In assessing the status of NZEB niche innovation, SNM and SIS, despite their stated limitations, both provide insights into the innovation process for the diffusion of sustainable

technologies. Although the two frameworks were developed independently (SNM derives from transition theory (in particular the MLP) and SIS from innovation systems (IS), they share conceptual grounds, and both can be used to explain innovation phenomena (Markard & Truffer, 2008).

The SNM framework represents processes of radical innovation in a protected niche, and the SIS approach is used in this paper to complement this on the premise that SIS address sector-level innovations (and the wider sectoral level context such as the building sector) which ultimately influence niche formation and growth. The resulting structural building blocks (which we see as 'enabling conditions for niche development) are used conceptually to assess the status of the NZEB innovation niche. Figure 11 presents the conceptual elements of the SNM and SIS frameworks (also in chapter 3). The arrows indicate conceptual commonalities.

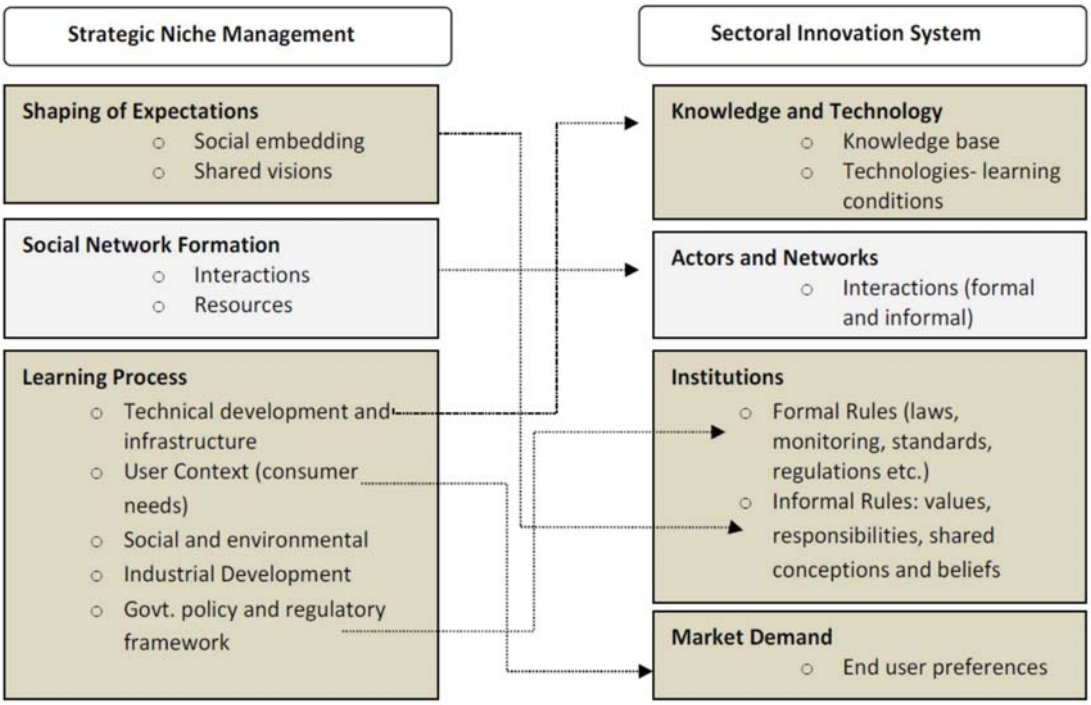

Figure 11 : SNM and SIS framework complementarities (Jain, Hoppe, & Bressers, 2014)

The *shaping of expectations*, *social network formation* and *learning process* components are derived from SNM and are complemented with two additional structural blocks, namely *institutions* and *market demand*, from the SIS framework to form five fundamental theoretical blocks that will be used to analyse the status and the transformative processes of an innovation

niche. The five building blocks jointly influence the sectoral niche formation process and the innovations that result from the formation of a new radical niche within a sector (see Figure 12).

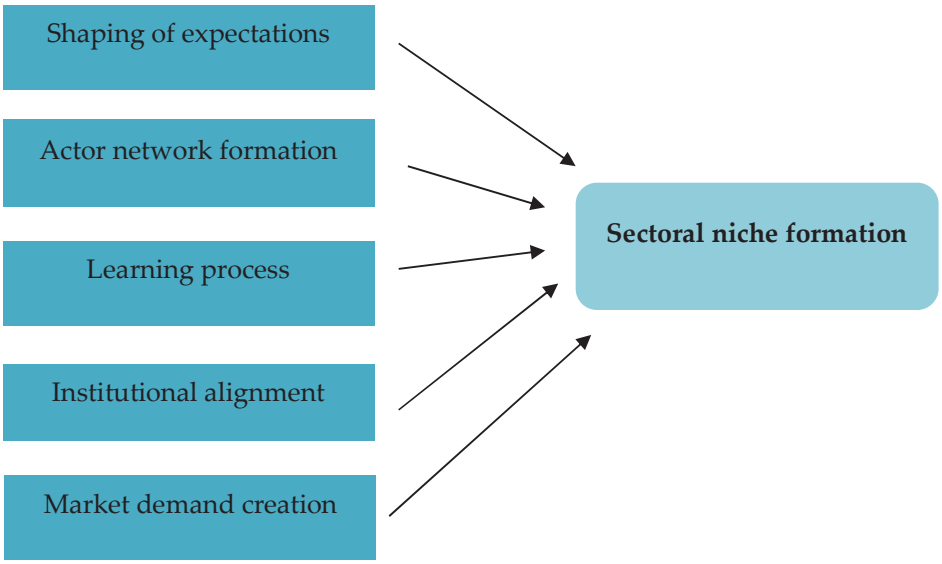

Figure 12 : Conditions enabling sectoral niche formation

4.4.1 Shaping of expectations

The promises and expectations of a new technology are considered important in niche development processes to attract attention; mainly to clarify what the benefits of the niche will be (in our case the benefits of NZEBs). Interested actors and stakeholders such as business firms, end-users, policymakers and entrepreneurs participate in niche development processes based on their expectations (Raven, 2005). According to Raven (2005), the process of shaping expectations is considered as good when (i) an increasing number of participants share the same expectations (converging towards a shared vision), and (ii) the expectations are increasingly based on tangible results from transitional experiments. Thus, positive expectations about a niche technology can support the concept to grow in scale, and attract more participants and resources, by translating the niche idea (in our case NZEBs) into the mainstream setting (Schot & Geels, 2008).

4.4.2 Actor network formation

Developing a niche may require new actors to get together and new social networks to emerge that provide and exchange the necessary resources (e.g. money, people and expertise). Mourik and Raven (2006) argue that social networks are favourable for a niche development when: (i) the network is broad (including firms, users, policymakers, scientists and other

relevant actors from the science and technology domains, the policy domain, the social domain and including both regime actors and regime outsiders), and (ii) when alignment within the network is facilitated through regular interactions between the actors. Interactive processes are seen as key to innovation and a major driving force for sectoral change (Hofman, 2002; Malerba, 2007; Caniëls and Romijn, 2008).

4.4.3 Learning process

A learning process is considered likely to spur innovations if there is a broad focus which not only addresses techno-economic optimization but also the alignment between the technical (e.g. technical design, infrastructure) and social (e.g. user preferences, regulation and cultural meaning) aspects. Hoogma (2002) identifies five aspects that are considered important in learning about innovation/niche development: (i) technical development and infrastructure, (ii) user context (i.e. user characteristics and consumer needs), (iii) societal and environmental impacts, (iv) industrial development and (v) government policy and regulations. Finally, a protected niche space may enable innovators to benefit from new learning opportunities.

4.4.4 Institutional alignment

The concept of institutions includes various formal and non-formal rules, such as values, routines, common habits, established practices, laws and standards, which all shape the cognitions and actions of agents, as well as the interactions between agents (Malerba F. , 2004). Formal institutions refer to 'the formal rules of the game', including rules, laws, monitoring and sanctioning, and government policies. Informal institutions describe the rules that provide legitimacy to individual practices by referring to values, responsibilities, obligations, shared conceptions or common beliefs (Scott, 1995). Existing sector-level institutions may facilitate or obstruct the growth and innovation of a niche. As such, this component taken from the SIS framework will provide insight into the institutional frameworks that support or resist the niche formation process and innovation.

4.4.5 Market demand creation

Market demand stems from the preferences of end consumers as largely revealed in actual consumer choices (Geels F. , 2004). However, Malerba (2007) argues that, in evolutionary economic approaches, the range of preferences of both consumers and producers stems from

asymmetry in information or skills, constraints on opportunity, or heterogeneity in intrinsic motivations. A large diversity in preferences gives rise to market fragmentation and, hence, to increased opportunities for radically new technologies to enter a niche market. The role of demand is important in understanding technological change and innovation in a given sector (Witt, 2011). Table 9 presents an overview of the key theoretical components of the assessment framework.

Table 9: Assessment criteria for sectoral niche formation

Shaping of expectations	• An increasing number of participants share the same expectations (converging to a shared vision). • Expectations are based on tangible results from transitional experiments.
Actor network formation	• Size of the sectoral actor-networks (including both primary agents and secondary agents[15], and both regime insiders and regime outsiders). • Extent of formal and informal interactions.
Learning process	• Broad learning (on technology and knowledge, techno-economic optimization, technical and social alignment). • Reflexive learning, self-governance, flexibility to change course. • First- and second-order learning.
Institutional alignment	• Formal institutions (rules, laws, regulations, monitoring). • Informal institutions (values, responsibilities, obligations).
Market demand creation	• Requirements and preferences. • Heterogeneity. • Role of niche markets. • Market structure, size and segmentation.

4.5 Research design and methodology

The research design concerns an embedded case study approach. For the empirical study, all the existing NZEB pilot projects in India were shortlisted. At the time of data collection, nine NZEB pilots could be identified as potential cases, of which seven[16] were used for primary data collection as our case study (see Table 10 and Figure 13). Three of these projects were

[15] Primary and Secondary agents: The primary agents in a sectoral innovation system are the key players that perform core innovative activities, experiments and capacity building. In the housing sector, the primary agents are the firms that design, develop and build, the suppliers, the installers, the main users including households and social corporations of all sizes, and the local authorities. Secondary agents contribute to supporting measures in knowledge diffusion, financial support, regulations and counselling. In the housing sector, this includes national government, banks, supportive information and extension agencies, research institutions, consultancies, architects and intermediaries (Faber & Hoppe, 2012).

[16] Seven projects were selected on the basis of availability of primary data collection (interview participation). Nevertheless, all the nine projects were reviewed using available secondary data.

completed NZEB projects (in the performance-monitoring phase) and four of those projects were either in the early design phase or in the construction phase. These projects can be considered front-runner and innovator projects in terms of using the NZEB concept, and thus can be considered as representative of projects contributing to the formation of a new niche.

Table 10: Overview of analysed NZEB projects

Project Name	Type	Stage	Interviews / other sources	Ownership
Project 1: Indra Paryavaran Bhawan, New Delhi	Location: New Delhi, India Project area: 9565 m^2 Built-up area: 32,000 m^2 Certification: LEED Platinum, GRIHA 5-star Climate type: Composite EPI[17]: 43.75 $kWh/m^2/yr$	Completed	3 Secondary research (articles, websites, publications)	Public sector
Project 2: Eco commercial Building: Bayer Material Sciences	Location: Greater Noida, India Built-up area: 891 m^2 Certification: LEED Platinum Climate type: Composite EPI: 71.56 $kWh/m^2/yr$.	Completed	1 Secondary research (articles, websites, publications)	Private sector
Project 3: A Living Laboratory (CEPT University)	Location: Ahmadabad, Gujarat, India Built-up Area: 498 m^2 Certification: LEED Platinum, GRIHA[18] 5- star Climate type: Hot and dry EPI: 58 $kWh/m^2/yr$.	Completed	1	Autonomous University (CARBSE supported by public sector)
Project 4: Nalanda University Campus	Location: Rajgir, Bihar, India Project area: 446 acres Certification: Adopted GRIHA rating	Conceptual Planning	2 Participation in project meetings	Central University (public support and international funding)
Project 5: Head Office Building, Uttar Haryana Bijli Vitran Nigam Limited (UHBVN)	Location: Panchkula, Haryana Project area: 8000 m^2 Built up area: 20,145 m^2 Certification: none Climate type: Composite EPI: 32 $kWh/m^2/yr$	Tendering stage	1 Participation in project meetings	Public sector

[17] EPI: Energy Performance Index
[3]GRIHA – Green Rating for Integrated Habitat Assessment

Project 6: Indian Institute of Technology (IIT)	Location: Jodhpur, India Project Area: 850 acres Status: Master Planning Climate type: Hot and dry	Master Planning	2	University (Public funding)
Project 7: Centre for Energy and Environment, MNIT	Location: Jaipur, India	Conceptual Stage	1	University (Public funding)

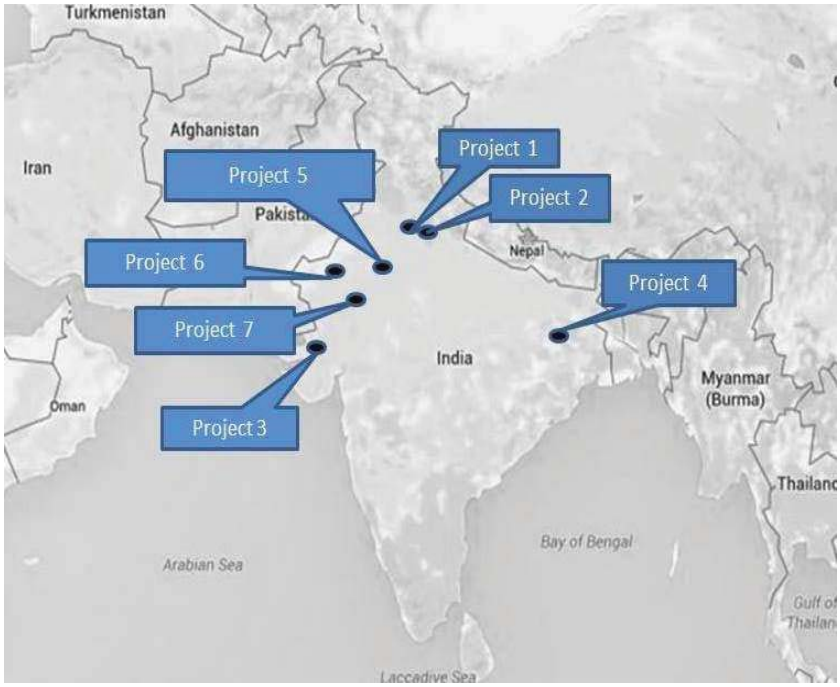

Figure 13 : Locations of NZEB demonstration projects.

Primary data were collected by conducting eighteen "in-depth" interviews, participation in meetings, and field trips to the selected project sites (by the main researcher, the first author of this paper), and a review of secondary data. The interviewees included building owners, architects, energy consultants, government officials, policymakers; building services designers (mechanical, electrical and plumbing (MEP), technology manufacturers and building occupiers. The interviews were divided into two sets: eleven participants who were directly involved with one or more of the above listed NZEB demonstration projects; and the remaining seven participants who had relevant knowledge about the sector and the concept of NZEB but no direct association with the NZEB pilots. This latter group was selected to provide a sector-level perspective on the formation of the new NZEB niche and so give insights into sectoral level innovations.

Semi-structured questionnaires were prepared for the in-depth interviews (see Annex A). The questions were largely based on the five components of the SSIAf to assess NZEB niche formation. All the interviews were conducted face-to-face, recorded and transcribed into text files, which were used for analysis in the Atlas.ti qualitative analysis software program. This program supports data (in this case interview transcripts) analysis by assisting researchers in locating, coding and annotating findings in text files, in weighting and evaluating their importance, and in visualizing the complex relationships (Muhr & Friese, 2004). The data were coded using a coding scheme that consisted of codes resembling the theoretical concepts of the SSIAf. This enabled a systematic assessment of the NZEB projects, and at a higher level of abstraction the NZEB niche formation process.

Each component of the SSIAf was a basis for developing codes for the transcribed documents. The five components became the main coding clusters in the Atlas. ti program and a set of sub-codes was further developed and matched with their occurrences. The sub-codes and their occurrences were then used to weight and evaluate their importance as part of assessing the status of NZEB development in India, and hence supported the data analysis.

4.6 Results

The results of the study are presented and analysed for each component of the SSIAf (see section 4.2). Each section elaborates on the sectoral perspective of NZEB niche innovation and its impact on the niche innovation process (assuming the conceptual building blocks are 'partial enabling conditions' for niche innovation processes). Before the results are presented, an overview of the building sector in India along with its energy consumption pattern is presented in sub-section 4.1. An integrated overview of the main results of the empirical study is presented in section 4.3.

4.6.1 Market description of the Indian building sector

The Indian building sector consists predominately of a residential sector and a commercial sector. Between 700 and 900 million m^2 of commercial and residential space is projected to be built each year until 2030 (Sankhe, et al., 2010). Figure 4 presents expected trends for the building sector in India (differentiated by type of building). In all sectors, the

number of buildings is expected to increase rapidly although most growth is expected in terms of residential buildings followed by the commercial sector. Given the significant increase in estimated demand for buildings (see figure 14), it is imperative that the building sector to manage its projected growth in a feasible and sustainable manner. This high growth will lead to a significant increase in the energy demand of the building sector and hence energy efficiency in this sector is a prime concern for energy planners including relevant governmental agencies. The growth of India's urban areas, both existing and projected, needs to be supported by clean energy solutions to manage the dramatic impact of energy consumption on urban cities (Rawal et.al., 2014).

The key stakeholders of the Indian building industry that have a significant role in promoting its energy efficiency in India include national government ministries, federal institutions, state government ministries, building sector associations, private sector construction organizations and service providers (architects, developers etc.), financial institutions, research and academia, manufacturers and, building material suppliers. National ministries[19] are considered as dominant stakeholders as they are responsible for formulating policies and supporting and monitoring programmes related to the building sector in India. Additionally, several bilateral/multilateral aid agencies (USAID, DFID, SDC, UNDP etc.) also play an instrumental role towards an energy efficiency transition in the building sector through their programmes that include pilot demonstration projects.

[19] MOP- Ministry of Power, MNRE – Ministry of New and Renewable Energy, MOUD- Ministry of Urban Development

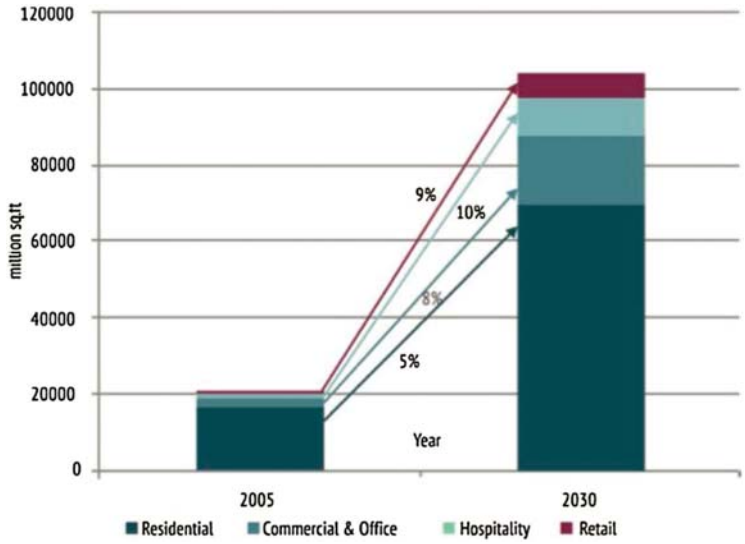

Figure 14: Estimated demand for real estate space for various sectors (2005-2030), Source: (Rawal et.al., 2014)

Buildings consume large amounts of energy throughout their lifecycle through design, construction, operation, maintenance and retrofitting. Energy consumption is predominantly in the form of electricity used to provide a variety of services such as thermal comfort (space heating and cooling), lighting, water heating and various appliances (Jain, Hoppe, & Bressers, 2014). In India, building energy use has increased from 14% of total primary energy use in the 1970s to nearly 30% in 2004–2005, with a near-consistent 8% rise in annual energy demand in residential and commercial sectors (Rawal *et al.*, 2012; NRDC & ASCI, 2012). Figure 15 indicates electricity consumption in India in the various sectors, and Figure 16 presents a more detailed breakdown for residential and commercial buildings.

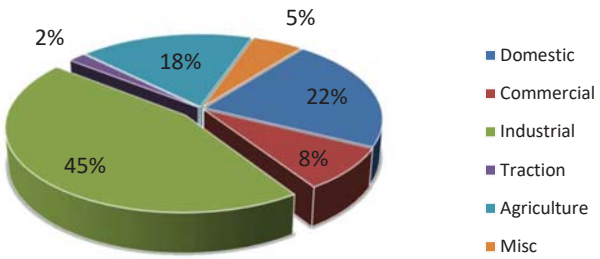

Figure 15 : Electricity Consumption in India (2012-13), Source: Central Electricity Authority, 2014

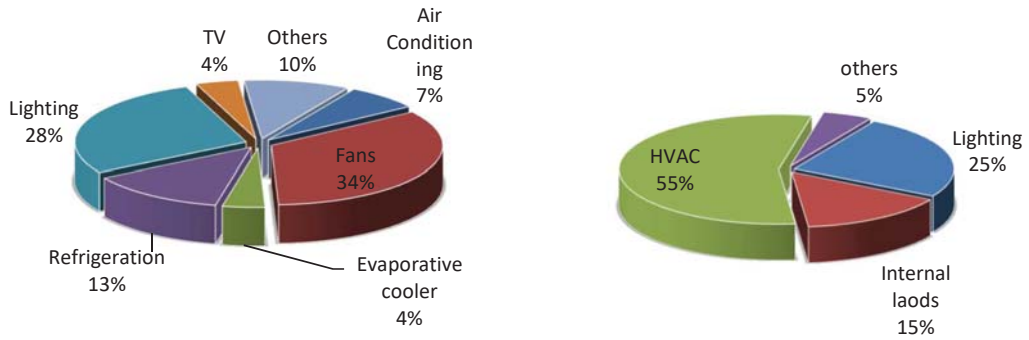

Figure 16: Electricity consumption pattern in residential (left) and commercial (right) buildings (Source: BEE, 2014)

4.6.2 Shaping of expectations

NZEB pilot projects were able to shape positive expectations of new sustainable technologies among the actors involved. Most of the studied NZEB pilots resulted from highly motivated project owners (mostly public-sector clients) who were aware of the long-term socioeconomic benefits of NZEBs (mostly from international NZEB demonstration projects). This client motivation garnered further interest among the project design and construction teams, creating a common project goal with a high visibility (drawing wider societal attention). To this extent, the innovation in the design and construction of these NZEB projects did garner wider attention. Expectations were also raised by four of these NZEB pilots being educational buildings or large-scale university campuses (projects 3, 4, 6 & 7 in Table 10), thereby attracting attention from academia and the research community. This is considered positive as it strengthens the expectations attached to this new niche. The projects received support from the government in the form of subsidies, additional budgets for public sector pilots, and through collaboration in bilateral NZEB programmes (USAID PACE D –TA[20] program).

However, on the sectoral level, actors were somewhat sceptical about the new NZEB concept and doubted the technical and economic benefits, which to some extent slowed the innovation process. This was mostly due to the lack of quantified benefits and outcomes, a consequence of most projects still being in the development stage. Developing robust and specific expectations and articulating a sound vision, of NZEBs may take more time, with the possibility of changing expectations in the future. The lack of solid data on the performance

[20] USAID PACE D –TA : USAID Partnership to Accelerate Clean Energy –Technical Assistance

of these buildings and the economic implications acts as a brake on the expansion of an innovation niche. A vision or concrete goals for the uptake of NZEBs in the building sector is needed, but is presently missing, and this is largely a task for the government. Additional successful pilots are considered essential to attract interest from the building sector for innovation.

4.6.3 Actor network formation

There was a high level of interaction between team members in each of the analysed NZEB project's boundaries. All the completed NZEB projects adopted an integrated design approach[21] that brought all the project stakeholders into the discussion from the conceptual design stage[22], thereby showing a considerable level of interaction and building of new networks between the project team members. This was despite most of the public-sector projects using a hierarchical system, with formal interaction and decision-making processes, which to some extent probably hampered the innovation process and discouraged informal network formation.

The project team configurations were diverse and appropriate for demonstration projects. Additional experts became involved as they were needed to achieve pre-set NZEB goals. Active participation and high levels of satisfaction were observed among those team members having sufficient knowledge and expertise about the NZEB concept (including passive design architects and LEED[23] consultants taking a leading role in the project, HVAC[24] experts). However, additional effort was needed to keep other stakeholders abreast of events and motivated.

The collective participation of the various actors within a niche is theorized to lead to an increased level of innovation, to knowledge creation, and to a reduction in complexity, risks and uncertainty (Mourik & Raven, 2006). However, this was not observed within the

[21] The conventional definition of integrated design is that project team members from all disciplines work together early and often throughout the project design process. **Integrated design** is an holistic method of **design** (and especially applied to **buildings**) that emphasizes management empathy to promote innovation and enhance energy performance of buildings through design.

[22] One interviewee mentioned being part of weekly design review meetings that were held over nine months and chaired by the additional director general of Central Public Works Department (CPWD). Similarly, on another NZEB pilot project, a similar approach was adopted with three in-person design workshops followed by nearly twenty virtual meetings with the entire project team during the design phase.

[23] Leadership in Energy and Environment Design (USGBC)

[24] HVAC – Heating Ventilation and Air-Conditioning

NZEB projects studied. In particular, there appeared to be a lack of interaction and an absence of social network formation between completed and on-going NZEB projects. Apart from a few formal interactions through conferences, each project developed in isolation from the other NZEBs in the country. As a consequence, there is a lack of coordination and alignment between on-going NZEB projects on the aggregated niche level. In the longer run, the failure to verify existing NZEB buildings will lead to ambiguity.

On the sectoral level, building sector stakeholders were apprehensive of the new NZEB concept. Many factors contributed to this situation including the NZEB actors operating in isolation. A consequence of this was that established building sector stakeholders were not being reached to form part of a new social network. Various other factors appeared to be considerable challenges: the high capital costs of NZEBs, a lack of verified and monitored data in the public domain, a general lack of awareness, a lack of credible information about NZEBs, and a general resistance to change. All of these contributed to increasing the gap between the niche insiders and niche outsiders, effectively blocking social network formation.

4.6.4 Learning process

None of the NZEB demonstration projects (either completed or in the design/construction phases) showed a high level of learning, hampering further innovation. Learning was seen to be situational and fragmented, often focused on first-order learning such that lessons were not transferred to other NZEB demonstrations projects. As such, the transfer of direct learning experiences did not take place. Technical solutions and knowledge about NZEBs were available but more aspects needed to be explored, especially concerning situational NZEB site definitions and aspects of buildings from a life-cycle perspective.

Key decision-making was in the hands of a small number of expert team members (energy consultants and project clients) who did not share critical information about project failures. In fact, the projects that were investigated tended to shy away from sharing performance information from the occupied NZEBs. In general, learning is expected to take place through interactions between project team members (within an individual project) and also between demonstration projects. The latter is viewed as important because it is assumed to enhance network formation and make the setting of expectations more robust. We would argue

that this is highly needed for the successful up scaling of NZEB innovation projects, but currently lacking in the present scenario. The role of educational institutions (as pilots) is seen as important since buildings with an educational function can stimulate holistic learning about the NZEB concepts and address both occupants' needs and experiences and the benefits of NZEBs for society at large.

On the sectoral level, the innovation process is slowed by the failure to learn from NZEB demonstration projects. It was also difficult to understand the technical explanations of the NZEB concept, and the learning process needs to focus on disseminating knowledge in a simpler way that matches the relevant stakeholders in the building construction value chain thus increase second-order learning.

4.6.5 Institutional alignment (formal and informal)

Currently, building sector institutions do not seem to be well aligned with NZEBs. To some extent, there is a separation between energy efficiency and renewable energy (since each aspect is looked after by different central government institutions). One of the main instruments – the ECBC) – is a voluntary code that indicates a minimum energy performance standard for commercial buildings. Future code implementation and compliance will lead to a promising shift towards the adoption of energy efficient buildings, which will support innovation. Similarly, from the renewable energy perspective, there have been some policies – such as the solar roof-top policy, feed-in tariff mechanisms and net metering – that can be considered supportive in achieving NZEB goals. All the investigated NZEB demonstration projects received government subsidies to integrate renewable energy technology in the buildings. In most cases, this was perceived as very positive, but a sign that it is still a 'technology niche'.

Informal institutions such as values, common practices, responsibilities and obligations also play an important role in niche innovation. An inherent shared practice observed in the studied projects was that NZEB actors refrained from sharing project failures. Moreover, radical innovators seemed obliged to highlight the successes of the demonstration projects in which they are involved. Since most of the NZEB demonstrations projects involved public sector buildings, they are typically scrutinized because they use special budgets available for such

demonstration projects. Consequently, actors tend to refrain from sharing information on project failures[25]. This shared reticence limits innovation in subsequent demonstrations. Further, government communication protocols and hierarchical systems put additional pressure on the project teams and client representatives to report project successes (to senior officials).

On the sectoral level, institutional fragmentation was observed, and this slowed the innovation process, limited the learning process and hampered network formation. Several national and state public authorities appeared only to be involved with their own separate activities. Developing an integrated well-aligned comprehensive institutional framework was of critical importance by most of the actors that were interviewed.

4.6.6 Market demand creation

There appears to be a low level of demand for energy innovations in the building sector, particularly for NZEBs. The fact that there were only a handful demonstration projects in India indicates that NZEBs are in an early stage of niche formation (or rather in an R&D stage) and more of a 'technology niche'. The replication of such projects is expected to take considerable time in terms of experimentation and testing (following the verification of existing NZEBs). Here, government initiatives (standards and policies) for creating a market demand are considered important. Since existing energy standards do not incentivize people to explore energy innovations, they tend to stick with conventional business-as-usual construction practices. This 'locks out' the potential adoption of innovative sustainable technologies in the building sector.

The involvement of end-users, and their preferences, can play an important role in the innovation process (Malerba F. , 2004). This can lead to co-development of new technologies by experimentation and gearing a technology to a specific demand (Faber & Hoppe, 2012). However, in the demonstration projects analysed, user involvement was restricted and limited. Hence, the users' preferences (as building occupiers) and their sensitization towards the use of NZEBs were badly missed. When it came to NZEBs, it was observed that the housing sector's participation in energy innovations was negligible with house owners lacking sufficient

[25] Gap in the designed and actual energy performance in the building (failing to achieve net zero status in a year)

motivation (due to financial implications and the lack of understanding of tangible benefits). Moreover, project developers tend to shy away from innovations due to perceptions of 'spilt incentives'[26]. It seems that construction companies and other actors in the building industry in India are not prepared to produce energy efficiency buildings in large numbers.

Perceived upfront costs, a lack of knowledge on the techno-economic feasibility, a lack of awareness of the possibilities, a limited workforce in the industry with the skills to deliver NZEBs and the limited technical know-how were the main barriers that were consistently highlighted during the case study analysis which also resulted in limited demand for NZEBs. For societal transformation and innovation to occur, private sector participation will be necessary on a large scale. However, due to lack of feasible business models and access to finance, clients and project owners were disinclined to accept the NZEB concept and adopt innovation. However, a parallel uptake of solar energy technologies was seen to be a result of subsidies and incentives from the government. Similar support from the government through policies and programmes (including financing an increased number of NZEB demonstration projects) is crucial by actors in the building sector.

4.7 Overview of the main results

In Table 11 an overview is presented of the main results using the SSIAF concepts.

Table 11: Overview of the main results of the empirical analysis

Assessment criteria for the NZEB innovation niche (SSIAf components)	observations	results (regarding NZEB niche formation)
Shaping of expectations a. Increasing number of participants sharing the same expectations (converging into a shared vision. b. Expectations are increasingly based on tangible results from transition experiments.	• NZEB project actors have positive expectations of the sustainable technologies demonstrated. • Expectations are not based on tangible results, hence neither robust nor specific. Possible to alter existing expectations in future. • Actors outside the NZEB projects do not have positive expectations from NZEBs (due to lack of tangible results), slowing the innovation process.	• Niche development is in a pre-development stage • Positive expectations are shared only by NZEB project actors and not by mainstream building actors. • Expectations are still not specific or based on tangible results (they are general and do not give guidance for setting goals). • Expectations are not converging to a shared

[26] In general, it is the end-user who, in the long run, gains most of the benefits of energy-efficient buildings.

		vision or NZEB goal.
Actor Network formation a. Size of the sectoral actor-networks (including both primary agents and secondary agents, and both regime insiders and regime outsiders). b. Extent of formal and informal interactions.	• There was a high level of interaction between actors within each demonstration project. • There was a relatively low level of interaction across the different demonstration projects (each one was developed in isolation). • There is a very low level of interaction between actors in NZEB projects and mainstream building stakeholders.	• Networks tended to be narrow and weak. • Minimal involvement of outsiders in the experiments (reducing second-order learning). • The network interactions are not deep: the people who are engaged are not able to mobilize commitments and resources and are based around the NZEB projects. • Lack of formal interactions through conferences, workshops etc. • Informal interactions are based around the projects.
Learning process a. Broad learning (on technology and knowledge, techno-economic optimization, technical and social alignment). ***b.*** Reflexive learning, self-governance, flexibility to change course.	• There is a low level of learning from both completed and on-going NZEB demonstration projects. • There is a lack of learning on the techno-economic feasibility, and the technical and social alignment of NZEBs. • There is a lack of learning from existing NZEB demonstration projects (limited one-on-one interactions with niche actors).	• Projects tend to focus on first-order learning based on accumulation of facts and data. • Lack of second-order learning.[27] • Limited learning from the demonstration projects – only within the NZEB project actors.
Institutional alignment a. Formal institutions (rules, laws, regulations, monitoring). b. Informal institutions (values, responsibilities, obligations).	• Formal institutions (policies, regulations, standards and protocols) are currently not aligned with supporting NZEBs. • Demonstration projects have received support through renewable energy technology subsidies (which were considered beneficial). • There is a lack of alignment of institutions and government policies towards NZEBs (institutional fragmentation).	• Institutions are supporting NZEB project-based innovations, fostering 'technological niche' development. • The existing institutional structure is less supportive of sectoral innovations. • Institutions also hamper the learning process between the niche and the regime.
Market demand creation a. Requirements and preferences. b. Heterogeneity. c. Role of niche markets. d. Market structure, size and	• Perceived high upfront costs, lack of techno-economic feasibility, lack of awareness of the NZEB concept, limited industrial capacity and lack of policies to support NZEB uptake are seen as barriers to uptake.	• The existing niche has yet to develop into a 'market niche'. • No demand for more NZEBs • Barriers to uptake:

[27] Second-order learning enables changes in cognitive frames and assumptions (derived from Grin and Van de Graaf 1996).

segmentation.	• Government policy instruments have potential to create market demand and initiate innovations. • More demonstration projects are needed to create sufficient evidence-based knowledge about NZEBs (as a reliable and affordable building concept). • More private sector participation is required to spur the uptake. • Lack of feasible business models to attract private sector players.	• Perceived high capital cost. • Lack of technical knowhow in the industry and lack of capacity. • lack of government support • lack of knowledge and awareness of NZEBs.

4.8 Discussion

The results reveal that, so far, the NZEB concept has not developed into a successful innovation niche. This is to a large extent due to the limited development of some of the SIS building blocks (institutions and market demand), reflecting relatively poor conditions for NZEB technology to mature. There are several reasons for this. Many NZEB demonstration projects were organized in an overly self-contained way–and this hampers the niche innovation process. Each of the five SSIAf components were independently evaluated and assessed, highlighting the limited success of the pilots in inducing further sustainable development of the niche. Only a small number of actors (and mainly NZEB project actors) seem to have positive and optimistic *expectations* of NZEBs. The expectations for the niche were not yet robust as there was a lack of tangible results. The new *social network* tended to be narrow with interactions taking place only within the demonstration projects and only during the project timelines. Both formal and informal social interactions were also limited. The lack of a cohesive actor-network may be a sign that that the niche is growing only slowly.

Our results support the views of those transition scholars who see social network formation as a crucial condition for the growth of a niche (e.g. Schot & Geels, 2008; Caniels & Romijn, 2008). Authors have stressed that sub-optimal involvement of mainstream actors (i.e. the building sector) in the niche formation process and insufficient internal niche interactions may eventually result in the complete failure of the niche (Schot & Geels, 2008). In the cases studied, actor networks were rather narrow and excluded sector outsiders (such as non-governmental organizations, policymakers, research institutions and financial institutions) which led to some scepticism over the realized projects, and a lack of second-order learning, that restricted sectoral innovations. Similar shortcomings were observed by Malerba (2004) and

by Faber and Hoppe (2013) who found that actor-networks were a key driver of sectoral change and defining a new sectoral structure (which is required to spur sectoral innovation).

Another recurring finding is that the nature of social networks determines the depth and breadth of learning processes. The NZEB projects tended to focus on *first-order learning* only (based on 'hard facts' and data), and this impeded potential niche expansion. The *institutional settings* apart from government subsidies did not provide incentives for innovation: the formal rules were not yet aligned with NZEB innovations although they were to an extent for energy efficiency in buildings. Similarly, several barriers were observed resulting in a lack of demand for NZEBs on the building-sector level, indicating that niche formation had yet to result in sectoral change.

We consider applying SSIAf useful in assessing the status of NZEB niche innovation in the building sector in India. The integration of the SNM and SIS frameworks showed that they were complementary, and this contributed well to answering the main research question. The use of SSIAf enabled us to systematically assess the niche development process and probably better than either of the two frameworks separately. For example, while the SNM focuses on its primary components of *shaping of expectations, the actor network formation* and *the learning process* to understand the niche formation process, it alone fails to gain from insights as to which *institutional alignment (formal and informal)* and creation of *market demand* components can contribute to the niche innovation process.

The *institutional alignment* component was seen to have a positive influence on the learning process and on social network formations. Formal institutional support (subsidies, incentives) motivated early adopters to go for NZEBs in the first place, which led to additional learning for the actors involved. Institutional support in terms of policies and strategies was, to an extent, conducive to raising expectations and legitimizing government support for new sustainable technologies. Using the SNM framework alone would have overlooked opportunities that the integrated framework highlighted. Similarly, existing barriers to large-scale adoption were highlighted by including *market demand* component in the SSIAf. This component was taken from the SIS framework and is relevant since it supports speculative growth of the niche. However, using the SIS framework alone would have excluded an

assessment of the *learning process* in our niche projects, despite learning potentially creating disturbances in an existing stable regime which can lead to sector-level innovations. As such, the SSIAf has merits when it comes to assessing a niche innovation at the sectoral level and hence builds upon the strengths of the two earlier frameworks.

The empirical study showed that the SSIAf components showed many mutual interdependencies. For example, the shaping of expectations and goals was to an extent dependent on other components such as the learning process (in resetting visions), and institutions influenced one another. Similarly, the strength of the actor network had a strong influence on the other four components. Also, it was seen that the five components are valued differently in all the potential development phases of an innovation niche, as such creation of market demand was low and close to negligible owing to the early phase of niche formation, however technological learning and actor formation are deemed of high value to ensure the strong formation of a new niche as also supported by various transition scholars (e.g. Hofman, 2002; Schot & Geels, 2008; Caniels & Romijn, 2008).

Most of the interviewees deemed broadening of the actor network as necessary and believed that government interventions were necessary to foster this, a view recognized by other scholars (e.g. (Caniëls & Romijn, 2008)). Informal institutions show significant interdependencies in terms of shared visions and patterns of thinking (Faber & Hoppe, 2012). Integrated concepts could also serve as foundations for policies aiming to promote radical transformative change.

Other frameworks, such as the MLP, also provide insights into technological transitions and regime shifts on both the niche and the regime levels, and also address changes at the landscape level. However, since the main aim of this paper has been to assess the NZEB innovation niche, the MLP is less appropriate as it does not provide an insight into sector-level innovation. This aspect is well covered by SIS (and incorporated in the SSIAf), which focuses on how the characteristics of a sector may determine the scope of innovation within that sector. It is possible that using the MLP alongside the SIS framework could bring further insights. However, given that the MLP focuses on regime shift from a technological and social perspective, and the SIS framework emphasizes a sector's capacity for innovation and through

this regime shift, we would argue that these conceptual differences justify the integration of the SIS and SNM frameworks as against using MLP.

Although SSIAf has many benefits – i.e. offering a broad conceptual understanding of sectoral niche formation, allowing for the identification and assessment of conditions that enable or disable sectoral niche formation, is arguably easier to use than more comprehensive frameworks (i.e. the failures framework, Weber and Rohracher, 2012), by presenting a systemic status quo which is attractive to policy makers and strategists to address when generating ideas for policy making, and by offering a way to analyse structural proximity of actors (e.g., niche and regime actors) – following the lessons from our case study analysis, there is also room for criticism and suggestions for improvement.

First, SSIAf analysis was found to be rather static. The framework analyses sectoral niche formation as a 'snapshot' in time and does not really allow for analysing niche development as a set of sequential historical events. Second, the framework assumes a form of developed niche formation, whereas the NZEB case study showed that niche development was basically in a state of 'pre-development'; i.e. the local projects were hardly coordinated from a niche platform at an aggregated level, which heavily impeded cross-project coordination and learning. Third, the focus on the economic sector and the status quo rather led to neglecting the multi-level character of the niche formation process (concepts and processes that are appreciated by the frameworks of Markard and Truffer, 2008 Weber and Rohracher, 2012, and Meelen and Farla, 2013). This limitation could possibly be resolved by adopting notions from these frameworks. To some extent, the SSIAf also gives insufficient attention to the environment and the context of sectoral innovation systems and niches (geographical conditions). Here, one could adopt some of the problem-oriented concepts from the sustainable transition failures framework (Weber & Rohracher, 2012). Other potential avenues for conceptual enhancement would be to explore analytical frameworks that give sufficient room for policy and politics (See for an overview: Hoppe et al., 2016 b) and pay attention to the contextual setting (e.g., Bressers et al., 2002). Fourth, like the failures' framework in data collection the use of SSIAf leads to collecting a comprehensive set of data, which is rather time consuming for the researcher. Fifth, it remains unclear why the five theoretical components of SSIAf do not have different weightings when

analysing niche formation; i.e. in early niche development market demand creation probably deserves a lower weighing than learning about technological performance and side effects of a given technology.

Perhaps, further conceptual development of the framework should assign different weightings to the theoretical components depending on the stage that niche formation is in; e.g., differentiating between pre-development stage, early development stage, late development stage and 'breakthrough' stage. Sixth, the framework assumes focusing on a single niche, whereas focusing on a given economic sector should allow for a more holistic view, and therefore the identification of multiple niches within an economic sector.

We also want to address a methodological limitation that should be kept in mind when reflecting on the results of this study. It entails the fact that the selected cases were in India, against the background of a developing country. This arguably contributed to focusing on a sectoral niche that was still in its pre-development stage. In future research we suggest SSIAf to also be used in empirical research comprising case studies of niches that are more developed, i.e. in further stages of niche formation (e.g., early niche formation, late niche formation). Analysing and comparing cases in different development stages would allow researchers to learn more about mechanisms that influence sectoral niche formation. This would probably entail to (also) select cases of sectoral niche formation in developed countries. Moreover, an attempt could be made to re-design SSIAf to make it more useful to dynamic forms of research, and not just to assess a status quo as a 'snapshot in time'.

Finally, the case study revealed the importance of donor aid to niche formation in India. One could wonder what the absence of this condition would mean. Moreover, it gives thought to how bottom-up development of local experimental projects and in the end niche (pre-) development is dependent on such a condition. In this sense, theoretically it makes sense to discuss whether donor aid can be labelled either as a 'landscape event' - because the condition is of great importance to niche formation and cannot be labelled a regime characteristic as it transcends the sectoral level; i.e. it is an international intervention or event – or rather as an instrument at the micro level; (niche) to foster niche formation.

4.9 Conclusions

This paper started by introducing the NZEB concept and how a transition towards large-scale uptake of this concept could enable countries such as India to deal with future energy challenges, and particularly those in the building sector. This would require structural changes encouraging innovation in the existing building sector regime. The paper attempts to assess the current status of the NZEB innovation niche by posing and then answering its main research question: *"What does the SSIA framework tell about NZEB niche formation in India?"* The paper explores transition and innovation theories (SNM and SIS) and develops an integrated framework, the SSIAf, to assess the current status of NZEB development in India. This has five theoretical building blocks: *shaping of expectations, social network formation, learning process, institutional alignment and creation of market demand*.

The results show that the NZEB innovation niche has yet to develop into a mature niche and is growing only slowly. This is evident from the marginal expectations that building sector stakeholders have regarding NZEBs. This is largely due to the lack of tangible results, despite the project actors being positive towards NZEBs regardless of their isolated character. New social networks were only strong within individual NZEB projects and there had been a failure to create a cohesive network with other NZEBs and with actors outside the NZEB projects. Consequently, the spurring of the innovations through network activities was limited. There was also a lack of interactions between the niche and the wider regime, and the NZEB niche therefore lacked the nurturing required to facilitate stabilization and growth towards maturity. The strength of the SSIAf was that it provided an in-depth analysis of each of the independent components of the framework. Several interdependencies were observed among the components and we were able to elaborate on the dynamic nature of the niche that is currently growing at a slow pace.

Based on the identified shortcomings of the SNM/MLP and IS approaches, we presented the SSIAf and positioned it among other integrative frameworks (TIS–MLP and SNM–TIS). The distinction is that the SSIAf is demarcated by a given industrial sector (in our case, the building sector). Having sectoral boundaries, it is more limited than the more comprehensive integrative framework suggested by Markard and Truffer (2008). As such, the SSIAf is more strongly

oriented towards actors and agency, paying greater attention to strategic actor interactions. Another component that differs from Markard and Truffer's suggested framework is the SSIAf's institutional component, which gives more attention to market, and societal rules and sectoral policies. The distinction with the approaches of Weber and Rohracher (2012) and Meelen and Farla (2013) is that the SSIAf does not have a strong policy orientation. In its current form, the SSIAf is basically a heuristic tool – as other IS approaches – to assess a given innovation system and niche market formation (such as here, NZEBs) on its inherent capability and capacity to spur and successfully diffuse the given innovation and generate a wider market uptake.

Chapter 5:
A Governance perspective on NZEB niche development in India: New Delhi

Mansi Jain, Thomas Hoppe & Hans Bressers (2017):
A Governance Perspective on NZEB Niche Development in India: The case of New Delhi. *Energies* 10 (2017)1144

Abstract:

The net zero-energy building (NZEB) concept has recently gained prominence worldwide. Large scale adoption and implementation of NZEBs would potentially contribute greatly to greening of the building sector. However, it is still at a nascent stage of niche formation. This paper aims to assess the governance context for adoption and uptake of NZEBs through niche formation in India by addressing the research question: ***What is the state of governance in New Delhi regarding NZEB niche formation?*** A case study research design is used to answer this question. The Governance Assessment Tool (GAT) and Strategic Niche Management (SNM) are used to analyze the New Delhi case. Data collection involved in-depth interviews with fourteen key stakeholders. Data were analyzed using the qualitative data analysis software (ATLAS.ti). The results reveal that the governance context is only marginally supportive towards NZEB niche formation due to qualities of moderate extent, flexibility and intensity. Actor network formation was identified as an important driver which influences other elements of governance, as well as factors stimulating strategic niche management.

Keywords: *net zero energy buildings; energy transition; governance; niche formation; strategic niche management.*

5.1 Introduction

As global warming and fossil fuel depletion highlight the need to save energy, demand for energy in buildings is bound to increase (IEA, 2013). Green buildings with the highest level of energy efficiency are now being projected as net zero energy buildings (NZEB) with the use of renewable energy technology for energy production. This has recently gained a lot of attention by research communities, early adopters of construction innovations, policy makers as well as green building rating systems (such as LEED[28]), setting ambitious targets to transform the building sector by adopting low, near or net zero energy building concepts. This can be achieved by adopting passive building design strategies, the use of energy efficient technologies, and integration with renewable energy systems to fulfill the remaining energy demand through self-generation (Marszal & Heiselberg, 2009; Voss & Musall,2011; J.Salom et.al, 2011). Such buildings offer a promising solution to deal with future energy challenges with limited environmental impact. However, currently there are only a handful of projects proving that it is a feasible concept (Gilijamse, W., 1995).

In India, however, energy efficient buildings and green buildings have seen an increased uptake in recent years, where the country secured the third position in the 2016 US Green Building Council (USGBC) annual rankings of top 10 countries for LEED. India has 15.90 million gross square meters (GSM) of LEED-certified space and an additional 89.28 million cumulative GSM of LEED-certified and registered space (Analytics, 2016). India is also among the top 10 countries outside the United States making progress in sustainable building design, construction and operations. In the recently published 'Smart Market' report it is stated that by 2018, the green building industry in India is expected to increase by 20 per cent, driven largely by environmental regulations and demand for healthier neighborhoods (Analytics, 2016). Despite this, green building uptake also meets with several challenges such as lack of public awareness, lack of public incentives, higher perceived upfront investment, and lack of market demand (Analytics, 2016).

[28] Leadership in Energy and Environment Design (LEED) -certified buildings save energy and water, helping residents and businesses make savings. Such spaces reduce carbon emissions and create a healthier environment for residents, workers and the larger community.

Although India's green building sector has gained momentum, numerically it can be considered rather small when compared to the number of buildings which are to be constructed in the country till 2030. When looking at the estimated 2030 building volume, 70% is still to be constructed (Kedia, et al., 2015). In this view scaling up NZEBs among the new to be constructed volume of buildings can be viewed as a potential "game changer" by curbing GHG emissions and drastically reducing energy demand of the building sector in India.

Currently, in India the building sector is responsible for nearly 33% of the total energy consumption (NRDC & ASCI, 2012). In this perspective, large scale development of NZEBs has the potential to deal with future energy challenges and ensure energy security for the country, which is especially urgent in urban settings (Iqbal, 2004). However, this requires structural changes and innovations in policy, regulations, user practices, market incentives, awareness as well as new technology to overcome the existing barriers for green markets (Boermans et.al., 2011). At the moment the market for NZEBs in India is at a nascent stage of niche formation, with only a handful of NZEB demonstration projects running. Results from previous research revealed that the NZEB niche is immature and growing only slowly (Jain, Hoppe, & Bressers, 2016). Currently, there is no single nationally accepted definition of NZEB in India as the concept is still in its infancy. However, frontrunners define it as, "highly energy efficient building with extremely low energy demand, which is met by renewable energy sources". Such buildings produce as much energy as they consume (annually) (Jain, Hoppe, & Bressers, 2016).

Governance arrangements play an important role in stimulating innovation and supporting diffusion and adoption of new sustainable technologies (in our case NZEB technology), for example by introducing innovation policies and a conducive framework for implementation of such policies (Edquist, 2005). This also applies to innovation systems, for instance incentives, networks, structure, and culture that have to do with the introduction and innovation diffusion of NZEBs in the building sector in India (Beerepoot & Beerepoot, 2007). In this perspective, this paper aims to analyze the state of governance in a selected region in India, in this case New Delhi, to assess how supportive or obstructive the governance context is vis-à-vis niche formation of NZEBs. The main research question is: ***What is the state of governance in New Delhi regarding NZEB niche formation?***

This paper is structured as follows. In section 5.2, the theoretical frameworks of the Governance Assessment Tool (GAT) and Strategic Niche Management (SNM) are presented. In section 5.3, the research design and methodology are presented. In Section 5.4, the results of the case study analysis are presented. In Section 5.5, the results of the analysis are discussed. And finally, in section 5.6, the conclusions are presented.

5.2 Theoretical framework

This section presents the two theoretical frameworks which will be of interest to understand the niche formation process of NZEBs from a governance perspective. Section 5.2.1 elaborates on governance and its influence on facilitating and stimulating innovation in a particular context. This leads to introducing the GAT and its conceptual background in the Contextual Interaction Theory (CIT). It provides a vision towards current and possible future pathways for the governance context regarding niche formation and diffusion-adoption of NZEBs. Secondly, SNM is briefly presented in Section 5.2.2. It explains the niche formation and diffusion of novel sustainable technologies through the formation of protected niches, and gradual breakdown of regime barriers. SNM and GAT will be compared to advance the understanding and the analytical approach of governance processes that have to do with niche development and deepen understanding of governance of innovations in a given economic sector. Theoretically, the focus of this paper is to analyze sectoral energy transition and niche formation of sustainable energy innovations from a governance and policy perspective. In this sense, it contributes to a growing body of literature in this domain (Hoppe, Coenen, & Van den Berg, 2016).

5.2.1 Governance assessment tool

The GAT was developed as an evaluative framework to assess the quality of governance in a specific context, specifically to evaluate a implementation setting (vis-à-vis certain issues, policy instruments or projects) in terms of supportive or restrictive for such implementation. The conceptual basis of the tool consists of a collection of insights on governance and has a background in the CIT (Bressers J. , 2009). The CIT is a third-generation implementation theory where implementation is not seen as a top-down process, but as multi-actor interaction process influenced by the actors who are involved. According to the CIT, there are three core characteristics per actor: motivation, cognition and resources. The “motivations, that may spur

the actors into action, their cognitions, information held to be true, and their resources, providing them with capacity to act individually and power in relation to other actors" (Bressers *et. al*. 2016) (p.45).

The governance model in the CIT consists of questions that attempt to determine: Where? Who? What? How and with What? (Casiano, 2017). These questions respond to characteristics that feature modern governance systems (Casiano, 2017). They are multi-level, multi-actor, multi-faceted, multi-instrumental and multi-source-based (Kuks, 2004).

The governance concept as used by the GAT has its roots in public policy, public administration and governance literature, and can be viewed as an attempt to organize the multiplicity of aspects mentioned in those literatures into a concise fashion (Bressers & Kuks, 2004). Governance refers to, "all processes of governing, whether undertaken by a government, market or network, whether over a family, tribe, formal or informal organization, or territory, and whether through laws, norms, power or language. Governance differs from government in that it focuses less on the state and its institutions, and more on social practice and activities" (Bevir, 2012) (p.1). Therefore, governance is "beyond merely government" and a context for decision-making and implementation; and it can be both supportive and restrictive for those processes. The governance context here, assumes the existence of a multiplicity of actors, levels, goals, instruments and different means that can be applied (Dinica & Bressers, 2003). As a context, governance, to some degree, restricts and to some degree enables actions and interactions in a certain part of society (Bressers & Kuks, 2004). The GAT helps to assess and identify the strong and weak points in the governance context (in our case this would be to support NZEB niche development). The tool predominantly draws attention to understanding of existing situations that can obstruct policies and projects under complex and dynamic conditions (Bressers & De Boer , 2011).

The dimensions of the GAT

The GAT framework introduces five dimensions that provide a clear overview of the governance context (or contents of a governance regime in a certain area with certain issues). Below are the dimensions of the governance context that are central to the GAT:

- *Levels* (not necessarily administrative levels): governance assumes the general multilevel character of policy implementation.

- *Actors and their networks*: governance assumes the multi-actor character of policy implementation.
- *Perception of the problem and objectives (not just the objectives)*: governance assumes the multifaceted character of the problems and objectives of policy implementation.
- *Strategies and instruments:* governance assumes the multi-instrumental character of policy strategies for policy implementation.
- *Resources and organization of implementation*: governance assumes the complex multi resource bases for implementation of policy (Bressers & Kuks, 2003).

There are four quality criteria in order to assess the aptness of the governance regime (Bressers *et.al.*, 2016). These four quality criteria include: *extent, coherence, flexibility and intensity* (Bressers & De Boer , 2011). The five governance dimensions and four qualities together form the core of the GAT. The quality criteria assess to what extent the governance context is supportive or restrictive for the policy process.

By analyzing the five dimensions of governance according to the four qualities of the governance regime, one can attain a very pragmatic understanding of how different elements of governance interact and hence influence an implementation setting, in our case adoption of NZEBs. ***Extent*** is a quality of a governance regime that refers to how completely it considers the various elements that have an impact on the process at stake (in this case NZEB niche formation). The ***coherence*** of that same regime relates to how the various elements of the regime strengthen each other (rather than weakening each other). Given that the actors are different and important in different settings within a governance context; effective implementation will also be influenced by the flexibility available. In a ***flexible*** governance regime, actors have formal and informal liberties and stimuli to act towards the implementation actions that assist in achieving goals. Finally, ***intensity*** is extent "to which the regime elements urge changes in the *status quo* or in current developments" (Bressers & De Boer , 2011). These dimensions can be used to follow up the first descriptive step and enable a more in-depth picture of the governance setting regarding a given issue (see Table 12).

Table 12: Matrix of the Governance Assessment Tool (adapted from: Bressers et.al., 2016; Gana & Hoppe,2017)				
Dimensions	**Extent**	**Coherence**	**Flexibility**	**Intensity**
Levels and scales	How many levels are involved and dealing with an issue? Are there any important gaps? or missing levels?	Do these levels work together and do they trust each other between levels? To what degree is the mutual dependence among levels recognized?	Is it possible to move up and down levels (up scaling and down scaling) given the issue at stake?	Is there a strong impact from a certain level towards behavioral change or management reform?
Actors and networks	Are all relevant stakeholders Involved? Who is excluded?	What is the strength of interactions between stakeholders? In what ways are these interactions institutionalized in joint structures? What is the history of working together? Is there a tradition of cooperation?	Is it possible that new actors are included or even that the lead shifts from one actor to another when there are pragmatic reasons for this? Do the actors share in 'social capital', allowing them to support each other's tasks?	Is there a strong pressure from an actor or actor coalition towards behavioral change or Management reform?
Problem perspectives and goal ambitions	To what extent are the various problem perspectives taken care of?	To what extent do the various goals support each other or are they in competition or conflict?	Are there opportunities to re-assess goals?	How different are the goal, ambitions from the status quo or business as usual?
Strategies and instruments	What types of instruments are included in the policy strategy?	To what extent is the incentive system based on synergy? Are trade-offs in cost benefits and distributional effects considered? Are there any over-laps or conflicts of incentives created by the included policy instruments?	Are there opportunities to combine or make use of different types of instruments? Is there a choice?	What is the implied behavioral deviation from current practice and how strongly do the instruments require and enforce this?
Responsibilities and resources	Are responsibilities clearly assigned and sufficiently facilitated with resources?	To what extent do the assigned responsibilities create competence struggles or cooperation within or across institutions? Are they considered legitimate by the main stakeholders?	To what extent is it possible to pool the assigned responsibilities and resources if accountability and transparency are not compromised?	Are the amount of allocated resources sufficient to implement the measures needed for the intended change?

5.2.2 Strategic niche management

SNM (Schot & Geels, 2008; Caniëls & Romijn ,2008 ; Geels & Kemp, 2005 ; Rip & Kemp, 1998; Hoogma *et.al*. 2002; Raveb,2005) provides insight into fostering technological and social change and at the same time initiates sustainable innovations at the niche level. SNM is an analytical framework designed to facilitate and study the introduction and diffusion of new sustainable technologies through societal experiments that contribute to forming a niche (Schot & Geels, 2008).

SNM advocates argue that successful radical innovations derive from socio-technical experiments in which various stakeholders collaborate, exchange information, knowledge and experiences. Therefore, SNM involves participation of several actors making it a multi-actor approach (Caniëls & Romijn, 2008). It states that governments (as participating actors) can be instrumental in facilitating wider transitions. It also illustrates how widespread technology change within well-established socio-technical systems can be achieved (Schot *et. al*., 1999; Rip & Kemp, 1998; Weber *et.al*., 1999). This can be done by facilitating the process of niche formation and setting up a set of successive experiments, often supported by policy instruments (government induced) that supports niche development processes (e.g. by subsidy schemes, regulatory exemptions, or programs that include pilot projects). Many SNM scholars explain the success or failure of niches by analyzing the interaction between the three main factors influencing niche processes, i.e. *shaping of expectations, building of social networks, and learning processes (*Mourik & Raven, 2006; Caniëls & Romijn , 2008 ; Schot & Geels,2008). SNM not only focuses on niche formation by organising experiments, but also by targeting the gradual breakdown of regime structures and barriers that block niche development (Geels & Kemp , 2006).

The Governance assessment tool and NZEB niche development

This paper uses the GAT as the main analytical framework. Using the GAT provides insights on the current governance context of NZEB demonstration projects and NZEB niche development in regions that are studied. The assessment can highlight the challenges in the governance regime which might obstruct or slow down the large-scale implementation and adoption of NZEBs but may also help to identify potential drivers and strengths. In addition, the results can be used to make a holistic ex- ante evaluation of how the governance context can

influence collaborative management of the NZEB niche development process in a particular region. It will also be of theoretical interest to use GAT in a way that allows for assessing niche development of a given sustainable innovation. This is rather novel since GAT has not been used for this purpose previously (and certainly not in transition studies research) to assess the development and diffusion of sustainable innovations in the built environment, nor in the energy domain.

Conceptually, the GAT and SNM reflect commonalities and can be used collectively to broaden the scope and understanding of long term transitions, sectoral innovations, policy implementation and the state of governance in niche development processes. In both the assessment frameworks, *actors and their networks* are highlighted as an important determinant for innovations and for assessing the governance context. Therefore, it should be right to assume that evaluating actors and their interactions (at niche level as well as at sectoral level) could play a key role in understanding innovation and diffusion of sustainable technologies, and the state of governance in a holistic way. Similarly, *problem perceptions and goals* (of where the governance is headed) which is a key aspect of governance in the GAT, shows similarities to *shaping of expectations* (converging towards shared visions and goals). Although *responsibilities and resources* (from the GAT) and learning process (from the SNM) do not specifically reflect any conceptual commonalities, they may be interdependent on each other (e.g. efficient use of resources (human and capital resource) can directly affect the learning process and vice-versa) Moreover, in facilitating learning processes sequential experimentation is required. This requires the mobilization of resources by actors who desire further experimentation, fostering learning processes, and inherently niche formation itself.

The GAT complements the elements of SNM and hence gives us the opportunity to assess complementarities of the governance setting through a "SNM lens". SNM on the other hand supports and complements GAT by understanding which policy and market barriers prevent innovation, which are largely termed as regime barriers. Moreover, it adds the niche-regime-landscape dimension to the (already multi-dimensionally) governance assessment framework. Therefore, this paper will first use GAT to assess case study data, and then subsequently assess conceptual complementarities and differences when reflecting on the case study data from a SNM perspective.

5.3 Research design and methodology

A case study design was used to analyze the governance of NZEB niche formation in New Delhi. The latter, the capital of India, was selected as a single case study to illustrate how the GAT can be applied to NZEB niche formation, and address how it compares and contributes to more traditional SNM analysis.

5.3.1 Case selection

Next to be an illustrative case, New Delhi is also important, because of its extremely high number of inhabitants and the degree of urbanization (which also includes a vast building sector) (see figure 17). In this situation, New Delhi should also reflect a high level of institutional and governance complexities, next to exhibiting developments in the green building sector or energy efficiency in buildings compared to the other parts of the country. Therefore, within the Indian realm, the New Delhi case would be the best case selected to study NZEB niche formation from a governance perspective. The highly-urbanized character of the region exerts a tremendous pressure on public delivery of services including housing, construction of new buildings, energy demand, and poses a great challenge for the city administration.

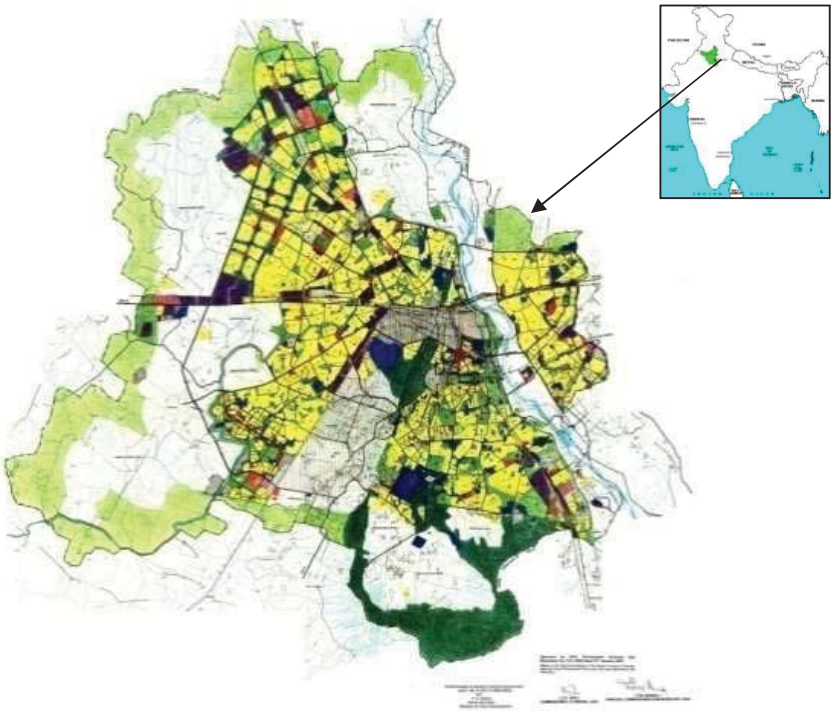

Figure 17 : Masterplan of New Delhi, 2021 (DDA, 2015)

5.3.2 The building sector in New Delhi

New Delhi comprises of a total geographical area of 14,300 hectares (DDA, 2017). According to the Masterplan 2021, land use distribution in the capital area is nearly 45-55% under residential buildings, commercial space comprising of 3-4 %, 4-5 % for industrial, 15-20% of green space, 8-10% of public and semi-public facilities and circulation comprise of 10-12%. Thus, nearly 60-70% of land use comprises of buildings (DDA, 2017).

Buildings consume huge amounts of energy in lighting, cooling and ventilation (Jain, Hoppe, & Bressers, 2014). New Delhi has the highest per capita power consumption among the States and Union Territories of India, with a consumption of 1,265 KWh per capita per annum as compared to the national average of 606 KWh (Kedia, et al., 2015). The power demand in New Delhi is vastly growing, at a rate of 5-6% yearly (IEA, 2013), and the number of electricity consumers in the region has grown by 90.47% during the last ten years, with the highest growth in residential and commercial buildings (Kedia, et al., 2015).

As far as growth of energy efficient or green buildings is concerned, a vast uptake was observed for green certified buildings either under LEED29, IGBC30 or GRIHA31 (which are three independent green building rating systems used in India). In New Delhi, LEED certified buildings encompass 3.2 million sqft of built up space (GBIG, 2017), LEED India (IGBC) comprises of 8.3 million sqft space (GBIG, 2017) and GRIHA certified building comprise of 612,487 sqm of built up area (Vij et.al., 2016).

The demand of energy conscious buildings has gained momentum mostly in the commercial building sector (Laustsen, 2008). Several green certified buildings have also seen the uptake of renewable energy integration (NHB & KFW, 2014). In GRIHA certified buildings, there is a mandatory criterion to offset 2.5% of annual energy load of the building by RE integration for daytime operated buildings, 0.5% by RE for 24x7 operated buildings and no

[29] Leadership in Energy and Environmental Design (LEED) is a rating system devised by the United States Green Building Council (USGBC) to evaluate the environmental performance of a building and encourage market transformation towards sustainable design.

[30] The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001. The vision of the council is, "To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025".

[31] GRIHA is a rating tool that helps people assesses the performance of their building against certain nationally acceptable benchmarks. It evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'.

requirement for residential buildings (Vij et.al., 2016). Additional points are given in the criteria if the client exceeds the mandatory requirement. Therefore, these buildings can arguably be viewed as low energy or near zero energy buildings. However, as far as NZEBs are concerned, there is only one office building by the Ministry of Environment, Forest and Climate Change (MOEFCC), Indira Paryavaran Bhawan which claims to be India's first NZEB office building, which is also a GRIHA and LEED certified building (Vij et.al., 2016). In addition to RE integration criteria, GRIHA gives incentives to developers for GRIHA certification in new construction in New Delhi with 5% extra floor area ratio (FAR)[32] in buildings (Vij et.al., 2016). This is seen a highly supportive.

Given these characteristics we view New Delhi as the region in India in which development and widespread uptake of NZEBs would be most urgent. For this reason, we consider it the most appropriate case in India (although it is somewhat of an extreme case) to assess its governance setting vis-à-vis NZEB niche development.

5.3.3 Data collection

Data collection involved both primary and secondary data sources. First, a stakeholder analysis was conducted to identify important and relevant stakeholders who are part of the governance setting, and directly or indirectly affect the NZEB niche development process in the building sector. This also included actors who have a significant role in promoting green building, energy efficiency and near- or net zero energy buildings. This involved experts from national ministerial authorities, state and city authorities (municipal bodies, development authorities), building sector associations, financial institutions, building owners, construction developers, utility providers, architects, sustainability consultants, research and academia, manufacturers, and technology suppliers. These identified stakeholders were then shortlisted according to their direct engagement in actual green building projects, sustainable building projects, or NZEB projects in New Delhi. For all the identified stakeholders, an attempt was made to contact at least two to three actors from each stakeholder category (e.g., architects, academics, or developers). Contacts were made via e-mails, which were followed by phone calls. In some cases, potential interviewees needed approval from their respective organizations. This especially applied to government agencies and international aid agencies

[32] Floor area ratio (FAR) is the ratio of a building's total floor area (zoning floor area) to the size of the piece of land upon which it is built.

(such as USAID PACE D-TA, EEREMC). The main researcher (first author)[33] also used existing her professional network of expertise to get access to some of the selected organizations. After contact was made, each of the contacted experts was briefed about the research project, its aims and objectives. As a result, fourteen in-depth interviews with the stakeholders who agreed to participate were conducted between September, 2015 and July, 2016.

A semi-structured questionnaire was prepared for the interviews, based on the GAT dimensions (see Appendix ii). The questions were largely based on the five dimensions of the GAT framework along with the four complemented quality criterions as described in section 5.2. In addition, key aspects of SNM were included. All the interviews were conducted face to face, recorded and transcribed into text files (interview transcripts), which were then used for analysis using the qualitative analysis software of ATLAS.ti. This software program assists qualitative researchers to locate, code, and annotate findings in text files, to weigh and evaluate their importance, and to visualize the complex relations, supporting data analysis (i.e. the interview transcripts) (Muhr & Friese, 2004).

In addition to collecting data via face-to-face interviews, the main researcher (first author of this paper) participated in important project-based meetings which included accelerating NZEB awareness and knowledge in the building industry. Finally, secondary sources of data were gathered and analyzed (e.g., published reports, newspaper articles, and project briefs).

5.3.4 Data analysis

Data were treated using a coding scheme, consisting of codes resembling the five dimensions and the quality criteria of the GAT. This allowed for a systematic analysis. Each dimension of the GAT framework that is the five components formed the basis for developing codes in the transcribed documents against the four quality criteria's. A set of sub codes was further developed along with their occurrences. These were then used to weigh and evaluate their importance to assess the context with respect to the governance dimensions, and hence supported analysis of the data. The coding clusters supported in conducting an unbiased assessment of the data available from the interviews.

[33] The researcher (the first author) was part of the USAID PACE-D TA program which included NZEB promotion and awareness as one of the work packages. The website can be accessed at http://www.nzeb.in/ .

Furthermore, to avoid personal bias the interview transcripts and results of the analysis had to be approved by experts, having participated in the interviews. This happened – amongst others - during an expert meeting. In addition to this, the main researcher (first author) did not conduct the analysis alone, but also received feedback from the other researchers (supervisors) on the preliminary results of the analysis. Finally, personal bias was avoided by selecting interviewees via systematic sampling of the stakeholders by conducting a thorough stakeholder analysis before contacting the actors for interview participation. Hence, selection of interviewees was not restricted to 'snowballing' within author's expert network only.

Interviews and meetings with the representatives of all relevant stakeholders provided a clear picture of the governance context by allowing its assessment along the four governance criteria of *extent, coherence, flexibility* and *intensity*. The essence of those criteria will be repeated each time before describing the observations done in the selected region.

5.4 Results

5.4.1 Governance assessment of the New Delhi case study

Extent: Are all relevant elements taken into account?

Levels and scales: All government levels ranging from national, state to local level relevant to NZEB niche formation were found to be present, however no specific NZEB goals formulated by those governments were observed. There were separate goals from related energy efficiency and renewable energy policies. These related policies encompassed different levels of government; i.e. from national government to state level and to urban local bodies (for implementation).

At national level, the Bureau of Energy Efficiency (BEE)[34] facilitates and coordinates energy efficiency initiatives as per the Energy Conservation Act (EC Act, 2001). Second, the Ministry of New and Renewable Energy (MNRE) develops and facilitates large scale adoption of renewable energy technologies through integration in buildings by design and implementation of instruments. And thirdly, building bye-laws are governed by the Ministry of Urban Development (MoUD). Thus, at the federal level there are three separate governmental bodies that deal with different aspects for potential NZEB adoption or for green buildings.

[34] The statutory body under the Ministry of Power; Government of India (GoI)

The regional or state level is the most prominent government agencies as far as implementation is concerned. They play an enforcing role to facilitate, and implement the policies. They exercise the power to amend policies to suit the regional and local climatic conditions and may, by rather legal and policy stipulations made by them, specify and notify the use of energy in the buildings. The Energy Efficiency and Renewable Energy Management Centre (EERMC), works as a State Designated Agency (SDA) to coordinate, regulate and enforce of the Energy Conservation Act of the region. It has also been designated as State Nodal Agency (SNA) for implementation of programs by the MNRE. The EERMC is responsible for promotion of renewable energy, energy efficiency and energy conservation in the New Delhi[35]. For these reasons context (extent) is considered as supportive due to completeness of the levels required for NZEB adoption.

Actors and networks: All relevant actors needed for NZEBs niche formation were present in the building sector in the region. However, only a handful of them were found to be actually involved and appeared to be sufficiently motivated towards the concept of NZEB, largely because NZEB is a relatively new expression for highly energy efficient green building with only very few running demonstration projects. Nevertheless, actors were found to be sufficiently involved with ongoing green buildings in the region. The actors that are motivated mostly concern energy efficiency experts, passive design architects, motivated clients (mostly public sector), technology manufacturers and suppliers (energy efficiency and on-site RE generation technology providers, advanced metering and building control technology providers). More relevant stakeholders – in particular government actors (in particular the EERMC) - "need to be actively involved to support the uptake and develop a mature NZEB niche, along with creating awareness," as stated by an architect during an interview.

There is sufficient potential to include architects, educational institutions, the research community, contractors, builders and developers, the industry association, and green building councils to make them aware about the NZEB concept.

In sum, all the actors that are necessary for decision making are basically present, but since the concept of NZEB is so new and under-researched in the Indian context many potential

[35] http://delhi.gov.in/wps/wcm/connect/doit_eerem/EEREM/Home/ last accessed on August ,2016

relevant actors are poorly motivated, and hardly involved. The present extent of actors is therefore considered 'neutral' but shows signs of progress.

Problem perceptions and goals: Actors have various perceptions, which were highlighted during the interviews. They include: poor and inadequate energy infrastructure along with inadequacy to deal with rising energy demand in buildings. It was also highlighted by 8 out of 14 interviewees that having only a few NZEB pilot demonstration projects is considered insufficient to raise the expectations (as they exhibit the potential, but do not drive the market). Economic benefits also need to be re-assessed as NZEBs are perceived as costly due to the use of expensive technologies (both related to energy efficiency and renewable energy). Interviewees also highlighted that green buildings still face resistance from mainstream developers and builders as they are largely concerned about increase in construction cost without resulting in higher selling price. Hence, developers and builders disregard anything that brings increased upfront costs. They are however, incentivized by giving extra FAR to GRIHA rated buildings in New Delhi. However, interviewees stated that developers are hardly attracted to this incentive in the region with very few applications for extra FAR.

In addition, various definitions describe NZEBs, and this varies across different contextual settings. In a dense urban setting like in New Delhi, interviewees argue that the NZEB needs to be re-assessed as per local and regional limitations and needs. For example, due to high urban density, on-site NZEBs may not be a feasible option in the case of high rise buildings or potential of wind energy may be very limited. Nevertheless, various problem perspectives were found to be taken into consideration by different actors who were interviewed, which can therefore be supportive in considering multiple aspects (e.g. technical, policy, economic aspects). However, the absence of goals for NZEB appears to restrict the adoption by many actors. Hence, when assessing the extent of problem definitions and goals it appears as to be rather neutral.

Strategies and instruments: Increased energy efficiency was seen as a high priority in the 12th five-year plan[36] with various non-price incentives to promote energy efficiency. Several of these

[36] 12th Five year plan - Since 1947, the Indian economy has been premised on the concept of planning. This has been carried through the **Five-Year Plans**, developed, executed, and monitored by the Policy Commission (NITI Aayog after 2014). With the

are included in the National Mission on Enhanced Energy Efficiency (NMEEE)[37]. Energy efficiency in buildings is one of the important five approaches adopted with a national Energy Conservation Building Code (ECBC)[38]. This is considered as highly supportive. Continued attention is also paid to renewable energy resources in the 12th five-year plan, with national solar mission program initiated by the Government as one of the eight programs under the National Action plan on Climate Change (NAPCC). The document emphasizes development of grid connected solar applications by offering feed-in-tariffs, net metering policy and other supportive policy instruments. The mission has set a target of 1,000 MW by 2017 reaching 1 million households in the country (GoI, 2011).

An addendum to the National Building Code (NBC)[39] 2005 was finalized in 2016, including a chapter on sustainable building design, namely, 'Approach to Sustainability', so that sustainable construction practices are to be adopted in all future building constructions. Previously, the government has shown interest towards developing a long-term roadmap for NZEBs through bilateral project agreements with the United States. The Energy Conservation and Commercialization (ECO) was implemented in three phases in which the NZEB concept was introduced in ECO III[40] phase (2006-12), and later again in the USAID PACE D TA Program phase (2012-17), focusing on the extension of ECBC (near zero energy goals), and introducing the NZEB knowledge dissemination portal[41]. These efforts were largely initiated by these agreements through international partnerships.

Prime Minister as the ex-officio Chairman, the commission has a nominated Deputy Chairman, who holds the rank of a Cabinet Minister. The Twelfth Plan is currently underway.

[37] which was launched in 2008 as one of the eight missions in the National Action Plan for Climate Change

[38] ECBC sets minimum energy standards for commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above. While the Central Government has powers under the EC Act 2001, the state governments have the flexibility to modify the code to suit local or regional needs and notify them. Presently, the code is in voluntary phase of implementation. About 22 states are at various stages of mandating ECBC. (https://beeindia.gov.in/content/ecbc).

[39] The National Building Code of India (NBC), a comprehensive building Code, is a national instrument providing guidelines for regulating the building construction activities across the country. It serves as a Model Code for adoption by all agencies involved in building construction works be they Public Works Departments, other government construction departments, local bodies or private construction agencies. The Code mainly contains administrative regulations, development control rules and general building requirements; fire safety requirements; stipulations regarding materials, structural design and construction (including safety); and building and plumbing services. the revised Code has been brought out in 2016 as **National Building Code of India 2016** reflecting the state-of-the-art and contemporary applicable international practices also including approach to sustainability in tandem with sustainable development goals.

[40] The ECO III project worked towards identification and development of a collaboration framework between the US DOE National Research Laboratories, U.S. academic institutes and research centres, and the CEPT University in India (PACE-R).

[41] A NZEB online knowledge dissemination portal has been launched by the Government under the USAID PACE D TA program.

Responsibilities and resources: There is disparity and inconsistency between the large range of responsibilities which have been assigned to multiple actors especially between the national, state and local level. And a large majority of interviewees consider it as imperative to demarcate a careful division of responsibilities between the state level government bodies, regional planning authorities and urban local bodies (ULB's). Moreover, there is the often-limited level of financial and knowledge resources, and for some of the stakeholders they are even decreasing. This also holds governmental parties that must cope with the limited level of resource input when formulating innovative and cohesive policies. For this reason, the building sector energy efficiency programs are often implemented through cooperation with international aid programs (e.g., the ECBC implementation with UNDP, EE high rise residential building guidelines with the Swiss Development Cooperation etc.).

In sum, the presence of various programs and instruments toward EE and RE for buildings are seen as highly supportive and reflect a high degree of extent in terms of separate instruments and can potentially in the future be combined into one holistic, integrated NZEB policy (as supported by 9 out of 14 interviewees). In sum, the extent of responsibilities and resources can therefore be viewed as rather limited.

Coherence: are the elements reinforcing rather than contradicting each other?

Levels and scales: At the national level, the three national level agencies of BEE, MNRE and MoUD work within their respective jurisdictions and authorities. Their interactions are limited, which restricts the opportunity to work together in an integrated manner. They appear to be isolated. This leads to institutional fragmentation and in turn to confusion at lower levels of government when the policies have to be implemented (and are depending on the compliance by municipalities, often using their own bylaws). They have separate goals and missions, and inter-ministerial coordination is absent. In addition, there is a lack of unified policy and national programs for NZEBs. This makes the context appear to be restrictive.

At the state level the institutional framework allows to work together for the implementation of EE and RE policies (with same SDA and SNA). This can be considered as positive and in support of NZEBs in future adoption. Currently, the SDA's do not collaborate at the local level with ULB's to initiate enforcement of the policies for energy efficiency and

renewable energy in buildings. In doing so, they follow the top-down hierarchical institutional framework. In sum, coherence regarding levels and scales is considered as neutral.

Actors and networks: The strength of interaction between the existing actors was found to be fragile and is only possible through a formal platform, for example in the form of a conference or a workshop. In the past this has been possible through bilateral project agreements. These programs brought all the important stakeholders from the building industry and technology providers from India and the U.S. (and other Western countries such as the United Kingdom. and Switzerland) together. This helped to raise awareness and initiate discourse about the new and relatively unknown concept of NZEBs in the Indian building scenario by engaging in a series of workshops and exchange programs.

Similarly, awareness raising initiatives have been launched by the bilateral programs in the past to activate and engage relevant building industry actors to increase actor interactions and operationalise an industry alliance. However, the interviewees also revealed that the relatively active NZEB actors fail to interact or develop synergies with each other, and only end up interacting in formal arenas. They appear to be engaged in direct components of the on-going bilateral programs (e.g. in alliance formation, and demonstration projects of their own). As a result, they compete with each other for projects[42]. This relates to limitation in innovating on common interest between configurations of different NZEB pilot projects.

The active stakeholders can be viewed as a relatively closed group. They operate in silos. As a result, there is a large gap in knowledge exchange between certain important stakeholders needed for innovation. Most of the stakeholders also refrain from sharing project data and exhibit a lack of trust towards others. Therefore, the coherence regarding actors and networks can be considered as poor.

Problem perceptions and goals: NZEB niche formation and its related problem perspectives are so far not reflected in the national government's policy goals. Currently, there is no shared goal nor a single goal nor target for NZEBs in India (both at the national and the state level). Various goals have been formulated by the government on EE and RE in separate visions and

[42] Actors are competing as they are part of the same industry and compete for projects.

programs. For example, the state government has announced an ambitious solar PV installation target for the year 2020 with a total installed capacity of 20,000 MW. A mandatory implementation of ECBC in the 12th five-year plan is expected to enable a greater shift in the building sector paradigm which sets minimum standards for energy performance in buildings. In addition, the government has set targets for reducing GHG emissions through the NAPCC which includes a mission for sustainable habitats. This encourages implementation of energy efficiency in buildings. In fact, the goals are there but to some extent they are enforced by different ministries and do not converge together as they are conceptualised in isolation. As a result, these goals conflict with each other and add to fragmentation and complexity. Hence coherence on problem perceptions and goals can be considered as limited.

Strategies and instruments: The related strategies and instruments that appear to support innovations in NZEBs are disconnected from each other both in both the policy making and implementation levels. They either focus on the energy efficiency or renewable energy component of a NZEB, but hardly on both. Moreover, they (policies like ECBC codes or net metering) are often considered as restricting due to their isolated character, and often exhibiting a lack of coordination. On the other hand, they are neither really working against each other. Each of these instruments needs to become strong at the ground level for implementation for a comprehensive NZEB policy, with strengthening of local administrative bodies or municipalities. One of the interviewees highlighted the increased emphasis on RE components while neglecting the energy efficiency aspect of building design and construction, thus sometimes downsizing energy efficiency policy implementation also. This may potentially impede future niche development for NZEBs. For these reasons coherence in terms of instruments and strategies can be considered as poor.

Responsibilities and resources: No clear responsibility for NZEB niche formation was identified among stakeholders. This leads to institutions working in isolation from each other, and follows top-down hierarchical structures, which show a lack of transparency in terms of responsibilities and role division regarding NZEBs. Most of the interviewees mentioned that these actors are given multiple responsibilities. Some of them are even overlapping between each other, which in turn leads to duplicity of efforts, which happens almost at all levels of implementation. This also creates competence struggles and thereby avoidance of cooperation.

A low degree of coherence is observed since these actors do not reinforce each other nor create synergies for effective implementation.

The existing responsibilities of the SDA's are not well supported by appropriate resources as they lack a substantially skilled labor force to understand and support NZEB adoption. Their resources are derived from sources that often have different goals. Since most of the actors have insufficient personnel and technological knowledge, they focus more on fulfilling their individual tasks than on recognizing and responding to the each other's needs. In sum, coherence regarding responsibilities and resources can therefore be considered limited since several actors are involved with different aspects of NZEB niche development.

Flexibility: are multiple roads to the goals permitted and supported?

Levels and scales: The institutional framework imposes decision making in governmental organizations in a top-down hierarchical manner as well. This also holds for responsibilities. Hence, these levels work within their own jurisdiction boundaries, and are restricted in this way. For instance, buildings with pre-set NZEB goals will also need additional approval at different stages of the project cycle. Hence many organizations are involved at various levels. However, ULB's, SDA's, and energy grid operators refrain from showing flexibility or convergence to other organizations. A fair degree of adaptiveness is only seen at the state level where states have the power and flexibility to modify the national government policies and programs to suit the local and regional needs and address them. However, the other stakeholders involved in local implementation actions are stringent and do not encourage any change from their business as usual, in terms of practices and procedures. For NZEB niche development this situation is viewed as restrictive with little opportunity for up scaling and downscaling policies between different government levels.

Actors and networks: Since the actor network is limited and hardly active, it is relatively easy for newcomers to enter networks. This also applies to entrance to readily established 'issue networks', can therefore be considered as 'flexible'. However, actors with fair knowledge about NZEBs (the actors who have directly worked on NZEB pilots) may get a better say and authority in the project implementation. The flexibility regarding actors and networks is assessed as rather good.

Problems perceptions and goals: Since NZEBs are not yet part of (official) government policy, reassessment of goals is possible. Technical and economic aspects can be explored, as the NZEB concept is still in its infancy. Therefore, case specific modifications are still possible, similar to those adopted in the Indira Paryavaran Bhawan project (a NZEB pilot project) in New Delhi, with a relaxation in a permissible built area and extension of roof projections to accommodate solar PV installations.

Few interviewees stated that NZEB definitions need reassessment specific to local context, which can be explored by front runners and public-sector pilot projects. The re-alignment of goals is potentially possible. This is considered as supportive for large scale NZEB implementation in the future. An optimized packaging of separate policies can be beneficial in the long run for the NZEB niche development and uptake thereafter. Hence, goals are supportive for re-alignment. The flexibility of perspectives and goal ambitions context is considered as relatively good. It should be considered that this degree of flexibility is partly a positive side effect of weak and fragmented government policies. Improvement on that side might endanger the observed flexibility, however.

Strategies and instruments: Existing instruments look flexible enough to be integrated with other existing policies and clusters. However, independent policies themselves are complex and have long process applications for implementation. For example, the net metering policy application process is extremely lengthy and is not considered user friendly. Even the process of approval takes a lot of time. Similarly, all the NZEB stakeholders considered ECBC to be complex and difficult to understand (in particular by contractors and project developers). Despite that, existing instruments can be applied in combination with each other. For example, ECBC compliant buildings can easily take incentives from MNRE for solar integration and for net metering application. In sum, the flexibility of strategies and instruments can be viewed as supportive to NZEB niche formation.

Responsibilities and resources: Since most of the NZEB concept is introduced to the Indian building sector by international bilateral programs, along with BEE, the responsibilities are not flexible and follow a bureaucratic approach of command and control. Moreover, there are only few opportunities to use resources for joint purposes. In addition, there is competition for the

scarce resources available due to dependency on external resources. Hence, flexibility regarding responsibilities and resources can be considered as limited.

Intensity: how strongly do the elements urge changes in the status quo or in current developments?

Levels and scales: Most of the stakeholders consider central level regulatory measures the strongest driving force for large scale implementation as well as innovation in the building sector. They view that the central government ministries should take an active role in developing a comprehensive set of unified NZEB policies and regulations. Currently, NZEBs are not present in the national government agenda's nor missions, but only in a piecemeal fashion, and used by various authorities. Hence, there is neither an integrated approach, nor a program from national government to support the uptake of NZEBs. In sum, the present intensity of levels and scales is considered neutral. However, according to our interviewees this may improve in the future.

Actors and networks: The existing actor network exerts only marginal pressure on any change from business as usual practices. A lack of support policies does not incentivize people to adopt NZEBs, but rather slightly incentivizes them towards taking an interest into energy efficient buildings (ECBC is a voluntary code) in New Delhi. This also applies to the GRIHA[43] rating tool, which is basically targeted to all new public-sector buildings. Moreover, most non-governmental stakeholders are looking for government initiatives to guide the actor network in the desired direction. However, currently this condition is absent. This limits the overall flexibility of actors and networks

Problems perception and goals: Stakeholders observe that only few NZEB pilots show that the concept is feasible and RE integration is possible in buildings. Moreover, they do not show large scale societal and economic benefits. More so, performance of existing NZEB pilots is not shared within the public. This does not cause any shift in the existing building sector's regime. An awareness and interest among the industry is seen about energy efficiency buildings (through other market based green certifications, such as LEED and GRIHA certifications), but not particularly for large scale adoption of NZEBs. However, present goals in the 12th five-year plan

[43] GRIHA is an acronym for Green Rating for Integrated Habitat Assessment. GRIHA attempts to minimize a building's resource consumption, waste generation, and overall ecological impact to within certain nationally acceptable limits / benchmarks.

and at the state level to implement ECBC code are considered to be in line with the market transition for energy efficient buildings. This is considered as rather positive. They can work towards a roadmap for large-scale NZEB uptake with large scale solar PV installation targets which have been recently initiated as the Delhi Solar policy, considered as positive. The goals that are accepted for the future at the state level are considered pretty ambitious but will be confronted with a still existing strong emphasis on low initial cost building. The intensity for problem perceptions and goals can therefore be considered as neutral, as many economic goals are much stronger and without ample evidence that NZEB can be profitable this will exert "neutral" overall influence.

Strategies and instruments: Due to ambitious national level targets on RE installation, the state SDA is implementing many solar specific instruments which are mostly subsidies and other incentive-based instruments. This, to some extent, increased the marketing value of the RE integration by raising more awareness and knowledge about solar integration in buildings and with reduced costs. Hence, these instruments have been rather successful in changing the expectations and move towards more technology interventions in buildings. A neutral degree of intensity is observed regarding strategies and instruments. Regulatory measures and incentives with lucrative financial implications are also viewed as an important impetus to manage the actor network.

Responsibility and resources: Implementation is expected to occur according to the goals determined by higher levels of government yet there is insufficient effort bestowed to ensure that the goals are met, and at minimal support for doing so. The existing intensity is weak as there is lack of financial resources, knowledge and skills for adoption and uptake of the NZEB niche in the Delhi region with only one NZEB pilot project. It is only through the public sector NZEB pilot demonstrations that the government agrees for additional budgets for the high cost of NZEBs. There is a perceived need to decrease the knowledge gap among the various actors in the building industry. In spite of the existing knowledge high upfront costs of these projects sometimes slows down the niche development process from private sector stakeholders. According to the interviewees, the state implementation agencies should get involved in increasing the stability of funding resources, recognizing and supporting innovative locally

tuned implementation process through flexible and supportive instruments and communication. The context on responsibility and resources is observed to be of restrictive nature.

5.4.2 Overview

A visual presentation of the governance of NZEB niche development in the New Delhi region is presented by means in Figure 18 (in the form of a 'GAT scorecard'). The green cells represent the results of the analyzed issues according to the issue matrix of the GAT in Table 12 that are satisfactory (positive); red cells, on the contrary, present results that are worrying (negative); and orange cells presents results that are rather unsatisfactory or uncertain (neutral). The (+) indicates that the present situation is changing in a positive direction or will change positively in the foreseeable future, whereas the (-) indicates that the situation is deteriorating and is not likely to improve in the foreseeable future.

The governance context is highly incoherent, with fair degrees of flexibility, intensity, and extent (see also Figure 18). From the extent perspective, New Delhi can be seen to be able to adopt NZEBs, with a supportive context for actors and networks, problem perspectives and strategies and instruments. In this context, actors neither have incentives, nor are motivated by policies, because they are not in line with the goals. The local level actors have the authority, flexibility and support to address their own issues (within a given project boundary). Hence the incoherent but flexible and moderately intense context of the selected region shows that the governance context is in a position that allows actors to actively collaborate and manage NZEB niche formation, provided that the supportive qualities are enhanced through collaborative management and uptake of more NZEBs.

In the case study it was seen that Government initiatives are largely taken through various strategies and instruments which partly support NZEB demonstration project implementation. In this region, existing NZEB pilots are supported by the government by showcasing public buildings as NZEBs, with increased budgets.

What is initially interesting is the wide variety of configurations that have been observed. Given the interpretative nature of the GAT, the factors leading to these differences brought into the picture, though a further examination of the cases could provide additional insights about

the influencing factors and whether or not there are relationships between the various qualities related to them.

In addition, the results can be used to make a holistic evaluation of how the governance context influences collaborative management of NZEB niche development, and useful in comparing the existing strengths and weakness in the governance context. The GAT reveals some regime barriers such as isolated sectoral policies while failing to cooperate with other regime policies, which leads to sectoral policies restricting NZEB deployment in pilot projects (and up scaling at a later stage) in addition to minimal incentives for builders and developers to go for such NZEB targets.

	Criteria			
Dimension	Extent	Coherence	Flexibility	Intensity
Levels and scales			(-)	(+)
Actors and networks	(+)			
Problem perspectives and goal ambitions	(+)	(-)	(+)	(+)
Strategies and instruments				
Responsibilities and resources				
	*Colours **red**: poor; **orange**: medium, **green**: good*			

Figure 18 : GAT results for the New Delhi NZEB case study.

While applying the SNM approach in assessing the governance setting in the selected case study, many insights can be drawn. As described in previous sections SNM uses problems and perceptions, social network formation and learning process as three important building blocks. Drawing from the data analysis it was inferred that network formation was rather weak, as shown in the GAT analysis as lack of coherence. Network venues only comprised a few workshops and a conference. Most NZEB actors were found to operate in isolation. This, in turn, hampered learning processes also which eventually led to slow growth of the niche. Project based goals and visioning were found to influence project outcomes by allowing the stakeholders to work together on the pre-set goal. However, a lack of knowledge, limitations in budget and resources proved serious challenge for niche formation process.

SNM also advocates protection of the niche. It was observed in the case study that the only NZEB demonstration project in the region was also protected by the government through increased budget allocated for the public-sector building. In addition to this, the roof-top solar panels were granted roof extension beyond permissible by-laws making it as a special case for NZEB demonstration. Thus, the pilot demonstration was highly protected by the government initiatives to showcase NZEB features. Hence, SNM highlights the protected space under which niches can grow. This however was not observed in any other public building in the region. Some of the regime barriers also led to the slow growth of the niche such as sectoral policies, while failing to cooperate with other policies restricts the niche development process.

5.5 Discussion

From an SNM perspective, using the GAT to analyze the governance system for niche formation was useful in assessing the state of governance for fostering such innovations. SNM uses the three theoretical building blocks of problem perceptions and visioning, social network formation and learning process as primary niche formation processes with the important issue of creating 'protection' from the market to hold niche experiments (Kemp & Schot, 1998). This shows similarities to some of the GAT components, namely: actor and networks, perhaps somewhat to (adjusting) 'problems and goals', and (getting access to) resources (to afford new sets of experiments).

Moreover, applying the GAT as an analytical tool was useful to understand and assess the governance context in the building sector in the selected case study vis-à-vis NZEB niche development. The study is of theoretical interest as GAT allows for assessing the governance component of niche development and sustainable innovations (like NZEBs). This is rather novel since the GAT has not been used thus far to assess developments and diffusion of sustainable innovations in the built environment, nor in the topical field of energy. The challenge to use GAT in this way, however, urges one to rethink how to incorporate key theoretical notions of SNM with GAT.

In both the SNM and GAT assessment frameworks, *actors and their networks* are highlighted as overlapping drivers for innovations and for assessing the governance context in which innovations evolve. Therefore, evaluating and assessing actor (and actor-network) interactions forms a critical part of the GAT assessment framework. As social interaction processes in multi-

actor arenas are mostly driven by actors involved, these interactions form a central stage in the theoretical basis that is key to both GAT and SNM. Hence, interaction processes are considered as an ultimate driver for niche formation, sustainability transitions and innovation. In this sense, actor-networks can be seen as the key units of analysis in both the GAT and SNM frameworks, in particular because they form the key social configuration in which other important drivers for supportive governance context occur, such as problem perceptions and goals, levels and scales, strategies and instruments, and resources and responsibilities.

The theoretical components of SNM can be viewed as similar to some key elements of the GAT. Combining insights from the two concepts may allow for broadening the scope and furthering understanding of long term sustainable transitions, sectoral innovations, implementation of transition–oriented policies, and assessment of the role and state of 'governance' in niche development processes in sectoral systems. Furthermore, the four quality criteria mentioned in the GAT framework can be used to evaluate the niche development process with respect to the three building blocks of the SNM. For example, actor interactions, expectations, learning process can all be evaluated as per the four quality criteria's (extent, coherence, flexibility and intensity) to understand the overlaps with the GAT framework. However, the validity can be further elaborated based on the future empirical research. It will be interesting to augment understanding of the governance context of niche development and sustainable innovations (like NZEBs) through more empirical cases along with the GAT.

The findings also reveal the importance of international aid instruments to initiate sustainable innovation in the building sector for NZEBs, also influencing the governance context. For example, actor network formation was initiated largely by networking platforms under aid programs (e.g., via NZEB conferences and workshops), which in turn also influence policy instruments such as developing the ECBC code for buildings with component of super ECBC buildings ready for RE integration (Jain, Hoppe, & Bressers, 2016). Hence, in developing countries, such as India, a large extent of building innovations is advocated and developed under those programs, thereby exerting a change of governance regime. The instruments used under those programs are important drivers to bring about transition in sustainable technologies by kick starting the niche formation process (Jain, *et al.*, 2016; Mdivani & Hoppe, 2016).

5.6 Conclusions

In this paper the state of governance towards NZEB niche development was analyzed in the selected city, New Delhi. We adopted a case study research design to assess the governance context against the four qualities used in the "Governance Assessment Tool" of *extent, coherence, flexibility and intensity* of the five structural components of the GAT. The five components are levels and scales, actors and networks, strategies and instruments, problem perspectives and goals, and responsibilities and resources. Our approach using the GAT was to contribute to more conventional transition theory, in particular Strategic Niche Management.

Analyzing the elements presented, the qualities observed in the selected case study revealed many interesting results. The governance context was found to be moderate in extent, incoherent, moderately flexible and intense. This shows that the governance context in the selected region is to some extent supportive towards NZEB niche development on the one hand, but restrictive to NZEB niche development on the other hand. The main results of the governance analysis are presented below:

- The study revealed that all of the levels relevant for NZEB adoption were present. However, they are currently isolated in relation to NZEB niche formation, however in the future having presence of all the institutional levels is considered positive for large scale adoption as stated by few of the interviewees.
- Similarly, most of the relevant actors needed for NZEB niche development are present, but were found to be less motivated towards building up the alliance network and initiate knowledge building and learning especially for NZEB, which is also seen as important element in SNM.
- An increasing number of critical aspects for NZEB adoption are taken into account by the existing NZEB stakeholders in the region which provide a good test bed for creating visions and goals for future uptake of the concept.
- Most of the instruments and strategies are also present both related to energy efficiency and renewable energy integration in buildings, but they are not holistic as one NZEB policy or a code for implementation at this stage.

- The responsibilities and resources are seen as a weaker component of the governance context for NZEBs, as the resources are limited both in terms of capital investment and knowledge capacity.

Using the GAT in our opinion was useful and brought many aspects to light regarding the quality of the governance of NZEB niche development. The assessment highlighted the challenges in the regime which are obstructing or slowing down the introduction and diffusion of NZEB innovations, and at the same time identifying potential drivers to spur NZEB niche developments. In addition, the results can be used to make a holistic ex-ante evaluation of how the governance context can influence collaborative management of the NZEB niche development process.

SNM is an analytical approach typically used to assess niche developments with primary evaluation based on: a) visioning and goal setting, b) social network formation, and c) learning processes. By using the GAT complementary to SNM, further understanding of the quality of governance in a given context was gained with additional insight into existing institutional levels, strategies and instruments, and the resources and responsibilities available. Having had a good experience in analyzing NZEB niche development while using both approaches, we suggest that the use of both can be recommended in future niche development studies, particularly those focusing on the governance of niche development. Therefore, the GAT as a qualitative assessment framework towards the state of governance which can be complemented with the mainstream SNM approach can potentially be used for informed decision making by the government and policy makers towards introduction and diffusion of new sustainable technologies in a developing country. Before doing so, we do, however, suggest researchers to pay attention to the presence of a few pre-existing conditions. These conditions concern:

- there needs to be some innovation in at least a certain (developed) phase of niche formation;
- there needs to be at least some form of 'governance' (hence, not only market actor involvement, and coordination via the price mechanism, but also public and civic involvement, and at least some form of government intervention to support niche formation);

- the siting of the case study needs to be in a developing country (i.e. not in a Western country).

Finally, we want to address limitations that should be kept in mind when reflecting on the results of this study. It mostly entails the fact that the selected case study is in India, against the background of a developing country. This arguably contributed to focusing on a sectoral niche that was still immature or under-developed. In future research we suggest GAT to also be used in empirical research comprising case studies of niches that are more developed, i.e. in further stages of niche formation (e.g., early niche formation, late niche formation). Analyzing and comparing cases in different development stages would allow researchers to learn more about mechanisms that influence sectoral niche formation in a specific region with a dynamic governance process. This would probably entail to (also) select cases of sectoral niche formation in developed countries. Moreover, an attempt could be made to compare governance of two regions within the country with separate state jurisdictions; this should be explored in future research.

Chapter 6:
A Governance perspective: Ajmer

6.1 Introduction

This chapter aims to analyze the state of governance in the city of Ajmer in the state of Rajasthan, to assess how supportive or obstructive the governance context is vis-à-vis niche formation of NZEBs. The main research question is: ***What is the state of governance in Ajmer regarding NZEB niche development?***

This chapter is structured as follows: Section 6.2 briefly describes the theoretical frameworks which are explained in detail in chapter 3 and chapter 5, to make this chapter separately readable followed by the research design and methodology in section 6.3. In Section 6.4, the results of the case study analysis are presented. And finally, in Section 6.5, the conclusions are presented.

6.2 Theoretical framework

The two theoretical frameworks that will be applied to understand the niche formation process of NZEBs from a governance perspective in the city of Ajmer are (GAT) and to some extent notions of SNM. Chapter 5, section 5.1 elaborates on governance and its influence on facilitating and stimulating innovation in a particular context. This leads to introducing the GAT as a tool considered useful to analyse governance aspects of niche formation processes. Secondly, notions and applicability of SNM will assess (as presented in Chapter 5, section 5.2). It explains niche formation and diffusion of novel sustainable technologies through the formation of protected niches, and gradual breakdown of regime barriers. SNM and GAT were previously compared conceptually in this thesis (see chapter 5 and Chapter 3) to advance the understanding and the analytical approach of governance processes that are relevant to niche formation and deepen understanding of governance of innovations in a given economic sector. Empirically, the paper uses GAT as the main theoretical framework to assess the state of governance in Ajmer City.

6.3 Research design and methodology

To assess the governance for NZEB niche development, the study uses the analytical framework of GAT which is complemented by four evaluative qualities. For the empirical study, the City of Ajmer is assessed on the strengths and weaknesses of the governance context

towards niche formation of NZEBs and addresses how it compares and contributes to more traditional niche formation analysis using SNM.

6.3.1 Case selection – Ajmer city

The Ajmer region is one of the fast-growing cities in the state of Rajasthan with a total population of 551,360 (as per 2011 census) and is the fifth largest city in the state in terms of population growth, which is 11.93% over the last decade (ADA, 2016).

Ajmer comprises a total geographical area of 8575.29 hectares. According to the master plan of 2033, land use distribution in the city is nearly 69% under residential use, 3.29% for commercial buildings use, 12.76% for industrial use, 12.52% of public and semi-public facilities and 12% of green space and forest area use. Nearly, 70-75% of land use in Ajmer comprises of buildings (ADA, 2016), refer figure 19.

Buildings consume vast amounts of resources, mostly during construction and operation. Energy consumption in buildings is attributed to lighting, heating and cooling facilities. With growing income and urbanization in the city, demand as well as affordability for energy has increased tremendously. Currently, 99.6% of the city's population is connected by electricity grids and 5% of the total power supply in the city comes from renewable sources (AVVNL, 2015). Due to increasing demand for energy in buildings, the city experiences several scheduled and unscheduled power outages (AVVNL, 2015).

The city lags in innovation and transformation of the building sector regarding energy conservation measures and various other sustainable initiatives (AMC, 2015). Currently there are no LEED[44] or GRIHA certified buildings (AMC, 2015). In 2015, the city Mayor proposed to run its railway station on solar energy. Moreover, on many public-sector buildings, roof top solar PV for energy generation has been installed following the use of net metering policy (AMC, 2015). The population is growing rapidly and so is the demand for more housing. This, in turn, will increase the demand for energy in the city. Low or zero energy buildings can bring innovation in the city's building sector.

Apart from this, Ajmer was selected for several national urban development schemes in 2014. The most prominent one concerned the flagship Smart Cities Mission under the Ministry

[44] Leadership in Energy and Environment Design –United States Green Building Council

of Urban Development (of the national government). Under the mission, a proposal was made to increase the adequate supply of electricity using smart metering, harnessing renewable energy by installing rooftop solar panels at all the public buildings and in open spaces, converting all the street lights into energy efficient lighting using solar energy, and constructing public buildings as green buildings, while meeting standards to attain green building certification (such as LEED or GRIHA). Implementation of these (proposed) initiatives is expected to encourage innovation in the Ajmer building sector and thereby paves the way of energy transition in the city.

Apart from the Smart City Mission, there are more schemes in the city which are being implemented: i.e. the *Atal Mission for Rejuvenation and Urban Transformation* (*AMRUT*); the Heritage City Development and Augmentation Yojana (HRIDAY) under the Ministry of Housing and Urban Affairs; Housing for All; the Swach Bharat Mission; and the National Urban Livelihood Mission. They focus on improving the city's existing infrastructure.

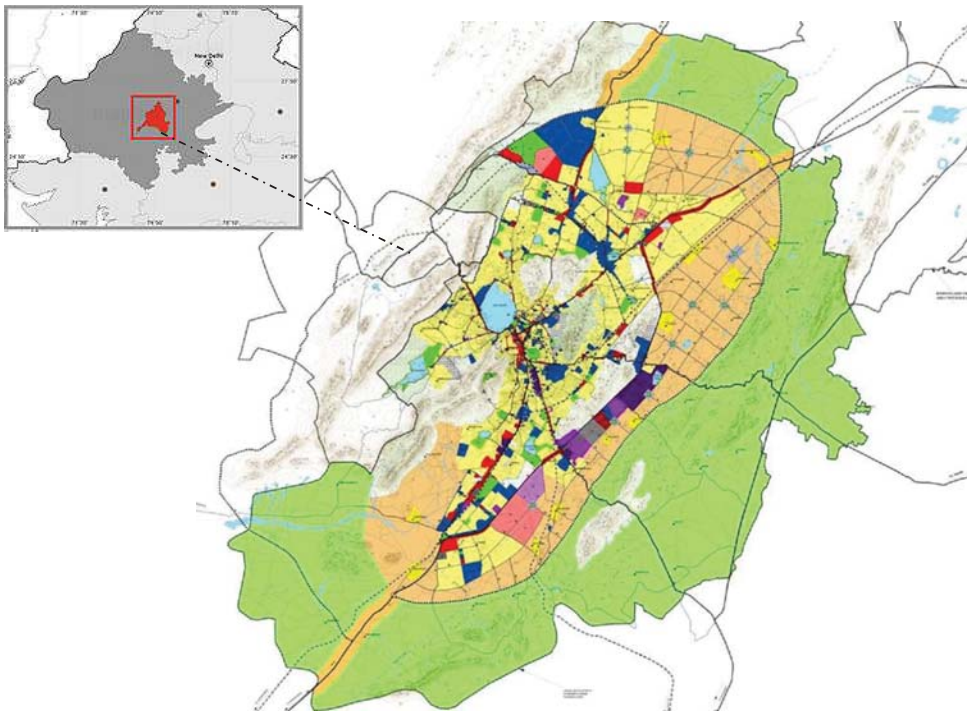

Figure 19 : Ajmer master plan 2033 (source: ADA, 2015)

Given these characteristics we view Ajmer as a city in India which is subjected to the implementation of several urban development and infrastructure schemes. The population is

growing rapidly and so is the demand for more housing. This, in turn, will increase the demand for energy in the city. Assessment of the energy transition in the building sector is of interest under the backdrop of growing population, increase in energy demand by buildings, as well as growing energy consumption patterns. For this reason, we consider Ajmer City an appropriate case to assess its governance setting vis-à-vis NZEB niche development. Thus, comparing the governance assessment of Ajmer city with New Delhi will be of great interest as New Delhi is overly urbanized and has the potential to lead the way for transitions in other cities or regions. In contrast Ajmer is relatively a smaller and growing city where concepts of energy efficiency in buildings are very new as well as of NZEB concept. Hence the two contrasting regions would provide a more pragmatic understanding of NZEB niche formation and the state of governance for future uptake in these regions. The comparative analysis will be conducted in concluding chapter.

6.3.2 Data collection

To assess the governance system, selected key stakeholders were identified for data collection which entailed a set of interviews in the Ajmer region followed by collection of secondary data sources (i.e., published reports, newspaper articles etc.), participation in meetings, and field trips to selected building sites. The interviews involved experts from ministerial authorities, state government officials, officials and civil servants from the city authorities (from the municipality and the development authority), building sector associations, financial institutions, private sector buildings owners, project developers, service providers, architects, consultants, (academic) researchers, manufacturers, and technology suppliers.

For all the identified stakeholders, an attempt was made to contact at least two to three actors from each stakeholder category (e.g., architects, academics, or developers). Contacts were made via e-mail, which were followed by phone calls. In some cases, potential interviewees needed approval from their respective organizations. This especially applied to government agencies and international aid agencies. The first author (who participated in the USAID PACE-D TA Program which included NZEB promotion and awareness raising activities in one of the work packages) also used her professional network of expertise to get access to some of the selected organizations. After contact was made, each of the contacted

experts was briefed about the research project, its aims and objectives. As a result, eight in-depth interviews were conducted between September 2015 and February 2016 with the stakeholders who agreed to participate.

In addition to collecting data via face-to-face interviews, the researcher participated in important project-based meetings which included accelerating NZEB awareness and knowledge in the building industry. Finally, secondary sources of data were gathered and analyzed (e.g., published reports, newspaper articles, project briefs, etc.).

A semi-structured questionnaire was prepared for the interviews (see Appendix A). The questions were largely based on the five dimensions of the GAT framework along with the four complemented quality criterions (as described in Chapter 5, section 5.2). In addition, questions containing key concepts from SNM were included. All the interviews were conducted face-to-face, recorded and transcribed into text files (interview transcripts), which were then used for analysis using the qualitative analysis software of ATLAS ti. This software program assists qualitative researchers to locate, code, and annotate findings in text files, to weigh and evaluate their importance, and to visualize the complex relations, supporting data analysis (i.e., the interview transcripts) (Muhr & Friese, 2004). The section below presents the results of the analysis using the GAT dimensions.

6.4 Results

6.4.1 Extent: Are all relevant elements taken into account?

Levels and scales: All governance levels ranging from the local level to the national level are relevant and present, but with some restrictions. No specific NZEB goals formulated by those governments were observed. The context is positive in terms of the large extent of the levels involved from national, state to local level implementation. Examples concern the presence of the Ajmer Municipal Corporation (AMC) and the Ajmer Development Authority (ADA), which work under independent jurisdictions and govern different regions within the city in terms of civic amenities, infrastructure, planning and enforcement of regulations. Similarly, for building approval, authorities such as AMC and ADA are important. However, for a building to get approval to become a NZEB or very low energy building it also needs (additional) approval from other authorities, such as the electricity department - Ajmer Vidyut Vitran Nigam limited

(AVVNL), and from renewable energy department. Therefore, several separate approvals and various stages of building construction in projects are required. This makes it a tedious and a complex process. In sum, it can be reasoned that the levels and scales dimension have a restrictive context.

Actors and networks: At the time of data collection there was no active NZEB stakeholder network in the Ajmer city. Absence of NZEBs or any green buildings in the region was the primary cause. It seems that existing mainstream building sector stakeholders lack technical capacity to design NZEBs due to a lack of awareness, knowledge and expertise. These actors viewed this as the responsibility of local bodies and the development authority's (AMC and ADA) to enforce, raise awareness and build capacity for green buildings. So far, the traditional building sector actors include architects, project developers, contractors, material suppliers, public sector, municipalities, development authorities and energy distribution operators. In addition, energy efficiency and renewable energy technology manufactures, and suppliers have not been able to establish a niche market in the Ajmer city nor have they been involved in any network that advocates the uptake of NZEBs. And neither educational institutions, the research community nor NGO's become motivated to participate. Due to absence of some of the key actors, the extent of the actor and networks context is considered as rather restrictive. In addition, multiple stakeholders involved in local level implementation create restrictions and make the context more complex.

Problem perceptions and goals: The Rajasthan state government has notified ECBC (Energy code for buildings) implementation which might bring several transformations in the commercial buildings sector pertaining to the use of energy efficiency design and technologies for the construction of new commercial buildings. Most actors see NZEB pilots from the public sector as crucial to raise knowledge and awareness. Many mainstream actors believe that NZEBs would be costly due to the use of new sustainable technologies. Hence, a lack of knowledge and expertise among existing architects was also brought to light. This could be a major challenge in the region as architects usually play a lead role in the design and supervision of building design and construction. Hence, demonstration projects may help in changing these expectations which will encourage learning and awareness about the concept and therefore support in goal setting at regional level. Recently, the AMC has

installed roof top solar PV systems to generate electricity and meet the buildings energy demand with self-generated power production. The extent of problem perceptions and goals can be considered as neutral.

Strategies and instruments: Several instruments are part of the policy strategy, but they do not particularly address the concept of NZEB, which makes it difficult for interested actors to understand the application of these instruments for construction of a holistic NZEB concept. There are regulatory based, and subsidy-based instruments which provide an impetus for investment to a certain extent. Examples are net- metering and a solar roof top policy. Awareness raising, and capacity building are important instruments to nurture a new niche for future large-scale implementation. However, sadly they are still missing. Therefore, the extent is considered as restrictive.

Responsibilities and resources: There is a lack of understanding on the level of responsibility with local government, energy distribution authorities, and with the development authority. The key officials from the local government are not aware nor are they updated about national and state level initiatives for EE and RE implementation or for NZEBs. There is also a lack of sufficient resources to raise the capacity of city officials who are active in NZEB or energy efficiency building implementation. The authorities (AMC and ADA) propose architects and project developers to take the initiative. However, private sector actors expect government authorities to be the key promoter and initiator of NZEBs and energy efficient buildings. This leads to a deadlock situation, in which no one wants to take any responsibility. For these reasons the governance context on responsibilities and resources can be judged as rather neutral.

6.4.2 Coherence: are the elements reinforcing rather than contradicting each other?

Levels and scales: At the 'levels and scales' dimension a rigid hierarchical approach is followed, making each level an isolated one, which in turn makes the implementation of the NZEB concept very difficult, particularly because there is little inter agency-cooperation. The various levels, the state and regional level governments follow a command and control (authoritative) approach. At the local level, various separate stakeholders deal with different aspects of NZEBs (e.g. getting building permits with ADA and AMC; getting approval for energy, net metering with AVVNL; a lack of implementation plan and communication for the

ECBC code implementation by the municipality). Due to a lack of coherence between the different government levels NZEB stimulation is likely to suffer in future. The coherence aspect of the levels and scales dimension is therefore viewed as restrictive and highly complex.

Actors and networks: Interaction between various mainstream actors seems absent. The actor network for NZEBs is negligible, especially with actors who are involved with issues regarding energy efficiency and renewable energy in buildings. Another observation was a lack of knowledge and expertise; current building sector stakeholders fail to collaborate or interact, and do not develop networks. Mainstream market actors have expectations that others take the responsibility and initiate network activities. For example, public agencies, such as the ADA and the AMC expect architects to take the lead in initiating; and vice versa architects expect the ADA and AMC to develop and expand the network formation spurring innovative concepts like NZEBs. Perhaps it is fair to state that there is a status of deadlock since there is nobody who initiates action, and the actors are only waiting at each other and nothing happens. Not surprisingly, thus far no awareness raising, or capacity building initiatives have been organized to garner interest from the important stakeholders in the building sector in the region. For these reasons the actors and networks context can be viewed as rather poor.

Problem perceptions and goals: The various perspectives on NZEBs held by actors do not look in conflict with each other as the problems highlighted mostly concern a lack of knowledge, expertise on NZEBs, and expectations among stakeholders that NZEBs are costly. In general, the stakeholders agreed on this, and see this is a rather easy way to neglect green buildings and NZEBs and expect nothing to happen afterwards. Thus, this coherence is in fact negative and the context is restrictive.

Strategies and instruments: Various isolated strategies were found present. They are directed from the state level on solar policy, and energy efficiency but not approached in a holistic manner for NZEB. The integration of energy efficiency and renewable energy in building design and construction is not dealt with in a combined fashion. Instruments such as subsidies for solar installations are present but with little awareness. In addition, there is complete lack of awareness raising initiatives by the local government. Hence, the context on coherence of strategies and instruments is rather seen as restrictive.

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Responsibilities and resources: Responsibilities and resources are disjointed in a very complex way with no clear boundaries mentioned at each local level. This encourages several authorities towards corruption and non-compliance of the responsibilities and under-utilization of resources making the context on coherence of responsibilities and resources rather restrictive.

6.4.3 Flexibility: are multiple roads to the goals permitted and supported?

Levels and scales: There is lack of flexibility between levels, in relation to both vertical and horizontal scales. The existing implementation framework leads to following a multi-level, hierarchical, system with little room for flexibility, making it difficult to move up and down a level when it is concerned with NZEB approvals with various organizations such as ADA, AMC or AVVNL. Therefore, this context can be viewed as rigid and restrictive for NZEB innovations to emerge.

Actors and networks: Since the actor network is not active, it is relatively easy for interested building sector stakeholders to conceptualise and initiate the network once the benefits of NZEBs or highly energy efficient buildings are known to them. Hence the context is supportive for new actors to join existing networks and projects. Any active and interested actor with knowledge about NZEBs can steer the network formation. These opportunities for dynamic development of the networks are making the flexibility of the context highly supportive.

Problem perceptions and goals: Since there are no concrete goals by the ADA and AMC for the building sector towards efficient use of energy, it is still possible to re-assess, 're-invent' or 're-formulate' any new goals or introduce them. Energy efficiency design, technology and renewable energy goals for the building sector can be jointly packaged under one holistic NZEB policy or building code. For these reasons the context can be seen as supportive for flexibility regarding goal setting and problem perspectives.

Strategies and instruments: Since the NZEB concept is still in a nascent stage with no pilots yet, it may be possible to combine and make use of different instruments. In 2017, the revised ECBC code was issued at the national level, setting a minimum energy performance standard

for commercial buildings which introduces super ECBC buildings with renewable energy integration, hence it allows for future updating to include NZEB goals within the ECBC code. In addition, the Rajasthan state solar policy will act as a supportive instrument to make NZEB goals more robust. These instruments are adjustable as per the local needs and climatic conditions and hence provide room for more innovation for NZEBs in future. The context is supportive.

Responsibilities and resources: The line between the practical responsibilities of the development authorities and municipality is mostly as sharp as it is on paper, which means it is stringent as mentioned and prescribed with less flexibility. Pooling of resources is also difficult between the authorities, even to an extent that officials work in silos devoid of any interaction between authorities such as no interaction between ADA and municipality. This situation was also observed between various departments within the same authority. This often obstructs the implementation of policies like ECBC, lack of information dissemination from one authority etc. Sometimes even discouraging pilot projects from becoming successful, discouraging flexibility. Finally, the flexibility of responsibilities and resources is also assessed as restrictive.

6.4.4 Intensity: how strongly do the elements urge changes in the status quo or in current developments?

Levels and scales: There seems to be no strong political nor national government support for forceful measures, but several national programs and schemes on city brands like 'Solar city', or 'Smart city' can help to make the integrated NZEB concept more acceptable among building sector stakeholders. However, most regulatory measures are only voluntary ones with a preventative nature. Intensity of levels and scales looks like a neutral governance context, for NZEB implementation.

Actors and networks: Since many stakeholders are not aware of the NZEB concept, and neither do potential end users (due to perceived high capital costs), there is an absence of (any) NZEB demonstration projects. Apparently, there is no pressure from an actor or coalition in support of behavioural change or management reform in relation to NZEB. This is likely related to a lack of awareness, or a lack of technical knowhow. The context does not motivate private sector

actors towards any strong changes from the business as usual scenario. Hence, the context is considered as restrictive.

Problems perceptions and goals: The goal of mandatory ECBC implementation with separate RE goals is ambitious as compared to the existing BAU scenario. This is particularly due to lack of compliance and implementation checks by public authorities who have no measurement and verification protocol at hand. The lack of awareness and capacity among the existing building sector actors may lead to the existing scenario to change much slower than might have been expected. The governance context is seen as restrictive.

Strategies and instruments: The existing instruments do not exert any transformation at large. Amending existing policies and bye-laws will take several years. Moreover, there is a lack of compliance to existing policies, there are violations of bye-laws, and there is a problem with corruption and public authorities, causing a restrictive context.

Responsibilities and resources: An increasing level of effort is made towards the adoption of solar roof top policy by installation of solar technology for self-generation in public buildings. The resources are being used with partial government subsidies. This creates interest from the building sector toward replication of the effort. However, it is difficult to say whether funds are sufficient for NZEB niche development. However, the authorities currently lack the capacity to facilitate the uptake of NZEBs. Hence, the governance context on intensity in responsibilities and resources can be considered as poor. The intensity of responsibilities and resources is also assessed as restrictive.

6.5 Overview

This section provides an overview of the overall governance context in Ajmer regarding the niche formation of NZEBs.

	Criteria			
Dimension	Extent	Coherence	Flexibility	Intensity
Levels and scales	(-)			
Actors and networks		(-)	(+)	(-)
Problem perspectives and goal ambitions				
Strategies and instruments	(+)			(-)
Responsibilities and resources	(+)			
	*Colours: **red**: restrictive; **orange**: neutral, **green**: supportive*			

Figure 20 : GAT results - Ajmer region

In the Ajmer city case study (figure 20), the governance context is considered as highly incoherent, with weak extent, moderate flexibility and weak intensity towards NZEB niche development. This poor governance condition makes the context less supportive towards NZEB adoptions as primary elements that are badly required for implementation are missing. Due to the deficiency in extent, relevant issues and problems, actors and policies are ignored. The incoherent, relatively flexible and weak intensity dimensions reflect limited governance capacity to initiate any innovation and transition of building sector towards more energy efficient buildings. Flexibility in terms of actor network formation, problem perceptions and policy instruments are given to lower level actors to enable them to overcome issues associated with incoherence existing in the five dimensions of governance. However, in this weak governance context, opportunities exist where the incoherence can lead to undesired (and unnoticed) defections from the intended goals. This condition can therefore be a small window of opportunity for NZEB niche to conceptualize in the city through on-set of few NZEB demonstration projects.

6.6 Conclusion

In this chapter, the state of governance towards NZEB niche development was analyzed in Ajmer city. The study adopted a case study research design to assess the governance against

the four qualities used in the "GAT" of *extent, coherence, flexibility and intensity* of the five structural components of the concept of "governance" as developed in the GAT. In the Ajmer region, the governance context was assessed as rather restrictive for NZEB niche development. The study shows a lack of extent, creating restrictive capacity of the governance to act towards development of a new NZEB niche. In addition, the region was incoherent, moderately flexible along with weak intensity. Therefore, NZEB niche innovation and adoption can be viewed as difficult for wider future uptake. The levels and scale are not in line for NZEB niche formation at city level. The actors are not aware and do not have enough knowledge about NZEBs, therefore the network for NZEBs is also presently missing. Due to lack of knowledge and awareness the visioning and goal setting is currently not present. Various instruments which can support NZEB adoption are only present on paper with very little adoption. Like the New Delhi region (chapter 5), the Ajmer region lacks resources in terms of both capital and skills-based capacity to design, construct, adopt and implement large scale NZEBs.

Chapter 7:
Transition to energy efficient buildings: comparing Singapore and India

7.1 Introduction

India's energy transition towards more energy efficient buildings like NZEBs shows slow growth as the niche status of NZEB is still rather immature (as resulted from the analyses in the previous case studies conducted in India in Chapter 4-6). To further our understanding of transitions and governance, I seek to learn from transitions in the building sector in other countries in South-East Asia. Considering the growth of the green building sector in countries such as Singapore, this should be seen as an extension to the study we conducted in India to capture the growth trajectory and lessons learned by comparing the two independent cases. Therefore, we feel it is necessary to study the current support system for green buildings and other low energy buildings (such as NZEBs) and assess whether the 'innovation system' have favourable conditions to spur large scale adoption of green buildings and bring transformative change.

In this chapter[45], we attempt to use the theoretical frameworks that were also used when analysing case studies in India (see previous chapters) - that is Sectoral System Innovation Assessment Framework (SSIAf) and Governance Assessment Tool (GAT) - to assess the quality of governance and the quality of sectoral innovation system. First, SSIAf will be used as the primary framework to draw comparisons between India and Singapore building sector for innovations in energy efficiency in building sector. The key components are *shaping of expectations, the actor network, institutions, learning process, and stimulating market demand.* As stated in chapter 3, the SSIAf framework is an integrated assessment framework adopted from SNM and SIS giving a more holistic approach to a niche innovations and transitions of new sustainable technologies. In addition, the study will further the analysis by drawing insights using the GAT framework to assess the quality of governance for transitions in both the countries. SSIAf components will be assessed against the four quality criterions of the GAT framework, i.e. *extent, coherence, flexibility, and intensity*.

[45] This chapter is partly adapted from a study by Vidu Siva et al. (2017)'. The thesis title "*Assessing the potential for an energy transition in the building sector in Singapore*" attempts to study the supportive conditions in the Singapore building sector for a large-scale uptake of green buildings in Singapore. The study used theoretical framework of Sectoral Innovations Systems (SIS) analyzing the key components of *Technology, Actor Network, Institutions and Market Demand*."

This chapter aims to provide greater understanding of transitions and quality of governance in spurring the transitions toward green energy efficient buildings in Singapore, when compared to India. Both countries have diverse building sectors, scales, climatic conditions, and existing socio-political and economic scenarios. For this reason, the focus of the analysis in this chapter is on Singapore, a country that quite successfully addressed innovations of "green buildings" principles and succeeded to some extent in "greening" its' built environment (Siva, Hoppe, & Jain, 2017). In this study, the conditions are explored that spurred and hampered innovation, and governance of "green buildings", and towards niche formation and innovation-diffusion of NZEBs, seeking to learn from the approach taken in Singapore and thereby drawing comparisons with the complex building sector in India.

The chapter is structured as follows: Section 7.2 presents the key characteristics of the green building niche and its policy support framework in Singapore. Section 7.3 elaborates on the conceptual and analytical approach that will be used to compare the two cases. Section 7.4 elaborates on the method used in this study. In section 7.5 the results of the analysis are presented. In section 7.6 the conclusions are presented and discussed.

7.2 Green building sector in Singapore

As one of the few countries in the world with a 100% urban population (World Bank, 2013), Singapore's building sector consumes up to half of the nation's total energy consumption (Serene Peh et. al., 2014). In 2005, the Building Construction Authority (BCA) of Singapore launched the "Green Mark" scheme to impel the construction industry towards a more sustainable built environment. According to the BCA, the Inter-Ministerial Committee on Sustainable Development (IMCSD) has set a target of "at least 80% of the buildings in Singapore achieving the BCA Green Mark Certified rating by 2030" (BCA, 2013). This will require a major transformation to change the way buildings in Singapore are designed, constructed, and operated. At present, more than ten years after the introduction of the certification scheme, it is estimated that green buildings in Singapore represent about 27% of the nation's total gross floor area (Sang & Chong, 2015). If this type of growth persists, it is uncertain whether Singapore will be able to meet the IMCSD target. Such targets also motivate the green building industry to expand further and beyond mere green buildings, and experiment with NZEBs.

In Singapore, the building sector is governed by the BCA. The BCA is an agency under the Ministry of National Development, "championing the development of an excellent built environment for Singapore" (Sang & Chong, 2015). According to Ho (2012), by 2020, 29% of Singapore's carbon emission is related to energy use in residential and commercial buildings. For this reason, it is important for the BCA to keenly address energy efficiency issues within this sector.

In 2010, the first Zero Energy Building (ZEB) in South-East Asia was established. In fact, it concerned a retrofitted existing building. This effort was an exemplary effort by the government of Singapore through BCA, NUS and MOE. The lessons learned, and the experience gained in the construction and operation of NZEB was considered very useful and valuable for the entire sector and green building niche as the building industry strives to achieve the set targets. The technologies in NZEB that are currently assessed in test beds can potentially be applied to many of the existing buildings, of which the owners strive to obtain a Green Mark Certification soon (BCA, 2010).

7.1.1 Green building rating tools in Singapore

In Singapore, the BCA adopted the so-called "Green Mark" scheme in January 2005. It has been described as the LEED scheme in the US for countries in the tropical regions. The Green Mark scheme places greater emphasis on energy efficiency; it has been tailored for a tropical climate with the cooling of inner spaces using air-conditioning; and it has higher standards of measurement and verification, using more precise instruments to monitor equipment performance (Sang & Chong, 2015). According to the BCA, "It provides a comprehensive framework for assessing the overall environmental performance of new and existing buildings to promote sustainable design, construction and operations practices in buildings. It is intended to promote sustainability in the built environment and raise environmental awareness among developers, designers and builders when they start project conceptualization and design, as well as during construction" (BCA, 2015; p45). The "Green Mark" scheme has been endorsed and supported by several ministerial bodies in Singapore, such as the National Environment Agency (Sang & Chong, 2015).

The assessment system of the "Green Mark" scheme awards points for specific energy efficient and pro-environmental features and practices that can be integrated into building projects and designs. These features must be more sustainable than the normal practice observed in conventional buildings. The total score provides an indication of the environmental friendliness of the building design and operation. Depending on the overall assessment and score, the building will be certified as having met the BCA "Green Mark Platinum" standard, the "Gold Plus" Standard, the "Gold" standard, or the "Certified" rating, with "Platinum" being the highest level of certification (Sang & Chong, 2015).

In line with the "Green Mark" scheme, since 2005 three strategic "Master plans" were issued and published by the BCA. In 2012, the Building Control Act was updated to include legislation on the certification of buildings. It stated that newly constructed buildings must at least achieve a certain minimum certification qualification. In 2013, it became mandatory to building owners to submit energy consumption data to the BCA. Since 2014, building owners are obliged to conduct periodic energy audits, and to at least achieve the minimum "Green Mark" certification level when updating or retrofitting their cooling system (Serene Peh et. al., 2014).

There is a requirement that certified "Green Mark" buildings must be re-assessed every three years to maintain their "Green Mark" status. Newly constructed and certified buildings will subsequently be re-assessed under the existing building criteria. The initial certification for new buildings will be awarded based on their design. However, after one year, assessment will be based on the building's actual performance (Sang & Chong, 2015)

7.2 SSIAf framework

The SIS and SNM frameworks represent different perspectives on how processes of innovation and socio-technical transformations develop (Markard & Truffer, 2008). Considering the commonalities and differences between the two frameworks, a further understanding was developed to complement the two frameworks and overcome each other's limitations if any. For this reason, an integrated framework was conceived (e.g., see chapter 3) to bridge the gap between the two frameworks in innovation and transition literature. This integration supported the development of an assessment framework for assessing the status

quo of a given (radical) niche development within a sectoral innovation system (i.e. innovation in the building sector towards low energy buildings).

In the case study analysis of NZEB niche innovations in India, the integrated framework provided us with new analytical insights to study niche development processes and further understanding in the innovation and diffusion processes of sustainable technologies within economic sectors (hence, a sectoral part of the regime level). In the integrated framework, we developed independent components which help as conceptual building blocks to understand sectoral niche development processes and innovations. These building blocks are: *shaping of expectations, actor networks, institutions, learning process and market demand creation* (figure 12, Chapter 4).

We envisage the use of this framework in our study to assess two embedded empirical cases (in this chapter a comparison between building sectors in India and Singapore). This allows for assessing and reflecting the cases using the SSIAf concepts. We expect that these components jointly influence the development of innovations and related niche formation. The integrated framework (SSIAf) forms the conceptual basis of our research. Table 1 presents an overview of its key conceptual components. For each component (or cluster of components) the key conceptual items are presented.

In addition to using the SSIAf, the GAT (Chapter 3, section 3.3) also helps us to advance understanding of the quality of governance in a given context (e.g., governance of NZEB niche developments in the Indian building sector, or governance of sustainable energy technologies that are relevant to the sustainable transition of the building sector in Singapore), or identification of barriers to the implementation of a given policy. Combining insights from the two theoretical frameworks allows for broadening the scope and furthering the understanding of long term sustainable transitions, sectoral innovations, implementation of transition–oriented policies, and assessment of the role and state of governance' in innovation processes of economic systems. The key qualities criteria of the GAT will be assessed per SSIAf component. The four quality criteria of GAT are: *extent, coherence, flexibility, and intensity*. See Chapter 3 for a more detailed description of the two frameworks.

7.3 Methods

The research design of the study presented in this chapter involves an in-depth case study of the Singaporean building sector. It will be compared against the innovation system and niche formation in India's building sector (the latter as presented in Chapter 4). A case study research design was chosen to investigate the phenomenon in detail in its existing context in Singapore (cf. using a rich set of qualitative data). Singapore was chosen as the case study for a variety of reasons; one being that Singapore is viewed as a frontrunner in the green building movement in the tropics and subtropics. Across Asia, Australia, and Africa, a total of 71 cities have adopted the "Green Mark" certification scheme. In line with this, and with the IMCSD's goal of having 80% of green buildings "Green Mark" certified by 2020, it is therefore valuable and interesting to explore the uptake of green buildings, and its contribution to the energy transition and innovations in the Singapore building sector towards NZEB niche formation. Singapore possibly serves as a good practice, from which valuable lessons can be drawn as compared to the building sector in India. Therefore, it is useful to explore the reasons (and conditions) that account for successful green building innovation in this country and thereby drawing comparative lessons with India.

Considering the advances in green building sector in Singapore, the case study can soundly be compared to innovation in the Indian building sector to provide us with a broader understanding of transitions and polices that spur sustainable transformations of economic sectors.

Data collection in Singapore involved a set of eleven in-depth interviews, secondary data, participation in two conferences, and a green building tour. The interviews[46] were divided into two sets: namely 'primary actors' and 'secondary actors' following the classification given in SIS theory. The first set of interviews involved six 'primary actors' who were directly involved in one or more green building projects. This group of interviewees consisted of building developers, architects, technology providers, and building occupants. These interviews provided primary knowledge regarding green building development in Singapore as these actors have been directly involved in green building demonstration projects (Siva, Hoppe, & Jain, 2017).

[46] Vidushini Shiva collected the data in Singapore under the supervision of Dr. Thomas Hoppe and Mansi Jain between May-September 2015

The interviewees represent almost all the relevant actors in the complex value chain of the building construction sector. Additional information was gathered using secondary data and information from the other interviewees addressing them (Siva, Hoppe, & Jain, 2017). The second set of interviews was conducted with five 'secondary actors'. This interviewee group consisted of government officials, representatives from consultancy groups and non-profit organizations, and academic researchers. This was done to further understand the dynamics between primary and secondary agents, and the role of the support system in facilitating the energy transition towards green buildings in Singapore (Siva, Hoppe, & Jain, 2017). The data collected for Singapore was first analysed separately following the SIS Framework and later with SSIAf framework.

The results are then compared with SSIAf results corresponding to the study of NZEBs niche innovations in India (Chapter 4). This comparison will largely focus on the SSIAf component that supports the uptake of low energy buildings in the two given regions and the quality of governance for innovation and transitions in that region. Quality of governance assessed against the SSIAf components that support such transitions is also explored in both cases and identified in the following sections. In the case of India, the interviews were conducted during field visits to India from September 2014-July 2016. It should be noted that actor interviews in the Singapore case study were shortlisted based on their presence as primary and secondary stakeholders from building sector and involved directly or indirectly with green buildings. In the case of India, the selected set of stakeholders included a set of niche actors (quite like 'primary actors') who were found to be directly engaged in NZEBs (which are also certified as 'green buildings'), and demonstration projects that were highlighted as innovation projects. In addition to niche actors, niche outsiders or 'secondary actors' were also included during the data collection process to understand sectoral actors' perception towards innovation niches such as NZEB niche in India. In total, 18 interviewees participated in the interviews focusing on SSIAf components, and 11 actors in interviews focussing on governance (GAT) (in total 29 interviews in India case study).

7.4 Results

The results of the analysis are presented as per conceptual component of the SSIf framework. The results are first drawn for the Singapore case, and are followed by results for

the Indian case. Each section, then, further elaborates on the quality of governance conditions which can spur these transitions in both the regional cases.

7.4.1 Actor networks and interactions

A wide range of actors were found to be involved in the building construction sector for green buildings and low energy buildings both in India and Singapore. Primary actors include architects, engineers, consultants, suppliers, technology providers, building owners, building developers, and tenants. Secondary actors include the BCA in Singapore and the Bureau for Energy Efficiency (BEE) in India and other government agencies, green consultants, investors, non-profit organizations and councils, and research institutes (often academic). However, in Singapore it was found that BCA occupied the most influential position and many interviewees agreed that they were heavily dependent on the BCA. Unlike in India where no single actor (especially government agencies) was found to strongly influence innovations in the building sector.

In Singapore, the national government was very active in trying to forge interaction among the various stakeholders. Eight out of eleven stakeholders acknowledged that the government has done a good job in providing platforms for interaction through consultation sessions. This resulted in the industry responding according to the agenda's set by the government making the discourse unidirectional and one-sided. This was perceived in one aspect as supportive towards transition and innovation initiatives taken by government; while on the other hand it was also found to limit the effectiveness of actor interactions for novel innovations to emerge. In the case of Singapore, concerns and ideas were not voiced in a multi-participant decision-making process, limiting the innovation process as unidirectional, and making it more incremental (unlike radical change, which is a condition that is required for upsetting the existing regime).

In the case of India, the national government (BEE) was not seen by most interviewees as the most influential actor in initiating the direction for green buildings or NZEBs innovations, with no formal platforms for interactions apart from some conferences under bilateral projects. Six out of seven interviewees (secondary actors) agreed that green building rating tools were mostly industry initiatives (adhering to organisations in the networks surrounding the LEED, IGBC and GRIHA rating tools) with less impetus provided by the government. This led actor

networks to emerge without any concrete direction and in multi-faceted discourse. However, for low energy buildings and NZEBs, actors were found to be apprehensive and reluctant to start a new social network on their own. Most often they only operated within (single) project networks. This situation led to a 'lock in' between government and the industry, each hoping that the other takes the first step towards such innovation initiatives.

Motivated private sector actors were found to operate in isolation waiting for the government to respond, adopting industry-led green building rating tools. Thus, no formal network emerged either via government initiative or via industry actors. This led innovation processes to be slow, and only located within localized demonstration projects as remote projects in the industry. However, this isolation led to an increased level of interaction amongst the project actors within each innovation project's boundary. Each of the studied innovation projects in India followed an integrated design approach which brought all the project stakeholders into the discussion from the conceptual design stage, thereby showing a considerable level of interaction and building of new networks between the project team members. Therefore, it can be observed that actor interactions were active with small niche projects failing to scale-up in the industry.

This situation was not found in the Singapore case, where collaboration between stakeholders was regarded by interviewees as 'poor'. This was related to the absence of an approach using an integrative design. Different stakeholders typically come in at different stages of building projects, which often leads to a lack of coherence and sub-optimal design. This means that project goals could become diluted due to the temporal involvement of stakeholders (Siva, Hoppe, & Jain, 2017). In Table 13, the actor-network situation in both countries is depicted as per the four quality criteria from GAT, to analyse the current governance conditions for establishing more robust actor networks. Each assessment is represented by a color code of green, orange, and red. Where green is signifying a positive condition for implementation, orange signifying the situation is neutral and not moving in any direction, and red signifying a negative governance condition.

Table 13: Assessment of actor networks and interactions

Extent	Coherence	Flexibility	Intensity
Are all relevant stakeholders Involved? Who is excluded?	*What is the strength of interactions between stakeholders? In what ways are these interactions institutionalized in joint structures? What is the history of working together? Is there a tradition of cooperation?*	*Is it possible that new actors are included or even that the lead shifts from one actor to another when there are pragmatic reasons for this? Do the actors share in 'social capital', allowing them to support each other's tasks?*	*Is there a strong pressure from an actor or actor coalition towards behavioral change or Management reform?*
Singapore			
All relevant actors for innovations in green buildings were found to be present.	Interaction between stakeholders is poor. They are institutionalized through initiatives and formal platforms provided by BCA.	The interaction between stakeholders proceeded mostly in only one direction to approach the BCA. This showed less flexibity limiting the effectiveness of such interactions, when concerns and ideas were not voiced in a multi-participant decision-making process.	BCA exerts strong pressure on behavioral change through its several policies and standards.
India			
All relevant actors for innovations were found to be present.	Interactions were strong within innovation project boundaries but weak between various projects. Interactions were not institutionalized and hence showed limited cooperation between projects. No effort was made by the government.	Since innovation in the niche is fragmented and not institutionalized, it is easy for new actors to be included giving room for flexibility.	No additional pressure is exerted by any actor especially by the government to exert behavioral changes or management reforms as regulations and new policies are not mandatory

While looking from the governance perspective, both in Singapore and India, completeness of extent of the actors available to initiate innovation processes in the building sector, was found to be present. It revealed a moderate level of coherence as far as the interaction between these actors to spur innovations is concerned. In Singapore, as the BCA occupied a central position in creating platforms for interactions and deployed a top-down approach, the context was found to be less flexible and only one-directional. On the contrary, due to absence of any central leader in initiating actor interactions, the context in India was more flexible to include and engage more interested actors and drive the discourse as multi–directional for innovations. The BCA exerts a strong influence on actors towards behavioural change in Singapore making the context very intense, unlike the case of India where it was open-ended with no external pressure on actors.

7.4.2 Institutions

Formal institutions

Formal institutions can include rules, regulations, policies, initiatives, and monitoring from the government (Jain, Hoppe, & Bressers, 2016). In Singapore, nine out of eleven stakeholders recognized that the government has done a lot in promoting the development of green buildings. There are several different initiatives by the BCA in place. Formal institutions such as regulations, laws and enforcements were found to be conducive for innovation in the building sector in Singapore. The BCA which is considered as an apex institute for regulations and enforcement in the building sector uses a set of several policy instruments and innovative approaches, such as grants as financial incentives. A mandate was issued in 2015 for organizations to reveal their energy performance data so that BCA could be enabled to do more effective benchmarking (Siva, Hoppe & Jain, 2017). In Table 14 the set of initiatives taken by BCA to move industry toward energy transitions in the building sector, is presented.

Table 14 : Policy instruments and actions adopted by the BCA in Singapore

S. no	BCA policy instruments and actions.
1	Govt. supports risk-taking technology through grant schemes like the Green Building Innovation Cluster (GBIC)
2	Govt. has made it mandatory for any building that undergoes any sort of change or retrofitting to meet the minimum level of the "Green Mark" standard.

3	Phase out of inefficient technologies from the market (such as air-cooled chillers).
4	The Housing and Development Board called for a large solar-leasing tender in 2014, under which solar panels will be installed on the roof of 500 residential buildings (Siau, 2014). This could promote the use of solar panels and cause it to become the dominant method of generating electricity in Singapore.
5	A new scheme by the BCA to encourage the certification of rental spaces, which would help to bring about increased engagement and education of end-users. High performance buildings (typically "Green Mark Platinum" certified) are given public recognition by the BCA. These buildings are usually open to the public for guided educational tours.
6	The Green School Roadmap scheme was also recently launched to facilitate the greening of school spaces and helps build a culture of sustainability amongst children and juveniles.
7	The BCA also has a pilot scheme called 'BREEF' (Building Retrofit Energy Efficiency Financing) which helps to counter the high upfront costs of investing in new technology by underwriting some of the risks when a company wishes to take a loan to pay for the technology. These have been effective in reducing risk aversion for building owners, investors or project developers.
8	BCA released its 3rd Master Plan for green buildings which has a greater emphasis on reaching out to building owners and tenants. There are several schemes in place, like the "Green Mark Portfolio Programme", which seeks to certify tenant spaces (as opposed to the entire building itself), and the "Green Lease Toolkit", which serves as a handbook for owners and tenants on good practices and sustainability targets.
9	BCA rolled out a scheme called the "Green Mark Gross Floor Area" (GM GFA) incentive scheme, wherein buildings can be afforded increased GFA if they are able to undergo substantial energy efficiency enhancements.

Through these schemes, industry has responded and taken various measures. It was also revealed by most interviewees that most people view BCA guidelines and regulations as their reference point and simply follow what is needed to achieve a "Green Mark" standard or meet with requirements of any scheme. With this initiative BCA was considered to influence consumer preferences and make sustainability become a higher ranked priority amongst building owners and users. On the one hand such initiatives can be seen as an impetus by the government towards energy transitions for adoption of green buildings, however in terms of effectiveness, six out of eleven interviewees conceded that the efforts from the government have only been moderately effective, and that goal attainment was mostly related to the implementation and enforcement of strict laws and regulations. This was also believed to hamper innovation as people (owners, tenants, and investors) tend to follow the guidebooks that are prescribed by BCA without innovating beyond the required standards. In this sense, Singapore tends to follow a top-down approach, which does create the minimum conditions for

innovation required to foster change in the building sector, but only under set guidelines and regulations, and when sufficient enforcement capacity is available.

On the contrary, the situation in India was found to be rather different as building sector institutions do not seem to be well aligned with NZEBs or green buildings. To some extent, there is a separation between energy efficiency and renewable energy (since each aspect is looked after by different central government institutions). One of the main instruments − the ECBC − is a voluntary code that indicates a minimum energy performance standard for commercial buildings. Future code implementation and compliance are expected to lead to a promising shift towards the adoption of energy efficient buildings, which will support innovation. Similarly, from the renewable energy perspective, there have been some policies − such as the solar roof-top policy, a feed-in tariff mechanisms and net metering − that can be considered supportive in achieving NZEB goals. All the investigated NZEB demonstration projects received government subsidies to integrate renewable energy technology in the buildings. In most cases, this was perceived as very positive, but also as a sign that it is still predominantly a 'technology niche' (Jain, Hoppe, & Bressers, 2016).

Informal institutions

Informal institutions refer to non-state actors like NGO or community projects, but also to the common habits, beliefs, standards, established practices of society in general. In Singapore, very little support seems to come from NGOs and there is a sparse presence of community initiatives vis-à-vis green buildings. Most of the initiatives stem from the government, and not from the grassroots level. All the interviewees agreed that from a cultural perspective, Singaporeans tend to be opposed to change. There is a generalized mindset on budgeting to only start fixing things once they are broken. This means that there is no initiative to optimize a system if its basic functionalities are perceived to be in good condition. In turn, people are typically risk-averse, and behave cautiously when deciding to adopt new technology. Despite this, BCA has made several efforts to introduce and force behavioral changes in people towards green buildings and low energy buildings however the effect is only moderate (Siva, Hoppe & Jain, 2017).

In the case of India, a few demonstration projects were initiated toward NZEB, and several LEED and IGBC certified building have emerged in the green building landscape in India.

Local community level initiatives are also considered very few as compared to the vastness of the building sector in the country. Interviewees mentioned that more government efforts are needed to bring about community level change in end users and consumers. From the ongoing innovation projects in India, a culture of non-sharing of ideas was observed as people were found to refrain from sharing the failure factors of (failed) experimental projects.

Moreover, radical innovators seemed obliged to highlight the successes of the demonstration projects in which they were involved. Since most of the NZEB demonstration projects involved public sector buildings, they are typically scrutinized because they use special earmarked budgets, which lead participating actors to refrain from sharing information on project failures. This shared reticence limits innovation learning between subsequent demonstration projects. Furthermore, government communication protocols and hierarchical systems put additional pressure on the project teams and client representatives to report project successes (to senior officials). On the sectoral level, institutional fragmentation was observed, and this also slowed the innovation process, limited the learning process and hampering network formation. Several national and state (public) authorities appeared only to be involved in their own separate activities. Developing an integrated well-aligned comprehensive institutional framework was considered by interview participants to be of critical importance by most of the actors that were interviewed.

From cultural perspectives, as was the case in Singapore, people are less flexible or not open to change as far as standard building construction practices are concerned. More so, acceptance of a new technology often depends on cost, hence people are found to be risk averse and reluctant to accept new technologies without knowing the results, or the profitability. In Table 15, the results of the assessment of governance conditions are presented for formal and informal institutions.

Table 15 : Assessing formal and informal institutions

Extent	Coherence	Flexibility	Intensity
What types of instruments are included in the policy *Strategy?*	*To what extent is the incentive system based on synergy? Are trade-offs in cost benefits and distributional effects considered? Are there any overlaps or conflicts of incentives created by the Included policy instruments?*	*Are there opportunities to combine or make use of different types of instruments? Is there a choice?*	*What is the implied behavioral deviation from current practice and how strongly do the instruments require and enforce this?*
Singapore			
All types of instruments are introduced by govt. It includes standards, regulations, financial incentives, awareness and knowledge dissemination etc. Most of these initiatives are mandatory for implementation.	The BCA initiatives are considered as well thought and synergized. Such as good incentives are provided to parties adopting and exceeding the required standards. Awareness and knowledge dissemination is provided to actors which are unable to reach desired energy performance.	Yes, it is possible to combine the various instruments in place by the government.	Instruments strongly encourage stakeholders to exert behavioral change. E.g. by mandating the sharing of energy performance data of organizations, certification of tenant spaces, mandating green mark minimum certification for any renovation project.
India			
Several instruments are included in the policy strategy. Building codes, certifications, awareness tools, guidebooks etc.	These initiatives by the government are not well synergies and are fragmented between energy efficiency and renewable energy enforced by different ministries.	Yes, instruments are flexible and can be combined, however may find difficulty during implementation due to different enforcing authorities.	Since most of the instruments are only at voluntary stage, they exert only marginal pressure toward behavioral change and only from aware and motivated stakeholders.

Table 15 revealed positive governance conditions for existing institutions in Singapore, making the situation favourable for adoption of green buildings or low energy buildings. In the case of

India, the situation was only positive for the most of instruments available, while medium to negative conditions were found on flexibility, coherence and intensity.

7.4.3 Learning process

In the case of Singapore, both primary and secondary agents made substantial efforts to ensure coordinated knowledge exchange between projects, stakeholders and the public. The stakeholders exhibited good level of openness in sharing knowledge and learning's. This was usually seen facilitated by the government through organizing conferences, workshops, and seminars. In terms of increasing their knowledge base, project developers in Singapore were keen to educate tenants and end-users. They provided guidebooks in collaboration with the BCA, called the "Green Lease Toolkit on sustainability practices". In 2015, a scheme was launched by BCA to encourage the certification of rental spaces, which would help to increase engagement and education of end-users. Moreover, buildings with high green building performance (typically "Green Mark Platinum" certified or NZEBs) are given public recognition by the BCA. These buildings were usually open to the public for guided educational tours.

As far as the academic knowledge was concerned, interviewees opined that a change or re-orientation of academic work was deemed necessary to pay more attention to green buildings. A need to increase research and publications on this subject was highly needed in addition to having actual test beds and demonstration projects. This would highlight the performance of specific technologies, and opportunities to save energy in real-life practice.

In the case of India, learning processes were seen as situational and fragmented, as learning only happened among niche actors, who were directly involved in innovation projects. Only seldom lessons were disseminated to a larger audience. As a consequence, only first order learning took place. Unlike in Singapore, no dedicated effort was seen by the government in spreading lessons from those projects, through media or publication. Only efforts were seen by the frontrunners to publish their work in building magazines or through social media. Critical information and experimental failures were, however, not easily shared, where stakeholders were only inclined to showcase project success, without paying attention to learning that comes from failures also. This was largely seen in demonstration projects which were funded by government or public-sector buildings.

On the academic front, interviewees supported that a huge change is needed in the way universities and architecture colleges include green building and NZEB concepts in academic curricula and programs and pay more attention to research and publications alike. In Table 16 the results of the assessment of the learning process is presented against the four quality criteria of governance.

Table 16 : Assessing learning process

Extent	Coherence	Flexibility	Intensity
Are all forms of learning on relevant innovations achieved and disseminated?	*To what extent is the learning process synergized?*	*Are there opportunities to recombine or make use of different types of lessons or knowledge ? Is there a choice how to disseminate?*	*What is the implied behavioral deviation from current practice about which the learning takes place and how strongly is this supported?*
Singapore			
In Singapore, stakeholders were found to be keen on sharing their learning experience with other actors. Also, government took good initiatives for awareness and knowledge dissemination programs	The learning process was found to be well synergized with a host of conferences, workshops, seminars and government initiatives to spread lessons and good practices through different initiatives	Yes, it is possible to recombine and make use of new knowledge. There are several opportunities to disseminate knowledge through seminars, workshops and conference and manuals largely facilitated by government.	The means of knowledge dissemination are mostly strong through strict codes and laws causing behavioural change among occupiers of dwellings.
India			
The learning process was limited to project actors and was not disseminated well.	The learning process was very fragmented and situational. No efforts made by government to synchronize learning.	The initiatives by the government were voluntary and were not enforced strictly. Hence, the learning processes were flexible, but just because of weakness (see intensity).	Government efforts were less intense to disseminate knowledge cause learning and thereby lead to behaviour change

The governance conditions for learning are rather positive in the Singapore case, with all aspects of learning covered by stakeholders providing a good coherence from government led

initiatives. Several schemes showed flexible ways of learning, and strict enforcement of these schemes made the condition intense. Whereas in India, the learning conditions were viewed by the interviewees as open ended and flexible; however, not all aspects of learning were explored, showing less coordinated efforts and less intensity due to poor enforcement by the government.

7.4.4 Market demand

As far as the demand for sustainable technologies and innovations therein is concerned in Singapore, cost effectiveness of these technologies was given high priority. Interviewees stressed low cost and high benefits to accept and readily adopt these technologies, with low payback periods. Some of the government institutes pushed technologies such as water-cooled chillers plants (which came with payback period of five to seven years) making them rather economically undesirable for consumers. The most easily adopted technology was energy efficient lighting systems, which led to high market sales, due to cost effectiveness and less operations and maintenance

Moreover, consumers were found to prefer well established technologies rather than ones that are still in the experimental stage. This was largely because consumers were reluctant to learn new knowledge about operating new unknown technologies and hence avoid adopting them. Most interviewees agreed on the risk-averse nature of the Singaporean market, in which consumers were conservative in their choices and prefer not to be the first to try out experimental, unproven technology. However, some front runners have emerged, and they largely comprise of educational institutions which are implementing new technologies as test beds. Apart from this, the BCA also issued a pilot scheme called "BREEF", which helped to counter high upfront costs of investing in new technology by underwriting some of the risks when a company wishes to take out a loan to pay for the technology. These measures were considered effective in reducing risk aversion among investors and project developers drive the demand to some extent.

A growing trend for green buildings was seen as a brand marketing and corporate social responsibility among corporate companies' offices with higher investment capital. This resulted in better knowledge of building occupants for green buildings and how to operate them.

Despite all these efforts, green buildings remained under-valued in the building market and were not sold or rented at premium, even if they were "Green Mark" certified. This would result in a lack of demand from investors. To address these and other issues, the BCA introduced a new scheme, called the "Green Mark Gross Floor Area" incentive scheme (GM GFA), in which buildings can afford increased 'GFA' on the condition that substantial energy efficiency enhancements are made. Furthermore, policy makers were in the process of integrating energy efficiency in the assessment and appreciation of buildings in the scheme, so that energy efficient buildings can attain a higher market value than conventional ones.

As far as demand for sustainable technologies in India is concerned, the situation for expensive and new green building technology was similar as was seen in Singapore. Consumers were found to be reluctant to adopt expensive technologies, despite the known benefits. From the interviewees, it was perceived that technical knowhow and operational knowledge for new technologies were less known which also resulted in low demand for such technologies. Consumers were also risk-averse and preferred technologies with low payback periods such as energy efficient lighting systems. The BEE has taken several initiatives to affect the adoption of new technologies by introducing standards and labelling programs both for technologies as well as buildings. This saw an incremental phasing out of some inefficient technologies from the market and the acceptance of new efficient technologies such as LEDS/CFLs over incandescent lamps, appliances, such as Star labelled air-conditioners.

Consumer participation and sensitization towards using new technologies were greatly missed which made end users even more reluctant to adopt and accept new technologies. Few private sector offices/ MNCs/ Hotels/shopping malls as well as construction developers were observed to adopt green building rating certifications (such as LEED/GRIHA and CSR initiatives on sustainability as brand marketing). In some states, an extra 5% Floor Area Ratio (FAR) was granted to buildings having "GRIHA" certification. These initiatives were viewed as positive for technology innovations and were found to increase market demand (but mainly by project developers).

The housing sector's participation in energy innovations was negligible, with home owners lacking sufficient motivation (due to financial implications and the lack of understanding of tangible benefits). Moreover, project developers tended to shy away from

innovations due to perceptions of 'spilt incentives'. It seems that construction companies and other actors in the building industry in India were not prepared to produce energy efficiency buildings in large numbers (Jain, Hoppe, & Bressers, 2017).

Table 17 : Assessment of market demand

Extent	Coherence	Flexibility	Intensity
Are all aspects taken into consideration to derive market demand for new technologies?	*Are all the efforts for increasing demand well synergized or coordinated?*	*Are there opportunities to combine or make use of different type of instruments to increase market uptake? Is there a Choice?*	*What is the implied behavioral deviation from current practice and how strongly does the market require and enforce this?*
Singapore			
Several initiatives are taken into consideration by the government to drive the market for sustainable technologies; however, more can be done.	Government has taken several initiatives which are well coordinated to address risk, cost, awareness, knowledge dissemination to increase the uptake of sustainable technologies.	There is flexibility for consumers to combine or choose different instruments and strategies which promote the uptake of new technologies.	Some mandatory instruments, such as sharing of energy performance of buildings, makes home owners adopt new sustainable technologies, and thereby enforce increasing market demand.
India			
Initiatives for increase of market demand are limited. More can be done.	Government instruments are fragmented and enforced by separate agencies; hence, they are not well coordinated. Risks, costs, learning, awareness and knowledge all are dealt with separately.	There is some extent of flexibility to choose between instruments to increase the adoption of new sustainable technologies. However, they are only voluntary instruments.	The instruments are not exerting enough pressure to bring behavioural change as they are mostly in voluntary stage.

For market demand, in table 17 supportive qualities of coherence and flexibility were observed in the Singapore case regarding the uptake in the industry. In the case of India, the creation of market demand was viewed as 'neutral' for initiatives taken to increase the demand

and pressure exerted to behavioural change. The context was incoherent as far as implementation of various instruments was observed. They seem to restrict rather than to support, as enforced by different ministerial authorities, unlike Singapore where BCA clearly takes the lead in such processes.

7.4.5 Shaping of expectations , problem perceptions and goal setting

In Singapore, only few green technologies were found to be popular amongst the green building industry. They include energy efficient lighting (systems) and chillers plant system (the latter due to its high energy usage). In addition, a recent uptake of solar PV panels was seen in past 2-3 years. Knowledge, awareness and popularity of these technologies show that consumers have positive expectations as far as some energy innovations are concerned in green buildings in Singapore. Despite their popularity, consumers find chillers plants and solar technologies expensive, as they exercise long payback periods. Hence, potential consumes are reluctant to adopt these technologies despite their high promises and expectations. However, these costs have reduced and have become more feasible compared to a few years ago. Additional impetus by the state government through incentives and financial instruments help in keeping up with increase in adoption of these technologies.

When looking at solar panels only, they become more feasible in Singapore when taking into account government subsidies to encourage the use of renewable energy sources. With high cost of unsubsidized electricity, more people are looking to alternative methods of energy generation. The government has subsidies for the use of solar cells and they are also looking into feed-in tariffs. Some energy companies also have enough capital to invest in the testing of solar technology. State government ongoing initiatives were seen as backbone for maintaining the expectations as promising, like e.g. Singapore government supports risk-taking technology through grant schemes like the Green Building Innovation Cluster (GBIC). The scheme provides funding for the experimentation, exhibition, and exchange of promising new energy efficiency solutions amongst industry stakeholders. This has been pushing people to try and embrace new technology. Hence, in Singapore various problem perceptions are taken into account largely by the government and hence goal setting is also defined by the government. According to the BCA, the IMCSD has set a target of "at least 80% of the buildings in Singapore

achieving the BCA "Green Mark Certified" rating by 2030" (Sang & Chong, 2015). This situation makes the shaping of expectations and goal setting as a progressive scenario.

Similarly, in India momentum for green buildings and pilot projects for NZEBs have shaped positive expectations about sustainable technologies for the building stakeholders. The adopters of green buildings and low energy buildings were found to be among highly motivated clients who were aware of the socio-economic benefits of energy innovations and new technologies in buildings. The client motivation garnered further interest among the project design and construction teams, creating a common project goal with a high visibility (drawing wider societal attention). Educational institutions were among the front runners in adopting the low energy building designs and was considered as positive. So were initiatives taken by the public sector with buildings to showcase as NZEB pilot demonstration projects for instance. This builds a strong and positive expectation from among the private sector regarding the role of government and educational institutes in initiating innovations. In this regard government initiatives through various instruments such as subsidies, incentives, feed-in-tariffs, net metering and extra FAR were seen in a positive light. However, these initiatives have not seen implementation on a large scale.

Few interviewees showed apprehension regarding the social and economic benefits of adopting green or low energy buildings (NZEBs) as energy performance of existing experiments was not widely shared, this to some extent lowered the expectations and increases scepticism as to whether buildings are performing as designed. Government supported targets were found present, but mostly for renewable energy technologies which leaves adoption of energy efficient technologies behind. Implementation and enforcement of ECBC in commercial buildings would, however, be viewed in a positive light, once it becomes a mandatory instrument.

Table 18 : Assessment for shaping expectations and goal setting

Extent	Coherence	Flexibility	Intensity
To what extent are the various problem Perspectives taken care of? What expectations does the industry hold?	*To what extent do the various goals support each other or are they in competition or conflict?*	*Are there opportunities to reassess goals?*	*How different are the goal ambitions from the status quo or business as usual?*

Singapore			
Various problem perspectives are considered while setting a level of expectation from sustainable technologies.	Various goals set by the state government support each other as they are designed and implemented by BCA alone.	As BCA follows a top down approach for design and implementation of the goals, it looks difficult for the industry to re-assess and change them. Even if government monitors the programs, involvement and input of the industry stakeholders in not included	BCA has set a highly ambitious goal for green buildings in Singapore; however, the industry is slow to respond.
India			
Various problem perspectives are considered while setting a level of expectation from sustainable technologies.	Goals seem to contradict or appear to be in competition with each other especially separate RE and EE goals.	There are opportunities to reassess the goals as the two separate ministries can combine their respective goals as one holistic NZEB policy (although initiatives were started by the BEE).	Goals are ambitious as compared to the business as usual scenario. Green buildings only represent less than 5% of the total building stock in India.

In table 18, the governance situation in Singapore was moderate for shaping expectations and goal setting, where completeness of extent and coherence showed positive signs. However, there was less flexibity to change. In India, the situation as seen as flexible to change and reassess goals and complete set of problems were assessed before setting expectations from any new technology. However, the goals seem to be in competition with each other, and there is a low level of intensity to exert any pressure for further innovations.

7.5 Discussion and conclusions

Singapore

From a governance perspective (figure 21) the overall quality of governance in Singapore on the SSIAf's quality criteria of extent, coherence, flexibility and intensity, was found to be rather positive. The situation was observed as improving vis-a-vis innovation and (large-scale) adoption of green buildings in the Singaporean building sector. By large, the formal institutions and the learning process played a crucial role in making this condition a supportive one as seen in table below with all green codes for both the components. The existing institutions (mainly BCA) and their well-defined roles and responsibilities, with sound support of financial resources from the government (through financial incentives, and subsidies) created a conducive environment that enabled actor network formation, shaping of expectations, and market demand creation to respond in a more supportive manner. It was, however, observed from the case study that actors and interactions were somewhat hampered due to lack of integrated design approach during building design and construction process. This led to fleeting interactions, a lack of coherence, difficult collaboration patterns, (making collaboration ties even less flexible), and in the end to sub-optimal design of green buildings. The push from the government in initiating interactions (through workshops and conferences) did exert some pressure on actors to interact and share project lessons. Similarly, as far as demand in the market for new sustainable technologies was concerned, a unidirectional push from the government did result in creating this demand as seen in the figure below.

	Extent	Coherence	Flexibity	Intensity
Actor networks				
Institutions				
Learning Process				
Market Demand				
Shaping expectations				

Figure 21: Singapore – quality of governance in SSIAf components

The innovation system in Singapore was found to be supportive towards fostering green buildings niche formation and for low energy buildings. The study shed light on the central role of the national government (via the BCA) in Singapore's green building innovation system. Most of the industry firms and stakeholders were largely following BCA, which took a prominent role in guiding innovations in the green building sector. Governments taking a central role is considered as favourable by many transition scholars as they claim that governments can play a defining role to transform existing systems by facilitating the process of niche formation and setting up a set of successive experiments, or by implementing particular policy instruments that support niche development, like subsidy schemes, regulatory exemptions, or programs that include pilot projects (Kemp, 1994; Schot, Hoogma *et al*, 1994; Kemp, Schot *et al*, 1998; Rip and Kemp, 1998; Smith, 2003; Weber, 2003). In line with this view some of the innovation scholars also argue that government ought to play an important role in innovation systems, and that government regulation should provide an incentive for innovation (Beerepoot & Beerepoot, 2007).

In the Singapore case study, it was observed that government, via the BCA, implemented several schemes and polices, making it the main actor which took full responsibility, with the industry and the private sector following its lead. The government was also found to govern the stakeholder network interactions (via innovation networks and innovation platforms) and setting the conditions under which green building projects could successfully operate.

These conditions also facilitated learning processes wherein both the government and the private sector were open to sharing lessons (success and failures) from their innovation projects, and disseminate information through the public domain, publishing guidebooks, conferences, and organizing workshops. Policy instruments proposed by the BCA to balance the risk of expensive new technologies, phasing out of inefficient technology, and introducing the green mark standard for rental spaces were few other initiatives. A few efforts paved the way for increased adoption rates, as well as increasing domestic market demand for sustainable technologies.

Cost effectiveness of technologies was considered important by end-users for adoption. Herein, the government took initiatives such as introducing a risk balancing instrument to

cause an increase of market demand. However, once such initiatives that are supportive in lowering risks are rolled back, there is a big risk that technology 'lock in' manifests and will slow down the market uptake, as the study revealed that Singaporean consumers were found to be rather reluctant adopting new non-tested high cost technologies. Hence, this condition could only be favourable if the government continues to provide grants and financial incentives. This reflects a system that is top down governed, in which market demand for new technologies is dependent on the government. This differs from the ideal typical phenomenon of market demand stemming from the private sector's initiatives. This situation also led to incremental innovation and hardly supports a radical innovation or creativity from the private sector companies. The same situation was also observed concerning the hopeful expectations that end-consumers have of new sustainable technologies on the pretext of the government's strict enforcement of several strategies and instruments that give end-users confidence. This is important given the risk adverse nature many of them have. However, this condition, again, depends much on government initiatives. In summary, for these reasons it can be argued that there is too much dependence of the innovation system on the government as the central actor.

Regarding this situation in Singapore, there are some contrasting viewpoints from both transition and innovation scholars. They consider this situation not solely supportive as government has to deal with system imperfections (Smith, 2006). Schot *et al.* (1994) argue that if only governments take the full responsibility niches may even fail. This view is also supported by many innovation scholars (Bartholomew, 1997) who claim that commercial firms and research institutions should typically take the lead, with the government playing only a supportive role, instead of a central one. Innovation was taking place as directed by the BCA in a more prescriptive manner with unidirectional approach, making the system favourable for incremental innovations rather than radical ones. Radical innovations, arguably, stem from a multi-directional discourse (as innovation can largely be a multi-actor process). Therefore, the sectoral system in Singapore looks rather favourable to incremental innovations. However, this condition will likely only prevail until the government decides to withdraw or terminate its polices and change some of its strategies. This will likely cause the innovation process to change, in a negative way.

In Singapore, formal institutions were well in place and well-coordinated towards initiating, designing as well as implementing various policy instruments incentivizing the industry to spur innovation. Support of risk taking technology through the GBIC, mandating the "Green Mark" scheme, phasing out of inefficient technologies, awareness raising, and knowledge dissemination programs had an impact on the end users and project developers, and arguably supported them to become more in favour of adopting green buildings technology. Having a central government agency in the BCA was also seen as a crucial factor to spur innovation. This is unlike India, where one observed formal institutions that were fragmented, and were set at distance from the central government, where separate institutions were dealing with energy efficiency and renewable energy policies, and programs making the system less favourable for the implementation of green buildings or NZEBs.

India

In the Indian case study, the quality of governance was observed to be only moderately supportive for innovation and adoption of green buildings and low energy buildings. A lack of collaboration (incoherence) was observed at each of the SSIAf elements (red codes in all the five elements in coherence) in figure 22, causing unfavourable conditions. For example, when it comes to institutions, several central and state level institutions are involved in highly fragmented manner, which makes collaboration even more difficult. The same was observed with learning process, market demand creation, and the shaping of expectations. The context was also observed to be only moderately intense as most initiatives were only voluntary having little incentives to innovate.

	Extent	Coherence	Flexibity	Intensity
Actor networks				
Institutions				
Learning Process				
Market Demand				
Shaping expectations				

Figure 22 : India – quality of governance in SSIAf components

In the Indian case study, it was observed that the sectoral innovation system was only moderately supportive towards innovation and adoption of green buildings and NZEBs. Unlike Singapore, the central government was not seen as an instrumental actor in governing transition and innovation processes. It was largely the efforts made by private sector that spurred innovation, by the Confederation of Indian Industries (CII), which introduced the first Indian Green Building rating tool as India's adoption of LEED under LEED-IGBC in 2001. Hence, the private sector took the initiative towards green buildings innovation in India which according to some transition scholars may be considered as favourable (Schot & Hoogma *et al.*, 1994). Later in 2007 the government (through MNRE) created an indigenous rating tool – GRIHA - in the country in 2007-08, launched the ECBC code for commercial buildings in 2007 and implemented some additional actions to foster its use. However, most of the efforts were only voluntary. Once more there was no single actor found to take the lead and govern the green building movement in India. The rating tools implemented enacted a rise in the Indian green buildings movement, without much government support. This, nonetheless, led to a slow uptake process. More so, niche development of NZEBs can be arguably can be considered to be rather immature (Jain, Hoppe, & Bressers, 2016).

The SSIAf analysis of the Indian case study revealed that although all important actors were present for the green buildings innovation, the level of innovation was low due to lack of single actor initiative in the process. Consequently, policy instruments, programs, actions and efforts made by the government can only be judged as moderately effective 'vis-a-vis' innovation diffusion of new sustainable technologies in green buildings and NZEBs. The study also revealed that the learning process was hampered as actors were only poorly motivated to share lessons on their projects (even more so in public sector building). This resulted in lack of expectations, low knowledge levels and little experience from the end users, and market demand creation was also a very slow process.

We consider the use of SSIAf useful in assessing the status of niche innovation of green buildings and low energy buildings in Singapore and India. The use of SSIAf enabled us to systematically analyse and assess the innovation and niche development status in both countries. In addition to using SSIAf, the study also attempted to integrate and use the GAT's four quality criteria to assess the status of governance in a particular contextual setting. We also

deemed this to be useful, as it was able to deal with limitations of SSIAf. Using GAT assessment provides us with quality of governance in terms of how supportive or obstructive the conditions are/or going to be in near future for implementation of green buildings or low energy buildings. The GAT quality assessment allowed us to give sufficient attention to the environment and the context of sectoral innovation systems and niches (geographical conditions) making it a more pragmatic tool in addition to using SSIAf.

Chapter 8: Conclusion

8.1 Introduction

This final chapter of this thesis is divided into three main subsections. The first part focuses on answering the main research question. To do so the five sub-research questions will be answered first. The second part reflects on the development and use of the theoretical frameworks in this doctoral study. This section will reflect on the usability of the integrated framework, its limitations, application challenges, and lessons learnt. Thirdly, the final section elaborates on the contribution of this doctoral study to society, and to policy makers who are working on sustainable transitions in building sectors within developing countries.

8.2 Results

8.2.1 Answering the sub-research question

In the previous seven chapters, this thesis has focused on delivering one final objective: to answer the main research question, which was,

What are the supportive and restrictive conditions for Net Zero Energy Buildings (NZEBs) niche development in the building sector in India?

To answer this question, this article-based thesis was structured as follows: The first chapter presented the general background of the thesis stating the problem and briefly introducing the theoretical frameworks which were to be used to answer the research question. This chapter also introduced the main research question, five sub-research questions, and the research approach. The second chapter entailed a literature review on the building sector in India, buildings and use of energy, green buildings in India, conceptualization of NZEBs, NZEB uptake in developed regions, and some of the barriers that prevent the wider uptake of NZEBs.

Following these introductory chapters, the thesis was divided into five research stages. The first stage concerned a conceptual challenge, which synthesized the theoretical frameworks of Strategic Niche Management (SNM), Sectoral Innovation System (SIS) and Governance Assessment Tool (GAT) into an integrated assessment framework (Sectoral System Innovation Assessment Framework –SSIAf) which could be used in empirical case study research. Chapter three helped to answer the first sub-research question, which was the first stage of this research. The second stage was presented in chapter four, in which the integrated assessment framework was empirically applied and used in a case study where NZEB demonstration projects were

evaluated and assessed to understand niche formation and the innovation process of NZEBs in India. The third and fourth research stages entailed the assessment of the governance context for NZEB niche formation in two independent regions in India, namely New Delhi and Ajmer (see chapters five and six, respectively). Two independent assessments were conducted to evaluate, map and explore governance quality, which either obstruct or support the introduction of NZEBs in the respective regions. The two regions were also compared on governance qualities. In the fifth and the final stage of this research, sectoral innovations and niche developments for green buildings and low energy buildings in India were compared to those of Singapore. The study in this chapter is an attempt to expand my study beyond the scope of a single country, in another Asian region, to develop further understanding on the applicability of the theoretical frameworks in countries with differing contextual backgrounds.

So far in previous research stage two, I integrate the two innovation approaches, but leave the GAT mostly as a complimentary approach. But in chapter 7, a step further was taken by applying the four GAT criteria to the SSIAf dimensions. The threefold integrated framework that I create that way does not replace the original GAT for other purposes, but it does add an interesting option for this kind of research.

The next section will briefly present the results of each chapter.

The first stage of this doctoral study was developed under an integrated framework entitled 'SSIAf', answering the first sub-research question in Chapter three.

1. ***What analytical assessment framework suits best to assess NZEB niche development in India?***

As commented upon in the introduction chapter, the purpose of this research stage was to explore and describe how well notions of innovations, niche development and governance could be synthesized in an integrated fashion. In doing so, I considered two theoretical frameworks relevant to system innovations and transitions (SIS and SNM) and identified complementary aspects in the two frameworks for assessing niche formation of sustainable technologies. Next, I developed an integrated assessment framework by combining those two frameworks. I called this the "Sectoral System Innovation Assessment Framework" (SSIAf). The study also addressed how governance was influential in niche developments and sectoral

innovation. This led me to compare this to SSIAf. I judged that more attention to governance was needed. Then, I looked at the GAT, to identify possibilities for the incorporation of governance aspects into SSIAf. The integrated framework which resulted from this process served as a theoretical and analytical basis for empirical research (presented in Chapter 3), starting with the assessment of NZEB niche development in India (presented in Chapter 4). In summary, this chapter contributed to both transition studies-related theory and governance-related theory by developing an integrated assessment framework that could be used to analyze innovation and diffusion of sustainable technologies, while combining insights from both disciplinary fields. For these reasons I argue that SSIAf is well equipped to assess NZEB niche development in India, to address both sectoral innovations and governance aspects.

In stage two of this doctoral research, a case study was conducted to assess the niche formation of NZEB in India using the integrated assessment framework to answer sub-research question 2 (as presented in Chapter 4).

2. *What does the SSIA framework inform us about NZEB niche formation in India?*

In this chapter, which was also published as an article in an academic journal (Jain *et. al*, 2016), the SSIAf was used to understand niche formation by analysing the conceptualization, emergence and growth of the NZEB demonstration projects in India. In the case study seven early NZEB demonstration projects were evaluated and analysed using a qualitative research approach by conducting eighteen in-depth interviews with primary and secondary actors between September 2014 to June 2015. The interview questions were based on the five components of the SSIAf.

The result showed that the NZEB innovation niche was yet to develop into a mature niche and is growing only slowly. This could be assessed from the results of the *shaping of expectations* component of the SSIAf which revealed that there were only marginal expectations of the building sector stakeholders regarding NZEB niche. The *social network formation* component revealed that new social networks were only strong within individual NZEB projects and there had been a failure to create a cohesive network with other NZEBs and with actors outside the NZEB projects resulting in a limited level of innovations.

The strength of the SSIAf was that it provided an in-depth analysis of each of the independent components of the framework despite of showing inter-dependencies between each of its components. The study also revealed that the nature of social networks determines the depth and breadth of learning processes. However, the NZEB projects tended to focus on first-order learning only (based on 'hard facts' and data, and this impeded potential niche expansion making the learning process only situational). The institutional settings and policy instruments part from government subsidies did not provide any incentives for innovation. The formal rules and regulations were not yet aligned with NZEB innovations although they were to some extent aligned well to support energy efficiency in buildings. Similarly, several barriers were observed resulting in a lack of demand for NZEBs at the building-sector level, indicating that niche formation had yet to result in sectoral change.

Stages three and four of this doctoral research assessed two independent case studies designed to evaluate the strengths and weaknesses of the governance context. This was done by using the GAT analytical framework to assess the implementation of NZEBs focusing on two regions in India, New Delhi and Ajmer. The selection of the two mentioned regions for the case study analysis was largely derived from the difference in size of the two regions, growth in demand for energy and the market for energy efficiency in buildings. The New Delhi region is a big metropolitan area in India and would serve as an interesting case to highlight certain governance aspects of the uptake of the NZEB niche and has the potential to lead and pave the way for other regions. In contrast, the Ajmer region is smaller, where concepts of energy efficiency in buildings have not yet been established with any green certified building. Hence the two contrasting regions would provide a more pragmatic understanding of NZEB niche formation in general, and more specifically the state of governance for future uptake in these regions. The two studies answer the following two research questions, and have been addressed in chapters five and six, respectively.

3. ***What is the state of governance in New Delhi regarding NZEB niche formation?***

4. ***What is the state of governance in Ajmer regarding NZEB niche formation?***

In the case study of New Delhi, which is a published as an article (Jain, Hoppe & Bressers, 2017), a stakeholder analysis was conducted to identify relevant stakeholders who are part of

the governance setting, and directly or indirectly affect the NZEB niche development process in the building sector. Data were collected among fourteen stakeholders' representatives who were interviewed between September 2015 and July 2016.

The results of the study reveal that the governance context was found to be complete in terms of extent, but rather incoherent, only moderately flexible, while intense in other areas. Hence from the 'extent' perspective the New Delhi region can be seen to be able to adopt NZEBs with a supportive context for actors and networks, problem perspectives, strategies and instruments. The aspects of incoherency are minimized in their impact on actors involved through the other qualities. In this context, actors are not incentivized to comply with policies or instruments that are not in line with the goals of an integrated NZEB adoption in a governance context. Furthermore, local level actors have high degrees of authority, flexibility to address their issues themselves (inside a given jurisdictional boundary). Hence the incoherent but flexible and intense context of the New Delhi region shows that the governance context is in a position to actively spur and manage NZEB niche development provided that supportive qualities of innovation systems are enhanced through collaborative management.

In the Ajmer case study, the governance context was highly incoherent, with a weak extent, moderate level of flexibility and weak intensity towards NZEB niche development. This situation resulted in poor governance conditions making the context less supportive towards NZEB adoption as primary elements that are badly required for implementation were missing. The existing governance qualities reflected limited governance capacity to initiate any innovation and transition of the building sector towards the uptake of more energy efficient buildings. Flexibility in terms of actor network formation, problem perceptions and policy instruments were given to lower level actors to enable them to overcome issues associated with incoherence existing in the five dimensions of governance. However, in this weak governance context, opportunities exist where the incoherence can lead to undesired (and unnoticed) defections from the intended goals. This condition can therefore be a small window of opportunity for the NZEB niche. Like for example, an incoherent actor context gives room for new actors to emerge, experiment and innovate without many restrictions, this in turn can provide opportunities for new transition insights to emerge.

In both the cases, government initiatives were largely taken through various strategies and instruments which partly supported NZEB demonstration project implementation. In the New Delhi case, existing NZEB pilots were seen to be supported by the government by showcasing public buildings as NZEBs, with increased budgets for construction. This initiative was however, not seen in the Ajmer case. In addition, the results can be used to make a holistic evaluation of how the governance context is influencing collaborative management of NZEB niche development in Ajmer and is useful when comparing the existing strengths and weaknesses of the governance context. The GAT analysis revealed a few regime barriers such as isolated sectoral policies, lack of awareness by policy actors, lack of knowledge and expertise of the NZEB concept, lack of network formation, and inadequacy in taking responsibilities among government actors. These aspects were observed in the Ajmer case study, which made the context restrictive.

The case study also revealed that network formation was completely absent to the extent that various stakeholders were only operating in isolation, as was shown in the GAT analysis by the lack of coherence, extent and intensity. However, improved levels of flexibility were positive to start the formation of an innovation network. There was a lack of knowledge, there were budget limitations, and there was a lack of resources, which proved to be serious challenges to the niche development process.

In the fifth and the final research stage, the research horizon was expanded beyond India in an attempt to apply the analytical frameworks to the Singapore building sector case, while comparing the status of sustainable innovations and governance conditions between both countries (i.e., India and Singapore). Singapore was selected based on its deviation from India in terms of its building sector characteristics, climatic conditions, and existing socio-political scenarios. Siva *et al*. (2017) found that Singapore has quite successfully addressed innovations of "green buildings" principles and succeeded in greening its built environment. This case study explores the conditions that either spur or hamper innovation, transitions and governance of "green or low energy buildings" in Singapore and thereby draws comparisons with the complex building sector in India. The comparative study was conducted to answer the following sub-research question (which was also presented in Chapter 7 of this thesis).

5. What does SSIAf tell about green buildings innovation in Singapore when compared to the building sector in India?

The results reveal that the sectoral innovation system in Singapore was generally supportive towards green building uptake with supportive governance qualities. The active role of national government – in particular by the BCA - is instrumental towards innovation and transition process for green buildings in Singapore, which is unlike the case in India. In Singapore most of the industry firms and stakeholders were largely following the BCA's green building policies and strategies. BCA also facilitated stakeholder network interactions (via innovation networks and innovation platforms). These conditions facilitated learning processes wherein both the government and the private sector were open to sharing lessons (on success and failures of green building projects) and disseminate important information. Other factors which were observed to be supportive for sectoral innovations, concerned policy instruments proposed by the BCA which paved the way for increased market demand for sustainable technologies in the Singaporean building sector.

From a governance perspective the overall quality of governance in Singapore on the SSIAf's quality criteria of extent, coherence, flexibility and intensity, were found to be rather positive, and to improving even further. By large, the formal institutions and the learning process played a crucial role in making this condition a supportive one. The existing institutions (mainly BCA) and their well-defined roles and responsibilities, with sound support of financial resources from the government (through financial incentives, and subsidies) created a conducive environment that enabled actor network formation, the shaping of expectations, and market demand creation to respond in a generally supportive manner.

In contrast, in the Indian case study, the quality of governance was observed to be only moderately supportive towards innovation and adoption of green buildings and low energy buildings. A lack of (incoherent) collaboration was observed at each of the SSIAf conceptual elements, causing unfavourable conditions in the sectoral innovation system. For example, regarding institutions, several central and state level institutions were found to be involved, and only in a highly-fragmented manner, which made collaboration even more difficult. The same was observed with the learning process, market demand creation, and the shaping of expectations. The context was also observed to be only moderately intense as most initiatives

were only voluntary and having little incentives to innovate. The same was observed for the sectoral innovation system as it was only moderately supportive toward innovation and adoption of green and low energy buildings. Moreover, unlike Singapore, the central government was not seen as an instrumental actor in governing the innovation processes.

The five research stages presented in this doctoral thesis allowed for further reflection, standardization and refinement of the assessment framework vis-a-vis different contextual settings; and thus, permitted a larger scope of analysis (niche demonstration projects, governance assessment of two regions and comparatives assessment between two countries). In general terms, the results showed that on a scale from restrictive to supportive, the qualities of extent, coherence, flexibility and intensity, in India, were mostly moderate to restrictive, with some exceptions pertaining to its local or regional specification. The SSIAf also assessed the conditions for innovations of NZEB niche formation. They were largely found to be less mature to enable a large-scale implementation or uptake of this concept. Hence, the SSIAf components revealed that the NZEB niche in India was immature and was also found to be growing only very slowly. In this context, when compared to Singapore, it was revealed that strengthening the role of the national government and improvements in institutional alignments can be instrumental in increasing the supportiveness of the existing governance, innovation as well as the conditions for sustainable transitions for NZEBs in India. However, a careful approach needs to be taken as too much of government intervention may also sometime pose risk to radical innovation as was observed in the case of Singapore.

8.3 Theoretical frameworks: lessons and limitations

This doctoral study developed a new analytical approach to transitions, innovations and governance phenomena. The study empirically applied the theoretical frameworks of SNM, SIS and GAT. All three frameworks were developed separately and have great significance in their own respective literatures on transitions, innovation and governance. Each of these frameworks has also documented their respective shortcomings which have been discussed in Chapter 3, 4 & 5. To answer the main research question of this thesis, I went beyond these frameworks and synthesized their strengths, while identifying common conceptual boundaries. I found that both SIS and SNM explain innovations phenomena under common conceptual grounds, which led to conceptualization and development of SSIAf presented in Chapter 3 of this thesis. SSIAf

was largely an integrated framework from SNM and SIS which was also compared with building blocks of the GAT. For the ease of usability of this new framework, the applicability was kept flexible which allowed the GAT to be seen as a rather independent framework. This attempt was first made when SSIAf was applied in the first case study of this thesis as presented in Chapter 4. The GAT framework was then applied in two subsequent case studies in Chapter 5 and Chapter 6, followed by an integrated SSIAf with GAT in Chapter 7 where the India and Singaporean building sectors were compared against the four quality criteria of GAT alongside using SSIAf.

Having used the SSIAf in multiple case studies, the framework is judged to be useful in assessing the status of NZEB niche innovation in the building sector in India. The integration of the SNM and SIS frameworks showed that they were complementary, and this contributed well to answering the main research question. The use of SSIAf enabled me to systematically assess the niche development process in India and probably better than doing this be using either one of the two frameworks separately. For example, while the SNM focuses on its primary components (i.e., shaping of expectations, the actor network formation and the learning process) to understand the niche formation process, it alone fails to gain insights as to which institutional alignment (formal and informal) and creation of market demand components can contribute to the niche innovation process (this component derives from the SIS framework).

Using the SNM framework alone would have overlooked opportunities that the integrated framework highlighted. Similarly, existing barriers to large-scale adoption were highlighted by including the market demand creation component in the SSIAf, which was adopted from the SIS framework, and was found to be relevant as it supports the growth of the niche. In addition to this, using the SIS framework alone would have excluded the possibility to assess the learning process of the niche projects analysed in this doctoral study, even though learning would potentially cause disturbances in existing stable regimes, which can lead to sector-level innovations. As such, the SSIAf has merits when it comes to assessing a niche innovation at the sectoral level and hence builds upon the strengths of the two frameworks mentioned previously.

Using the GAT to assess governance systems for niche development was useful in assessing the state of governance for fostering innovations in the two selected regions in India

(see Chapters 5 and 6). The SSIAf components showed similarities to some of the GAT components, namely: actor and networks, perhaps somewhat to (adjusting) 'problems and goals', and (getting access to) resources (to afford new sets of experiments) (Jain, Hoppe & Bressers, 2017). Moreover, applying the GAT as an analytical tool was useful to understand and assess the governance context in the building sector in the selected case study vis-à-vis NZEB niche development. The study was of theoretical interest as GAT allowed for assessing the governance component of niche development and sustainable innovations (i.e., NZEBs). This is rather novel since the GAT has not been used thus far to assess developments and diffusion of sustainable innovations in the built environment, and only much recently in few energy domain research projects (Siva, Hoppe & Jain, 2017). Using the GAT was useful and brought many aspects to light regarding the quality of the governance of NZEB niche development in India and Green buildings in Singapore (Chapter 7). The assessment highlighted regime challenges which were obstructing and slowing down the introduction and diffusion of NZEB innovations. At the same time the GAT helped to identify potential drivers to spur NZEB niche development. In addition, the results can be used to make a holistic ex-ante evaluation of how the governance context can influence collaborative management of the NZEB niche development process.

By using the GAT complementary to SSIAf (as presented in Chapter 7), further understanding in the quality of governance in a given context was gained with additional insight into existing institutional levels, strategies and instruments, and the resources and responsibilities available. Having had a good experience in analysing NZEB niche development and green building innovations in two distinct countries while using both approaches, I suggest that the use of both can be recommended in future niche innovation development studies, particularly those focusing on the governance and innovations of niche development. Therefore, the GAT as a qualitative assessment framework for the governance context - which can be complemented with the SSIAf approach - can potentially also be used for informed decision making by policy makers who seek to introduce sustainable innovations in both developed and developing countries.

Combining insights from the two concepts allowed for broadening the scope and furthering understanding on long term sustainable transitions, innovations in sectoral systems,

implementation of transition-oriented policies, and assessment of the role and state of 'governance' in niche development processes in sectoral systems. Furthermore, the four quality criteria mentioned in the GAT framework can be used to evaluate the niche development process with respect to the five components of SSIAf. For example, actor interactions, expectations, and learning processes can all be evaluated as per the four quality criteria (extent, coherence, flexibility and intensity) to understand overlap with the GAT framework (as was presented in Chapter 7). It will be interesting to augment understanding of the governance context of niche development and sustainable innovations (like NZEBs) through conducting more empirical cases that are also analyzed using the GAT. It is important to emphasize that the GAT has an institutional perspective, as it includes contextual considerations and it is an integral but not necessarily an interdisciplinary approach. The GAT has been created by social scientists and environmental policy scholars with inputs from practitioners and various stakeholders. It is still under development and requires refinement (Casiano, 2017). My doctoral study makes some important revelations. It shows the GAT's value to assess developing country cases and to further develop operationalization of the GAT variables.

8.3.1 Limitations and recommendations for future research

In addition to the above-mentioned strengths of the new frameworks, some limitations must be addressed which were noticed while conducting the four case studies.

- First, the SSIAf analysis was found to have a rather low dynamic nature and to be a rather static framework. It provided room for analysis as a 'snapshot' in time rather than a set of sequential historical or ongoing events. Therefore, I recommend further research that can focus on making this framework more dynamic and assessing the notions of ongoing events in a given economic sector.
- Second, the SSIAf assumes a form of developed niche formation, whereas the NZEB case study of India showed that niche development was basically in a state of 'pre-development' (Raven, Strategic Niche Management for Biomass: Phd Thesis, 2005) or rather a premature niche. Further research needs to be conducted to be able to identify and discern various niche development processes with set criteria that apply to certain stages of niche development, ranging from early to mature niches.

- Third, the focus on the economic sector and the status quo rather led to neglecting the multi-level character of the niche formation process (concepts and processes that are appreciated by the frameworks of Markard and Truffer, 2008; Weber and Rohracher, 2012; and Meelen and Farla, 2013). This limitation could possibly be resolved by adopting notions from these frameworks. Indeed, this doctoral study only focused on niches and regimes, and their inter-dynamics, while neglecting landscape level events.
- Fourth, to some extent the SSIAf gives insufficient attention to the environment and the context of sectoral innovation systems and niches (geographical conditions) like giving attention to contextual setting (e.g., Bressers et al.,2002), which to a good extent was overcome by synthesizing it with the GAT (see Chapter 7). Further empirical research is needed to study and overcome the limitations of contextual settings.
- Fifth, the SSIAf does not have a strong policy orientation and gives less attention to politics (in line with Hoppe et al., 2016). In its current form, the SSIAf is basically a heuristic tool − as other IS approaches − to assess a given innovation system and niche market formation (such as here, NZEBs) on its inherent capability and capacity to spur and successfully diffuse the given innovation and generate a wider market uptake. However, a further conceptual enhancement can be explored in future research.
- Sixth, the five theoretical components of SSIAf do not have different weightings when analysing niche formation; i.e. in early niche development, market demand creation probably deserves a lower weighing than learning about technological performance and side effects of a given technology. Thus, further conceptual development of the framework should assign different weightings to the theoretical components depending on the stage that niche formation is in; e.g., differentiating between pre-development stage, early development stage, late development stage and 'breakthrough' stage.
- Seventh, the SSIAf framework assumes focusing on a single niche, whereas focusing on a given economic sector should allow for a more holistic view specially to analyse sustainable innovations in/of given economic sector, and therefore the identification of multiple niches within an economic sector can be explored in future research.

8.4 Societal Relevance

This doctoral study can greatly contribute to the society by providing a sound platform for policy making bodies (such as governments) in suggesting an analytical framework that can be

used to facilitate and guide sustainable innovation process in desired directions. The results of this study reveal the usability of the framework proposed in this thesis, with its existing limitations as well as its flexible character. The flexibility in using this framework for NZEB niche development highlights some important aspects.

The society (to a large extent building end users) can get a pragmatic understanding of transitions in progress and sustainable innovation processes. This gives an important impetus to stakeholders such as NGOs, academic institutions as well as community groups to enhance and further sustainable innovation agendas. The results of this doctoral study can be used as a foundation to further explore the impact of the niche development process and innovations using the newly developed frameworks. First, making (policy) suggestions to policy makers in India to foster NZEB niche development, and second, addressing the issue of sustainable transitions (and niche development of sustainable energy innovations) in developing countries.

The frameworks can be well applied to assess the niche formation and innovation process of new sustainable technologies or concepts such as NZEBs in society as well as for policy making. It is worthwhile to note that governments, policy makers, as well as NGOs can find this research useful in assessing the stage of niche development and thereby proposing and developing strategies. Like GAT identifies weak spots in the governance context that could guide where to aim additional policies at, and to 'repair' those weak spots. When doing so, the results of this study can be used as benchmarks for the niche in development stages and can provide insights for future action by transforming it into a policy making tool (with set standard criteria for assessment of any given situation in transition). To do so, participation of government in initiating sustainable transitions and innovations and policy makers can be instrumental in making the framework more robust and applicable.

Stakeholder participation is currently the most discussed topic in transition, innovation as well as governance literature (Bergek et.al. 2015; Casiano, 2017; Siva et.al. 2017). Engagement of a larger group of stakeholders (i.e. completeness in extent of actors in GAT) will enhance the implementation process or will lead to furthering the complexities that come with diverse and complex building sectors such as in case of India. This research contributes to this debate and it also brings unanswered questions. The topic still requires further exploration; in this sense this

study should only be seen as a first step of a long research journey and also in developing societal relevance and policy implications.

This doctoral study can also provide additional insights to sustainable innovations in other developing countries where the assessment framework can provide understanding of gaps in the transition process and in the state of governance. These empirically tested frameworks can be applied or further developed as per local context to frame and design strategies and polices for a desired sustainable innovation process in building sector. This also leaves room for further exploration of the framework in sectors other than buildings and how would they respond to for e.g. transition, innovation and governance for zero emissions transport sector for instance.

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Annexure i

Table 19 : Integrated Assessment Framework (Sectoral System Innovation Framework-SSIAf)

Shaping of Expectation – (Shared visions, expectations based on tangible results)
Q1. Which factors led to the development of NZEB pilot and demonstration projects? (Motivations, expectations, govt. support etc.) Q2. What were your expectations from the NZEB project? Are these expectations shared among the group of niche actors? Q3. Are niche actors satisfied with the results of the NZEB demonstration projects; do they think NZEB expectations are realistic, or should they be modified? Q4. What is the role of government in articulating a vision for NZEBs? (e.g. NZEB -2030, support for NZEB pilot project protection)
Actor networks and interactions – (broad social network, formal and informal interactions)
Q 5. Is a wide range of relevant actors involved in the pilot demonstration project, and is the group diverse? How does this actor-network appear? (members, size of network). Who is the key actor (in influencing decision-making)? Q6. How often do niche network interactions/meetings take place? How is the niche network managed and by whom? Q7. Is there a network platform on NZEB niche development? (e.g. an NZEB alliance or consortium) Q8. How are NZEB niche actor interactions facilitated by the government?
Institutions (formal: rules, laws, regulations, sectoral polices, monitoring and sanctioning etc.; informal: common habits, routines, established practices, laws and standards, responsibilities, obligations, beliefs etc.)
Q9. To what extent are rules, regulations, policies and monitoring aligned with NZEB niche development? Q 10. What is the role of national and regional governments in providing protection to the NZEB demonstration projects? (subsidies, tax rebates, financial incentives, co-financing etc.) Q11. How do informal institutions (such as common habits, beliefs, standards, established practices) support the NZEB niche development process?
Learning Process (Technical and knowledge, Techno-economic optimization, Technical/social alignment (user preferences, regulations, cultural meaning), Environmental impact, Reflexive self-governance (i.e. the flexibility to change course)
Q 12. Have NZEB pilot demonstrations been successful in making the technical, economic and environmental feasibility of NZEBs explicit? (clear definition, standards, cost benefits, sound outcome indicators etc.)

Q13. How has the newly acquired knowledge on NZEB been disseminated among the various stakeholders including end-users (e.g. NZEB web portal, magazine articles, open days, newspapers, public media) and how is knowledge exchange managed in the niche actor network?
Q14. Have user preferences or user involvement been given importance in the project's progress? Are end-users aware of specific aspects of occupying NZEBs that directly influence their comfort? (Metering, smart metering, mechanisms for energy saving, expertise on automated systems, guidance, manuals, user-behaviour etc.)
Q 15. Did niche actors illustrate explicit reflexive learning in experimenting with pilot projects (e.g. monitoring the niche development)? Did it proceed according to the plan, and if not, was the experimentation strategy revised? Did they critically reflect on their role and the way they do things in designing and constructing NZEB demonstration projects?
Market Demand - (requirements and preferences, market structure, size and segmentation)
Q16. To what extent were end-users (and NZEB clients) satisfied with the results of NZEB pilot projects?
Q 17. What are the main barriers to developing a market demand for NZEBs? How is the creation of a market demand expressed in NZEB demonstration projects? In what ways is the creation of a market demand reflected? (e.g., awareness-raising campaigns, advertisements, marketing strategies, field trips for potential users to demonstration project sites).

Table 20 : Case study questionnaire for sector-level actors outside the NZEB niche

Shaping of Expectations - (shared visions, expectations based on tangible results)
Q1. What are the expectations of the regime actors regarding NZEB niche development? (positive or negative + argumentation) Q2. Have these expectations changed after NZEB pilot demonstration projects have been successful? (positive or negative and why) Q3. Has government support (funding, incentives etc.) to NZEB demonstration projects influenced the expectations of the regime actors?
Actor networks and interactions – (broad social network, formal and informal interactions)
Q4. What is the level of formal and informal interactions between niche and regime actors over NZEBs? (High or low – through conferences, workshops etc.) Q5. Which barriers do regime networks impose on NZEB niche development?
Institutions (formal: rules, laws, regulations, sectoral polices, monitoring and sanctioning etc.; informal: common habits, routines, established practice, laws and standards, responsibilities, obligations, beliefs etc.)
Q6. What key sectoral policies and regulations target NZEBs? (e.g. ECBC code development, energy efficiency finance, building regulations) Q7. How stringent or flexible are the formal institutions towards NZEB niche development?
Learning Process (Technical and knowledge, Techno-economic optimization, Technical/social alignment (user preferences, regulations, cultural meaning), Environmental impact, Reflexive self-governance (i.e. the flexibility to change course)
Q8. Are regime actors learning from demonstration projects about major regime barriers preventing niche development? (sectoral policies, regulations, user preferences, cultural values, infrastructure, etc.) Q9. What is the role of educational institutions in building technical and knowledge development regarding NZEBs?
Market Demand - (Requirements and preferences, market structure, size and segmentation)
Q10. What reasons can be identified for the low current market demand for NZEBs? Q 11. What characteristics of the building market go against increasing the market demand for NZEBs?

Annexure ii

Table 21 : GAT Questionnaire - Case study 2 ,3

Governance Dimension	**Quality of the governance regime**
Levels and scales	Extent: How many administrative levels are involved and dealing with NZEBs? Are there any important gaps or missing levels? Coherence: Do these govt. bodies work together and do they trust each? To what degree is the mutual dependence among levels recognised? Flexibility: Is it possible to move up and down levels (up scaling and downscaling) given the issue at stake? Intensity: Is there a strong impact from a certain government level on NZEB niche development (e.g. on learning, networking, more pilot projects, scaling up of NZEB best practices.
Actors and Networks	Extent: Are all relevant stakeholders involved? Are there any stakeholders not involved or even excluded? Coherence: What is the strength of interactions between stakeholders? In what ways are these interactions institutionalised in stable structures? Do the stakeholders have experience in working together? Do they trust and respect each other? Flexibility: Is it possible that new actors are included or even that the lead shifts from one actor to another when there are pragmatic reasons for this? Do the actors share in 'social capital' allowing them to support each other's tasks? Intensity: Is there a strong pressure from an actor or actor coalition towards stimulation of NZEB niche development
Problem perspectives and goal ambitions	Extent: To what extent are various problem perspectives taken into account? Coherence: To what extent do the various perspectives and goals support each other, or are they in competition or conflict? Flexibility: Are there opportunities to re-assess goals? Can multiple goals be optimized in package deals? Intensity: How different are the goal ambitions from the status quo or

	business as usual?
Strategies and instruments	Extent: What types of instruments are included in the policy strategy? Are there any excluded types? Are monitoring and enforcement instruments included? Coherence: To what extent is the incentive system based on synergy? Are trade-offs in cost benefits and distributional effects considered? Are there any overlaps or conflicts of incentives created by the included policy instruments? Flexibility: Are there opportunities to combine or make use of different types of instruments? Is there a choice? Intensity: What is the implied behavioural deviation from current practice and how strongly do the instruments require and enforce this?
Responsibility-ties and resources (implementation)	Extent: Are all responsibilities clearly assigned and facilitated with resources? Coherence: To what extent do the assigned responsibilities create competence struggles or cooperation within or across institutions? Are they considered legitimate by the main stakeholders? Flexibility: To what extent is it possible to pool the assigned responsibilities and resources if accountability and transparency are not compromised? Intensity: Is the amount of allocated resources sufficient to implement the measures needed for the intended change?

SUMMARY

Among the developing nations, India's economic growth is accelerating at fast pace, causing the demand for energy to increase manifolds. Economic growth also leads to an increased demand for buildings in cities which accounts up to 40% of the total energy consumption in the country. The current energy infrastructure is poor and incapable of coping with this exponential increase in demand for buildings and energy requirements. For these reasons, it is imperative for the Indian building sector that projected energy growth is managed in a feasible and a more sustainable manner. To cope with this, there seems to be an urgent need to design and implement policy instruments, and governance mechanisms that influence key systemic conditions to overcome barriers that are essential in the transition of the building sector towards low energy or low carbon energy systems, and towards near zero energy goals. Currently, green buildings account for less than 5% of the current building stock in the country. Green buildings with the highest energy efficiency level are now being projected as 'near' or 'net zero energy buildings' (NZEB) in the western world. They use renewable energy for energy production. NZEBs are buildings with an extremely low energy demand, and in which the remaining energy demand is met by on site renewable energy.

This doctoral study starts from exploring key theoretical frameworks which deem suitable to assess sustainability transitions, sustainable innovations and governance conditions needed for radical transformations and structural change towards large uptake of NZEBs in India's building sector. These theoretical frameworks include Strategic niche management, Sectoral innovation systems and Governance assessment tool. The doctoral study answers the main research question "***What are the supportive and restrictive conditions for Net Zero Energy Buildings (NZEBs) niche development in the building sector in India?*** Consequently, this article-based research starts with analyses of the integration of these theoretical frameworks and develops a new integrated assessment framework called as *"Sectoral System Innovation Assessment framework"* (SSIAf). Three empirical case studies were selected to explore the applicability of the integrated framework to assess the niche development of NZEBs in India from innovation, transitions and governance perspective. Data collection involved 40 semi-structured in-depth interviews with key stakeholders in India and also collection of written documents, site visits, and participation in workshops and meetings. The main conclusions

were that the NZEB innovation niche was yet to develop into a mature niche and is growing only slowly. This could be assessed from the results of the *shaping of expectations* component of the SSIAf framework which revealed that there were only marginal expectations of the building sector stakeholders regarding NZEB niche. The *social network formation* component revealed that new social networks were only strong within individual NZEB projects and there had been a failure to create a cohesive network with other NZEBs and with actors outside the NZEB projects resulting in a limited level of innovations. From governance perspective, the study revealed that the governance context in New Delhi region was found to be complete in terms of extent, but rather incoherent, only moderately flexible, while fairly intense in other areas. Hence from the 'extent' perspective the New Delhi region can be seen to be in a position to adopt NZEBs with a supportive context for actors and networks, problem perspectives, strategies and instruments. On the contrary, in the Ajmer case study, the governance context was considered to be highly incoherent, with a weak extent, moderate level of flexibility and weak intensity towards NZEB niche development. This situation resulted in poor governance conditions making the context less supportive towards NZEB adoption as primary elements that are badly required for implementation were missing. The existing governance qualities reflected limited governance capacity to initiate any innovation and transition of the building sector towards the uptake of more energy efficient buildings in the selected case.

In addition to the case studies conducted in India, innovations of green buildings in Singapore were analysed and compared to the situation in India. The case study integrated SSIAf and GAT to analyse and draw comparisons to the cases in India. The results reveal that the sectoral innovation system in Singapore was generally supportive towards green building uptake with supportive governance qualities. The active role of national government – in particular by the BCA – could be seen as instrumental towards innovation and transition process for green buildings in Singapore, which is unlike the case in India. From a governance perspective the overall quality of governance in Singapore on the SSIAf's quality criteria of extent, coherence, flexibility and intensity, were found to be rather positive, and to improving even further. In contrast, in the Indian case study, the quality of governance was observed to be only moderately supportive towards innovation and adoption of green buildings and low energy buildings. The five research stages presented in this doctoral thesis allowed for further reflection, standardization and refinement of the assessment framework vis-a-vis different

contextual settings; and thus, permitted a larger scope of analysis (niche demonstration projects, governance assessment of two regions and comparatives assessment between two countries).

SAMENVATTING

Te midden van de andere ontwikkelingslanden versnelt de economische groei van India zich voortdurend en veroorzaakt daarmee een verveelvoudiging van de vraag naar energie. De economische groei leidt ook tot meer vraag naar gebouwen in de steden, die al zo'n 40% van het totale energieverbruik van het land veroorzaken. De huidige energie-infrastructuur is zwak en niet in staat om te voldoen aan de exponentieel groeiende vraag naar gebouwen en hun energiebehoeften. Om deze redenen is het nodig dat de Indiase bouwsector op een haalbare en meer duurzame manier met de voorziene energiebehoefte omgaat. Om dit te bereiken, is er een urgente behoefte aan het ontwerpen en implementeren van beleidsinstrumenten en sturingsmechanismen die de wezenlijke systeemvoorwaarden beïnvloeden om zo de barrières te slechten die de transitie van de bouwsector in de richting van laag energetische en koolstofarme systemen en uiteindelijk nagenoeg nul energievraag in de weg zitten. Op dit moment zijn groene gebouwen nog slechts 5% van de bestaande bouw in het land. De groene gebouwen met het hoogste energie efficiëntie niveau worden nu in de westerse wereld "net" of "near zero energy buildings" (afgekort tot NZEB's; 'nulenergiegebouwen' in het Nederlands) genoemd. Dit zijn gebouwen met een extreem laag energieverbruik waar in de resterende vraag met hernieuwbare energie wordt voorzien.

Dit promotieonderzoek startte met het verkennen van theoretische raamwerken die geschikt lijken voor onderzoek naar transities naar duurzaamheid, duurzame innovaties en de benodigde sturingscondities die nodig zijn voor radicale transformaties en structurele veranderingen in de richting van een brede marktopname van NZEB's in de bouwsector van India. Deze theoretische raamwerken omvatten Strategisch Niche Management (SNM), Sectorale Innovatie Systemen (SIS) en de Governance Assessment Tool (GAT). In lijn hiermee startte dit op artikelen gebaseerde onderzoek met het analyseren van de mogelijkheden tot integratie van deze theoretische raamwerken en het ontwikkelen van een nieuw geïntegreerd beoordelingskader, "Sectoral System Innovation Assessment framework" (SSIAf) genaamd. Drie empirische cases werden geselecteerd om de toepasbaarheid van het geïntegreerde raamwerk te onderzoeken bij het beoordelen van de niche-ontwikkeling van NZEB's vanuit een innovatie-, transitie- en governance-perspectief. In India omvatte de gegevensverzameling onder meer 40 semigestructureerde diepte-interviews met sleutelfiguren. De belangrijkste

conclusies waren dat de NZEB-innovatieniche zich nog verder moest ontwikkelen tot een volwaardige niche, en maar langzaam groeit. Dit kon worden afgeleid uit de component van het *scheppen van verwachtingen* uit het SSIA-raamwerk, die liet zien dat er slechts marginale verwachtingen onder de sleutelfiguren in de bouwsector bestaan wat betreft de ontwikkeling van de NZEB-niche. De component *sociale netwerkvorming* liet zien dat de sociale netwerken alleen sterk waren binnen individuele NZEB-projecten en dat het mislukt was om een samenhangend netwerk te scheppen met andere NZEB-projecten en met actoren buiten de NZEB-projecten, hetgeen resulteerde in een beperkt innovatieniveau. Vanuit een governance-perspectief liet de studie zien dat de governance-context in New Dehli weliswaar compleet was in termen van omvattendheid, maar nogal onsamenhangend, slechts gematigd flexibel, maar tamelijk intensief in andere opzichten. Vanuit het perspectief van *omvattendheid* kan de New Delhi-regio worden gezien als in een positie om NZEB's te ontwikkelen, met een ondersteunende context voor actoren en netwerken, probleempercepties, strategieën en instrumenten. In de Ajmer-casestudie werd daarentegen de governance-context beoordeeld als zeer onsamenhangend, met een zwakke mate van omvattendheid, een gematigd niveau van flexibiliteit en een zwakke intensiteit in de richting van de ontwikkeling van de NZEB-niche. Deze situatie resulteerde in zwakke governance-condities die de context minder ondersteunend maken voor de ontwikkeling van NZEB's, omdat wezenlijke elementen die hard nodig zijn voor implementatie worden gemist. De bestaande governance-kwaliteiten geven een beeld van een beperkte governance-capaciteit om wat voor innovatie dan ook op te starten. Dit geldt in het bijzonder voor de transitie van de bouwsector in de richting van meer energie-efficiënte gebouwen in de Ajmer-regio.

Naast de casestudies in India, is ook een vergelijking gemaakt met de energietransitie en innovaties van groene gebouwen in Singapore. Deze casestudie gebruikte een geïntegreerde versie van SSIAf en de GAT om deze te analyseren en te vergelijken met de cases uit India. De resultaten laten zien dat het sectorale innovatiesysteem in Singapore in het algemeen ondersteunend was voor de nicheontwikkeling en marktopname van groene gebouwen, met ondersteunende governance-kwaliteiten. De actieve rol van de nationale regering – in het bijzonder de Building Construction Authority (BCA) – wordt als instrumenteel gezien voor de innovatie en het transitieproces naar groene gebouwen in Singapore, wat verschilt van de situatie in India. Vanuit een governance-perspectief werd de algemene kwaliteit van de

governance in Singapore voor wat betreft de op de SSIAf-componenten toegepaste kwaliteitscriteria van omvattendheid, samenhang, flexibiliteit en intensiteit, als tamelijk positief gezien. Bovendien bleken zij zich nog verder te verbeteren. In India, daarentegen, werd de governance-kwaliteit slechts als matig ondersteunend voor innovatie en de verspreiding van groene en laag-energetische gebouwen gezien.

De vijf stappen van het onderzoek dat in dit proefschrift is gepresenteerd, vormen een basis voor verdere reflectie, standaardisatie en verfijning van het beoordelingskader voor verscheidene contextuele situaties. Daarmee maken ze een bredere reikwijdte van analyse mogelijk die ook nichedemonstatieprojecten, de governance-beoordeling van twee regio's en een vergelijkende beoordeling van twee landen omvat.

About the Author

Mansi Jain was born and raised in Ajmer, India. She has lived and studied in India, England and the Netherlands. She obtained her Masters in Construction Economics and Management from University College London, United Kingdom. She studied for bachelor's program in Architecture at Malviya National Institute of Technology, Jaipur, India.

In her professional work, Mansi has provided policy advocacy and consulting to government institutions, municipal bodies and various stakeholders. She has participated and coordinated range of advocacy projects which include energy efficiency in buildings, uptake of net zero energy buildings , smart cities, energy access of marginalized communities, energy- gender nexus, and GHG emission accounting of cities. She has also tutored research students in the Netherlands and India. Mansi has participated as an active speaker in several international sustainability transition conferences in countries such as the Netherlands, Germany, United Kingdom, Indonesia and in India.

Mansi has research interests in sustainable transitions, sustainable innovations and governance for low or zero energy buildings both in developed and developing regions. In her career, she would like to work both in academia and in policy advocacy supporting governments to achieve long term sustainable transition goals.

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