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Assessing governance of low energy green building innovation in the building sector: Insights from Singapore and Delhi

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ABSTRACT

This paper explores the governance of sectoral innovation and niche formation of green buildings and other low energy buildings (like NZEBs). Two analytical frameworks are used and synthesized: the Sectoral Systems Innovation Assessment framework (SSIAf) and the Governance Assessment Tool (GAT). The key components of the former are: shaping of expectations, actor network formation, institutions, learning process, and stimulating market demand. The SSIAf components are then assessed against the four quality criterions of the GAT framework, i.e. extent, coherence, flexibility, and intensity. The research design presented in this paper applies the analytical framework developed to case studies of two cities: Singapore and Delhi. Data collection involved participant observation and expert interviews. The results of the study reveal that the overall governance conditions in Singapore are fairly strong and highly supported by the government, unlike Delhi where governance quality was found to lack coherence and intensity, and can be considered only moderately supportive to green building innovations. The results also reveal the role of government actors in steering the energy transformation process in building sector. The analytical framework developed in this paper can be further elaborated, also as a potential policy tool to support cities in managing energy system innovations like energy infrastructures, smart grids or community energy storage in diverse and complex urban settings.

1. Introduction

Strong economic growth and expanding population in developing non-OECD nations[1] is resulting in an exponential rise in energy demand (IEA I.E, 2013). In these nations, urban energy systems are attracting increasing attention owing to the challenges as current decisions will lock in emissions, thereby strongly influencing a city's ability to pursue a sustainable future (Corfee-Morlot, 2009). Consumption of energy in the building sector in cities is expected to grow by 2.1% annually from 2012 to 2040, which comprises nearly three times the growth rate of OECD nations (IEA I.E, 2013). In coping with this increasing energy demand, it is important – in particular for fast growing cities - to manage their expected energy growth in a feasible and a sustainable manner. There is a pressing need to find innovative solutions in the built environment which is considered as the sector using the largest amount of energy in urban regions. For instance, by using more innovative technologies, energetically efficient and ecologically supported construction materials and methods (Svajlenka and Kozlovska, 2018).

This calls for a transition to low energy consuming buildings like the new concept of near or net zero energy buildings, which currently draws a lot of attention in many developed nations (EU Commission, 2016). Attention to this type of buildings is also required in developing and fast growing urban areas. Ways to do this pertain to the introduction of policies and environmental regulations to push the supply of low energy buildings, targeting the introduction of new sustainable technologies and their uptake, energy efficiency in building design and the integration of renewable energy technology (IEA I.E, 2013). This paper seeks to analyse governance support systems for green buildings and other low energy buildings (such as Net Zero Energy Buildings; NZEBs) in the highly developed urban region of Singapore and the fast growing city-state of Delhi (in India). The objective of this paper is to provide a deeper understanding of diverse governance arrangements supporting energy innovations and adoption of energy efficient buildings and NZEBs, contributing towards a transition of sustainable urban energy systems. In using a qualitative case study research approach the present study contributes to the research domain of low energy build-

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ing innovation in which in-depth qualitative studies are rare (Kivimaa and Martiskainen, 2018).

Whereas the 'green buildings' movement in Singapore is already in a fairly advanced stage (Siva et al., 2017), in Delhi the growth and innovation of such low energy or NZEBs is still maturing (Jain et al., 2017b, 2017a). The present study attempts to explore governance conditions that can support or restrict energy innovations for large scale adoption of green buildings or NZEBs, in seemingly diverse urban settings. Two research questions are central to this paper: a.) *What analytical framework works well to assess the governance of energy innovations and transitions in cities?; and b) What lessons can be learned from Singapore as frontrunner in green building transitions using the analytical framework*? The main objective of this paper is to advance understanding on analytical approaches to assess governance of sustainable innovations in cities. We hypothesize that government plays an instrumental and driving force in governing sustainability transitions and green innovations in the buildings sector.

The paper is structured as follows: Section 2 provides an overview of green buildings, energy efficient buildings and NZEBs. Section 3 presents the analytical approach that will be used for understanding governance for energy innovations in the selected cities. In Section 4 the research methods used are addressed. Section 5 presents the case study descriptions of Singapore and Delhi. In section 6 the results of the analysis are presented. And finally, in section 7 the conclusions are presented and discussed.

2. Green buildings and NZEBs

Buildings account for 30% of global energy-related carbon emissions (Urge-Vorsatz, 2012). Several countries are now innovating and searching for effective ways to reduce these detrimental environmental effects from buildings. The green building concept can contribute to this. *They increase the efficiency of resource use in buildings regarding energy, water, materials and waste during both the construction and the operation phase. This is ideally achieved through improved site planning, design, construction, operation and maintenance as well as in retrofits, i.e. focusing on the complete life cycle.* Green buildings can be defined as, "… healthy facilities designed and built in a resource-efficient manner, using ecologically based principles" (Kibert, 2008) (p.9). *They aim to optimize the use of energy by incorporating various passive design strategies, energy efficient construction materials and equipment, operation and maintenance resulting in reduced energy loads compared to the conventional building design* (Mamta, 2015).

Certification schemes such as LEED (US) and BREEAM (UK) have been developed in various parts of the world to assess and rate green buildings (Zhao, 2014). The schemes - which are voluntary in most countries – assess on different criterions of sustainability for building design, construction as well as operation. These rating tools mostly differ taking account of different climatological conditions or the types of buildings assessed (such as hotels, hospitals, commercial or residential buildings).

In addition to scaling up of green buildings across the world, the new concepts of low, near or net zero energy buildings have found recognition through several successfully demonstrated projects. The research community views them as long-term solutions to the rising environmental effects from buildings globally (Hermelink et al., 2013a,b). NZEBs are commonly understood as buildings with extremely low energy demand where the remaining demand is met by integration of renewable energy technologies, accounted for over a year. Torcellini et al. (2006), define NZEBs as, *"residential or commercial buildings 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: reducing energy demand as far as possible, and applying renewable power generated on the property or purchased on the market (Marszal and Heiselberg, 2009). NZEB approaches can differ between nations depending on climate, resources for (green) electricity in the grid, and heating and cooling grid infrastructures (Hermelink et al., 2013a,b).

3. Analytical framework - SSIA framework and Governance Assessment Tool

In this paper the Sectoral Systems Innovation Assessment framework (SSIAf) is used as analytical framework along with the Governance Assessment Tool (GAT). SSIAf is based on two distinct research traditions. The first entails (i) Strategic Niche Management (SNM), and the second (ii) Sectoral Innovation Systems (SIS). The two present alternative perspectives on how processes of innovation and socio-technical transformation generally develop (Jain et al., 2014).

SNM is an analytical framework designed to facilitate and study the introduction and diffusion of new sustainable technologies through societal experiments (Schot and Geels, 2008). The concept of SNM was introduced by the late 1990s as a theoretical framework and potential policy tool to manage technological innovations, and to facilitate the market introduction of sustainable technologies (Schot and Geels, 2008). The theoretical background of SNM draws on insights from constructivist science and technology studies (such as Constructive Technology Assessment; CTA) and evolutionary economics as developed by Nelson and Winter (1982) and Dosi and Brighton (1982). SNM refers to the process of deliberately managing niche formation processes through real-life experiments. It is also argued that, in order to understand innovation activities at the niche level, it is important to understand sector-level innovations through a lens that highlights sectoral innovation systems (Weber and Hoogma, 1998).

The SIS literature, pays attention to how the characteristics of an economic sector determine the scope of innovation (Beerepoot and Beerepoot, 2007). Within SIS, the core building blocks are: knowledge and technology, actor and networks, and institutions (Malerba, 2004a,b). Faber and Hoppe (2012) elaborated the SIS framework and used it to assess sustainable energy transitions in the Dutch construction sector. In their view, SIS contain building blocks pertaining to 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).

3.1. Sectoral System Innovation Assessment Framework

Based on conceptual overlap between SNM and SIS an attempt was made to compare and integrate the conceptual elements of SNM and SIS together into single a conceptual framework, entitled the *Sectoral System Innovation Assessment Framework (*Jain et al., 2014*)*. The main components of the integrated SSIA framework are its five building blocks: (i) *shaping of expectations; (ii) actor networks; (iii) institutions; (iv) learning process; and (v) market demand creation* (Jain et al., 2017b, 2017a). They can be seen as independent variables explaining for sectoral niche formation as innovation process. In Table 1, an overview is given of the key conceptual components of SSIAf. For each component (or cluster of components) the key conceptual items are presented (See Table 1).

3.2. The Governance Assessment Tool

The Governance Assessment Tool (GAT) concerns a framework that helps to analyse the quality of governance in a given context, or identification of barriers to the implementation of a given policy. The conceptual basis of the tool consists of a collection of insights on gover-

[1] Outside the Organization for Economic Cooperation and Development.

Table 1
Overview of the conceptual components of the SSIAf (adapted from (Jain et al., 2017).

Shaping of expectations	a. Shared visions and expectations (converging into shared visions for niche development). b. Expectations based on tangible results from (social) experiments. c. Expectations based on tangible results from niche experiments.
Actor network formation	a. Size of the sectoral actor network (including both primary agents and secondary agents, and both regime insiders and regime outsiders). b. Extent of formal and informal interactions.
Institutional alignment	a. Formal institutions (e.g., rules, laws, regulations). b. Informal institutions (e.g., values, responsibilities).
Learning process	a. Broad learning (e.g., on techno-economic optimization, technical and social alignment). b. Reflexive, self-governance. c. First- and second-order learning.
Market demand creation	a. Requirements and preferences. b. Heterogeneity. c. The role of niche markets. d. Market structure, size and segmentation.

nance, and has a background in the Contextual Interaction Theory (Boer and Bressers, 2011). This theory should be seen as a third generation policy implementation theory where implementation is not only viewed as a top-down process but as multi-actor interaction process influenced by the actors who are involved (also in a bottom-up way). In turn, the GAT also sheds light on multi-actor, multi-level situations that influence the implementation of policies and projects under complex and dynamic conditions (Boer and Bressers, 2011). These situations are typically also found in projects and social experiments within socio-technical niches. For this reason, we argue that it is of interest to incorporate the GAT into niche development analysis to deepen the understanding of transitions while taking the complex governance context into account. The GAT uses five dimensions to assess the governance conditions, that correspond (i.e., show similarities) with the five components of SSIAf. They are: (i) *levels, (ii)actors and their networks, (iii)perception of the problem and objectives, (iv) strategies and instruments, and (v) resources and organization of (policy or project) implementation.*

To assess the appropriateness or quality of a governance system, the five dimensions mentioned previously are complemented by four quality criteria of the GAT to assess tsuitability. They include: *extent, coherence, flexibility and intensity (*Bressers et al., 2016*)*. These qualitative indicators can be used to assess to what extent the governance context is supportive or restrictive for the policy process. They can generally be understood by posing the following four questions (Bressers et al., 2013):

a) *Extent*: Are all relevant aspects taken into account? Is the scope complete?
b) *Coherence:* Are the elements of the dimensions of governance reinforcing rather than contradicting each other?
c) *Flexibility*: Are multiple pathways to reaching the goals, depending on opportunities and threats as they arise, permitted and/or supported?
d) *Intensity:* How intensively do the governance context elements urge and support changes of the *status quo*?

3.3. Integration of SSIAf with GAT

This paper integrates the conceptual elements of SSIAf and GAT. Fig. 1 shows that the core elements of SSIAf share common analytical grounds with the GAT components. Perceptions and goals (where the niches are heading) which form a key aspect of governance in the 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. Market demand creation 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 emerges from the user context (Jain et al., 2014). Fig. 1 presents the comparisons between GAT and SSIAf.

The integrated SSIAf provides an analytical approach to assess niche development, innovation and diffusion of sustainable technologies. Simultaneously, the GAT helps in advancing understanding of the quality of governance in a given context (e.g., governance of NZEB niche developments in the building sector in Delhi or Singapore, or governance of water systems), or identification of barriers to implementation of a given policy. Combining insights from the two frameworks allows for broadening the scope and furthering understanding of 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.

The overlapping conceptual basis of the five elements of SSIAf (Fig. 1) can be assessed by using the four quality criterions of GAT, simultaneously giving the opportunity to assess governance conditions which can influence innovations processes. Fig. 2 presents a new version of the GAT's 'score card' of governance context diagnosis' , which now includes the five building blocks of SSIAf (in rows) and the qualitative indicators of GAT (in columns). This allows the former to be assessed as per the four quality indicators of GAT pertaining to extent, coherence, flexibility, and intensity. The need to integrate the SSIAf and GAT arrives from the potential to broaden the scope of this study and to look beyond mere innovation by furthering the understanding of the governance dimension, and implementation of transition-oriented policies. In sum, the five SSIAf elements of *shaping of expectations, actor networks, institutions, learning process and market demand creations* can now be assessed against the four quality criterions of the GAT framework namely, *extent, coherence, flexibility and intensity*. These four criterions are looked as indicators for transformative change in qualitative terms.

4. Research design and methodology

The research design of the study presented in this article involves case studies of the building sectors in Singapore and Delhi.

4.1. Case selection and case descriptions

Two cases were selected: Singapore and Delhi. Both are urban mega cities.

4.1.1. The green buildings sector in Singapore

Singapore is an intensive urban community, a city-state with the population of 5.64 million people (DOS, 2019). Singapore's building sector is responsible for more than 30% of the total energy consumed by the country. The government of Singapore embarked on the green building movement by launching the BCA[2] (Building and Construction Authority) Green Mark scheme back in 2005. The BCA Green Mark scheme serves as a benchmark for evaluating environmental sustainability in buildings. It also formed the basis for Singapore's first Green Building Masterplan developed in 2006 to encourage, enable and engage industry stakeholders to adopt new green buildings, along

[2] The Building and Construction Authority (BCA) is an agency under the Ministry of National Development, whose mission is to shape a safe, high quality, sustainable and friendly built environment (https://www1.bca.gov.sg/about-us/about-bca).

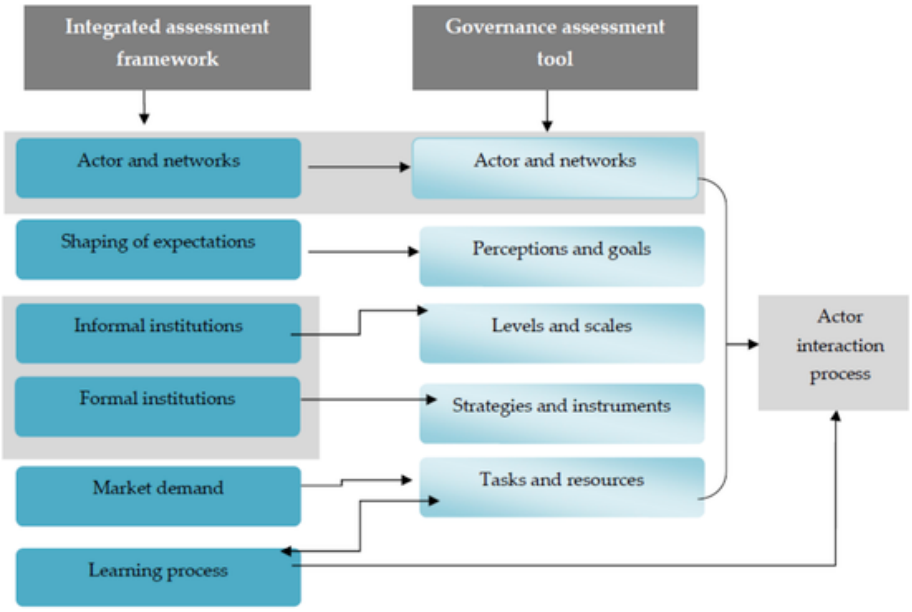

Fig. 1. Comparing GAT components with SSIAf (Jain et al., 2014).

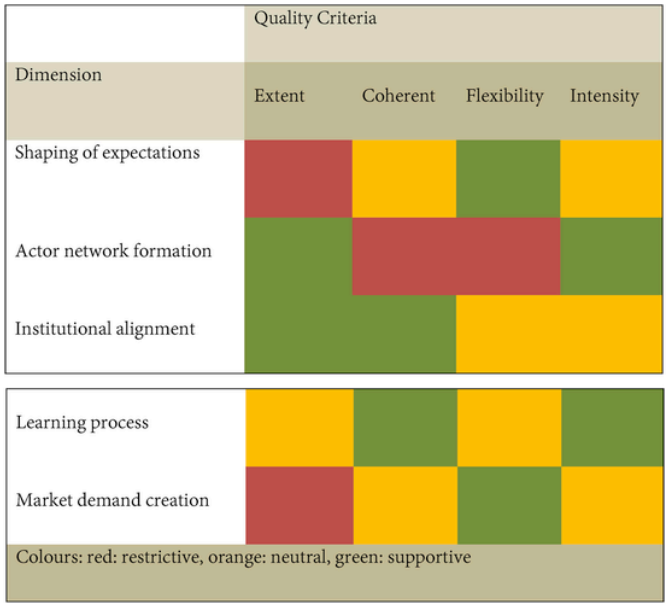

Fig. 2. A revised version of the GAT 'score card' including the five 'building blocks' of SSIAf.

with host of Green Mark Incentive schemes (GMIS). The second and third Singapore Green Building Masterplan (SGBMP), launched in 2009 and 2014 respectively, focused on converting at least 80% of the buildings in Singapore to green by 2030. Much recently both BCA and Singapore Green Building council are co-leading the creation of next Singapore Green building Masterplan 2020 (SGBMP 2020), with a vision of making Singapore "a global leader in green buildings, with special expertise in the tropics and sub-tropics" (BCA, 2020). The SGBMP 2020 aims to review mandatory minimum environmental sustainability standards in buildings, and raise the bar for minimum energy performance standards for both new and existing buildings. In 2018, BCA had already launched the Super Low Energy (SLE) (also known as nearly zero energy buildings), to go beyond the existing Green Mark Platinum standards, push the envelope of environmental sustainability in Singapore, and create NZEB/SLE niche in Singapore for enlarging the green building sector to achieve the policy goals.

Singapore can arguably be seen as a frontrunner with its widely implemented "Green Mark" certification scheme, which is now adopted in more than 70 cities across Asia, Australia and Africa. It can be argued that Singapore entails a good practice in this domain, with paradigm shift in the consumption behaviour of building occupants, the development of industry knowledge, and the building of green building expertise which Singapore is ultimately poised to share with the rest of the world. Through a combination of innovative policies and industry engagement, BCA has gained global recognition for Singapore over the last decade and placed the city-state on the map of the global green building landscape (BCA, 2020).

The lessons from the Singapore building sector innovations and highly the supportive governance conditions that apply can arguably be of use to other cities or regions (particularly tropical or sub-tropical climates) where the demand for buildings and the energy they use is increasing, for example in developing and fast urbanizing cities such as Delhi in India.

4.1.2. The green buildings sector in Delhi

Delhi, the city-state, is the capital of India with sub-tropical climate, is considered as the second most populous urban agglomeration. Currently, it is the fastest growing urban region in India with population of 16.8 million (with 97.5% urban population) (GOI, 2020). The latest UN report highlights that Delhi could become the most populous city in the world by 2028 estimating nearly 37.2 million people (UN, 2018). Currently, Delhi has the highest per capita power consumption among the States and Union Territories of India, with a consumption of 1265 KWh per capita per annum as compared to the national average of 606 KWh (TERI, 2015). The energy demand in Delhi is vastly growing, at a rate of 5–6% yearly, 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 (TERI, 2015). Owning to the magnitude of growth expected in the coming decade, it is quite obvious to also reflect on the growing demand of energy in the building sector and how the sector is responding with uptake of low energy buildings or NZEBs in the city.

In 2001, the Energy Conservation (EC) Act was introduced by the Indian government to emphasize the national priority on energy effi-

ciency in all sectors. In 2007, the Energy Conservation Building Code (ECBC) was introduced by Bureau of Energy Efficiency (BEE) (Ministry of Power) to mainstream energy efficiency in the building sector, applying to both new buildings and those subject to renovation. The ECBC 2017 updated version (for commercial buildings) was launched with stringent energy efficiency measures, with vision of Near Zero Energy Buildings (ECBC+ and super ECBC) for India. The ECBC Residential (ECO Niwas Samhita) was launched for residential building in 2018 (BEE, 2019). While the ECBC developed at federal level (Govt. of India -GoI) by BEE, its enforcement lies with the States. In Delhi, the Energy Efficiency and Renewable Energy Management Centre (EEREM; within the state Department of Power) exercise powers to work as a State Designated Agency (SDA)[3] to coordinate, regulate and enforce the EC Act in the state of Delhi. It has also been designated as State Nodal Agency (SNA) for implementation of programs from the Ministry of New and Renewable Energy (MNRE), Govt. of India. The EEREM has recently released its draft Delhi ECBC (with modification as per the climate of Delhi) in 2018, to be notified in 2020. The draft ECBC aims to create minimum requirements for the energy-efficient design and construction of commercial buildings in the national capital (EE and REM, 2019). In addition to ECBC, there are three voluntary rating systems motivated by the Industry players. These are: (i) the Indian Green Building Council (IGBC)/LEED – India; (ii) Leadership in Energy and Environmental Design (LEED) USGBC; and (iii) the Green Rating for Integrated Habitat Assessment (GRIHA). However, uptake of green buildings, low energy buildings or NZEBs has been rather slow and fragmented (Jain et al., 2017b, 2017a).

According to the World Green Building Trends 2018, the number of developers constructing green buildings in India is expected to double by 2021 from 28 percent to 55 percent. This also applies to highly urbanized city of Delhi. The rise of green building or low energy buildings will be mostly driven by recently drafted ECBC code in Delhi. However, there are certain challenges that the green building market and the low energy building market faces. They include lack of awareness, rigid governance regime, and lack of educated green building professionals, to name but a few (IIHS, 2015).

Despite the many differences in the building sector, climatic conditions and governance structures, there are reasons to believe that studying Singapore and Delhi while using SSIAf and GAT will provide valuable lessons into how governance of green buildings innovation works and it can be understood from a sustainable transformations perspective.

4.2. Data collection

Data collection involved primary and secondary data sources. In the Singapore case, data collection involved a set of 11 interviews (semi-structured), to go with secondary data, and participation in two conferences and a green building tour. In the case of Delhi, 14 interviews were conducted along with participatory observation by the first author as part of the ongoing NZEB uptake and transformation program.[4] The interviewees were shortlisted in both cities by first conducting stakeholder analysis to identify important and relevant stakeholders who are part of the governance setting, and directly or indirectly affect green building uptake in the building sector. For both cities the interviewees include both primary and secondary actors. Primary actors, directly involved in green building projects, pertained to building developers, architects, technology providers, building owners, and building occupants. Secondary actors, indirectly involved in green building projects, pertained to government officials, energy consultants, building engineers, international aid organizations, representatives from consultancy agencies, non-profit organizations, and academic scholars. The semi-structured questionnaires used comprised of questions pertaining to the use of the five building blocks or SSIAf and the four quality criterions of the GAT (each component of Tables 2–6 was used in the questionnaire used).

4.3. Data analysis

After collecting data, data treatment and analysis using qualitative data analysis software took place. All the interviews were conducted face-to-face, were recorded and transcribed into text files. The latter 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 and Friese, 2004). The data were coded using a coding scheme that consisted of codes resembling the concepts of the SSIAf and GAT namely shaping expectations, actor networks, institutions, learning and market demand creation. This allowed for a systematic assessment. The five components became the main coding clusters in the Atlas.ti program and a set of sub-codes (these sub-codes match with the variables in Table 1)

Table 2
Assessment of actor networks formation.

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 behavioural 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 the BCA.	Stakeholder interaction was mostly one directional as to approach the BCA. This showed a low degree of flexibility. As such it limited the effectiveness of the interactions. Concerns and novel ideas were not issued during decision-making processes.	The BCA exerts strong pressure on behavioural change through its several policies and standards, considered positive.
Delhi			
All relevant actors for innovations were found to be present.	Interactions were strong within innovation project boundaries but weak between various implementation projects. Interactions were not institutionalized, and hence showed limited cooperation between projects.	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 behavioural changes or management reforms as regulations

[3] States in India have the powers under EC Act to notify/issue directives for ECBC. Notification can also be done through amendments in local (municipal) building bye-laws. The implementation lies with the municipal bodies by amending the building bye-laws.

[4] The first Author was part of the USAID PACE -D TA program for the component on upscale of NZEB in India. Which included NZEB promotion and awareness raising activities in one of the work packages.

Table 3
Assessment of 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 policy instruments included?*	*Are there opportunities to combine or make use of different types of instruments? Is there a choice?*	*What is the implied behavioural deviation from current practice and how strongly do the instruments require and enforce this?*
Singapore			
All types of instruments are introduced by government. It includes standards, regulations, financial incentives, awareness and knowledge dissemination. Most of these initiatives are mandatory for implementation.	The BCA initiatives are considered as well thought and providing synergy. Good incentives are provided to parties adopting and exceeding the mandatory standards. Awareness was raised and knowledge were provided among actors which are unable to reach desired energy performance.	Various policy instruments by the government could be combined.	Policy instruments strongly encouraged stakeholders to exert behavioural 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.
Delhi			
Several policy instruments were included in the policy strategy. E.g., building codes, certifications, awareness tools, and guidebooks.	Government initiatives suffer from poor synergy. They are fragmented between energy efficiency and renewable energy. Moreover they are enforced by different ministries.	Policy instruments were flexible and could be combined. However, difficulties occurred during implementation processes due to different authorities enforcing regulations.	Since most of the instruments are of voluntary use, they only exerted marginal pressure, and reached only aware and motivated stakeholders.

Table 4
Assessment of learning processes.

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 learning? Is there a choice how to disseminate?*	*What is the implied behavioural 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 experiences with other actors. Also, government took sound initiatives for awareness raising and knowledge dissemination programs.	The learning process was found to be well synergized with many conferences, workshops, seminars and government initiatives to spread lessons and good practices through different initiatives.	It proved possible to recombine and make use of new insights. There were several opportunities to disseminate knowledge through seminars, workshops and conference and manuals. This was largely facilitated by government.	The means of knowledge dissemination were mostly strong through strict codes and laws incentivizing behavioural change among building occupiers.
Delhi			
The learning process was limited to project actors and was only poorly disseminated.	The learning process was very fragmented and situational. No efforts were made by the government to synergize learning.	The initiatives by the government were voluntary and were not strictly enforced.	Government efforts were less intensive to disseminate knowledge.

was further developed and matched with their occurrences as per the four quality criterions. The sub-codes and their occurrences were then used to weigh and evaluate their importance as part of assessing innovation and transitions process hence supporting the data analysis. The results were then compared between the two cases.

5. Results

For both the Singapore and Delhi cases the results are presented using the SSIAf as an analytical framework. The results are first drawn for the Singapore case, and are followed by results for the Delhi case. Each section, then, further elaborates on the quality of governance criterions.

5.1. Actor network formation

Many actors were found to be engaged in the building construction sector for green buildings and low energy buildings both in Delhi and Singapore.

In Singapore, the national government was found to be heavily engaged in initiating interaction among the various stakeholders. Eight out of eleven interviewees acknowledged that it did well, especially through the organization of consultation sessions. This resulted in the building industry responding to the agenda's set by the government often making the discourse unidirectional and one-sided. On the one hand, this was perceived as supportive towards transition and innovation initiatives taken by the government. On the other hand, it was also found to limit the effectiveness of actor interactions to create innovations. A lack of multi-stakeholder participation in decision making processes allegedly limited radical innovation process, and making it more incremental. The interviewees observed ‘poor’ collaboration efforts between stakeholders due to lack of integrated design approach method in projects. Project stakeholders collaborated at different project stages resulting in an incoherent and sub-optimal design, diluting the stakeholders' goals (Siva et al., 2017).

In the case of Delhi, the majority of interviewees voiced that the national government (through BEE) or state agency (EEREM) was not seen as the most influential actor in initiating the direction for green buildings or NZEBs innovations (since the launch of ECBC back in 2007), with no formal platforms for interactions apart from some conferences and outreach under bilateral projects. Six out of seven interviewees agreed that green building rating tools were mostly industry initiatives (adhering to organizations in the networks surrounding the LEED, IGBC and GRIHA rating tools) with limited impetus provided by the government (the draft ECBC code was launched only in Delhi in 2019). This led actor networks to move without any concrete direc-

Table 5
Assessment of market demand creation.

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 behavioural 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.	The Government has taken several initiatives that 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 policy instruments and strategies which promote the uptake of new technologies.	Some mandatory instruments, such as sharing of energy performance of buildings, influence home owners to adopt new sustainable technologies, and thereby stimulate increasing market demand.
Delhi			
Initiatives for increase of market demand are limited. More can be done.	Government policy 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.

Table 6
Assessment for shaping of visions and expectations.

Extent	Coherence	Flexibility	Intensity
To what extent are the various problem perspectives taken care of? What expectations does the building? 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 were considered while setting a level of expectation from sustainable technologies.	Various goals set by the government have supported each other as they were designed and implemented by BCA (alone).	It was difficult for the industry to re-assess and change them. Even when the government monitored the programs, involvement and input of the industry stakeholders was not included.	BCA set a highly ambitious goal for green buildings in Singapore; however, the industry was slow to respond.
Delhi			
Various problem perspectives were considered while setting a level of expectation from sustainable technologies.	Goals seemed to contradict or to compete with each other, especially discerning between RE and EE goals.	There were opportunities to reassess the goals as the two separate ministries could combine their respective goals as one holistic NZEB policy (although initiatives were started by the BEE).	Goals were set as ambitious as compared to the business as usual scenarios. Green buildings only represent less than 5% of the total building stock in India.

tion and in a multi-faceted discourse. However, for low energy buildings and NZEBs, actors were found to be apprehensive and reluctant to start a new social network of their own. Most often they only worked together within (single) projects. This situation led to a stalemate between government and the industry, each hoping that the other would take the first step towards such innovation initiatives.

Motivated private sector actors were found to operate in isolation waiting for the government to respond, adopting green building rating tools (LEED, GRIHA, and IGBC) led by the construction industry. Because of this no stable network emerged; neither via government initiative, nor via industry actors. Each of the studied innovation projects (mostly NZEBs) in Delhi followed an integrated design approach showing a considerable level of interaction but only within small niche projects, without scaling-up in the industry.

In Table 2, the actor-network situation in both cities is depicted as per the four quality criteria from the GAT. Each assessment is represented by a colour code of green, orange, and red (Figs. 3 and 4). 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. The table also mentions the semi-structured questions used in the questionnaire.

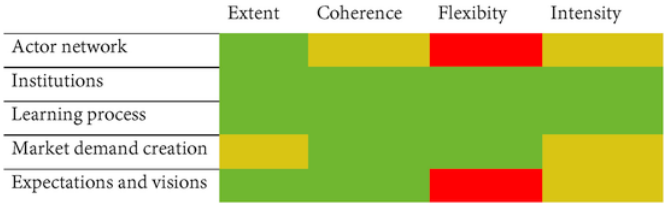

Fig. 3. Singapore – quality of governance in SSIAf components.

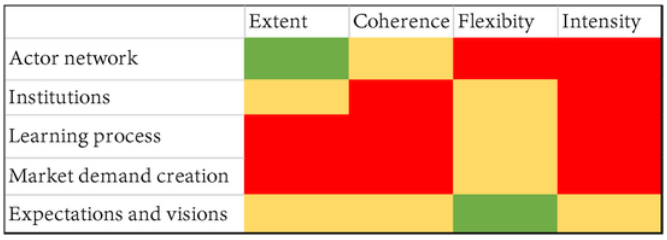

Fig. 4. Delhi – quality of governance in SSIAf components.

5.2. Institutional alignment

5.2.1. Formal institutions

In Singapore nine out of eleven stakeholders argued that the government did a lot to promote 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 Singapore. Singapore is a sovereign city-sate and is administra-

tively subdivided into 5 regions and 55 planning areas. The BCA[5] is still considered as an apex institute for implementing regulations and enforcement in the building sector was found to use a set of distinct policy instruments and innovative approaches, like several financial incentives (Siva et al., 2017). The interviews also revealed that most people view the BCA guidelines and regulations as the point of reference 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 given by the government to support the adoption of green buildings. However, in terms of effectiveness, six out of eleven interviewees argued that government efforts were only considered as moderately effective. Goals were only achieved when laws and regulations were strictly enforced. This was also believed to hamper innovation as stakeholders (i.e., owners, tenants, and investors) were only willing to follow the guidebooks prescribed by BCA and to achieve its minimum standards, and did not pursue innovating beyond these required standards. In this sense, Singapore tends to have taken a top-down approach, which created minimum conditions for radical innovation required to foster transformative change in the building sector, but only under set guidelines and regulations, and with sufficient enforcement capacity available.

On the contrary, in Delhi institutional alignment was only moderately supportive to the uptake of green buildings, although this situation may improve in the near future. While the central government formally implements the EC Act 2001, the state governments (including Delhi) have the flexibility to modify the code to suit local or regional needs and notify them. Currently, Delhi has recently published the draft ECBC code inviting suggestions before it can be notified (EE and REM, 2019). In Delhi a single agency is responsible for enforcing the energy efficiency and renewable energy programs (the EEREM, is the SDA for Department of Power, Delhi and SNA for implementation of renewable energy programs in Delhi). This is considered as positive, however, the potential can only be explored once this agency gets to implement the code in near future. The actual implementation of policies however lies with the three municipal bodies[6] operating in Delhi through means of modifications in building byelaws. This will however likely cause capacity and technical knowhow challenges to municipalities (Jain et al., 2017b, 2017a).

5.2.2. Informal institutions

Informal institutions refer to forms of cooperation between non-state actors like NGOs or community projects, and also to the common habits, beliefs, standards, established practices of society in general. In Singapore, support from NGOs as well as community level initiatives did not reveal active participation for the uptake of green building concepts. Most of the initiatives stemmed from the government, and not from the grassroots level. The majority of building users were found to be less open to change their practices and routine, which can be seen as a problem that can be perceived from a cultural perspective (Rip and Kemp, 1998). Despite this, BCA made several efforts to introduce and force behavioural change. However, the effects were only moderate.

In the case of Delhi, a few demonstration projects were initiated toward NZEB, and several LEED and IGBC certified buildings have emerged. However, there were only few local community level initiatives when compared to the vastness of the building sector in the city. Interviewees mentioned that more government efforts would be needed to foster community level change and to stimulate user and consumer action. From the ongoing innovation projects, a culture of not sharing ideas was observed as people were found to refrain from sharing the failure factors of (failed) experimental projects. Moreover, showcasing the project successes is seen as mandatory by stakeholders involved in NZEB pilots and green building projects. Since most of these projects involved public sector buildings with additional earmarked budgets, they were typically scrutinized, which led participating actors to hold back the information on setbacks and project failures. This non-sharing of failures limits learning process in subsequent projects.

From cultural perspectives, as was observed in Singapore, people in Delhi were hardly flexible and not very open to change, as far as standard building construction practices were concerned. More so, the acceptance of new technology often depends on cost; hence users were found to be less willing to take risks and were reluctant to accept new technologies without knowing the results, nor the profitability. In Table 3, the results of the assessment of governance conditions are presented for formal and informal institutions along with the questions asked by interviewer.

5.3. Learning process

In the case of Singapore, both primary and secondary actors made substantial efforts to build local capacity through knowledge exchange between actors involved in projects, stakeholders and the wider audience. The stakeholders exhibited a good level of openness in sharing knowledge and lessons with tenants and end-users. This was facilitated by the government which helped to organize workshops, seminars, and conferences. It also provided guidebooks in collaboration with BCA. For example, a guideline on the "Green Lease Toolkit on sustainability practices". In addition, BCA encouraged giving rental space certification by means of giving public recognition to "Green Mark Platinum" rated buildings, and facilitating guided educational tours to exceptional energy performance buildings. This increased the involvement and knowledge of end-users and the public. As far as the academic knowledge (research and publications) was concerned, it was necessary to introduce and have a re-orientation in academic studies, put more emphasis on green buildings.

In the case of Delhi, learning processes were seen as situational and fragmented, as learning only happened among niche actors who were directly involved in innovation projects. As a consequence, only first order learning took place. Unlike in Singapore, no dedicated effort by the government in spreading lessons from those projects was undertaken, either through media or publication, despite most of the demonstration projects came from the public sector. 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 from failures as well (mostly seen in publicly owned buildings). In Table 4 the results of the assessment of the learning process is presented against the four quality criteria of governance.

5.4. Market demand creation

As far as the demand for sustainable technologies and innovations therein were concerned in Singapore, cost effectiveness of these technologies was given high priority. Interviewees stressed low cost and high benefits with low payback periods to accept and readily adopt these technologies. The most easily adopted technology with a high market uptake was energy efficient lighting systems, due to cost effectiveness and low maintenance. Moreover, consumers were found

[5] The Building and Construction Authority (BCA) is an agency under the Ministry of National Development, whose mission is to shape a safe, high quality, sustainable and friendly built environment.

[6] The Union Territory of Delhi is divided into three statutory urban regions: the Municipal Corporation of Delhi (MCD), the New Delhi Municipal Council (NDMC), and the Delhi Cantonment Board. The MCD was trifurcated in 2012 (North Delhi Municipal Corporation, South Delhi Municipal Corporation, East Delhi Municipal Corporation).

to prefer well-established technologies over ones that are still in the experimental stage and were conservative in their choices. Indeed, generally consumers were found to avoid operating techniques for new or unproven technologies. However, some frontrunners did emerge, largely involving educational institutions which are implementing new technologies as test beds.

Among construction companies a growing trend was observed indicating that companies endorse their real estate assets (commercial offices) more commonly with green branding (i.e. using the "Green Mark" certification label), despite the high investment costs that go along with it. However, the economic valuation of green buildings did not escalate. To support this initiative, the BCA introduced a new scheme (entitled the "Green Mark Gross Floor Area" incentive scheme (GM GFA), that encouraged building owners by providing excess gross floor area for offices with Green Mark certifications (BCA, 2015).

As far as demand for sustainable technologies in Delhi was concerned, the situation for expensive and new green building technology was similar as was observed in Singapore. Consumers were found to be reluctant to adopt expensive technologies, despite being aware of the benefits. The interviewees 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 prefer technologies with low payback periods such as energy efficient lighting systems. The BEE had 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 BEE star labelled air-conditioners and refrigerators.

Few private sector offices, MNCs, hotels, and 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 from project developers).

5.5. The shaping of expectations, problem perceptions and goal setting

In Singapore, only few green technologies were popular amongst the green building industry. They include energy efficient lighting (systems) and a chillers plant system[7] (the latter due to its high energy usage), and uptake of solar technology in recent years. Knowledge, awareness and popularity of these technologies support setting of positive expectations for energy innovations with installation of these technologies. Despite their popularity, consumers find chillers plants and solar technologies expensive, as they have long payback periods. Additional impetus by the government through incentives and financial instruments were found helpful in increasing the rates of adoption of these technologies.

Government initiatives were the backbone for maintaining solar market expectations as promising. The GBIC scheme provided financial support for the industry to organize experiments, exhibitions, and diffusing promising new energy efficiency technologies. In Singapore the government understood various problems concerning the lack of uptake of sustainable technologies and thereby set some concrete goals such as the IMCSD target, supporting in making positive expectation more concrete.

Similarly, in Delhi momentum for green building and pNZEBs (pilots) contributed to shaping positive expectations about sustainable technologies. Both adopters of green buildings or NZEBs (e.g. the investors, the builders or users) were highly motivated clients who had sufficient knowledge of the socio-economic benefits of energy innovations and adoption of new technologies. The project design and construction teams received additional inspiration from clients' motivation to purchase NZEBs or green buildings. This led to the emergence of shared project goals, leading to higher visibility of the projects, drawing an increasing attention from the general public. Education institutions and a few government office buildings were seen as frontrunners for low energy buildings. This builds a strong and positive expectation from among the private sector. In this regard government initiatives through various instruments such as subsidies, incentives, net metering, and feed-in-tariffs and extra Floor Area Ratio (FAR)[8] reflect positive steps. However, these initiatives were not implemented on a large scale. There were doubts and inhibitions, reflected by the interviewees regarding the economic benefits of such projects as building performance data were not widely shared. Hence, there was no way to know if the buildings were performing as planned in terms of reduced energy consumption, to some extent lowering the expectations.

6. Analysis

Figs. 3 and 4 present the overall quality of governance of green building innovation in Singapore (Fig. 3) and Delhi (Fig. 4).

6.1. Singapore

Fig. 3 presents the overall quality of governance in Singapore on the SSIAf's quality criteria of extent, intensity, coherence, and flexibility, which was found to be rather strong. The situation was observed as improving vis-à-vis innovation and (large-scale) adoption of green buildings in the Singaporean construction sector. By large, the formal institutions and the learning process played a crucial role with high performance for the components in all four indicators. With all aspects of learning covered by stakeholders providing a good coherence from government-led initiatives. The existing formal institutions (mainly related to leadership of government through the BCA) and their well-defined roles and responsibilities, and sound financial resources from the government (through financial incentives, and subsidies) created a favourable environment that enabled actor network formation, shaping of expectations, and market demand creation to respond in a more supportive manner. However, actors and interactions were somewhat hampered as there were only few interactions, poor coherence, difficult collaboration (making collaboration ties even less flexible), which in the end led to sub-standard 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, demand in the market for new sustainable technologies was essentially created by a unidirectional push from the government.

The present study shed light on the central role of the national government (via the BCA) in Singapore's green building innovation system. Most of the building firms and construction sector stakeholders were largely following the BCA, which took a prominent role in guiding innovations. This situation is considered as favourable by many transition scholars as they claim that government can play a defining role

[7] A chiller plant is a centralized system that cools the air for a building or for a collection of buildings and provides the air-conditioning portion of HVAC systems.

[8] The floor area ratio (FAR) is the relationship between the total amount of usable floor area that a building has, or has been permitted to have and the total area of the lot on which the building stands.

to transform existing systems by supporting niche formation processes, setting up successive experiments, and by implementing particular policy instruments, like subsidy schemes, regulatory exemptions, or programs that include experimentation and pilots (Kemp, 1994; Schot, Hoogma et al, 1994; Kemp, Schot et al, 1999; Rip and Kemp, 1998; Smith, 2015; Weber and Rohracher, 2012). In line with this view some of the innovation scholars also argue that government should have an important role in innovation systems, and that government regulation should incentivize stakeholders to innovate (Beerepoot and Beerepoot, 2007). The Singapore case study findings supports this claim.

The 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 also coordinated stakeholder network interactions (via innovation networks and innovation platforms) and set the conditions under which green building projects could successfully operate. It also facilitated learning processes wherein both the government and the private sector share knowledge from their innovation projects (e.g., success and failures), by means of the public domain, guidebooks, conferences, and workshops. A few efforts paved the way for increased adoption rates, as well as increasing domestic market demand for sustainable technologies. Risk balancing instruments were introduced by the government to spur market demand.

However, once such initiatives are rolled back (terminated), there is a risk that technology 'lock in' manifests, which will slow down green building market uptake. Indeed, when Singaporean consumers were found to be rather reluctant to adopt new non-tested high cost technologies. Hence, this condition could only be favourable if the government would continue 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. It 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. A similar situation also concerns the hopeful expectations that consumers have of new technologies under the government's strict enforcement of several strategies and the provision of instruments that give end-users confidence. This is important given the risk averse nature of the end-users. However, this condition, again, depends on government initiatives. In summary, for these reasons it can be argued that the innovation system is too much depending on the government as the central actor.

In contrast, there are some opposing views between transition and innovation scholars. As they, consider it not solely supportive as government has to deal with system imperfections, i.e. (Smith, 2006). Schot et al. (1999) argue that, if only governments take the full responsibility, innovation niches may even fail. This view is also supported by innovation scholars, such as (Bartholomew, 1998), who argue that 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 a 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 only for 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.

6.2. Delhi

Assessment of governance for innovation in Singapore can provide some very important lessons for the immature Delhi green building sector, where the quality of governance was observed to be only moderately supportive for innovation and adoption of low energy buildings and NZEBs, rather is was only in its formative stage. A lack of collaboration (incoherence) was observed at most of the SSIAf elements (red codes in three of the five elements in coherence) presented in Fig. 4, causing unfavourable conditions. For example, when it comes to institutions, Delhi being the city-state, there is only one agency (i.e. EEREM) responsible for regulating and implementing the ECBC code and other RE integration programs. The actual implementation lies with the three distinct municipalities[9] within the region of Delhi, who amend the building bye-laws. However, these local municipalities have the history of largely working in isolation without showing much collaboration. This might cause the green building niche to grow only in isolation or as discrete demonstration projects. In the learning processes, market demand creation, and the shaping of expectations, similar conditions were observed. The context was only moderately intense due to voluntary initiatives having little incentives to innovate.

In the Delhi case the sectoral innovation system is considered only moderately supportive towards innovation and adoption of green buildings and NZEBs. Unlike Singapore, the state government cannot be considered as an instrumental actor in governing transition and innovation processes (state governments notify the ECBC), but the private sector activities mainly through the LEED and GRIHA rating systems, which according to some transition scholars may be considered as favourable (Schot & Hoogma et al., 1994). There was no single actor to take the lead and govern the green building movement in India though a systematic implementation process. The rating tools implemented (although voluntary) 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 or green buildings in Delhi can be arguably be considered as immature. There are only few experimental projects, and success is not yet validated nor monitored (Jain et al., 2017b, 2017a).

The SSIAf analysis of the case in Delhi revealed that although all important actors were present for green building innovation, the level of innovation was low, also attributed to a lack of single actor initiative in the process as was seen in Singapore. Consequently, policy instruments, programs, actions and efforts made by the government can be judged as moderately effective vis-à-vis innovation diffusion of new sustainable technologies in green buildings and NZEBs. 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.

The present study provides insights in how transition and innovation processes take place and are governed in urban areas. Although the cases analysed are specific and are bounded to selected (mega) cities (i.e. Singapore, and Delhi), there are reasons to believe that the Singapore case can provide deeper insights, lessons and recommendations for other cities which are at the onset of enlarging their green building stock. For instance, the role of leadership among the existing actor network can bring important insights, and is considered instrumental and of prime importance in spearheading transition processes in a desired direction. The results of the present study are in line

[9] Delhi Municipal Corporation (East, North and South Delhi Municipal Corporation), New Delhi Municipal Council, Delhi Cantonment Zone.

with what Mourik and Raven (2006) highlighted as that the collective participation of the various actors within a given niche or context that is theorized to lead to an increased level of innovation, knowledge creation, and to a reduction in complexity, risks and uncertainty (Mourik and Raven, 2006). In the present study among the five components of the framework, it is the actor network which outweighs the collective impact of the other four elements, where active leadership is seen as instrumental.

7. Conclusion & discussion

This paper started with two research questions. *What analytical framework works well to assess the governance of energy innovations and transitions in cities? And what lessons can be learned from Singapore as frontrunner in green building transitions using the analytical framework*? We hypothesized that government plays an instrumental and driving force in governing sustainability transitions and green innovations in the buildings sector.

Based on existing theoretical frameworks in innovation studies on the one hand and policy studies on the other an analytical framework was synthesized that was used to analyse green buildings innovation in urban settings. The framework was applied to assess the state of governance vis-à-vis sustainable innovation in the building sector. The qualitative indicators can further support governments in policy making while balancing the components of actor networks, institutions, learning process, expectations and market demand creation to govern radical and long term sustainability transitions.

Results from the case studies of Singapore and Delhi show that government role is instrumental in spearheading the innovation and transitions process. The two cases, however, showed variation in the role government exercised in governing the green building transition. The Singapore case shed light on the central role of the national government (i.e. the BCA) in the green building innovation system. Most of the building firms and construction sector stakeholders were largely following the BCA, which took a prominent role in guiding innovations. This situation is considered as favourable as it is argued that government can play a defining role to transform existing systems by supporting niche formation processes, setting up successive experiments, and by implementing particular supportive policy instruments. The Singapore government implemented several schemes and policies, taking a leadership role while taking full responsibility, with the industry and the private sector following its lead. The government also coordinated stakeholder network interactions and set the conditions under which green building projects could successfully operate. Moreover, government pro-actively facilitated learning processes wherein public and private sector actors share knowledge from innovative projects.

In both cases, though, the transition process observed was incremental, far from radical. The transition pathway in Singapore was found to greatly depend on centralist government intervention. Despite its merits, this approach is in theory quite vulnerable as it runs the risk that this process is hampered, once the government decides to adjust or to terminate the progressive financial instruments. This situation can provide important lessons for the yet to mature and nascent green building sector markets like the one in Delhi, where systematic and long term uptake of green or NZEBs is crucial, but is limited by a lack of extent, coherence and intensity in the institutional domain, which in turn also hampers innovation learning processes, and in the end market demand creation. This can be seen as an important conclusion, where the strength of actor networks within the context and the leadership role of government is ideally balanced to give conducive grounds for disruptive innovations, and long-term sustainability pathways to emerge.

Green buildings, including low energy building, passive building and NZEBs, potentially have added value over conventional buildings and homes, i.e. in sustainable performance, energy efficiency or even cost savings (Hermelink et al., 2013a,b). For instance, they use wood or structural elements based on wood, which replace the use of non-renewable resources, and increase overall sustainability performance over a building's life span (Švajlenka and Kozlovská, 2019 and Švajlenka and Kozlovská, 2020). Despite these benefits (as presented in other studies like Faber and Hoppe, 2012 & Kivimaa and Martiskainen, 2018) the present study has shown that innovation and market take up in this sector are troublesome. In common with those other studies key drivers for green building innovations are national and local policies, and more specifically financial instruments, and instruments targeting to knowledge sharing and dissemination. Whereas the focus in the present study was to a fairly strong extent on governance and the role of government intervention, future studies might also look into factors that are more related to the private sector, like the role of intermediaries supporting innovation processes and operational activities within multi-player networks that focus on reinforcing conditions and communication between green building system actors (Mlecnik,2016; Kivima & Martiskainen, 2018).

7.1. Policy recommendations and suggestions for further research

Designing and implementing policies to support innovation diffusion of green buildings or NZEBs in particular, and sustainable energy transition in general, remains necessary in the respective cases, with the comment that Delhi and Singapore are in different phases of the innovation process. As Singapore is more advanced and can play a pioneering role to lead other cities or urban regions, given the importance of formal institutions and role of government found in the analysis of this paper, with a caution to balance the actor network formation between the state and non-state actors. Insights from the Singapore case can provide valuable recommendations to the local urban context in Delhi with well-defined roles and responsibilities in formal legislation, supporting implementation of financial and supportive policy instruments and at the same time giving room of industry players to innovate. This could enable the uptake of low energy buildings and NZEBs by public and private actors (i.e. both citizens and corporate enterprises) in the urban settings which will further contribute towards sustainable urban energy systems and low carbon cities of the future.

Concerning suggestions for future research we suggest studies to follow up on the integration the GAT's quality criteria in the SSIAf framework in order to assess the status of governance in a particular contextual setting. Using GAT assessment provided us with insights in to qualitative indicators in terms of how supportive or restrictive the conditions currently are and are going to be in near future for implementation of green buildings or low energy buildings. The GAT quality assessment allowed us to sufficiently address situational context of sectoral innovation systems and niches making it more of a pragmatic tool in addition to using SSIAf. The merger of SSIAf with GAT that was developed in this paper can be further explored in other energy transition contexts and between different contextual settings to develop it into a more fine-grained decision-making tool for policy makers.

The framework applied in the two case studies can be further tested to assess or analyse other (sustainable) urban transformation topics like energy, waste, water or mobility infrastructure in cities. To policy makers the framework can be of use to assess how the transformation process can be measured, monitored and eventually evaluated. The assessment however, reveals the importance of the actors involved in the given context and their role in steering the transition process. It highlights the aspect of power and politics and the motivation of specific actors which drive or obstruct the transformation process. However, this can be elaborated in future research using the same (or expanded version of) the framework used in the present study.

The present study has some limitations that need to be addressed. For instance, the analytical framework presented in the present pa-

per can only provide qualitative assessment for governance conditions. To develop the framework further as a policy decision making tool, the analytical framework could also integrate quantitative indicators with visual representation of the status of transformation process. The quantitative indicators can provide concrete recommendations for policy interventions in cities. In the present paper the framework was used to assess a situation with static representations (as a snapshot in time). This falls short of capturing the dynamic and continuously changing socio-technical environment of fast changing, growing cities. A time lag may occur between the time at which assessment takes place and when policy recommendations are actually implemented. This can be explored in future research. Another limitation pertaining to the analytical framework concerns the conception of its dimensions originating from two separate theoretical frameworks. Whereas the analytical framework currently uses five dimensions it could arguably benefit from using seven. In order to do so two more dimensions pertaining to the GAT can be added. They are: 'levels and scales' and 'tasks and resources'. In the current analytical framework these dimensions are only implicitly covered by other dimensions. We leave it up to future theorists and researchers to add these two dimensions. For instance, when reflecting to the case studies capturing differences in multiple levels of governments involved might have revealed interesting contextual differences between the Singapore case and the Delhi case, with the latter having a more multi-level federalist governance setting.

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CRediT authorship contribution statement

Mansi Jain: Conceptualization, Methodology, Formal Analysis, Investigation, Data curation, Writing - original draft, Writing - Review & Editing, Visualization, Project Administration. **Vidusini Shiva:** Investigation, Data Curation. **Thomas Hoppe:** Conceptualization, Methodology, Formal analysis, Writing - review & editing, Supervision. **Hans Bressers:** Conceptualization, Methodology, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Bartholomew, S, 1998. National systems of biotechnology innovation: complex interdependence in the global system. Int. J. Bus. Stud. 241–266.

BCA Retrieved October 23, 2017, fromhttps://www.bca.gov.sg/zeb/whatiszeb.html2010www.bca.goc.sg https://www.bca.gov.sg/zeb/whatiszeb.html

BCA, 2015. Build Green. Retrieved May 19, 2017, from. https://www.bca.gov.sg/Publications/BuildGreen/others/.

BCA green-building-masterplansRetrieved from www1.bca.gov.sg:https://www1.bca.gov.sg/buildsg/sustainability/zero-energy-building2020, April 22

BEE Retrieved August 16, 2017, fromhttps://www.beeindia.gov.in/content/new-construction2015https://www.beeindia.gov.in/

BEE https://www.beeindia.gov.in/content/buildings2019, September

BEEP Retrieved August 16, 2017, fromhttp://www.beepindia.org/beep-commercial2015http://www.beepindia.org/

Beerepoot, M, Beerepoot, N, 2007. Government regulation as an impetus for innovation: evidence from energy performance regulation in the Dutch residential building sector. Energy Pol. 4812–4825.

Boer, C D, Bressers, H, 2011. Complex and Dynamic Implementation Processes. Enschede: University of Twente.

H. Bressers C.d. Boer M. Lordkipanidze G. Özerol J.V.-D. Kruijf C. Furusho ... A. Browne DROP- Water Governance Assessment Tool 2013 DROP PROJECT Netherlands

Bressers, H, Bressers, N, Kuks, S, Larrue, C, 2016. The governance assessment tool and its use, in governance for drought resilience. In: Bressers, H, Bressers, N, Larrue, C (Eds.), Governance for Drought Resilience: Land and Water Drought Management in Europe. Springer International Publishing, Dordrecht, pp. 45–65. doi:10.1007/978-3-319-29671-5_3.

Bressers, J, 2009. From public adminstration to policy networks:Contextual Interaction analysis. In: Narath, S, Varone, F (Eds.), Rediscovering Public Law and Public Administration in Comparative Policy Analysis: a Tribute to Peter Knoepfel. Presses polytechniques et universitaires romandes, Lausanne, pp. 123–142 Rediscovering public law and public adminsitration in comparative policy analysis: a tribute to Peter Knoepfel,S.Narath and F.Varone.

Corfee-Morlot, J K-C, 2009. Cities, Climate Change and Multilevel Governance. OECD, Paris.

DOS, 2019. Yearbook of Statistics Singapore 2019. Department of Singapore Statistics, Singapore.

Dosi, G, Brighton, U K, 1982. Technological Paradigms and Technological Trajectories. Science Policy Reseaech Unit, University of Sussex.

EE and REM, 2019. Draft Delhi ECBC. EEREM, Delhi.

EU Commission, 2016. The Road from Paris: Assessing the Implications of the Paris Agreement and Accompanying the Proposal for a Council Decision on the Signing, on Behalf of the European Union, of the Paris Agreement Adopted under the UNFCC. European Commission, Brussels.

Faber, A, Hoppe, T, 2012. Co-constructing a sustainable built environment in The Netherlands—dynamics and opportunities in an environmental sectoral innovation system. Energy Pol. 52, 628–638. doi:10.1016/j.enpol.2012.10.022.

GOI Retrieved fromwww.Census2020https://2021census.in/

Hermelink, A, Schimschar, S, Boermans, T, Pagliano, L, Zangheri, P, Armani, R, et al., 2013. Towards Nearly Zero-Energy Buildings—Definition of Common Principles under the EPBD—Final Report. Ecofys, Cologne.

Hermelink, et al., 2013. Towards Nearly Zero-Energy Buildings: Definition of Common Principles under the EPBD. Ecofys.

IEA I.E World Energy Outlook 2013- Executive Summary 2013 Retrieved from www.worldenergyoutlook.org http://www.iea.org/publications/freepublications/publication/WEO2013_Executive_Summary_English.pdf

IIHS, 2015. Urban India 2015: Evidence. IIHS, Bengaluru.

Jain, M, Hoppe, T, Bressers, H, 2014. Introducing the Sectoral System Innovation Framework (SSIf) for Assessment of Niche Development on Net Zero Energy Buildings in India. Netherlands Institute of Government, Delft, pp. 1–26.

Jain, M, Hoppe, T, Bressers, H, 2017, November. Analyzing sectoral niche formation: the case of net-zero energy buildings in India. Environ. Innov. Soc. Trans. 25, 47–63. doi:10.1016/j.eist.2016.11.004.

Jain, M, Hoppe, T, Bressers, H, 2017. A Governance Perspective on Net Zero Energy Buildings Niche Development in India: the Case of New Delhi. Energies 10 (8), 1144. doi:10.3390/en10081144.

Kemp, René, 1994. Technology and the transition to environmental sustainability: The problem of technological regime shifts. Futures 26 (10). doi:https://doi.org/10.1016/0016-3287(94)90071-X.

Kibert, C J, 2008. Sustainable Construction: Green Building Design and Delivery. John Wiley and Sons, Hoboken, New Jersey.

Kivimaa, P, Martiskainen, M, 2018. Innovation, low energy buildings and intermediaries in Europe: systematic case study review. Energy Effic. 11, 31–51. https://doi-org.proxy.library.uu.nl/10.1007/s12053-017-9547-y.

Malerba, F, 2004. Sectoral Systems of Innovation. Cambridge University Press, Cambridge.

Malerba, F, 2004. Sectoral Systems of Innovation: Concepts, Issues and Analysis of Six Major Sectors in Europe. Cambridge University Press, Cambridge.

Mamta, 2015. Green building: a new wave in India. Int. J. Sci. Res. Manag. 3 (12), 3781–3790.

Marszal, A, Heiselberg, P, 2009. A Literature Review of Zero Energy Buildings (ZEB) Definitions. Department of Civil Engineering, Aalborg University, Denmark.

Mlecnik, E, 2016. Activating the adoption of innovation: lessons from a passive house netwrok. Built. Environ. Proj. Asset. Manag. 6 (2), 205–217.

Mourik, R, Raven, R, 2006. A Practioner's View on Strategic Niche Management. Energy Innovations and Transitions Department (Policy Studies Unit). Eindhoven University of Technology, Eindhoven (ECN).

Muhr, T, Friese, S, 2004. User's Manual for ATLAS.ti 5.0.. www.atlasti.com/manual.html..

Nelson, R, Winter, S, 1982. An Evolutionary Theory of Economic Change. The Belknap Press Of Harvard University Press, Cambridge.

Rip, A, Kemp, R, 1998. Technological change. Human choice and climate change. Vol 2. In: Rayner, S, Malone, E L (Eds.), Human Choice and Climate Change, 2. Battelle Press, Ohio, pp. 327–399.

Schot, J, Geels, F W, 2008. Strategic niche management and sustainable innovation journeys: theory , findings, research agenda and policy. Technol. Anal. Strat. Manag. 20 (5), 537–554.

Schot, J, Hoogma, R, et al., 1994. Strategies for shifting technological systems: The case of the automobile system. Futures 26 (10). doi:https://doi.org/10.1016/0016-3287(94)90073-6.

Schot, J, Kemp, R, Truffer, B, Maruo, K, Prätorius, G, Potter, S, Sørup, P, 1999. ENV4-CT96-0275- Strategic Niche Management as a Tool for Transition to a Sustainable Transport System (SNMT). University of Twente, Centre for Studies of Science Technology and Society, Netherlands Retrieved from. https://pdfs.semanticscholar.org/ad90/cd0ad643ea66986e83f7d023f859399502e6.pdf.

Siva, V, Hoppe, T, Jain, M, 2017. Green Buildings in Singapore; Analyzing a Frontrunner's Sectoral Innovation System. Sustainability 9 (6), 919. doi:10.3390/su9060919.
Smith, 2006. Alternative technology niches and sustainable development. Manag., Pol. Pract. 220–235.
Smith, R M, 2015. March). "Green" building in India: a comparative and spatial analysis of the LEED-India and GRIHA rating systems. Asian Geogr. 32 (2), 73–84.
Svajlenka, J, Kozlovska, M, 2018, May 9. Houses based on wood as an ecological and sustainable housing alternative—case study. Sustainability 10 (5), 1502. doi:10.3390/su10051502.
Švajlenka, J, Kozlovská, M, 2019, September. Effect of accumulation elements on the energy consumption of wood constructions. Energy Build. 198, 160–169. doi:10.1016/j.enbuild.2019.06.006.
Švajlenka, J, Kozlovská, M, 2020. Evaluation of the efficiency and sustainability of timber-based construction. J. Clean. Prod. 259, 120835. doi:10.1016/j.jclepro.2020.120835.
TERI, 2015. Green Growth and Building Sector in India. TERI, New Delhi.
Torcellini, P, Pless, S, Deru, M, Crawley, D, 2006. Zero Energy Buildings: A Critical Look at the Definition. National Renewable Energy Laboratory - ACEEE Summer Study, California National Renewable Energy Laboratory and Department of Energy, (US).
UN, 2018. World Population Prospects. Retrieved from. https://population.un.org/wup/.
Urge-Vorsatz, 2012. Best Practice Policies for Low Energy and Carbon Buildings. A Scenario Analysis. Global Buildings Performance Network.
USAID https://www.pace-d.com/building-energy-efficiency-3/2016https://www.pace-d.com Retrieved August 16, 2017, from
Weber, K M, Rohracher, H, 2012. Legitimizing research, technology and innovation policies for transformative chance: combining insights from innovation systems and multi- perspective in a comprehensive 'failures' framework. Res. Pol. 41 (6), 1037–1047. doi:10.1016/j.respol.2011.10.015.
Weber, M, Hoogma, R, 1998. Beyond national and technological styles of innovation diffusion: a dynamic perspective on cases from the energy and transport sectors. Technol. Anal. Strat. Manag. 545–566.
Zhao, Z-Y, 2014. Green building research–current status and future agenda: a review. Renew. Sustain. Energy Rev. 30, 271–281.