Mobilizing Low Carbon Transition: Transnational Practice of Energy Efficiency in the Urban Building Sector

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Abstract. In many countries worldwide, low carbon sustainable transition has been planned and implemented through decoupling the economic growth from GHG emissions. Some nations are leading the scene by developing corresponding low carbon development strategies and policy measures to encourage socio-technical innovations. One of the key areas for low carbon urban development is the energy efficiency in buildings. The tendency of the rapidly growing population and urbanization asks for better narratives and practices improving the built environment. Cities and countries are keen on learning from best practice. Through international joint development projects, the “knowledge resources” - transnational, governmental, NGOs, practitioners, and academic actors - are disseminating the low carbon urban development ideas globally. What drives a successful translation of knowledge emerged from one social, economic, cultural, political, climatic and geographical context into a new one needs better clarification. This study explores the process of global circulation of sustainable innovation from a mobility and transition perspective. A conceptual framework is explored and tested through analysing the Passive House concept transferred from Germany to China. The study shows how the succinct form, co-evolving and re-contextualising attributes are key factors in circulating urban sustainability across context. Acknowledging the notion of adaptation and mutation in the translation process is a first step to address the discrepancies between the knowledge lending and receiving side, and further to foster the transformative learning.

1. Introduction
In the international community, transformative actions have been planned and implemented in many countries endeavouring climate change mitigation through decoupling the economic growth from greenhouse gas emissions [1]. They generate proven synergies with Sustainable Development Goals (SDGs) [2]. It is widely acknowledged that a socio-technical transition is necessary for an ecological friendly sustainable development [3]. One of the key approaches for climate mitigation is the energy efficiency and renewable energy in building sector [2], which accounts for 31% of global energy use, and 23% of global energy-related GHG emission [4]. The tendency of increasing population and urbanisation asks for better narratives and practice for better built environment. The largest energy saving potential is in heating and cooling demand, largely due to building envelope improvements and energy-efficiency and renewable energy adoptions [1, 2]. As a result, low-energy, low-carbon design and construction concepts such as ultra-low-energy buildings, passive houses, and plus energy buildings are receiving growing interest globally.

While the COP21 climate negotiations adopted the first ever global climate deal, some nations are
already leading the scene by taking corresponding low carbon development strategies through socio-technical innovations. In building sector, socio-technical changes have been observed, for example the development goals and policy measures are promoting the increase of renewable energy equipment in China [5] and net zero-energy building (nZEB) in Europe [6].

Countries are keen to learn from “best practices”. Through international practical networking and cooperation, the “knowledge resources” - transnational, governmental, NGOs, practitioners, and academic actors - are disseminating the low carbon urban development ideas globally. However, what makes an idea of low carbon innovation globally transferable? How is the knowledge adapted during the process of translating from the emerged context to the adopted one? What makes a success/failure of transferring low carbon development model into a new geographic, social, political, economic, cultural context?

This study explores a theoretical tool drawn from the literature of knowledge mobility and transition studies, and further investigates the translating process of Passive House concept from Germany and Europe to China.

2. Conceptual Framework
The knowledge circulation process is conceptualized in the literature of policy mobility from international development experience. The conceptual framework drawn from the policy mobility literature helps to understand how policy ideas flow transnationally, interacting with the local actors and adapting into a new context [7, 8, 9]. It addresses the “struggles involved as particular ideas are drawn into—localized—in new situations” [11]. The result is co-evolving of the ideas as they travel into the new social, cultural, institutional, and economic situations [10]. It brings up the questions of the actual impact by disseminating the “best practices” or sustainable development models. It highlights the traveling process as the processes of disseminating, translating and adapting [12], addressing the driving forces from both idea lending and receiving contexts [13]. It interprets the process of policy/knowledge transferring with the notion of mutual learning [14]. The green innovation is subject to a re-combination with pre-existing on-site knowledge that can lead to further innovations [15].

Recently, the growing interest in green innovation, climate change and sustainable development has been drawn on transition studies, which focus on interaction of social and technological changes [15]. The discussions help to identify the drivers and barriers of low-carbon sustainable transitions in the urban system, particularly on the topics of transport, energy and building sector [15, 16, 17, 18]. The transition process is conceptualized by the multi-level perspective model (Figure 1, [19]). It identifies three hierarchic and co-evolutionary levels to analyse the complexity of changes in socio-technical systems: 1. A micro-level of niches, where innovations occur e.g. experimental projects or policies, inventions, and community initiatives; 2. A socio-technical regime where the dominant standards, norms, structures, institutions or market rules are stabilised over time; 3. A socio-technical landscape level, where changes usually take place slowly in this wider context including cultural norms, values, demographic trends or political strategies [19].

Experiments can trigger social change. Experimental niches are protected from the normal rules, for example pilot projects or special subsidy programs. These niches are tested and developed. Successful ones can be translated to the regime level and formulate new regular conditions. The ones who cannot trigger aligning changes at regime and landscape level will fail. The three levels are co-evolving and subject to external driving forces [15, 19, 20]. For example, the oil crisis and Chernobyl nuclear disaster triggered the transformative power for the Energiewende (German energy transition).
Figure 1. Multi-level perspective on transitions (source: [20])

Affolderbach and Schulz (2016) further explored the synergies of the transitions and policy mobility framework by proposing the concept of “mobile transitions”. Transition studies focus on the impact of local experimental niches on the local or national socio-technical regime, which lead to transformation. Policy/knowledge mobility framework offers better understanding of the traveling process of ideas cross-locally or transnationally. Combining the transition with mobility frameworks can provide a better understanding of overall process of cross-local knowledge translation [15].

Based on the conceptual framework of policy mobility and transition studies, this paper examines the case of European low-energy building experiment of the Passive House, and its translation into Chinese context. The data sources include design documents, technical reports, policy documents, academic publications, conference presentations, websites and media articles.

3. Passive House in Germany: From Experiment to Standard
The Passive House concept was developed in 1980s when the oil crisis triggered economic depression and environmental social movements in Germany and Europe. Nationwide, there was growing concern on energy security and climate change. The civil society, policy, and culture were synchronously moving towards an ecological modernisation [21, 22]. The strategy underlying the Passive House experiments was to create a low energy, low emissions, resource efficient building through strict heat conservation: thermal protection and heat recovery. While some of the passive house principles have been applied over the world in vernacular buildings and research projects, the Passive House concept is considered being created by Professor Bo Adamson of Lund University (Sweden), and Dr. Wolfgang Feist of the Institute for Housing and the Environment (Germany) in 1988 [23]. The approaches of Passive House
are excellent insulation, prevention of thermal bridges, airtightness, insulated glazing and heat recovery ventilation. The concept is designed to fit central European climate with no necessity for active heating facilities [24].

The concept was materialised in 1991 in the city of Darmstadt to the result of passive house feasibility research funded by the Hessian ministry for economics and technology. A Passive House Developers Society composed of four families, with Dr. Feist’s among them, was formed in the city quarter of Kranichstein and commissioned the architects Bott, Ridder and Westermeyer to build a row of four family houses. Each of the 156m² apartment was designed with perfect thermal features in roof, exterior wall (275mm EPS), basement ceiling and windows (triple-pane low-e glazing), together with heat recovery ventilation, ground heat exchanger for preheating the fresh cold air and solar collectors for hot water supply. The maximum heating loads in Kranichstein passive house was 10 kWh/(m²a), which saved 90% energy than conventionally built houses [24].

Although there was local political support from Hessen state and Darmstadt city government, established policies and funding incentives to support this development did not pre-exist, until later in 1990 KfW bank began to provide low-interest loan to encourage energy saving projects [24]. There was reluctance from the private owners to invest into such buildings: the price is relatively high although 50% of the building cost was covered by the state of Hessen; energy was not so expensive as it is today; there was no mandatory regulation for such low-energy building [26].

In 1996, Passive House Institute (PHI) was found to further research, develop and promote the Passive House model. The technical and economical practicality of implementing Passive House standard was tested through the European sponsored research project - Cost Efficient Passive Houses as European Standards (CEPHEUS). In 1997, European Commission funded 262 passive houses projects in Austria, Switzerland, Germany, France and Sweden, and to present the result in the Expo 2000 in Hannover. The passive house built by PHI is located in Kronsberg district of Hannover, beside the site of EXPO 2000. Through the CEPHEUS project, the Passive House concept demonstrated itself to be technically and economically feasible across Europe [27, 28].

Since then, the Passive House concept was “traveling” widely, applied not only in buildings but also in urban districts, for example the Bahnstadt residential area in Heidelberg [29]. Currently there are approximately 25,000 passive houses in the world and 80% of the projects published by PHI are built in Germany and Austria [30].

The Passive House concept includes three formulations: Passive House standard, Passive House Planning Package (PHPP) design tool and the certifications to buildings and components. The framework also supports the policy goal of energy efficiency. In Germany, KfW bank provides funding support for the passive house construction and retrofit [31]. The international consultants, academics, NGOs began to introduce Passive House as a good practice toward low-energy, low carbon sustainable urban development to other places around the world [32, 33, 34, 35, 36].

Passive House developed as a traveling concept, was evolving as the result of interacting with the local and global actors. At the beginning, the Passive House standard is designed to fit central European climate and the requirements are on space heating demand ≤ 15kWh/(m²a), primary energy demand (for all energy services) ≤ 120 kWh/(m²a), and airtightness (Ionescu et al., 2015). Later the cooling demand requirement of ≤ 15 kWh/(m²a) was read in the Passive House standard, responding to the hot climate zones. In 2010, European Union issued updated Energy Performance in Building Directive [37], which introduce the nearly-Zero-Energy Building (nZEB) as goal for all new buildings by 2021 and for new public building by 2019. Meanwhile, the energy efficient innovations in construction industry further developed, for example the Plus-Energy-Building concept [23, 38]. In 2014 PH standard is re-classified as PH Classic, PH Plus, PH Premium, and EnerPHit for retrofitting exiting buildings [39]. In the new rating system, the primary energy demand is replaced by PER (Primary Energy Renewable) to support the energy transition agenda in Germany and worldwide. The PER calculates energy demand in detail through PHPP, responding to each of climate zone globally. The component requirements are correspondingly adapted to the climate zone and cost efficiently optimised for the applied zone [40].
Passive House was developed as a nearly zero energy building model. The experiment was driven by engineering pioneers to test the technical principles, design options, design tools and to develop the cost-effective solutions, which could be promoted and adapted in a wider socio-technical context [24].

4. **Passive House in China: Disseminating, Translating and Adapting**

China has ratified the Paris Agreement and is engaged in its post-2020 nationally determined contributions (NDCs) to mitigate and adapt to climate change. In China, the building sector accounts for 28% of the energy consumption, and the number is rising due to the growing population, rapid urbanisation and industrialisation [41]. The resource and energy security concerns brought China’s growing emphasis on energy efficiency in the 11th, 12th and the current 13th National Five-Year Plan. From 1986 to 2015, China issued about 44 building energy efficiency-related standards [42], and since 2002 initiated series of energy efficient and green building pilot projects [43]. Policy implementation, financial incentives, accelerated approval processes, and priority of land allocation boosted the investors’ interest in developing energy-efficient profile properties and therefore increasing their competitiveness [43, 44].

Additionally, the Chinese government considered the energy efficient and green building technologies as pathways to modernise Chinese building industry [45, 46, 47]. Energy efficient and green profile projects also helped to attract international financial and technical support and increase attraction for foreign business and investment [45]. Moreover, solar and wind energy had rapidly development in China thanks to the policies and subsidy programs [48]. The launching of emissions trading system in 2017 and potentially later carbon tax helps to trigger greater demand for renewable energy and energy efficient technologies [49], [50]. Passive House’s suitability to adopt renewable energy [51] aligns with China’s strategy to increase the market demand for energy-efficient and renewable energy products and services.

The first passive house in China was the Hamburg House built by Hamburg city in Shanghai World Expo 2010. The 2,094 m² exhibition centre was designed to meet the German Passive House Standard and Hamburg HafenCity Environmental Standard, aiming to promote the best practice of the “European Green Capital 2011” [51]. During the Expo, the dissemination of passive house concept was facilitated through relative events and mass media attention. But translating the idea into Chinese context confronted difficulties due to its requirement to transform local existing regulations, construction process and production. After the Expo, the Hamburg city government did not further fortify the translation process on Passive House [52].

The translating process was greatly facilitated through the “German-Chinese Working Group for the Promotion of Energy-Efficient Building” partnered by the Ministry of Housing and Urban-Rural Development of China (MoHURD) and the German Energy Agency (dena) established in 2006. Dena worked directly with the socio-technical system through political dialogue, knowledge transfer and strategic market development [53], with benefit from the long-term political support and national branding programs such as “Sustainability - Made in Germany”, “GreenTech – Made in Germany”, and “Energy Efficiency – Made in Germany” [54, 55, 56]. Under this partnership, dena and the Science Technology and Industrialization Development Center (CSTC), an affiliation of MoHURD, jointly developed pilot projects with low-energy and passive house approaches. in 2012, a 6718 m² high-rise residential building in Qinhuangdao city of Hebei province was built as the first pilot Passive Ultra-Low-Energy Building [57]. Thermal performance of the building envelope is excellent with passive design approaches such as thermal-bridge-free well-insulated (220 mm EPS) exterior wall, triple glazing low-e windows, air-tightness, and energy recovery ventilation system. The energy demand for heating and cooling is 16 kWh/m²a, primary energy demand is 102 kWh/m²a. The project was nation-wide promoted as a show-case of successful knowledge transfer on German energy-efficient technologies, products and construction processes with potential to proliferate on the large scale in China [52]. Subsequently Hebei province released the first voluntary passive building standard guideline based on German passive house standard: Design Standard for Energy Efficiency of Passive Low-Energy Residential Buildings in 2015 [57, 58]. Later that year, based on the passive house experiment through
transnational cooperation e.g. with Germany and US, MoHURD issued trial version of Technical Guidelines for Passive Ultra-Low-Energy Green Residential Buildings [59]. At provincial level, policies, financial incentives and standards are developed in Beijing city, Hebei, Shandong, Henan, Heilongjiang, Jiangsu and Jiangxi provinces [52].

In 2016, the concept of passive house appeared in the Guidelines on Urban Planning and Development released by Communist Party of China Central Committee and the State Council [60]. Regulations released by State Council set the tone of rules, standards, plans and financial incentives released by ministries, for example MoHURD and Ministry of Finance [61]. Thus, this policy document is considered as an evidence to mainstream the Passive House concept in energy efficient buildings in China.

In 2017 MoHURD issued 13th Five-Year Plan for the Building Energy Efficiency and Green Building Development [62]. Referring to the international narratives, the nearly-Zero-Energy Building (nZEB) has become a crucial concept, targeting on building over 10 billion m² pilot nZEBs by 2020. Recently, MoHURD is developing the National Technical Standard of Nearly-Zero Energy Building. The framework directly referred to the experiments of Passive House pilot projects. For example, the airtight building envelope is required although it is still new to Chinese construction process and no Chinese standard on air tight construction exists yet [63, 64, 65].

Nationwide, there are more than 100 projects built through passive house approach. Some are awarded certificates based on different standards, namely the Passive House Certificate, Sino-German Energy-Efficient Buildings and CPBA Certificate (Table 1). The Passive House concept can be adapted to the rich Chinese vernacular architectural styles and different climates. Although most of the certificated passive low-energy buildings are in severe cold and cold climate zones, there are also trial adaptations to the hot summer-cold winter and hot summer-mild winter climate zones. Passive House approaches have been adapted to local context and are moving towards creating a new socio-technical regime.

**Table 1 Certificated passive low energy building in China by 2017**

| Certification                                           | Quantity | Awarded by                                      | Standard                                      | Description                                                                 |
|---------------------------------------------------------|----------|-------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------------------------|
| Passive House Certificate                                | 20       | Passive House Institute, Germany                | Passive House Standard                        | Category: office building, residential building, industrial building, exhibition enter, health centre, and kindergarten in China’s 4 climate zones |
| Sino-German Energy-Efficient Buildings – Passive Low-Energy Building Quality Certificate | 30       | Dena and Science Technology and Industrialization Development Centre (CSTC) (affiliated to MoHURD) | Sino – German Energy Efficiency Standard     | Category: office building, residential building, exhibition centre, school in China’s 4 climate zones |
| China Passive Ultra-Low-Energy Buildings - CPBA Certificate | 34       | China Passive Building Alliance (affiliated to China Association of Building Energy Efficiency) | Technical Guidelines for Passive Ultra-Low-Energy Green Residential Buildings (MoHURD) | Category: office building, residential building, exhibition centres, health centre and kindergarten, covering 4 climate zones in China |

(Source: [66, 53, 52])

The recent Passive House urban district development in Gaobeidian, which locates 100km south of Beijing, tests the practicality of proliferating the Passive House principles in China at large scale.
Bearing the same name after the German Passive House district Bahnstadt in Heidelberg, the Bahnstadt Gaobeidian includes 30 high-rise buildings, several multi-story and single-family buildings in over 1,000,000m$^2$ [67]. Implementing the world’s largest Passive House settlement project in China requires to overcome the discrepancy between PH standard and Chinese construction routines, to develop construction knowledge and capacities to apply PH technology in large scale projects, and to formulate economically feasible solutions, which are by no mean guaranteed through the knowledge gained from successfully implemented small pilot projects [68].

The adaption of the Passive House approaches to the Chinese context was supported greatly by active dialogues with the local actors (local administrators, professionals, construction supervisors and component producers) through seminars, conferences, training programs and study tours, facilitated by German consultants, academics, NGOs and development agencies [53, 69, 70, 71, 72]. It encouraged to foster a context-oriented passive house development model and nurtured the mutual learning process.

The Passive House’s process of translating into local context also confronted difficulties. For example, the current regulation on floor area calculation doesn’t allow the extra insulation thickness to be deducted from floor area, which can be discouraging to the private energy efficient property development [52]; Evidenced by documents, experts are holding different arguments if the passive house concept is suitable to be adapted in Chinese climate zones with hot summer, and there exist few closely monitored and proven evidences in China; Both construction and industrial production capacity is increasing but slowly [73]; The Chinese culture is not yet co-evolving with the technical change. For example, 20 out of the 21 Chinese passive houses published by PHI are consulted by planners, architects and engineers with German background. To the most of Chinese developers, the Passive House is merely “a mirror image of German Passive House technology in China” [74].

5. Discussion and Conclusions

The Passive House concept developed from the experiments in Germany and Europe successfully disseminated and translated into Chinese practice. The standard criteria are smooth to be circulated with its simple and concise narrative character, which merely requires control for heating, cooling, primary energy and airtightness. The challenges are on implementation which inform the existing routines, regulations and culture of building industry. However, the provided design tool (PHPP) to support the design choices, educational and networking programs facilitating the planning decision making, and PH certification for incentives and promotion significantly increase the capability of the Passive House to be translated and inhabited into the new context. It shows that the translatable knowledge distilled from an experiment needs to be clearly defined and succinct. Its form should be able to overcome the context (socio-technical regime and landscape) from which the knowledge emerged and re-align with the context into which it is translated.

The narrative of Passive House appears to be evolving, on account of changing climate and energy policy narratives, market trends, knowledge transferring actors, and practice evidences. Through the translating process the Passive House framework interacts with the socio-technical regime on the recipient side. For the transnational practitioners, it presents the necessity to recognise this eco-evolving nature throughout the translation process. In the cross-local practice, the contexts (socio-technical regime, landscape and their driving forces) from both knowledge supplying and demanding sides should be full addressed and understood, if improved outcomes are to be achieved.

Combining mobility with a transition conceptual framework is very useful to clarify the overall translating process of knowledge distilled from experiments in the original socio-technical context into a new one. It extends the notion of “adaptation” and “mutation” in the mobility conceptual framework. This study is limited to the documentary evidence on general base. Further endeavour should be to develop a clearer conceptual model to better articulate the translating process. Detailed case studies based on stakeholder interviews and document reviews should be conducted on the translating process of Passive House from German and Europe to China, in order to examine the theoretical framework with detailed empirical evidence.
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