Chapter 10
Replication and Upscaling of Energy-Efficient Solutions in the Building Sector

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Absract This paper presents relevant theories, approaches and concepts that focus on replication and upscaling of energy-efficient solutions in the building sector. It describes an analytical framework that can be used as an overall guidance/reference for replication and upscaling of solutions from the building level to the district (or neighbourhood) level. The framework consists of multi-level perspective (MLP) and technology innovation systems (TIS). Furthermore, this paper presents two more topics – (1) long-tern dynamic modelling of building stocks and (2) a socio-economic view on the demand side – to provide a better understanding of the dynamics that are involved in the replication and upscaling initiatives. These two topics would provide additional, relevant information and insight that could strengthen the application of the framework mentioned above. Within the framework and the two supporting topics, this paper highlights three aspects that should be specially considered when it comes to replication and upscaling of solutions from the building level to the district (or neighbourhood) level. They are stakeholders, contextual factors and knowledge (training and knowledge development). These three aspects are related to each other. This paper would contribute to provide support/guidance to replicate and upscale energy-efficient solutions in the building sector at the district (or neighbourhood) level. This is a conceptual paper based on narrative literature study and the authors' project experience.

Keywords Renovation · Stakeholder · Contextual factors · Knowledge · Sustainability

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10.1 Introduction

Sustainability and energy efficiency are topics that have gained much attention recently in many sectors, including the building sector. Several authors point out that buildings are responsible for 30–40% of global carbon emissions and that there is hence a significant improvement potential for energy saving in the building sector – e.g. Johansson et al. (2017) and Baumhof et al. (2018). In addition to the existing buildings, there is new construction. New construction efforts are expected to increase the current stock at a rate of 1% per year (Vilches et al., 2017; Xing et al., 2011). In this context, what will be the status of building renovation? A description provided by European Commission (2015, page 11) says: 'The biggest challenge when reducing energy use in buildings is to increase the rate, quality and effectiveness of building renovation (currently only at 1.2%/year). To do this, it is necessary to reduce renovation costs and also to increase the speed at which it can be carried out in order to minimise disturbance for occupiers. To achieve an ambitious increase of the renovation rate (up to 2–3% per year), effective solutions need to be widely demonstrated and replicated.'

The above description not only points out the importance of building renovations in the future of the European building sector but also sets the premise of this paper, that is, replicating and upscaling of effective solutions and contributing to greater benefits for the society.

This paper is connected to an EU project called REZBUILD (https://rezbuildproject.eu/). The main objective of the REZBUILD project is to develop one refurbishment ecosystem based on the integration of cost-effective technologies, business models and life cycle interaction for deep nZEB renovation to diverse residential renovation typologies and interconnecting both building renovation stages and stakeholders. Several solutions were developed in this project such as 3D printing facades, BIPV (building-integrated photovoltaics) integration, super thermal insulation materials, HVAC (heating, ventilation and air conditioning) systems by radiant floor and solar heat pump solution (solar-assisted heat pump, SAHP). A part of the study in the REZBUILD project was to look at the potential for replicating and upscaling the REZBUILD solutions in the building sector at the district level.

This paper aims to find out how to approach such replication and upscaling efforts. Here, we first look at completed or ongoing energy-efficient building (EEB) projects to identify their experiences (lessons learned) on replication and upscaling efforts. This study and the study on sustainability related concepts and approaches provide us with a background knowledge to develop and present an analytical framework that can be used as an overall guidance/reference for replication and upscaling of energy-efficient solutions in the building sector. The contribution of this paper can be considered in connection with Sustainable Development Goals 11 (sustainable cities and communities) and 13 (climate action), at least to a certain extent.

This paper is based on narrative literature review (NLR) and the authors' experience. A brief description on NLR is provided first, followed by the summary of the results from the study on the selected EEB projects, and then concepts and approaches related to sustainability, which are key building blocks of the framework, are described. Finally, concluding remarks wind up the whole discussion.

10.2 Research Method

This paper is based on a narrative literature review (NLR). NLR takes into consideration various studies of a topic and allows the reviewer to gain an understanding of various views associated with the topic and to make a holistic interpretation of the studies by using his/her experience as well as existing theories and models (Campbell Collaboration, 2001; Kirkevold, 1997). Jahan et al. (2016) say that NLR does not necessarily require to report more rigorous aspects that characterise structured literature review – aspects such as research methodology, search term, database that was used and inclusion as well as exclusion criteria.

10.3 Study on EEB Projects

10.3.1 Example Projects

We have chosen a narrative literature review approach including document analysis in this study as it enables for a holistic interpretation of existing EEB projects within H2020 and respond to the complexity of the research topic. We identified 39 completed and ongoing H2020, FB 7[1] and IEE[2] projects and did a literature and document analysis to describe their experiences/reflections (lessons learned) on replication and upscaling efforts. Here are some existing R&D projects addressing the potential for replication and upscaling:

- Pro-GET-OnE (2017–2021): https://www.progetone.eu/
- 4RinEU (2016–2020): http://4RinEU.eu/
- TP2Endure (2016–2020): https://www.p2endure-project.eu/en
- MORE-CONNECT (2014–2018): www.more-connect.eu/
- STUNNING (2016–2019): https://renovation-hub.eu/
- ConZEBs (2017–2019): https://www.conzebs.eu/
- ZEBRA2020 (2014–2016): http://zebra2020.eu/

In our study, we have found that only a few (seven) of the reviewed projects published documents or papers that thematise the potential for replication and

[1] FB7 refers to the EU 7th Framework Program for Research and Technical Development covering the timespan from 2007 to 2013.

[2] IEE refers to projects funded by the Intelligent Energy Europe Program.

upscaling of the tested processes and products. Amongst these are projects dealing with deep renovation processes focussing on consumer- or user-centred approaches (Pro-GET-OnE), robust and reliable technology concepts and business models (4RinEU), prefabricated plug and play (PnP) systems (P2Endure) and prefabricated, multifunctional renovation elements for the entire building envelope (façades and roof) (MORE-CONNECT). Other projects aim at developing a stakeholder community built around a knowledge-sharing platform with information on innovative solutions for building renovation and novel business models (STUNNING), solution sets for cost reduction of new nearly zero-energy buildings[3] (nZEBs) (ConZEBs) or monitoring systems to track the market uptake of nZEBs (ZEBRA2020).

The results in this section are based on documents published as deliverables in the reviewed projects (STUNNING, ConZEBs, ZEBRA2020) and a published paper addressing technical, financial and social barriers and challenges in deep renovation project defined through a joint workshop of four H2020 cluster projects (Pro-GET-OnE, 4RinEU, P2Endure and MORE-CONNECT). We present the results in a chronically order.

10.3.1.1 P2Endure

P2Endure has implemented upscaling as a central part of the project, and this is the focus of one of the work packages: WP 5 Exploitation, standardisation and market upscaling. The work package '[…] will deliver generic exploitation, business and replication plans that are eligible for adjustments and implementations in different market networks' (P2Endure, 2022). In close collaboration between the four H2020 innovation actions P2Endure, 4RinEU, Pro-GET-OnE and MORE-CONNECT, a workshop was organised with the focus on summarizing the experiences from the projects. One of the objectives of this event 'was to support the market upscaling of P2Endure solutions' (ibid.). The main barriers found in deep renovation processes were divided into the following macro-groups: technical, financial and social barriers (D'Oca et al., 2018) (cf. Table 10.1).

10.3.1.2 ZEBRA2020

Based on the experiences in the ZEBRA2020 project, Toleikyte et al. (2016) describe four overarching conditions that should be addressed to ensure effective policy processes that are needed for the market uptake of nZEBs:

- Involvement from a broad set of stakeholders
- Long-term strategies to upgrade the building stock

[3]A nearly zero-energy building is defined as a building that 'has a very high energy performance' where the energy required should be covered to a 'significant extent by energy from renewable sources' (BPIE, 2011, p. 5).

Table 10.1 Identified barriers for upscaling

Barrier type	Description
Technical barriers	A lack of consistent and standardised solutions or integrated solutions to comply with new and different building standards requirements on energy saving Lack of skilled workers to carry out the work Shortcomings in technical solutions and long processes discouraging owners Safety/seismic risk connected with the deep renovation processes (damages can be done to the homes whilst retrofitting or unsure perception of the current safety of the existing buildings) End-users' and owners' lack of technical expertise and trust in effective energy renovation savings
Financial barriers	High up-front costs and owners reluctant to borrow funds for energy renovation purposes Long pay-back times of retrofitting interventions Lack of confidence of the potential investors Insufficient and instable available funding Lack of attractive financing for homeowners with low to medium incomes who are usually not eligible for regular bank loans The fact that existing financial tools are insufficient and unattractive
Social barriers	Decision-making processes that are long and complex, especially in cases of multi-owner houses (condominiums) The lack of consensus, understanding and support from the inhabitants that often hinder the effective approval of the interventions The problem of disturbance during site works and/or relocation (in case owners/users need to leave their homes during the process) Low awareness about energy efficiency and nonenergy benefits of renovation Lack of dialogue between the different stakeholders.

Based on D'Oca et al. (2018)

- Continuous assessment and review including data collection and quality assurance to ensure and monitor progress
- Empowering local level or private initiatives to go beyond the set goals and lead by example to help accelerate the rate and depth of nZEBs (Ibid., p. 28)

The ZEBRA2020 project forwards a total of 35 recommendations for EU Member States categorised within six topics (Toleikyte et al., 2016, p. 29):

- Legislative and regulatory (e.g. regulating minimum standards for building performance through building codes, improvements to the use of energy performance certificates, providing tailored advice to building owners and investors and implementing standardised methodologies for data gathering)
- Economic (e.g. incentivising the market uptake through active price signals, providing financial support for renovation according to long-term benchmarks, clever legislation to mitigate the problem of split incentives)
- Communication (e.g. branding of nZEBs, promotion of demonstration projects that exemplify benefits of high-performance buildings, facilitation of knowledge sharing)
- Quality of action (e.g. development of quality frameworks for nZEB techniques and technologies, training of building professionals, enhancement of the expertise of certifiers)

- New business models (e.g. fostering the uptake of industrialised renovation, encouragement of new business models, enabling the market to support new features of buildings as micro energy-hubs)
- Social measures (e.g. defining energy poverty, specification and increase in support measures for vulnerable target groups, improvement of all social housing to nZEB standards)

The overarching conditions described in ZEBRA2020 are relevant to look at reported experiences from other projects. In the final report documenting the lessons learned from the STUNNING project, the learning outcomes and guidelines for replications are described for each of the five demos included in the project. Amongst the lessons learned concerning technical issues, they find that the innovation potential of the construction methods and processes is case-specific and demands a step-by-step approach, depending on the competence of contractors. The stakeholders involved (building owners, tenants and planning partners) must all be involved in the development of innovative methods. Regarding social issues, the experiences with the demos demonstrate that there is a need for a fundamental change in both awareness and quality of communication and the need for increased involvement amongst inhabitants. Another learning outcome is that the reduced construction time caused by a high degree of prefabrication had a positive effect on all participants, including the inhabitants who experienced less disturbance (Laffont-Eloire et al., 2019). The positive effect of time reductions in the construction period is also amongst the key added social values from the innovation actions P2Endure, 4RinEU, Pro-GET-OnE and MORE-CONNECT (D'Oca et al., 2018).

10.3.2 Discussion

The study on the 39 R&D projects in the field of EEB shows that only a limited number of projects have published and shared their experiences of upscaling. The seven projects that present their lessons learned approach different levels of transition. Whilst the P2Endure and the STUNNING project focus on the market uptake of specific technologies as prefabricated building elements, the ZEBRA project approaches the nZEB concept and its market penetration as a whole with a focus on policymaking on the landscape level.

P2Enduro and STUNNING follow a bottom-up approach by investigating the drivers and barriers of upscaling in the contextual setting of the demo sites and identify the three thematic areas of technical, finance and social aspects. Their contribution is thereby to deliver findings on practical implementation of the technologies. In all of the three dimensions identified, the end-user plays a prominent role.

Findings from the ZEBRA project addressing the upscaling of the nZEB concept are more general and on the policy level as they are not addressing a specific technology but an interplay between different technologies that in combination enable the realisation of environmental ambitious goals as the nZEB concept. The measures identified in ZEBRA on the policy level match with barriers identified in the STUNNING project – e.g. the providing of financial support for renovation fits with the identified lack of insufficient and instable available funding. Additionally, we see that the integration of contextual factors of the specific demo sites contributes to identify specific end-user needs – e.g. the homeowners with low to medium incomes who are usually not eligible for regular bank loans.

Besides the necessity of identification of contextual factors and their incorporation in respective policy measures, our results point the attention to stakeholders and their specific roles in the upscaling process.

The results show that stakeholders play an important role as contributors to open innovation processes and that therefore a broad involvement of all stakeholders should be realised. This is in line with academic literature and the concept of open innovation processes (Chesborough, 2003). The results also stress the importance of knowledge of the diverse stakeholders and the diffusion of knowledge to diverse stakeholder groups.

10.4 Developing a Framework

10.4.1 Key Parts of the Framework

Academia has produced several theories and approaches that explain the process of upscaling and that point to different factors that influence the process. We have chosen the multi-level perspective (MLP) in Transition Theory (Geels, 2002) to elaborate on the process from the primary invention (niche) of a new energy efficiency building technology to market application. MLP enables a deeper understanding of the coevolution of technologies and the incorporation of different stakeholders' role and their interplay as a system-wide interaction. The theoretical approach of Technology Innovation Systems (TIS) (Hekkert et al., 2007) identifies seven functions of these systems and its inherent influence factors for their performance. Thereby, the concept of TIS helps us to identify influencing factors of upscaling for energy-efficient building technologies within the broader framework of sustainable transition of the built environment as elaborated in Transition Theory. We present Transition Theory first, followed by TIS, and then we combine these two approaches in an analytical framework.

10.4.1.1 Socio-technical Transition and the Multi-level Perspective

The socio-technical transition approach is an umbrella term that includes the multi-level perspective (MLP), transition management (TM) and strategic niche management (SNM) and is mainly explored by Dutch researchers. A socio-technical system comprises of three interrelated elements: a network of actors and social groups;

formal, cognitive and normative rules that guide their activities; and material and technical elements as artefacts and infrastructures (Geels & Schot, 2007). MLP is a prominent transition framework to analyse and indicate appropriate transition pathways. The MLP posits that transitions will be enabled through interaction processes within and amongst three analytical levels: niches (micro-level), socio-technical regimes (meso-level) and a socio-technical landscape (macro-level).

The niche level (micro) is the level in which space is created for experimentation and technology development as done in the REZBUILD project. On this level, the strategic niche management (SNM) highlights the importance of protected 'incubator' spaces, user involvement as well as learning to develop new technologies that can either be an incremental or radical innovation. The regime level (meso) presents the current structures and practises in the market, characterised by established institutions, technologies and rules and that provide stability and reinforcement to the current socio-technical systems. The landscape level (macro) is the overall socio-technical setting that encompasses the dynamics of deep cultural patterns, macro-economics and macro-political developments that make up the environment or context of socio-technical transition (Twomey & Gaziulusoy, 2014).

In transition studies, three success factors are generally recognised when it comes to market uptake of technological inventions from the niche to the regime level (van den Heiligenberg et al., 2017). Successful niches have the following:

- Visions which are shared by many actors, specific and of high-quality building of social networks,
- Broad and deep networks
- Learning processes at various dimensions, i.e. first-order learning (maintenance learning) and second-order learning (reframing, or reordering of assumptions; Sterling, 2007). Raven (2005) emphasises that learning processes that take place align the technical features of the niche experiment with its social dimensions (e.g. regulation, user preferences) and that induce the actors to reflect about their underlying norms and values about the niche experiment

10.4.1.2 Technology Innovation Systems (TIS)

Many authors see technological change as one of the major determinants of economic growth, and the concept of sustainable technology development contributes to understand technological development within a bigger system approach. The system and its inherent components must change to enable for sustainable development (Weaver et al., 2000). Technological development and change are analysed in a heuristic approach within the field of innovation systems. The concept of technology innovation systems (TIS) is developed to analyse all societal subsystems, actors and institutions contributing in one way or the other, directly or indirectly, intentionally or not, to the emergence or production of new technologies and the upscaling of them (Hekkert et al., 2007). As technology development is not an autonomous and self-going process, management of the process is necessary. The specific emphasis of TIS lies in the identification of activities within the system – Hekkert et al. (2007) call them functions of the system. An analysis of the TIS and its functions will deepen the understanding of what kind of activities that fosters or hampers innovation.

We present the seven functions of TIS developed by Hekkert et al. (2007) in a chronological order:

1. Knowledge development: creation of new knowledge, which include different types as, e.g. science-based research activities as well as experience-based knowledge
2. Knowledge diffusion: diffusion of knowledge within the innovation system and abroad
3. Guidance of the search: selection of a development pathway of the technological development as management asset
4. Entrepreneurial experimentation: exploration and exploitation of business models and opportunities on the basis of new technologies and applications
5. Market formation: interplay between the type of innovation within the spectrum from incremental to radical and the formation of the market
6. Resource mobilisation: availability and usability of different resources (e.g. financial and human capital) to enable innovation system activities
7. Creation of legitimacy: creation of legitimacy through diverse activities (e.g. lobbying, marketing, capacity building) to counteract to resistance to change

10.4.1.3 The Combination of MLP and TIS

Our analytical framework is based on the MLP approach within transition studies and the concept of TIS and its functions. The TIS approach focuses on the technology itself and how an upscaling process can lift the technology from the niche level to market uptake on the regime level. The multi-level perspective (MLP) is another heuristic framework, which takes a broader approach than TIS theory by looking at transformative societal processes (Twomey & Gaziulusoy, 2014). The MLP frames a broad understanding of sustainable transition by technological innovations within the socio-technical system and points the attention to the different levels and its inherent stakeholders.

We therefore combine both approaches to develop an analytical framework. The MLP contribute with the multi-level perspective and its specific stakeholders as well as the focus on policy measures, whilst TIS gives us a deeper understanding of the necessary functions/activities to consider to upscale a technology from the niche level to the market performance.

10.4.2 Two Supporting Topics

The two topics that we will present below (long-term dynamic modelling of building blocks and a socio-economic view on the demand side) provide additional, relevant information and insight that could strengthen the application of the key parts of the framework mentioned above.

10.4.2.1 Long-Term Dynamic Modelling of Building Stocks

The REZBUILD project has developed several innovative technologies for enabling energy-efficient refurbishment solutions. To understand the possible upscaling and wider implementation of new solutions, it is important to have some understanding of the dynamics of building stocks, their composition and their likely development.

A dynamic building stock model developed primarily for Norway, but applied also to a selection of other European countries, is called RE-BUILDS 2.0 model (Sandberg et al., 2021). RE-BUILDS 2.0 uses material flow analysis (MFA) methodology to predict future developments in stock size and composition and associated flows of demolition and construction. In addition, different renovation scenarios have been implemented in the dynamic modelling to understand the impacts of various renovation and upgrading measures. In the dynamic building stock model for residential housing, the key driver for determining the size of the building stock is the population's need to reside and associated lifestyle parameters. This includes population size and demand for number and floor area of dwellings.

10.4.2.2 A Socio-economic View on the Demand Side

Several of the EU projects that we have looked at focused mainly on the supply side of the renovation market whilst making assumptions about the demand side. Similarly, research focussing on the barriers for sustainable retrofitting highlights that the problems are informational and economic and not necessarily technical (Ástmarsson et al., 2013). In short, without demand there will be no market for the developed technical solutions. Thus, in order to understand how to facilitate a large-scale system-wide deep renovation adoption, the underlying mechanics of demand for such products should be understood.

There has been some research into the demand side of deep renovation. For example, Ástmarsson et al. (2013) point out some demand-side barriers: political consciousness, lack of information and understanding amongst main stakeholders regarding the technical solutions available in the market, the property itself and which solutions should be prioritised. Moreover, in the EU projects 4RinEU, ProGETonE and P2Endure, the residents themselves were considered a barrier to upscaling.

There can be many possible variables that can affect the deep renovation market, including the demand side of it, in the future. It is thus important to find out what factors that have been historically important and would mostly likely be central for explaining future variation within the respective market. This can be achieved by utilizing machine learning (ML) methods to analyse time series data that are relevant to the green transition for the property market.

10.4.3 Highlighting Three Aspects/Areas

Within the framework and the two supporting topics, we highlight three aspects/areas that should be specially considered when it comes to replication and upscaling of energy-efficient solutions:

1. Stakeholders: replication and upscaling of the solutions at the district level involve many actors with varying degree of knowledge, interest and influencing power. And, the number, nature dynamics of stakeholder tend to change over time. Hence, it is important to map, involve, engage and manage stakeholders in project that focus on replication and upscaling of solutions. The importance of good stakeholder management and project success is widely mentioned in project management literature – for example, please refer Joslin and Müller (2016).
2. Contextual factors: focus on contextual elements can be seen in two dimensions:
    - Micro-level: here, the focus is on the context of the renovation project. In this regard, technical, organisational and people issues (knowledge transfer between individuals) are specially taken into consideration.
    - Macro-level: it deals with national and international standards, as well as regulations and long-term strategies that various countries have when it comes to building renovation.
3. Knowledge (training and knowledge development): Learning, training and knowledge sharing play a prominent role to make sure that the requirements, functioning and effects of the solutions are correctly understood and that the installation is properly done with a systemic understanding of the dynamics of the district (or neighbourhood) where the solutions are replicated and upscaled. In addition, there is a need to ensure that the users have adequate knowledge and information to use the solutions in an appropriate way so that the intended positive effects can be accomplished effectively.

These three aspects are related to each other.

10.5 Concluding Remarks

As a summary of the discussion so far, we present the following model (cf. Fig. 10.1). The framework/model would contribute to provide support and guidance to replicate and upscale energy-efficient solutions in the building sector at the district level (or neighbourhood level).

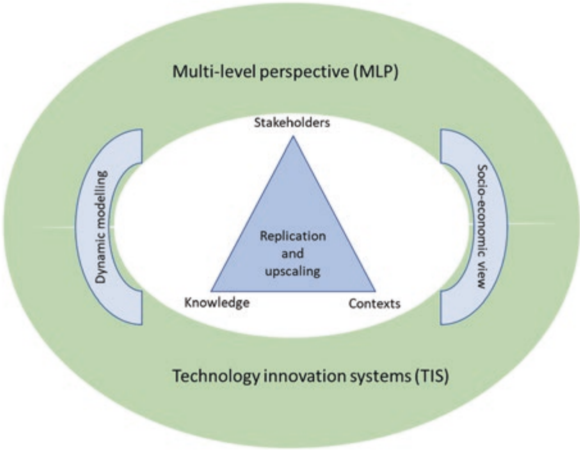

Fig. 10.1 A model for replication and upscaling

Our study of lessons learned of upscaling processes within R&D projects and the incorporation of learnings from the REZBUILD project has highlighted the three areas that play a specific role in the upscaling process: stakeholders, contextual factors and knowledge. These findings are in general in line with existing literature studies but also stress the interplay between these three areas. Especially findings in the REZBUILD project have shown that different types of knowledge are located at different stakeholder groups and need specific measures to develop within the specific contextual setting of a geographical area. This poses the question to the management of learning activities and stakeholder cooperation in the uptaking of EEB technologies from the niche level to the market. Little is said about the governance structures behind upscaling activities of EEB technologies. Whilst specific stakeholders' roles and respective activities are identified at different phases of the innovation process including upscaling, little could be found on the leadership of the process as a whole and the specific management approach. We therefore pose the questions of responsibility and leadership of upscaling of EEB technologies from the early invention to market penetration. The management of upscaling needs to be addressed in all phases of the innovation process and needs to relate to all presented functions of a TIS, the incorporation of policies on the landscape level and with a specific eye on the three elements of stakeholder and knowledge management as well as contextual factors since no 'one solution fits all'.

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