A study on the Resilience of

Sustainability Transition

of the Danish building industry

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STUDENT REPORT

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Abstract:

The goal of this research is to evaluate the resilience of the adopted 'general strategy' for the sustainability transition of the Danish building industry, namely the capacity of the transition process to withstand unexpected changes. Publicly available documents of the last twenty years about strategies, principles, guidelines, recommendations, rules, and experimental projects, along with interviews from practitioners, have been analysed through the lens of the conceptual framework Resilience of Sustainability Transitions. The analysis focuses on the *predevelopment* phase of the sustainability transition, corresponding to the stage it is passing through, hence where the data are available to be studied.
The analysis is carried out on a qualitative basis, using subjective judgement of the author guided by objective elements of relevance (e.g., reported topic, importance of topic, issuing institution, time of publication) of the studied document. The results are built on non-quantifiable information extracted through the reading of those documents. The research contributes to the existing knowledge around sustainability transitions of socio-technical systems, investigating what factors can uphold their progress.

Preface

This Masters' Thesis is the result of a 4-month research study, between February 2 and June 4, 2021, carried out by the student Daniele Costantini from the Master program of Sustainable Design Engineering at Aalborg University in Copenhagen.

The choice of the topic was driven by a long-standing interest developed by the author on matters of resilience connected to humanity and sustainability. Having had the opportunity to live and work in different countries, a genuine and spontaneous interest has been developed in the author about the capacity of humans in adapting to changing, and sometime very harsh, boundary conditions.

This Master Thesis offered the opportunity to deepen this interest with regards to what is globally considered as one of the biggest and most important change ever experienced in human history. A change that profoundly differs from other historical accounts of transformational patterns, for its size (global) and its strongly normative and goal-oriented attributes.

The author would like to take this opportunity to thanks all the fellow students, teachers, and lectures, that accompanied this amazing scientific and human journey, a deeply transformative learning process.

Special thanks goes to Susse Georg, professor at the Department of Planning at Aalborg University, for her supporting and inspirational supervision throughout all the research project.

Finally, the biggest and deepest thanks goes to the author's wife Juliana for her invaluable support through these two challenging years, and for showing to the author the real meaning of resilience. Thanks for keeping up the family routine (while also working and studying!), and for persistently being a positive and motivating partner. Also, a huge thanks to Sophie and Lorenzo, that blindly and faithfully believed in their dad most recurrent words: "it's almost done! we'll soon go back playing and camping together!!!".

About the author

Daniele Costantini is probably not the most typical master's student. 47 years old, some twenty years of professional experience in business management, human centred design, and social innovation. First master's degree in Telecommunications Engineering, received from the University of Pisa in 2001. Since then, Daniele has had the chance to work and live in several countries and to spend 9 years in Brazil with his family, where he first developed his knowledge and experience around design thinking. He also opened and successfully run two design consultancies with projects all around South America. In June 2019 Daniele and his family moved from São Paulo to København. Since March 2020 Daniele has been employed as Student Research Assistant at the Copenhagen Business School where has been working on sustainability projects ever since.

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Chapter | 1
Introduction

There is a shared consensus within the scientific, social, and political communities that the anthropogenic action is putting unsustainable pressures on the environment of our planet, and that we may be very close in reaching dangerous tipping points challenging our very existence on earth (Brundtland 1987, Rockström 2015). A radical turn in our development is needed so that we can shift toward a more sustainable[1] paradigm in all aspects of human activities (Sachs et al 2019).

1.1 The Building Industry

The building industry is not escaping this fate and, as many other industrial/economic sectors, is required to undergo a radical transformation[2] of its core practices and infrastructure. For this reason, it is obliged to embark on a transition journey towards sustainability lasting several decades. In fact, according to the "Global Status Report 2020", the sector accounts for 38% of total global energy-related CO2 emissions. In order to meet the global climate ambitions, set out in the Paris Agreement, "*the energy intensity per square meter of the global buildings sector needs to improve on average by 30% by 2030 (compared to 2015)"* (Unep 2017, p6).

Dealing with the building sector means dealing with complexity. It is in fact a context characterised by a large variety of actors with intertwined needs, interests, and perspectives, and a fairly complex value-chain composed by a fairly long list of stakeholders, i.e., investors, construction/installation/demolition/waste management companies, designers, product manufactures, raw material suppliers, users, distributors, investors, facility managers, municipalities, and communities. On top of that, the building sector is characterised as a mature and slow-to-change ecosystem, subject to several lock-ins and path dependence, and high degree of inertia, that not only makes it hard to change, but once the change starts it can take several years to be completed and can be hard to steer when a change of direction it might be necessary (Uusitalo & Lavikka 2020).

1.2 Sustainability Transitions

For more than two decades many sustainability scientists have devoted their attention and research to the concept of sustainable transformations and how important they are for the very existence of human life on the planet (Rockström 2015). In this perspective, the concept of sustainable transition has been also introduced and developed, as a way to describe the possible theoretical frameworks and processes to help "shift" a societal system to a more sustainable state (Rotmans et al 2001).

[1] This research applies the 1987's Brundtland Report (Our Common Future) definition from the United Nations, as the main reference when addressing the concepts either of sustainability or sustainable development: "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

[2] According to Hölscher et al (2018, p 1) "*transition and transformation are not mutually exclusive; they provide nuanced perspectives on how to describe, interpret and support desirable radical and non-linear societal change*". This research will hence use the term of sustainability transformation as the 'desirable change of sustainable state of the socio-technological system', that can be pursued through 'a process of moving (figuratively speaking) from the current state to a more sustainable one'.

The general idea behind those theories is about providing analytical frames supporting the definition of strategies for a journey to reaching predefined envisioned states and normative goals. They are characterized as "*long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption*" (Markard et al 2012, p 956).

1.3 Sustainability of the Danish Building Industry

Denmark is one of the leading countries in sustainability performances, and in the last decades it has achieved remarkable advancements in the field of energy efficiency of buildings (DEA 2020, EPI 2020). From a more general perspective though, the challenge of a sustainable building sector goes far beyond energy saving strategies. It should in fact considers the reduction of resource utilisation along the entire lifecycle of a building (Thuesen et al 2016, Röck et al 2020).

Back in August 2002 "*A shared future*" was published by the Government of Denmark, representing one of the first real tentative of defining a strategy for a national sustainable development. The document provides general sustainability guidelines and principles for the productive sectors and for the civil society. Although generic, principles for a sustainable building industry were already established: "*The Government's primary objective is to promote sustainable development of towns, housing and buildings. Residents and users in individual urban and housing areas should participate actively in this development, for instance through a lifestyle that calls for everybody to consider the environment and limit resource consumption as much as possible in their everyday lives*." (Pub01 2002, p 67).

Currently, one of the leading concepts expected to bring the industry to a more sustainable state, is the Circular Economy concept (Pub10 2018, Pub21 2020). The journey for a circular building industry has just begun and much work must still to be developed on this field. There are of course obstacles and uncertainties along the way, but also interesting drivers and opportunities (Leising et al 2018, Eberhardt et al 2019, Hossain et al 2020). In fact, even though the concept is undoubtedly gaining momentum, it is important to remind that it is still regarded as a niche within the current socio-technical regime of the building industry (Geels 2002).

Finally, in 2020 a large majority in the national parliament approved the Climate Act 2020 (Pub20 2020). The new law sets new national binding goals such as the reduction of greenhouse gas emissions in 2030 by 70% compared to 1990 levels. In the case of the building industry, in March 2021 the "*National strategi for bæredygtigt byggery*" was approved, bringing new binding rules and principles in support of a more sustainable development of the industry (Pub32 2021).

1.4 A Long Journey with Many Uncertainties

A sustainable transition of a complex system requires a constant tuning to new internal and external conditions, meaning that we are not just coping with the complexity of the system itself but, concurrently, with the complexity of the evolution of the transition process over the time (Geels 2002).

When it comes to the building sector, also a complex system, a transition process can take several decades with sometimes radical changes in many of its historical practices, such as the use and type of materials, the design and construction processes, the end-of-life, investment schemes, or the operation and maintenance of the buildings (Thuesen et al 2016).

On top of that, the recent Covid-19 global pandemic has shown the exposure of the system to disruptive and, often, non-considered pressures that can generate radical consequences on the system. One of these was induced by the introduction at a global scale of the so-called Non-Pharmaceutical-Interventions (NPIs) such as "social distancing" and the consequent associated measures aimed to reduce the spread of the virus, e.g., travel restrictions, quarantines, business and school closures, home-office, and even curfews (CDC 2021, Sebhatu et al 2020). This condition left entire buildings empty and unused for many months, with radical economic and social consequences on a global scale. Through the words of the UNDP: "*The COVID-19 pandemic is far more than a health crisis: it is affecting societies and economies at their core*" (UNDP 2021).

Armed with this understanding and considering the large time span (30 years) it seems to be plausible to assume that sustainability transition processes are likely as they run their course, to be subjected to several expected and unexpected perturbations over time. This could lead to the altering of its development and potentially even drifting it to a contrasting state (Folke et al 2010). These influences can arise from very different sources: the introduction of a disruptive technological innovations, the arrangement of new business and financial models, the definition of new investments priorities, or the change of boundary conditions, such as the political landscapes, the legal frameworks, or even the public support (Schilling et al 2018).

In this perspective, unexpected changes are not necessarily meant to be negative a-priori. Some of them may in fact result beneficial to the transition process, leading to the dilemma of how much openness the system should allow in order for these changes to happen. Truth to be told, no matter how much planning and envisioning, the future remains unpredictable, and dealing with a complex system enduring radical transformations such as the case of a sustainability transition of a national building industry, is not helping.

1.5 The Research Question

The sustainability research field is teeming with a wide and comprehensive literature on the different concepts and theories of transitions and transformations of socio-technical systems (Markard et al 2012, Loorbach et al 2017). As a matter of fact, transition theories are primarily based on historical accounts of past events (Geels 2002, Geels 2005a), while in the case of sustainability transitions, we are in fact dealing with something close to the opposite, normative envisioned future states of the system.

Armed with this understanding, this research is interested in studying the capacity of the sustainability transition of the danish building industry to deal with unexpected change, while concurrently maintaining its ability to fulfil the core strategic mission, namely, to deliver a proper sustainability transition process. According to Walker et al (2004, p4) this is called 'resilience' and it is defined as "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function*".

In the sustainability transition literature, little space is reserved to studies on the resilience of transition processes. Empirical finding from the grey literature, also confirm the tendency to assume the validity of the process without questioning the basic conditions for a transition to happen. It seems that a common and tacit assumption dominates the discourse, namely, the performing acts of defining, promulging, sharing and complying with strategies are necessary and sufficient conditions for the transition process to proceed. Armed with this knowledge, this research represents a tentative to understand to what extent the *general strategy*[3] for the sustainability transition of the building industry in Denmark, can be considered resilient.

More precisely, this study is interested in investigating the following research question and the consequent sub research question:

How resilient is the sustainability transition of the Danish building industry?

1) *What are the recommendations in support of a more resilient sustainability transition in the case of the Danish building industry?*

In answering these questions, the thesis draws on insights from transition studies, resilience thinking literature and relates them to recent developments within the sustainability transition of the building industry in Denmark. The study is primarily based on existing grey literature regarding sustainability in the Danish building industry, augmented with insights from interviews with practitioners.

[3] *General strategy* is an empirical definition used by the author to address the outcome of an 'in-the-making' process for the definition of an evolving leading strategy for the sustainability transition of the building industry in Denmark. It is 'in-the-making' because, even though documents from the government proposing official strategies exist, they are nonetheless the results of a constant and continuous process of consultations, negotiations, and experiments, carried out in Denmark by a wide range of relevant actors from the building industry. In this perspective, the *General Strategy* is composed by a constellation of documents issued by public institutions and private organizations, during the last 20 years, reporting strategies, recommendations, guidelines, principles, roadmaps, and targets for the sustainability transition to take place.

Chapter | 2
Theoretical Framework

This chapter is about the theoretical background used as analytical framework for this research. It is divided in two sections. The first part regards the theory of the Multi-Level Perspective, an evolutionary approach providing an explanation of how long-term socio-technical transitions take place in complex societal systems (Geels 2002, Geels 2005a). The second part introduces the conceptual framework of Resilience of Sustainability Transitions (Schilling et al 2018).

2.1 The Multi-Level Perspective (MLP)

This part presents the theory of Multi-Level Perspective. MLP is an evolutionary theoretical approach that helps to understand how transition processes of complex societal systems take place (Geels 2002, 2005a). it is sometime referred also as co-evolutionary because technological innovations can prompt social innovations and the way around. In this perspective, the social and the technological domains co-evolve (Geels 2005a, Raven et al 2010).

In MLP point of view, transitions are considered nonlinear processes that are the outcome of the interaction between three different analytical layers, namely: the socio-technical landscape (exogenous context), the socio-technical regime, and the niche-innovations level (Fig. 1) (Geels 2002).

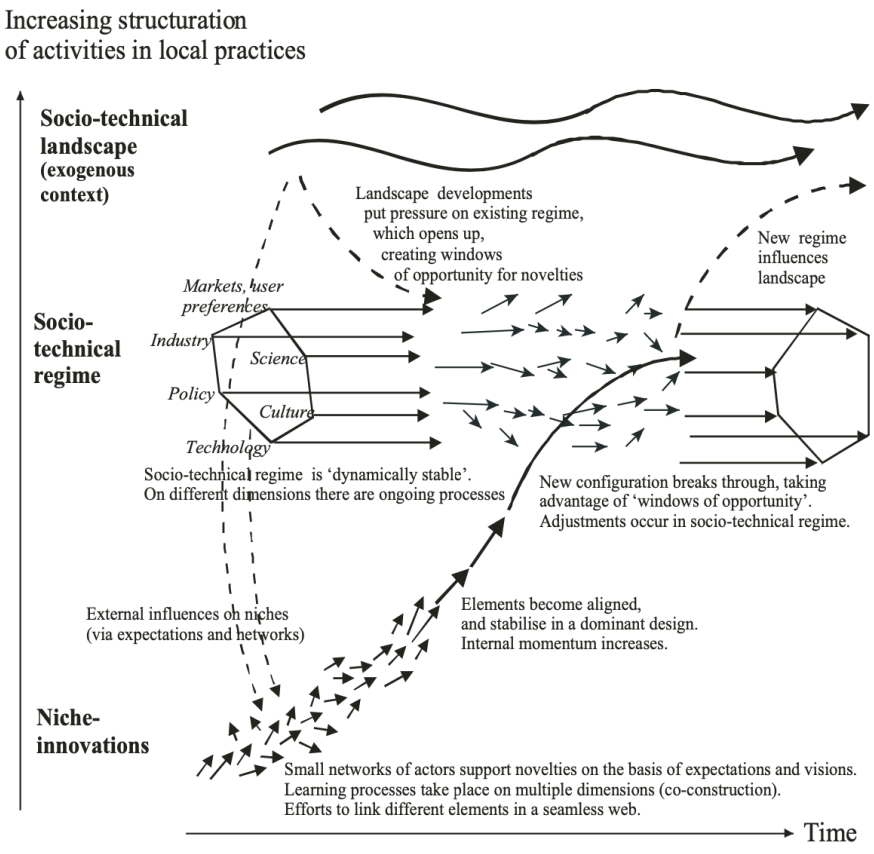

Fig. 1 The Multi-Level Perspective on transitions (Geels 2002)

2.2 The MLP Levels (Landscape, Regime, Niches)

When using *landscapes (macro level)*, the MLP refers to exogenous socio-technical configurations, a background setting and development for the regimes and the technological niches to exist (Geels & Schot 2007, Geels 2011). The concept of landscape is used in the literature of transitions to identify a set of independent and slow-paced developments that are out of reach for single actors or group of actors to influence or change. Actors can though strongly be influenced by the landscape, when it comes to their choices and behaviours (Raven et al 2010).

With *socio-technical regime (meso level)*, MLP refers to a set of particularly stabilized institutional structures where the agency of individual actor for influencing is very limited and indirect (Raven et al 2010). As outlined by Geels (2002, 2005a, 2011), *socio-technical regimes* can be also seen as deep-structures constituted by a configuration of formed practices. Set of related rules are formed, whose goal is to stabilize the practices. Regimes are often associated with the negative notion of innovations blockers, partially true due to existing rules and institutional settings that make the actors 'blind' to change (Raven et al 2010), unless the system is dealing with incremental innovations made of small-sized changes that normally end up aligning with existing stable trajectories (Geels 2011).

Finally, with *niche-innovations (micro-level)* the MLP refers to entities, 'spaces' or 'locations', where novel innovations can take place and thrive, without being crushed by the incumbent regime (Raven et al 2010, Geels 2011). Niches are also characterized by a network of actors with common rules, but they result to be much less structured and stabilized than the regimes. In fact, as highlighted by Geels and Schot (2007), their very existence depends on the fact of being constantly 'in-the-making' processes. They can be many things and have different meanings: protected spaces, a new set of rules supporting innovative solutions, experimental projects and pilots supporting the feasibility and illustrating their potential benefits compared to the existing regime configuration (Geels 2002, Geels & Schot 2007, Raven et al 2010, Smith & Raven 2012).

2.3 The Interplay Between Levels on the Practitioners

From a practitioners[4] point of view, it is of relevance what Raven et al (2010) highlight about transition experiments: 1) practitioners need to act strategically and be able to connect problems with solutions that are sometimes placed at different levels, 2) for different practitioners the perspective on what belong to a regime, to a niche or to a landscape, and what does not, can be different, 3) transitions only happen when there is enough openness, stability and adaptability from the regime, but also when landscapes provides enough pressure for a change, and the niche-innovation reached an optimal development for being 'safely' introduced in the regime.

This means that the opportunities for a practitioner to steer a transition are in reality limited and that radical innovations are indeed necessary, but not sufficient for the transition to happen. In this perspective, Geels

[4] We use the definition of Practitioners as provided by Raven et al (2010): those actors that are interested in participating in transition experiments, from a practical point of view and not for purely research purposes. Practitioners can be policy makers working on transition rules, sector associations interested in promoting a competitive advantage related to transition for its members, consultants supporting others with transition processes, and non-profit organizations interested in pursuing their agenda for sustainable transition.

(2004) underlines the importance of institutions and how they should not be only seen as stability-oriented mechanism, but also as supports in conceptualizing the dynamic interaction between actors and structures.

2.4 Four Transition Pathways

One last important consideration on the MLP is the difference existing in the transition paths. Drawing on Geels and Schot (2007), we can define 4 types of transition paths. The starting point for their definition is the *Timing of the interaction*. This means that it is necessary to identify the type of relationships the landscape and niche-innovations are having with the regime. These can either be *reinforcing*, meaning that the stability of the regime increases, and no room is left for real transition to happen, or *disruptive*, meaning that they can provide sufficient pressure onto the regime and then opening opportunities for change.
Now, niche-innovations also can have two types of relations with the regime. They can either be *competitive* or *symbiotic*. They are competitive when they aim to take its place, while they are symbiotic when it ends up being adopted for improving it.

It is then possible to distinguish the following four types of transition path (Geels & Schot 2007):
P0. *Reproduction process*: no landscape pressure appears to be enough to initiate any substantial change, hence the system keeps reproducing its patterns.
P1. *Transformation path*: a moderate pressure from the landscape is present, but niche-innovations have not been reaching a sufficient degree of development for enacting a real change and the regime reacts by adjusting the development paths.
P2. *De-alignment and re-alignment path*: in this case the landscape pressure is strong and sudden, creating destabilizing conditions for the regime and causing the actors to lose faith on the existing configuration, generating a de-alignment and erosion of the incumbent system and opening a window opportunity for change. In this perspective, if the niche-innovations have not reached sufficient development, no clear replacement has been defined and the several innovations strive to gain a dominant position for creating the new core for realigning the new regime.
P3. *Technological substitution*: this is the case of strong pressure on the landscape combined with a sufficient development of niche-innovations that will eventually break-through and take the place of the incumbent regime.

2.5 The Choice of MLP

This research finds that MLP, as analytical frame, can provide a proper reading of the structures and the actors composing the building industry. It is also functional in understating the interplay occurring between the different levels. In this perspective the following points are presented for supporting this choice:

1) MLP offers a multi-dimensional reading of the socio-technical context of the building industry, hence giving a perspective on where the agency is accommodated "*in the form of bounded rationality (routines, search activities, trial-and-error learning) and interpretive activities*."(Geels 2011, p30).

2) MLP provides a 'vertical' reading of the building industry, allowing to understand the interplay happening between the different layers, and thus providing a functional framework for the identification of possible actions and policies aimed to favour the sustainability transition process.
3) MLP offers a time perspective that, even though not precise, contributing with a useful setting for the study of the phases. This is helpful for the identification of proper measures and interventions with a time perspective.
4) Finally, MLP does not have a prescriptive approach and governance is not appointed a-priori, as some specific entity governing the process. This seems to be the case of the building industry where, governance is being performed, the sustainability transition develops as an evolutionary process.

2.6 The Building Industry Through MLP Lens

The following section's aim is to provide an understanding of a possible configuration of the MLP approach as applied to the building industry. It is important to recall that there is no exact way to define the three MLP's levels, also because, as outlined by Raven et al (2010), different practitioners may have different points of view in configuring what does belong and what does not to a layer rather than to another. On top of that, Raven et al (2010, p63) remind us that "*The distinction between the three levels is therefore analytical, and not ontological, i.e., the levels are useful for categorizing and better understanding socio-technical change rather than that the levels are real entities 'out there'*".

Drawing on literature review findings on the building sector and on empirical evidence came to light throughout the development of this research, the following descriptions are presented.

2.6.1 The Landscape level

Socio-technical landscape refers to exogenous socio-technical configurations, a background setting and development for the regimes and the technological niches to exist (Geels & Schot 2007, Geels 2011).

The current macro-economic landscape is a linear model of development, characterized by a logic of material extraction, manufacturing, use, and dumping. This is no longer sustainable, in fact the climate and environmental changes induced by the incumbent model are putting pressure at the socio-technical regime level, demanding a radical turn in our development and a shift toward a more sustainable paradigm in all aspects of human activities (Rockström 2015, IPCC 2018, Sachs et al 2019).

2.6.2 The Regime level

With *socio-technical regime*, MLP refers to a set of particularly stabilized institutional structures where the agency of individual actor for influencing is very limited and indirect (Raven et al 2010).

For the definition of the socio-technical regime of the building industry, this research was inspired by Geels (2002) and its approach for the identifications of the elements composing the socio-technical configuration in personal transportation. Based on the same logic, this research identify the followings main elements: industry network (Associations, Unions), building elements (raw materials, products, machineries, tools, energy), building's processes (design, construction, demolition/disassembly, maintenance, certification),

building's type (residential, non-residential), regulations and policies (legislation, standards/norms, guidelines), societal aspects (user experience, services, intended use), financial aspects (interest rates, loans, investment funds), market aspects (marketplaces/platforms, offer/demand dynamics, supply-chains), research/education (academic, tech/vocational). In Fig. 2 a visualization of the socio-technical configuration designed by the author and inspired on Geels (2002, p1258).

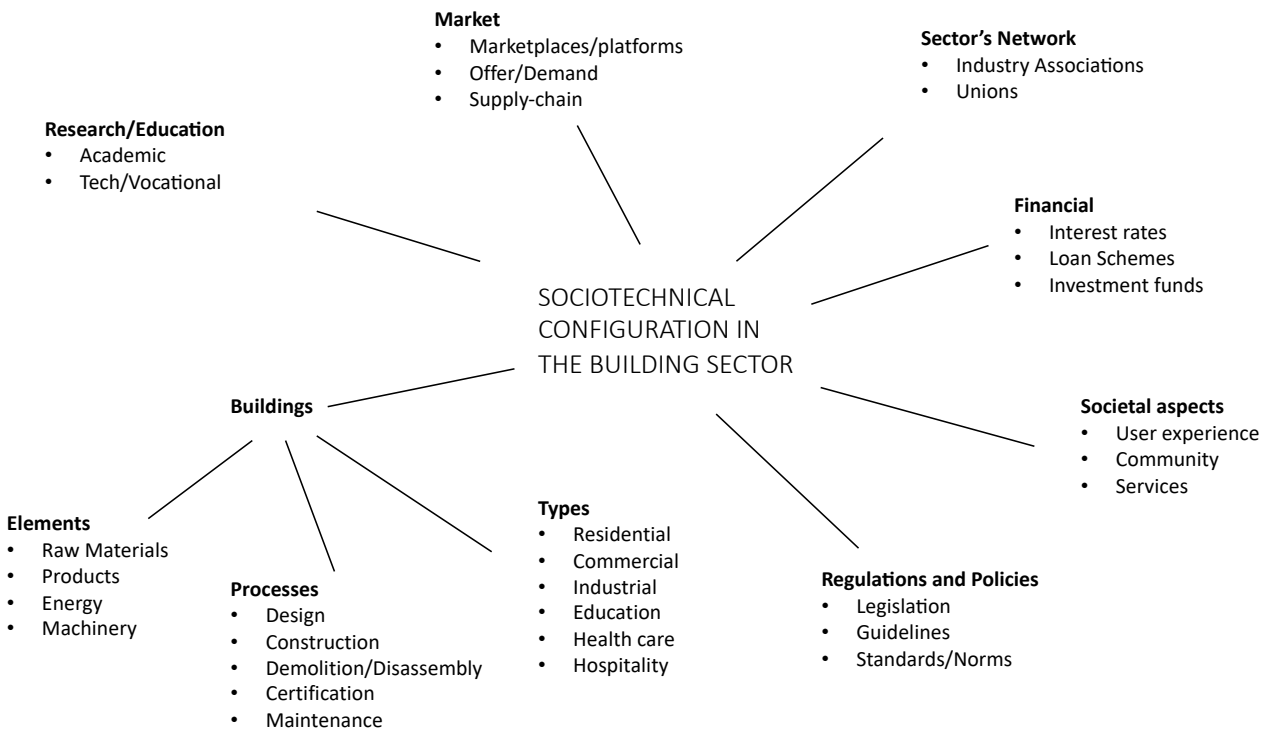

Fig. 2 Socio-technical Configuration of the Building Sector (own design, based on Geels 2002)

2.6.3 The Niche-innovations Level

With *niche-innovations* the MLP refers to entities, 'spaces' or 'locations', where novel innovations can take place and thrive, without being crushed by the incumbent regime (Raven et al 2010, Geels 2011).

The following elements, dealing with different sustainability challenges, are consistent with the niche-innovations framing. Experimental projects about construction materials, products, processes, business models, etc. Ad-hoc temporary strategies, promoted by both public and private organisations, and specifically addressing alternative approaches in the application fields of construction and demolition processes. Ad-hoc research grants for the study of new materials, technologies, processes, business models, etc.

2.7 The Conceptual Framework of Resilience of Sustainability Transition (RST)

This section introduces the basic principles and key dimensions characterising the Resilience of Sustainability Transitions (RST) conceptual framework, as it has been proposed by Schilling et al (2018).
The main purpose of Schilling et al (2018) paper is to analyse and deepen factors that can potentially affect the sustainability transition's progress. They do so through the analysis of the energy transition in the region of Weiz-Gleisdorf in the eastern part of Austria. The transition process in the area started at the end of 1980s and it is still on its way to be fully completed.
The framework is built on the combination of two of the key common concepts from the resilience literature, Stability and Adaptability (Olsson et al 2014, Folke 2016, Binder et al 2017), with the more generic concept

of dynamic Progress presents in the sustainability transitions discourse, framed as a consequence of the evolutionary reconfiguration processes occurring through the interaction between innovation (niches) and resistance (regime) at a systemic level (Markard et al 2012, Geels 2014).

Through the analysis of Stability and Adaptability dimensions in connection with the Transition progress dimension, Schilling et al (2018) provide a practical understanding of the more general concept of dynamic equilibria as presented in the resilience literature. According to Walker et al (2004), dynamic equilibria represents the necessity of a stable system to withstand disturbances and interferences from external sources. While doing so, it still must be able to adapt to some of the desirable changes, and also be able of providing the expected system's outcome, in our case filling the societal need for buildings.

2.7.1 Transition Progress (Drivers, Resistance)

The progress of a transition is very much related to the kind of actions engaged by actors looking for a change in the incumbent socio-technical regime (Grin et al 2010). Per definition, transitions are dynamic processes of change and one of their most relevant aspects is the pace at which the system undergo a transformation in a certain time frame (Mühlemeier et al 2017).

The pace of this process is primarily conditioned by *Drivers* and *Resistance*. The first supporting the shift of the system, the latter actively and passively working against it. Through the definition of the Transition Progress elements, it is possible to empirically identify the level of change undergoing in a system transition.

Drivers

Schilling et al (2018, p6) define a transition driver as "*an innovation that causes system state changes and thus affects the transition progress*". There is not exact science or a precise measurable way to know the actual impact that a driver may or may not have on the overarching transition, especially when the transition is at an early stage and expected to last for several decades. That being said, this research represents also a tentative to make a qualitative empirical evaluation of which drivers are upholding a system change.

Resistance

For the transition progress to advance, it is not only a matter of having effective drivers, but also about framing, containing, and reducing the effects of possible resistance. Resistance can have different forms and influence, and they can be associated to: A) the expected reaction of the incumbent regime to resist the changes, but also to B) the lack of planning and action from the actors in charge of upholding the transition process (Schilling et al 2018). Drawing on the words of Geels (2014, p26) "*the basic idea is that policymakers and incumbent firms can be conceptualized as often forming a core alliance at the regime level, oriented towards maintaining the status quo*".

2.7.2 Stability

Transition process in a complex system can take up to several decades to be accomplished, with radical changes expected in many aspects of the original system. Such a large range of time can clearly expose the

transition to a wide range of events and potential influences from internal and external factors. Sometimes those changes are expected, desirable and, to some extent, controllable, sometimes they are not at all. With this mind it is then important that actors from the industry can cope with uncertainty, reacting properly to possible unexpected events, while keep supporting the transition process (Grin et al 2010).

According to Schilling et al (2018) the Stability dimension is composed by the following elements A) the Stability of the Sustainability Transition Process and the B) System Resilience. The first element can be split into two further sub-dimensions: A.1) Stability of the Envisioned System State with the corresponding Sustainability Goals (SESG), A.2) Stability of the Transition Pathway (STP).

A.1) Stability of the Envisioned System State with the corresponding Sustainability Goals (SESG)
With reference to the SESG, we are basically talking of the capacity of the future system's state to attract actors into the transition journey to meet the sustainability goals. This capacity, according to Schilling et al (2018), derives from the following elements: the specificity of the goal set, the clarity and outreach of communication about the goals, and from the perceived advantages between the future state and the current one. Building the sub-dimension around those elements create a strong and shared vision of the future state, making possible deviation from the pattern less probable.

A.2) Stability of the Transition Pathway (STP)
The STP sub-dimension refers to the ability of the transition pathway to maintain its stability in front of change in the boundary conditions. The large time scale of the shift exposes the transition to possible alterations in the political and market landscape, that could force new directions on the original agreed path, hence creating potential frustration and dealignment of crucial actors that could try to adopt new pathways. Considering this, it is then of paramount importance to ensure that the transition pattern is maintained stable, and this is attainable through building large support in the governance system and, more in general, within all industry's relevant actors (Schilling et al 2018).

System Resilience
System Resilience represents the ability of the transition process to withstand and recover from disruptive and radical changes that could occur along the path. Disruptive interventions (desirable or not desirable) can in fact compromise the capacity of the related industry in supplying the expected outcome, made of products and services. An important element that can help to ensure the System Resilience is the definition of a stable, yet flexible, regulatory framework preserving the ability of the system to keep providing buildings, without impeding new solutions to be integrated along the process (Schilling et al 2018)**.**

2.7.3 Adaptability

The third key dimension of the RST concept is Adaptability. It is about the capacity of the transition process to adapt to new possible circumstances. Change in the boundary conditions can happen, meaning that new technologies, new business models, new political scenarios, can arise and alter the running configuration. In this perspective, the governance system must be ready to identify quickly what can be configured as a threat

and what as an opportunity. This means that it is recommendable to allow and promote the setting of fertile ecosystems for the system's actors to adapt to the new emerged order (Schilling et al 2018).
Sustainability transitions of complex systems can last decades. Such a long-term process implies that plausible changes in the structure of the system may occur in regards of regulations, entities, resources, actors' power, etc. This long-term process leads to the creation of new path dependence. On the one hand, path dependence can be seen as a prerequisite for the emergence of stable ecosystems for the system actors to work peacefully and properly. On the other hand, it can also bring the system to an excessive state of rigidity and so preventing the system itself to accept emerging opportunities that could eventually benefit the evolution of the transition process in terms of its sustainable development (Schilling et al 2018).

According to Engle (2011) institutions, governance and management, and the way the formal and informal communication is built and organised among those actors, play a fundamental role in configuring the adaptive capacity of the system.

2.7.4 Transition phases

In order to have a refence for the phase definition and the consequent level of transition development, this research relied on two major framings, Martens & Rotmans (2005), and Geels and Schot (2007) in combination with Geels et al (2017).

According to Martens and Rotmans (2005) there are 4 transition stages (Fig. 3):

- **Predevelopment**: a phase where the status quo is subject to no visible change.
- **Take-off**: the initial shift in the system stimulates the process of modification to start.
- **Acceleration**: where evident systemic changes occur thanks to the interactions between different socio-cultural, economic, ecological, and institutional changes.
- **Stabilisation**: where the velocity of the societal shift become slower, while a new dynamic equilibrium is met.

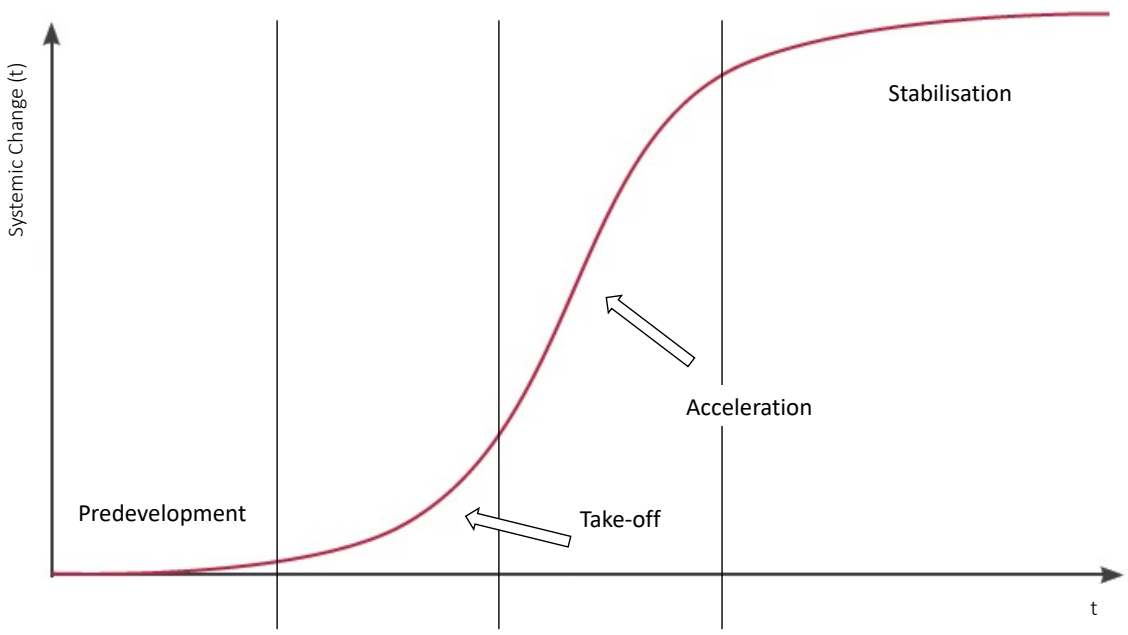

Fig. 3 The four phases of a Transition (based on Martens and Rotmans 2005)

Geels & Schot (2007) and Geels et al (2017), also uses the similar logic of 4 stages, to define the phases of a socio-technical transition (Fig. 4). Following a brief description:

- **Phase 1** – Niche-innovations are emerging, but too fragile to impose on the regime, yet opening to reflections and new design options.
- **Phase 2** – Niche-innovations gain attention on the market even though they are still small and need investments and protection to thrive further. A dominant design start to emerge and a new set of related rules begin to take place.
- **Phase 3** – This is when innovations from Phase 2 gain momentum up to making the break-through and becoming more and more direct competitors of the incumbent regime.
- **Phase 4** – In this phase regime substitution is on the process of stabilization, meaning that it is being institutionalized and a new, or adjusted, infrastructure start to settle with new markets and policies taking place. The transition has reached its peak.

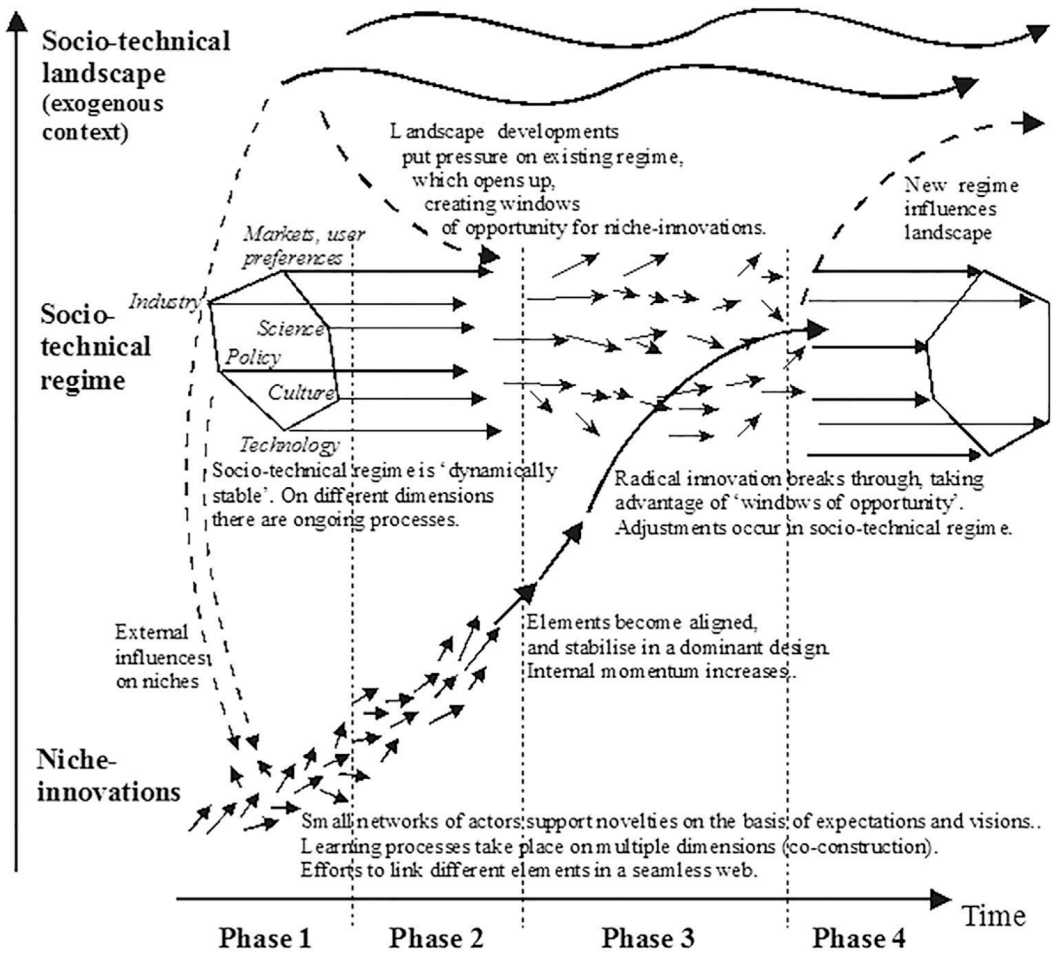

Fig. 4 Phases of the MLP on Socio-Technical Transitions (Geels et al 2017)

Geels & Schot (2007) and Geels et al (2017), as expected, pay more attention on the evolution of agency that niche-innovations have along the transition process. Martens & Rotmans (2005) approach, on the other side, is focusing more on the type of change undergoing in each stage, rather than on the agency provoking it. The main difference between the two framings is descriptive and two approaches can be considered complimentary.

2.7.5 The choice of RST

RST is a conceptual framework that was designed to analyse the resilience of sustainability transition of socio-technical systems. Following, the reasons for having chosen it for this research.

1. In order for this study to be able to produce an informed answer consistent with the research question and associated research questions, a framework for the understanding of the resilience of a sustainability transition was necessary. The Schilling et al (2018) proposed solution, is functional do the goal of the research
2. RST draws on resilient thinking but also on transition theories such as the Multi-Level Perspective. This fits perfectly with the theoretical frameworks chosen for this research study.
3. Most of literature on resilience thinking in combination with sustainability, approach the transition from a socio-ecological system perspective. This research's focus though is the socio-technical regime of the building industry.
4. The framework offers a simple, flexible, and functional approach, with steps and recommendation, for a whole analysis of the resilience of sustainability transition.

Chapter | 3
Methodology

This chapter presents the methodological approach used to build an informed answer to the Research Question and the associated sub research questions. The focus of the study is the analysis of the resilience of the Danish building industry's sustainability transition.

The study was realized based on empirical material (data), consisting of insights obtained from the following sources: scientific literature, grey literature (documents), a selected number of interviews.

The so-called grey literature is characterized by the theme of sustainability of the building industry in Denmark, and it is composed of the two following macro types: 1) documents reporting on strategies, principles, guidelines, recommendations, and laws, and 2) documents relating on experiments around themes like new design and construction processes, production and use of new materials and components, new maintenance and operational approaches, disassembly processes and take back schemes.

The section is divided into two main parts. First, an overview of the scientific literature researched and used as an analytical framework for developing the rationale of the research. Second, an explanation of how the empirical data (grey literature and interviews) was collected, organized, and analysed, in preparation of the RST analysis.

3.1 Literature Review

In conducting this study, and before collecting empirical data, a research in the scientific literature was conducted on the theme of Resilience in combination with Sustainability.

The theme has been brought to the attention of the researcher during the initial round of interviews with Danish practitioners from the building industry. An insight about how little was known about factors conditioning the stability of the transition during the large time span in which they are directly involved. Scientific literature around the theme of "success of a transition" and "effectiveness of a transition" has been collected and collated. Most of this literature shares the common theme of 'resilience' but in almost all the cases it is approached by a socio-ecological perspective (Bonassi & Wolter 2002, Rozelle & Swinnen 2004, Smith & Stirling 2008, Folke et al 2010, Feola & Nunes 2013, Walz and Kholer 2014, Khan et al 2020).

The scope of the search has been narrowed down through the inclusion of the binomial 'socio-technical system'. Two interesting articles stands out, Binder et al (2017) and Schilling et al (2018). They both address resilience and sustainability transition of socio-technical systems, more precisely energy systems in two Austrian regions. Binder et al (2017) analyse the ability of the system, hence its resilience, in providing energy to the citizens without disruption of the service during the transition. They do so by defining and measuring two major elements: diversity and connectivity of the network. The Schilling et al (2018)'s article proposes a conceptual framework built on elements recurrent in the resilience thinking literature, with elements from the transition theories of socio-technical systems. The framework, called Resilience of Sustainability Transitions (RST) helps to identify and study the three basic dimensions, Progress, Stability, and Adaptability,

"*that influence the dynamics of a sustainability transition process.*" (Schilling et al 2018, p1). Furthermore, the authors make of versatility a point of strength of their concept hence the possibility to be used in combination with transition theories such as: Multi-Level-Perspective (MLP) (Geels 2002) and Transition Management (Smith et al 2005).

The other part of the scientific literature research concerned the choice of the theoretical approach to be used to describe the transition of the socio-technical system represented by the building industry. An analysis of the dominant characteristics of the sector like its complexity, its high inertia, the difficult to change, and the absence of an appointed direct governance overseeing the transition, suggested the adoption of an evolutionary approach as the optimal analytical tool to frame the context.

Geels (2002), Geels (2005a), and Geels (2017), base their rationale on the evolutionary change process emerging by the interplay between three analytical levels: landscape, regime, and niche-innovations. They all give historical accounts of three different cases: the shift from sailboats to steamboats in commercial routes, the shift from horses to cars as a personal means of transportation and, finally, the shift of the German electricity system towards a sustainable state. The exposed narratives highlight the evolutionary characterisation of the three socio-technical transitions. Unlike the Transition Management approach, that gives a strong relevance to the active governance and management of the transition (Smith et al 2005), the Multi-Level Perspective does not prioritise nor require the definition and the appointment of a governing entity for managing the transition. Based on that rationale, and once the problem statement clarified, the choice for MLP Multi-Level Perspective occurred almost spontaneously.

3.2 Data Collection

This section explains how the data for this project were collected and organised for the purpose of carrying out the RST study of the Danish building industry.

3.2.1 Rolling a Snowball

Snowball sampling is the method that inspired this study's approach for the search of documents that formed the grey literature. The snowball sampling, or rolling a snowball method, was initially introduced by Bijker (1995). Specifically, it refers to a process where a researcher identifies a set of individuals relevant to a specific context and asks them to appoint other individuals that could be also considered relevant to the same context, and so on. The idea behind is to create an informed search method of relevant profiles for the researcher to collect empirical data.

Inspired by this approach, this researcher applied the same logic for the search of relevant publications (grey literature) aimed at documenting the strategies and initiatives carried out in Denmark to support the sustainability transition of the building industry. The search was organized in two levels. The first level, European, looked for documents from EU institutions, reporting sustainability transition strategies adopted by the Union. The other level, Danish, looked for documents from Danish institutions, reporting sustainability transition strategies adopted in Denmark.

The use of these two different levels was inspired by the fact that many of the national macro-policies on the theme of sustainability, are normally the reflection of European directives, usually defined in a collective

process among the member states. It was also justified by the fact that often local documents are in Danish, hence out of reach (or almost) if English is the only used language for the search.

The European level approach helped to identify reference documents which in return helped to identify reference Danish documents, that were later used as a starting point for a national-centred search. The European level resulted to be also functional in the identification of the general concepts and principles around which the strategies were ultimately designed. Following, examples of the strings used in the search engine:

'EU' search strings: *<sustainability transition policy building industry european union>, <sustainability transition strategy building industry european union>, <sustainability transition report building industry European union>, <sustainability transition concepts building industry european union>.*

The same logic has been basically applied at the Danish level. First, using the references appointed by the previous approach by which further local documents were identified. Secondly, by rolling the snowball in the Danish context the search goal was expanded to non-institutional documents reporting about knowledge and initiatives carried out by national actors in support to a sustainability transition.

Denmark has an extensive use of English, most of the time also for institutional official documents. Despite that, the use of Danish has sometimes resulted necessary[5] for this study. The use of Danish strings has been though limited to two scenarios. First, to identify those relevant documents that only presented 'generic summary' in English, hence not sufficient for the analysis. Second, when the English string was not delivering the expected results, while being aware of the existence of specific documents.

'DK' search strings: *< denmark sustainability transition policy building industry >, <sustainability transition strategy building industry denmark>, <sustainability transition report building industry denmark>, <sustainability transition concepts building industry denmark>.*

This has been the approach applied by this research to collect the grey literature used as a baseline for the analysis of the resilience of the danish building industry's sustainability transition. The time frame applied for the search of the documents has been established in 20 years. The number was empirically defined according to the expected duration of the sustainability transition that in 2050 is supposed to reach its goal of carbon neutrality.

3.2.2 The type of Content

When using the term Publication this research refers to documents publicly accessible through online channels. The documents are characterised by carrying different types of information such as strategies, guidelines, principles, commitments, recommendations, directives, laws.

The Publications consider different aspects of the building industry with regards to sustainability. Most of them deal with purely technological aspects, such as materials, products, construction processes, and tools.

[5] The researcher has an elementary knowledge of the Danish language that allows a vague understanding of the context and of the relevance of the documents. A digital translator tool was subsequently used to acquire proper understanding of the content of documents' relevant sections.

Nevertheless, there is a portion of these documents addressing and negotiating also social sustainability aspects, such as indoor climate, social well-being and community life, or even economic perspectives like sustainable business models and marketplaces.

3.2.3 Organization of the Publications

In order to facilitate the organisation of the documents, the collected Publications have been organized into the following five groups: *Government Non-Binding, Government Binding, NGO/Foundation, Industry Association, Think-Tank*. The organization is based on the type of the institution publishing the document. In the case of Publications from a governmental entity, a further division in binding and non-binding seemed appropriate for a better understanding of the context. The choice of the groups has been based on the logic of distance from the regime. As it is showed in Fig. 5, the closer to the centre, the more part of the regime.

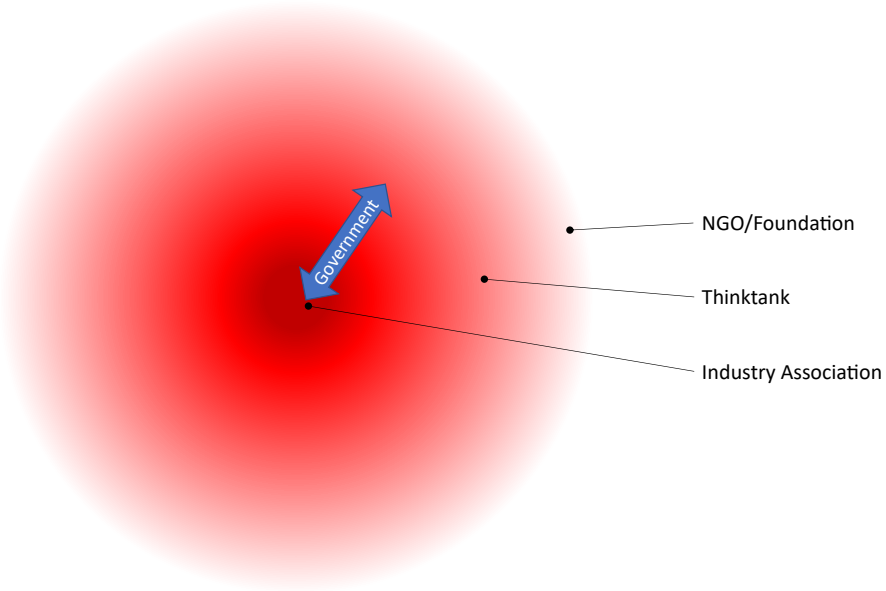

Fig. 5. A visualisation of the actor's position in relation to the regime (own design)

Following, a description of the five groups:

- **Government non-binding (GNB)** – This type of publications, issued by public institutions, nationally, regionally, or locally, are the result of an intense work of study, lobbying and pressions from exogenous and endogenous forces, whose primary goal is to inform the government on the supposed best path to follow and the reasons for it. They normally offer an institutional perspective about the transition pathway, providing a description of the problem, and a series of guidelines, commitments, and strategies on how to move towards a more sustainable building sector. These publications do not tie up the practitioners to any new set of rules and regulations, they rather offer them a vision of how the future of their industry will probably look. Hence, they provide some sort of legal insider's heads-up on where to start to invest, what technology, materials, processes, and tools to learn to use and adopt. They are also aimed to recomfort the incumbent socio-technical regime that things are under control. These documents, normally launched during dedicated events and shared both via digital channels and more traditional means, perform an act of transparency and a statement of accountability of the institutions towards their citizens and relevant actors, and informing them of the advantages of the new patterns.

- **Government binding (GB)** – These documents normally take the form of laws issued by public institutions at a national, regional, and local level, establishing the constraints and obligations that the building industry have to follow now and in the future. They typically represent the consequent step of a previous process of negotiation, orientation, and alignment among relevant actors, normally performed through the above-mentioned non-binding publications. These documents are eventually going to influence the definition of new norms, regulations, and standards in the building industry.
- **NGO/Foundations (NGOF)** – These publications are normally the result of an intense and passionate work of dedicated people, motivated by their strong beliefs and ideas. Depending on who is paying for their existence, they sometimes exist to fight for a more sustainable building sector, others for simply amplifying the voice of the current regime. Those that manage to question the status-quo of the incumbent regime by proposing alternative perspectives and narrative around it and, consequently, about its failure and issues. These documents and initiatives are usually science-based, accompanied by practical and referrable case-studies, and offer spaces for experimenting new untested solutions. They sometimes offer financial aids and other kind of support for helping niches to develop.
- **Industry Association (IA)** – The approach of these publications is generally very conservative and, as expected, they tend to preserve as much as possible of the current socio-technical regime. They somehow act as spokesperson of all the past sunk costs and large investments realized in the building industry. They tend to represent their interests and privileges. They are inclined to support incremental and non-disruptive changes, and more in general they prefer a more cautious fit and conform to a stretch and transform approach. They aim to negotiate and prioritize their own strategy, roadmaps, and goals. They also tend to reassure their members of the ongoing strong defence of their interests.
- **Think-Tank (TT)** – The work of this group and their respective publications and initiatives, are similar to those of the NGO/Foundations, main difference being a narrative of independence and objectivity, still based on facts and science, but less driven by ideology and beliefs. Yet they mostly exist to support the sustainable transition of different sectors of a country, by providing specific knowledge and tools to all those interested in pursuing a change. For their reputation of independence and transparency are often used to negotiate among the parties.

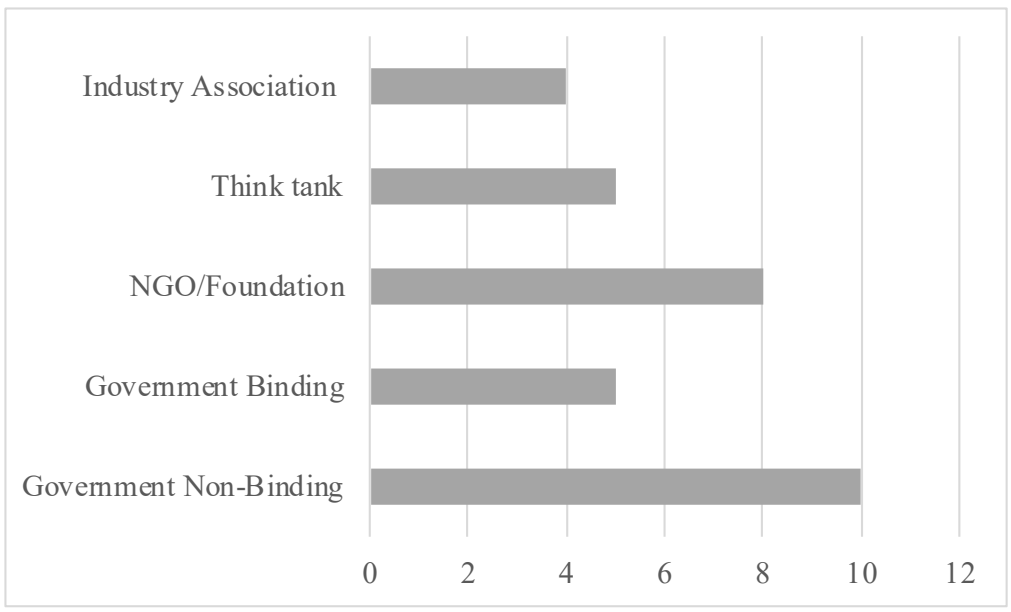

Fig. 6. Number of publications per group

The following tables (Table 1,2,3) present the final selection of the Publications, organized according to the publishing year. It is possible to also identify the following elements: reference, title, type, focus, description.

	Title		Issued by	Type	Relevance	Description
Pub1 2002	*Denmark's national strategy for sustainable development A SHARED FUTURE - balanced development*		Government of Denmark	**GNB**	Sustainable Development – Chp on Housing: General guidelines, urban develop., sustainable buildings	It is one of the first official documents on sustainability, providing the national strategy for sustainable development. There are guidelines and principles on how to decouple economic growth from environmental impacts, considering all sectors.
Pub2 2009	*Education for Sustainable Development – a strategy for the United Nations Decade 2005-2014*		Danish Ministry of Education	**GNB**	Education for sustainable development, vocational education	It introduces the goal of a Danish Strategy for Education for Sustainable Development. It incorporates sustainable development in curricula. It highlights that since 2005 sustainable development has been incorporated in primary and secondary education programs, including vocational programs.
Pub3 2012	*2050 Something's Green in the State of Denmark Scenarios for a sustainable economy*		Realdania & Monday Morning	**TT**	Scenario for 2050. Chp on Housing and Urban Dev: General guidelines, Energy saving, Technology and IoT.	it provides a forecasting scenario for a "green" Denmark. It analyzes the trends that could shape the future of the country, and what they supposed it is required to achieve green growth. A great focus and attention are given to the technology aspects, with AI and IoT as the dominant factors.
Pub4 2013	*Hvidbog Om Bæredygtighed I Byggeriet*		Klima-, Energi- og Bygningsudvalget	**GNB**	integrated design process, holistic approach in sustainability, closing loop principles, financing forerunner, collaboration	This is a pioneering publication addressing systematically the sustainability concept in the building industry and considering the triple bottom line as reference. It introduces concepts relative to circular economy as it is currently supported in the sustainability transition of the sector. It works with concepts such as 'holistic approach' and 'integrated design process'. It promotes the possibilities for achieving construction of the best possible quality, both technically, aesthetically, functionally, environmentally, socially and economically, within the given framework.
Pub5 2014	*Energipolitisk redegørelse 2014*		Klima-, Energi- og Bygningsministeriet	**GB**	Energy policy on the medium term. Energy saving in buildings, goals, guidelines, and expectations	This document can be considered a milestone in the sustainability transition of the building industry, since establish the policy and the targets for 2020 and 2050 (Thuesen et al 2016). It makes a translation of EU directives into national policy. It illustrates how the government supports a target for greenhouse gas reduction of at least 40% compared to 1990. The general goal for renewable energy is established at 30 per cent. In addition, the document proposes a discussion table to set binding targets for energy efficiency in 2030.
Pub6 2014	*Strategi for energirenovering af bygninger*		Klima-, Energi- og Bygningsministeriet	**GNB**	Guidelines and strategy on energy saving in the building sect., benefits	This is the translation of the Pub 4 (2014), into guidelines on how to implement the stated requirements. It provides concrete set of initiatives that can be take to reduce the energy consumption in buildings, according to their type and function. It still a focus on the operational energy, hence the CO2 related to the running of the structures, no mention of the embodied CO2 construction of it.
Pub7 2015	*Potential for Denmark as a Circular Economy - A Toolkit For Policy Makers*		Ellen MacArthur Foundation	**NGOF**	General CE – Chp on Buildings: Materials, Processes/Tools, Use, Construction	This is a document commissioned to the EMF by the Danish Government, as a tool for the policy makers to understand the opportunities, the barriers and the policy options of introducing the concept of Circular Economy at a national level.
Pub8 2016	*Bæredygtigt byggeri*		Trafik- og Byggestyrelsen	**GNB**	CE in Buildings, LCA, Embodied CO2, principles, guidelines	The document offers a clear and simple overview of main principles (highly centered on circular economy concept), good practices and tools for building more sustainably. It explains its social, environmental, and economic benefits. For the first time the strategy recognizes the concept of embodied CO2 in buildings. Explicit purpose of the publication is to ensure that Denmark has a common basis working on sustainable construction.
Pub9 2017	*The Advisory Board for Circular Economy Recommendations for the Danish Government*		Advisory Board for Circular Economy	**TT**	General CE – Chp on Buildings: Vision, Regulations, Products, Materials, LCA, Marketplaces. Recommendations: Education, Economic, Finance, Standards …	The publication is the results of the research of a government appointed advisory board, composed by 12 industry leaders. The goal is to provide a list of specific recommendations and initiatives for supporting the transition of the Danish industry into a more circular paradigm in 2030.
Pub10 2018	*Strategy for Circular Economy - More value and better environment through design, consumption, and recycling*		Miljø- og Fødevareministeriet og Erhvervsministeriet	**GNB**	General CE – Chp on Buildings: Definining Initiatives. Product design, Sustainability class, Demolition/Disassembly	The document is the exposition of the danish Strategy for a transition towards a circular economy. It has a strong focus on the benefits of the transformation, highlighting the importance and advantages of reducing material use and increase recycling, not only for the environment but also for the competitiveness of the Danish companies.
Pub11 2018	*Research 2025 – Promising Future Research areas*		Uddannelses- og Forskningsstyrelsen	**GB**	Strategy and investments. Chp on B. CE in Buildings, Material, Construction, Energy efficiency, Indoor climate, Digital Tools	The RESEARCH2025 catalogue provides a deep overview of the priorities about knowledge needs in Danish society, as a way for growth and wellbeing. It gives strong directions on where to invest in research in the future. It is based a total of 476 contributions from organizations, municipal and regional public administrations, academic institutions, and a wide variety of different stakeholders.

Table 1

	Title		Issued by	Type	Relevance	Description
Pub12 2018	*Description of services for Building and Landscape*		FRI & DAC	**IA**	Guideline related to Sustainability in all sections. Section on Sustainability Services. Sust. Manag., Sust. Cert., Sust. Serv.	The document is the description of services, and it must be seen as a basis for consultancy agreements for building works and construction. It includes tenders based on a building project and instructs on how to manage contracts and disciplines.
Pub13 2018	*Guide to Sustainable Building Certifications*		Realdania and The Dreyer Foundation	**NGOF**	Strategic comparison of available certification, based on Triple bottom line.	The goal of this publication is to provide a knowledge base and transparency on different sustainability certifications in the construction industry. It is also a resource for decision making for sustainable certification of buildings. It can be used as a tool to show, describe, and explain certification systems, and so providing the basis for an improved exchange between parties within the building sector such as clients and consultants.
Pub14 2018	*Sammen om en grønnere fremtid Klima - og luftudspil*		Energi-, Forsynings- og Klimaministeriet	**GNB**	National commitments, strategies and goals. Chp. on Housing, only heating and energy saving	With this document the government is taking the next step on the road to a Denmark with better air and less burden on the environment. 38 concrete initiatives, addressing transport in urban and rural areas, agriculture, shipping and a housing and industry.
Pub15 2019	*Building a Circular Future - 3rd Edition*		GXN Architects	**TT**	CE buildings. Five Circular Business Models. Economic benefits Cases. Materials, Construction proc., Tools, Products, Collaboration.	First published in 2015, this is the third edition. The goal of this publication is to challenge and rethink the way resources are used and reused in the building industry, and thus to bring to zero the concept of waste. In the new edition, there has been a significant advancement and more stakeholders from the building sectors and other industries have engaged in the circular economy.
Pub16 2019	*Vælg Bæredygtigt – for mennesker, miljø & økonomi*		DI – Dansk Byggeri	**IA**	Sustainable construction principles and guidelines. Circularity background. Products, Materials.	The explicit goal of the project is to increase awareness around sustainability in construction among the professionals of the sector. The document has been developed in a collaboration between Dansk Byggeri, Brancheforeningen Danske Byggecentre and Smith Innovation.
Pub17 2019	*Bæredygtighedpolitik 2019*		DI – Dansk Byggeri	**IA**	Sustainable construction, 19 proposals. Circularity. LCA. Education. Goals	According to the document still a lot can be done in the sector even under the current framework. There is an open call for a close collaboration on the decision-making process with the political authority to work in the direction of sustainability. In this perspective, they present 19 concrete proposals to politicians for a sustainable development.
Pub18 2019	*Byggeriets Energianalyse 2019*		DI – Dansk Byggeri	**IA**	Focus on Energy in building. Benefits of energy renovation, Tools/IoT, Energy Saving, Renewable Energy for buildings	The document provides a focused perspective on potentials and instruments for energy savings in buildings
Pub19 2019	*Cirkulær økonomi og DGNB – Guide til cirkulære principper i DGNB bæredygtighedscertificering*		DGNB – DK-GBC	**NGOF**	Building certification based on DGNB system, focus on CE in	The danish version of the DGNB manual for sustainable buildings from a Circular Economy perspective.
Pub20 2020	*Lov om klima 2020*		Government	**GB**	Waste and CE. Goals, initiatives. Reduction waste from buildings, demolition/disassembly	This is the agreement reached among all spectrum of parties in the parliament and providing national climate binding goals. With this law the country establish that it must reduce greenhouse gas emissions in 2030 by 70% compared to 1990 levels. And stating a long-term target for the country to become carbon-neutral society by 2050.
Pub21 2020	*Klimaplan for en grøn affaldssektor og cirkulær økonomi*		Government	**GB**	Waste and CE. Goals, initiatives. Reduction waste from buildings, demolition/disassembly	This is the agreement reached among all spectrum of parties in the parliament and providing 8 initiatives on the treatment of waste materials and recycling from a circular economy perspective.
Pub22 2020	*Vejledning om den frivillige bæredygtigheds-klasse*		Trafik - Bygge- og Boligstyrelsen	**GNB**	Knowledge and capacity building, sustainable voluntarily class. 360 approach. Cases. Reporting. Collaboration.	The document sets the basis and the rules for the initiative of the Voluntary Sustainability Class, whose ambition is to define and offer an easily accessible and uniform ground on which to realize sustainable buildings. Its long-term goal is to introduce requirements for sustainability in the building regulations, based on a solid collaboration between the parties and a broad involvement in the making.

Table 2

	Title		Issued by	Type	Relevance	Description
Pub23 2020	*14 Erhvervsforsker-projekter skal gøre byggebranchen grønnere*		Realdania	**NGOF**	14 projects. Collaboration, Circular Solutions, Business models, Design, Disassembly, materials, products, processes …	The document talks about the launch of launching 14 Business Researcher projects, where companies, public organizations and research institutions will develop new solutions within circular construction. The projects will contribute to the sustainable transformation of the construction industry in Denmark. A joint initiative supported by Realdania and the Innovation Fund.
Pub24 2020	*Recommendations to the Danish Government from the Climate Partnership of the construction industry*		Klimapartnerskaber	**TT**	Design, waste, building site, Energy renovation, operational energy of buildings	The document was carried out with the collaboration of 13 large actors, that have worked to resolve the important task of proposing concrete recommendations to the government on how to proceed and which measures may contribute to reaching the target to reduce Denmark's CO2 emission by 70% in 2030.
Pub25 2020	*Videncenter for Cirkulær Økonomi i Byggeriet (VCOB)*		Dansk Teknologisk Insitut	**GNB**	Knowledge centre for CE in the building industry. Processes, Materials, Products, Waste, Hazardous substances, etc …	The Knowledge Center for Circular Economy in Construction - VCØB - gathers, develops, and disseminates impartial and concrete knowledge about circular economy in the construction industry. At VCØB building owners, contractors, craftsmen, consultants, architects, manufacturers, or municipality can get free guidance on circular economy in construction.
Pub26 2020	*Bæredygtigt byggeri giver også bedre liv*		Concito/ Rådet for Grøn Omstilling	**TT**	Sustainability from a social well-being perspective. Pushing for social aspect to be in sust class	An important document from Concito, about the importance of the social wellbeing dimension in the sustainability transition discourse and how to integrate it into the process. Sustainable construction can alleviate loneliness and poor well-being, but there is the need of goals set for social qualities. It can save billions; it is thus imperative to include social sustainability in the sustainable construction strategy.
Pub27 2020	*DGNB SYSTEM Building in use Criteria set*		DGNB	**NGOF**	Sust. Certification for Building IN USE. Guidelines on social well-being, CE, Design quality, SDGs, Innovation, Climate protection	The two documents are about the DGNB System for existing and new buildings respectively. This is the most recent version. The goal of DGNB System is not just to provide certification but also it uses certification as a tool through which an overall quality standard of the building sector can be ensured. The first to be used as an optimisation tool to make buildings future-proof and positively contribute to climate action. The second as a tool in planning and construction stages to help finding the right answers to the most pressing questions regarding sustainability.
Pub28 2020	*DGNB SYSTEM New Construction, Buildings Criteria set*		DGNB	**NGOF**	Sust. Certification for NEW Buildings. Guidelines on social well-being, CE, Design quality, SDGs, Innovation, Climate protection	
Pub29 2021	*2 danske teams af forskere og virksomheder er udvalgt til at accelerere cirkulært byggeri*		Realdania	**NGOF**	Focus on CE, reuse of materials, products and buildings. Marketplace, Business and material passport. wide cross-collaboration and innovation.	2 Danish teams of researchers and companies have been selected to accelerate circular construction. It must be easy and safe for the construction industry to choose recycled materials. The quality of the recycled materials must be documented. And then they need to be far more accessible. Universities and the construction industry are now joining forces in two large consortia - selected by Realdania and the Innovation Fund - to accelerate the green transformation of the construction industry.
Pub30 2021	*Circle House Lab – Publications*		BLOXHUB	**NGOF**	CE in building industry. Focus on Business models, Take back system, Disassembly, Building passport, etc.	Undoubtedly one of the most important knowledge hub about circular economy and sustainability on the building sector. As from 2019, it provides free accessible knowledge about the best practices in the field. Publications made by collaborative works and multifaceted approaches and perspectives, experts from different schools, business and technology sectors.
Pub31 2021	*Forståelsespapir vedr. fossilfri byggepladser*		Vejdirektoratet	**GB**	Focus on machineries on the construction site. Collaboration, test and goals	A document officialising the collaboration between Vejdirektoratet, the City of Copenhagen and DI Dansk Byggeri, with the objective to achieve fossil- and emission-free construction sites. Setting the basis for a working group for: All machines that can use emission-free propellants (for example electricity and hydrogen) must do so where it is practically usable and possible. All diesel-powered machines must use biofuels
Pub32 2021	*National strategi for bæredygtigt byggeri*		Government	**GB**	New rules and thresholds for CO2 in new buildings, strategies, principles, guidelines. Milestone	This document explains the details the national strategy for sustainable construction and constitutes the government's sector action plan for the construction sector. It sets goals and initiatives for the achievement of the sustainability transition.
Pub33 2021	*Status Outlook 2021 Denmark's national and global climate efforts*		Klimaradet	**GNB**	Monitoring of the achievement of Sustainability goals. Steering Recommendations, critics on policy and goals	This is the most recent report carried out by the Danish Council on Climate Change, analyzing the efforts made at a national level by government initiatives (strategies, rules, goals, etc.).

Table 3

3.2.4 The Experiments

Besides the Publications, this research also relied on the analysis of documents reporting on current experiments in the building industry and regarding sustainability aspects. For a matter of simplicity, we will henceforth refer to these types of documents as “Experiments”.

The search process in the case of the Experiments was much more straightforward than the one of the Publications. In fact, the identification of relevant Experiments was often guided by the content presented in the Publications, and only a refining process was necessary in order to uncover useful details only partially explained in the Publications. In order to identify the corresponding impact area, the Experiments were organized according to the following 5 stages: Design, Product, Construction, Use, End-of-Life (Table 4). The stages are derived from the Building Life-Cycle Phases framework as it is defined by the European standard for the sustainability of construction works (EN 15978: 2011). Table 5 provides a summary with the relevant information on the Experiments

BUILDING LIFE CYCLE PHASES AND INFORMATION				
DESIGN	**PRODUCT**	**CONSTRUCTION**	**USE**	**END-OF-LIFE**
Tasks/Actions	Tasks/Actions	Tasks/Actions	Tasks/Actions	Tasks/Actions
• Pre-design • Development Planning • Building design	• Material Extraction • Manufacturing • Transport	• Transport • Process • Construction Site Machinery	• Use • Maintenance • Repair • Replacement • Refurbishment	• Disassembly • Demolition • Transport • Construction Site Machinery • Waste Treatment/Disposal
Actors	Actors	Actors	Actors	Actors
• Investors • Architects • Designers • Engineers • Consultants	• Manuf. Companies • Extract Companies • Second-hand Mat. • Second-hand Prod. Comp. • Transportation Companies	• Constr. Companies • Install. Companies • Architects • Engineers • Transportation Companies	• Occupants/Users • Owners • Maintenance Comp.	• Demolition Companies • Disassembly Companies • Transportation Companies

Table 4. Building Life Cycle Phases and Information (inspired by EN 15978: 2011)

Experiment	Initiative by	Dimensions	Description
MiniCO2 Husene	• Realdania • Lendager Group	• Design • Product • Construction • Use	Family Housing, Nyborg, Aarhus, 6 units. Six experimental houses in Nyborg whose aim is to demonstrate how it is possible to reduce carbon emissions by 45 percent using prefabricated homes. The project comprises a total of six detached houses, each of which illustrates different aspects of reducing CO2 emissions in resp. construction, operation and maintenance of a house.
Circle House - Denmark's first circular housing project.	• Lejerbo, • GNX, • Lendager Group • Vandkunsten	• Design • Product • Construction • Use • End-of-Life	Public Housing, Lisbjerg, Aarhus, 60 units. Circle House is 60 public housing built according to the principles of circular economy. The experiment will show to the concerned actors, that is a scalable demonstration solutions and that can provide the construction industry with fresh and consistent knowledge about the experiences of building circular. The target is that 90% of the homes' materials can be recycled, without significantly losing value. The project involves more than 60 companies from the Danish construction industry across the value chain.
Mini CO2 etagebyggeriet i træ.	• Realdania • By&Byg	• Design • Product • Construction	Multi–storey residential building , Fredericia, 1 unit. The experiment aims to increase knowledge about the possibility to build multistorey buildings for residential purposes, with the least possible CO2 emissions, by using wood as the dominant material. The project is supposed to challenge the current use of wood and should help to come up with new, innovative solutions for its use in construction.
Det effective byggeri	• Realdania • By&Byg	• Design • Construction	Multi–storey residential building , Fredericia, 1 unit. The goal is to support the understanding on how digital solutions and tools can contribute to creating a more efficient construction process, by which it will create an increased knowledge about how the construction industry, through these tools can create a building with less shortcomings and more sustainability in the projects. Many parties from different fields of the building and engineering join forces to build the answer.
Bæredygtigheds klasse casebank	• Bolig og Planstyrelsen	• Design • Product • Use	Housing, business, single-family house, chain- and terraced housing, multi-storey residential building, office building, institution's building. National territory, 100+ units. It is possibly the largest set of experiments ever conducted concurrently (time span between 2019 and 2026) for sustainability transition of the building sector, supported at a national level. The casebank is under the umbrella of the Voluntary Sustainability Class (Pub_21 2020) national project, that will become obligatory as from 2023. The projects deal with several aspects of the building life-cycle stages. It also introduces the use of LCA/LCC and the application of DGNB Certifications. The goal is to provide a common ground of knowledge for the transition to take place in an effective way and with all the actors involved.
Reuse and recycling in public tenders - City of Copenhagen	• København Kommune	• Design • Product • Use • End-of-Life	Institutional, multi-storey residential building, København Kommune, 9 units. First round of tests part of the European project Circuit, under the Horizon umbrella. 9 projects based on circular principles, with focus on D, RR, MP selective demolition for new construction, and for refurbishment and repurposing, but also on brand new constructions, and repurposing and refurbishment with new sustainable solutions. Another set of 9 projects with different foci, are expected to be launched in 2022.
Forståelsespapir vedr fossilfri byggepladser	• Vejdirektoratet • København Kommune • Dansk Byggeri	• Construction	Machinery in construction sites, København Kommune, 2 projects. The experiment is about testing solutions with the objective to achieve fossil- and emission-free construction sites. Setting the basis for a working group for: All machines that can use emission-free propellants (for example electricity and hydrogen) must do so where it is practically usable and possible. All diesel-powered machines must use biofuels as a phase-out technology until all will be powered with fully renewable resources.

Table 5. A summary of the analysed Experiments

3.2.4.1 Experiments' relevance

This section provides an overview of the dimensions the Experiments are working with (Table 6). As we can see, collectively they cover the whole set of the Building Life-Cycle Phases.

	EXP1 - 2011	EXP2 - 2017	EXP3 - 2019	EXP4 - 2020	EXP5 - 2020	EXP6 - 2020	EXP7 - 2021
	MiniCO2 Husene	*Circle House*	*Mini CO2 etagebyggeriet i træ*	*Det effective byggeri.*	*Bæredygtigheds klasse casebank*	*Reuse and recycling in public tenders - KK*	*Forståelsespapir vedr fossilfri byggepladser*
DESIGN	✓	✓	✓	✓	✓	✓	
PRODUCT	✓	✓	✓		✓	✓	
CONSTRUCTION	✓	✓	✓	✓			✓
USE	✓	✓			✓	✓	
END-OF-LIFE		✓				✓	

Table 6. Focal areas of the Experiments

Even though the original configuration of the Experiments is more articulated and richer in detail of than the above representation, the latter provide is functional in providing a quick overview of the Experiments' focus in relation to the Building Life-Cycle Phases.

3.2.5 Semi-structured Interviews

An important part of this research is represented by the empirical evidence from the two rounds of semi-structured interviews with practitioners from the building industry. With semi-structured interviews we refer to a specific type of conversations one-to-one and employing a mix of open-ended questions with closer ones, that are in most of the cases followed by a "why" or a "how" about that specific answer (Galletta, 2013). More precisely this research conducted a total of 15 interviews divided int two rounds. 10 in the first round, 5 in the second round. Due to the Covid19 restrictions were realized through video calling.

The first round was conducted with 10 practitioners and adopted what Galletta (2013) refers to as the "*repertoire of possibilities*" approach and was primarily realized with the intention of gaining insights on possible research areas for this study. The baseline for this round of interviews was the general understanding of sustainability in the building industry in Denmark. It also discussed aspects like the current practices adopted in support of the transition, benefits, hurdles, and possible weak points.

The second round of interviews was realized with a smaller group of interviewees (5 in total) two months after the first one. It aimed to identify details and specific aspects of the experiments and tools they have been using to work on the sustainability transition.

The interviews were transcribed through the use of a dedicated software and then analysed.

Chapter | 4

Sustainability of the Danish Building Industry

This section is divided into two main parts. The first part is meant to provide an overview on the sustainability transition of the danish building industry. The second part offers considerations on where the transition is standing and what kind of transition pathway seems to follow.

4.1 A Sustainability transition

Denmark is undoubtedly one of the leading countries in sustainability performances (EPI 2020). For a long period of time, basically since the global oil crisis in the 1970s, the country focused primarily on the optimization of operational use of energy in buildings (Marsh et al 2010). Denmark has in fact became a champion in this filed achieving remarkable advancements globally regarded as reference in the field of energy saving in buildings (NEEAP 2017, DEA 2020).

From a more general perspective though, the challenge of a sustainable building sector goes far beyond the energy saving strategy and must also consider reduction of resource utilisation along the entire lifecycle of a building, and not just operational aspects (Thuesen et al 2016, Röck et al 2020).

4.1.1 Towards a Systemic Approach

Since 2013 (Pub4 2013) there is an expanded understanding of sustainability in the building industry that includes concepts like the triple bottom line used as reference for a sustainable development of the sector.

The publication of "*Energipolitisk redegørelse 2014*" (Pub5 2014), is though considered a turning point (Thuesen et al 2016), since for it establishes policies and binding targets for the greenhouse gas reduction of at least 40% compared to 1990 levels.

In the years of 2016, 2017, and 2018, the concept of circular economy in the building industry is initiated, shared, and consolidated, respectively. "*Bæredygtigt byggeri*" (Pub8 2016) is undoubtedly a milestone, as the document offers a clear and simple overview for practitioners of the main principles (highly centred on circular economy concept), good practices and tools for building more sustainably. It explains its social, environmental, and economic benefits. For the first time a document recognizes the importance of dealing with the embodied CO2 in buildings, as a key strategy for achieving a really sustainable industry. Explicit purpose of the publication is to ensure that Denmark has a common basis working on sustainable construction.

"The Advisory Board for Circular Economy Recommendations for the Danish Government" (Pub9 2017) can be considered as a sort of validation tool used by the government for consolidating the idea of the viability

of Circular Economy as a strategy for a national sustainable development. The document provides 27 recommendations, of which 4 address directly the building and construction sector.

With "*Strategy for Circular Economy* (Pub10 2018) the government finally confirms the Circular Economy concept as the main strategy for the future development of the country. A chapter is reserved to the building industry with a strong focus on the benefits of the transformation, highlighting the importance and advantages of reducing material use and increase recycling, not only for the environment but also for the competitiveness of the Danish companies. Circular Economy has formally entered the portfolio of strategies for a sustainable development of the building industry.

4.1.2 A New Horizon for the Sustainability of the Danish Building Industry

Between 2018 and 2021, many initiatives supporting the sustainability transition of the industry followed. In 2018 with "*Research 2025 – Promising Future Research areas*" (Pub11 2018) the government directs some of the research efforts towards specific aspects of the sustainability of the building industry. It highlights importance of CE in the sector, and support research for materials, construction processes, energy efficiency and new digital tools for the design of sustainable buildings.

In 2020, the new Climate Act is approved with the support of a vast majority of the political spectrum in the danish parliament (Pub20 2020). It replaces the 2014 law, and it is possibly the most ambitious law approved in support of the country sustainability transition. It provides national climate binding goals for 2030, but also the more general goal of a carbon neutral country in 2050.

In 2020 the long-awaited Voluntary Sustainability Class is finally launched (Pub22 2020). The initiative is a call for companies from the building industry to voluntary apply for the sustainability class. A class made of a series of 'educational' initiatives in combination with the execution of real cases (24 projects) that must follow specific sustainability elements like LCA/LCC, use of special materials, achieve a reduction of CO2 emissions, strengthening the collaboration among actors, etc. The ambition is to offer an easily accessible and uniform ground to build sustainably. Its long-term goal is to introduce requirements for sustainability in the building regulations, based on a solid collaboration between the parties and a broad involvement in the making. The class will be mandatory as from 2023.

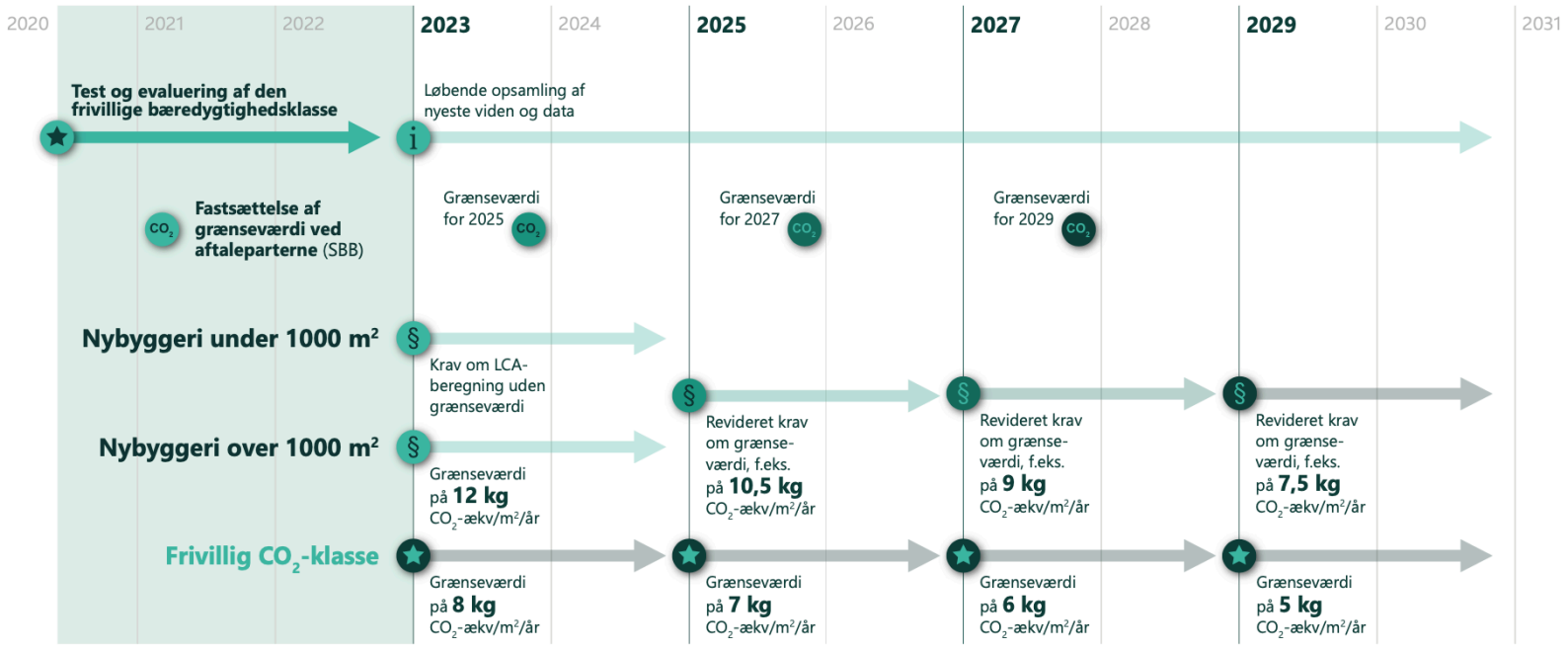

Fig. 7. Step-by-step phasing in and tightening of CO2 requirements

Finally in 2021, the government publish the national strategy for sustainable buildings (Pub23 2021). It is the translation of the 2020 Climate Act into specific guidelines, principles, and binding progressive targets on CO2 emissions per sqm for new buildings, up to 2030 (Fig. 7). It also sets as a requirement the use of LCA methods for the design of buildings.

4.1.3 In the meantime, Dansk Byggeri …

Dansk Byggeri is the largest industry association of Denmark representing a community of more than 6,000 companies within construction, civil engineering, and the construction industry. Companies associated with the union employ around 73,000 employees[6], out of a total workforce in the sector of 187.000 units (1st quarter 2021 – Danmark Statistik).

Dansk Byggeri has released its first document advocating for a change of state of the system only in 2019 (Pub16 2019). In this first approach, the association promote the idea of following new principles for the construction of new building. They provide guidelines based on circular economy principles, still vague and mostly promotional.

With their 2019 *Bæredygtighedpolitik (Pub17 2019)* they promote the importance of focusing on what can still be done with the current framework to achieve more sustainability. Their strategy, that arrives quite late in the timeline, is centred in putting together companies, politicians and the authorities working to create a more sustainable society. In this perspective they offer 19 concrete proposals to politicians that can strengthen sustainable development, turning around 4 main strategic areas: circular economy, climate adaptation and coastal protection, a sustainable construction industry, energy efficiency improvements and renewable energy.

The document is full of good intentions, but lack of real commitments and demands to the politicians and the government to take action.

[6] https://www.danskindustri.dk/brancher/di-dansk-byggeri/

Things gets a bit more specific in 2020 with the document filled with recommendations and issued under the initiative Klimapartnerskaber (Pub24 2020). According to their suggestions to the government, it is possible to achieve the target to reduce Denmark's CO2 emission by 70% in 2030. The report is organised around three main working areas: *Implementation of energy efficiency measures in existing buildings, CO2 reduction from operation of buildings, Design and the CO2 content of materials in buildings, CO2 reduction at the building site.*

4.1.5 The transition phase of the Danish building industry

Dealing with the building sector means dealing with complexity, a context characterized by a large variety of actors and stakeholders. Defining exactly where the transition is standing right now is a guessing exercise, but an initial empirical evaluation seems to appoint the industry somewhere in the early stage, possibly in the so-called *predevelopment* phase (Fig. 8). The indicator suggesting this initial conclusion is provided by Geels & Schott (2007, p405) when affirming that for niche-innovations to stabilize one of the conditions to be met is that "*the innovation is used in market niches, which cumulatively amount to more than 5% market share*". According to Dansk Byggeri, in the past 10 years only 4% of all ongoing property constructions are to be considered sustainable (Deloitte, 2020). This topic will be further elaborated and analysed in Chapter 5.

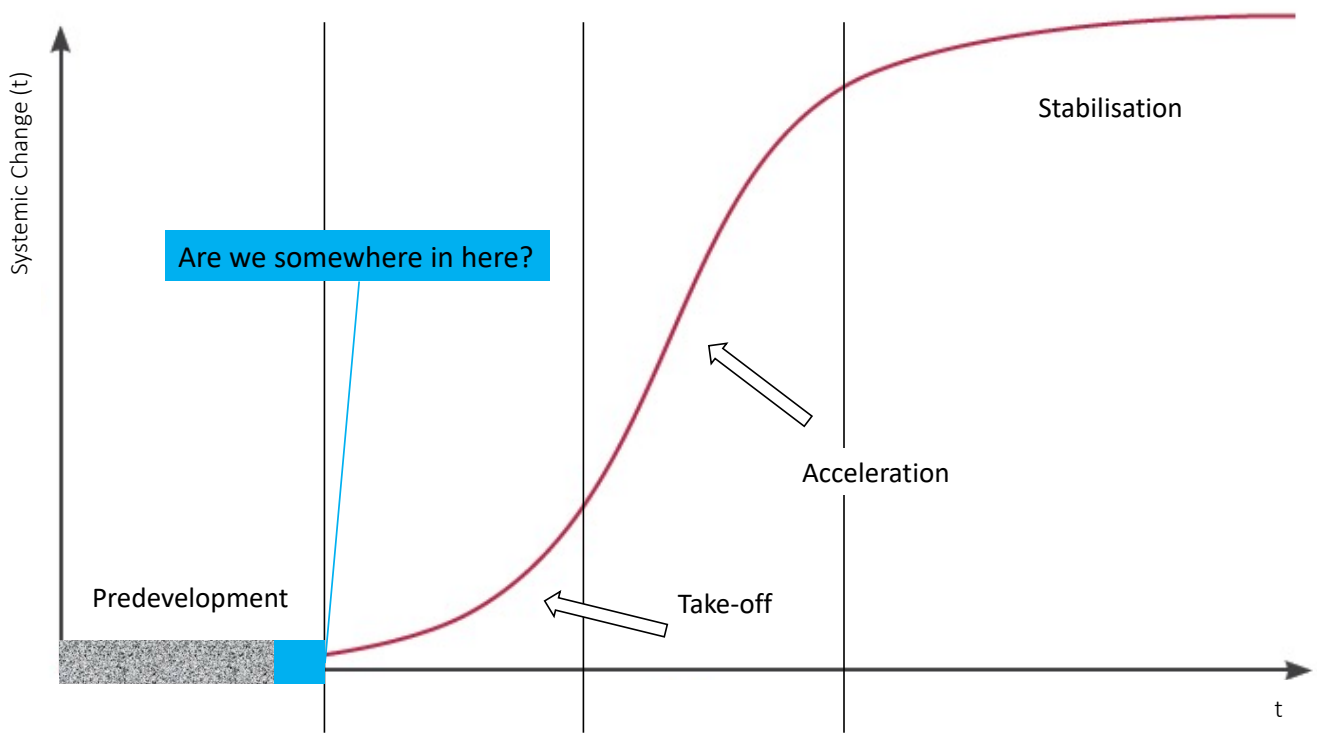

Fig. 8. The current supposed position of the Sustainability transition of the danish building industry (based on Martens and Rotmans 2005)

Chapter | 5
The Resilience of The Sustainability Transition of the Danish Building Industry

This research has its core focus on the analysis of the resilience of the sustainability transition of the building industry in Denmark, based on the RST framework as elaborated by Schilling et al (2018), whose main purpose is to define and analyse factors that potentially can affect the sustainability transition's success.

The framework is built on the combination of two of the key common concepts from the resilience literature, Stability and Adaptability, with the more general concept of dynamic Progress in socio-technical transitions, seen as a consequence of the evolutionary reconfiguration processes occurring through the interaction between innovation (niche level) and resistance (regime level) at a systemic level.

5.1 Analysis of the Resilience of Sustainability Transition

As it has been already anticipated Chapter 4, the building industry is currently somewhere in phase 1 of the sustainability transition.

According to Schilling et al (2018), each transition phase, comes with a different configuration set of weights in regard to the three key dimensions (Fig. 9): Progress (P), Stability (S), Adaptability (A). In the *predevelopment* phase the highest priority should be given to the Progress dimension and the Stability dimension. This is justified by the rationale that in Phase 1 it is too early to take care of adaptation issues. The system has not yet reached any relevant change of state, by consequence not much to be adapted to newly emerged regulations and ad-hoc infrastructures. This will be a concern more ahead once the *take-off* phase has started.

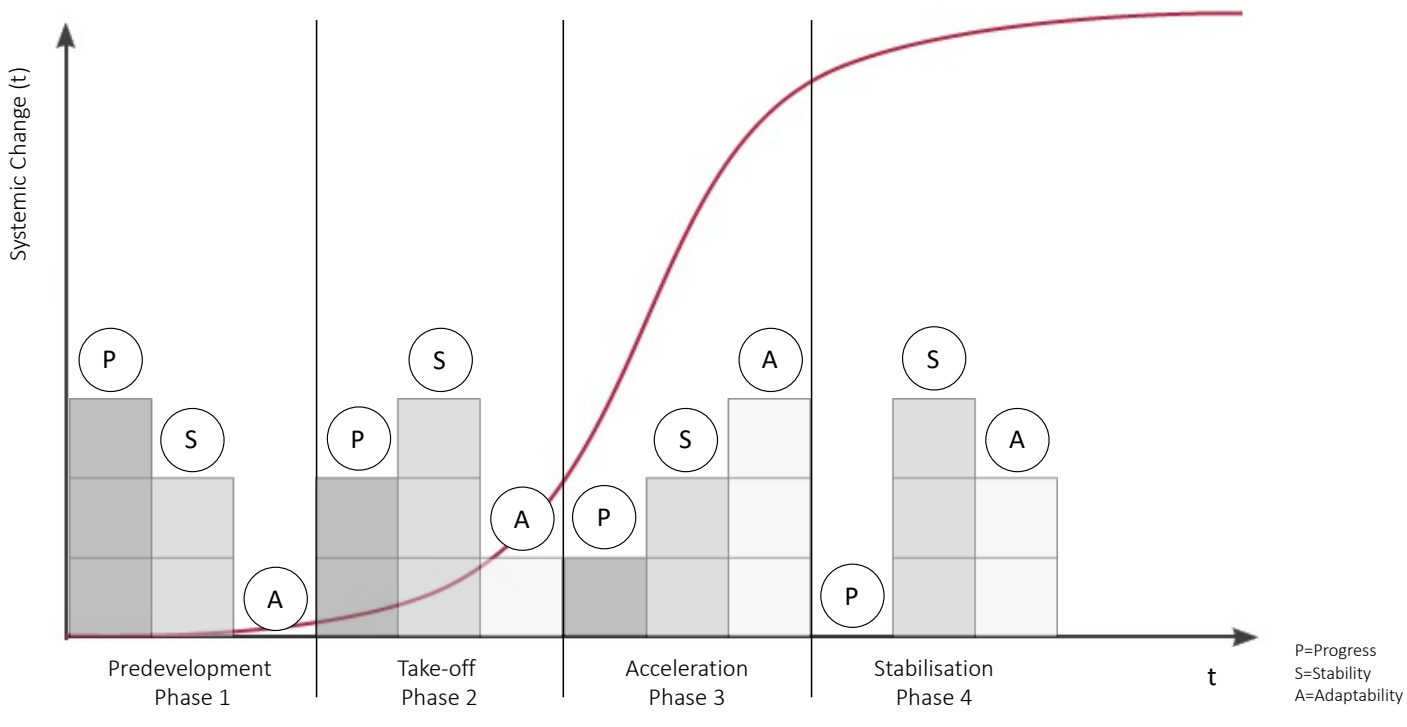

Fig. 9. Different phases and the respective RST dimension's weight (own design – based on Schilling et al 2018)

Armed with this understanding, the core of the case analysis is carried out only around the *predevelopment* phase, since it is the period of time of available data on the initiatives supported by a series of entities. It is an ex-post analysis, and not a predictive one. In fact, going through the successive transition phase (take-off) would have required to have access to strategic decision-making tables and working sessions with a range of actors from public administrations, from within the regime and from outside of it. This was incompatible with the limited duration of the project (4 months). Admitting this possible, it would have also required a time span of a few years of participation for acquiring enough useful information.

The analysis was carried out on a qualitative basis, using subjective judgement of the author, and guided by a principle of relevance (reported topic, issuing institution, year of publication) of the studied document. The results are built on non-quantifiable information extracted through the reading of past and current documents about strategies, guidelines, recommendations, principles, laws, and experimental projects.

5.1.1 Transition Progress

For the system reaching the take-off phase, it depends on the interplay between *drivers* and *resistance* produced by the actors, and how this interplay results in supporting the system to pass through the regime resistance. There is in fact the risk that, without proper drivers, the sustainability transition might fail to impact the current system state.

The three following sections (5.1.1.1, 5.1.1.2, 5.1.1.3) go through the following points: identification of the actors playing some role in this phase of the transition, main drivers, main resistance.

5.1.1.1 The Actors

The progress of a transition is very much related to the kind of actions engaged by interested actors and group of actors from the sector, looking for a change in the incumbent socio-technical regime. It is then interesting to understand, who these actors are in this research study case. Actors working for a change, con also change in time. It is plausible that actors at the beginning of the predevelopment phase, are mostly those from out of the regime or from its fringes. They are mainly represented by frontrunners and highly sensitive to the landscape pressure, mavericks that are interested in alternative approaches, and in challenging the regime. They normally do that because of ethical reasons and for the mission that follows it (let's save the world!). To this group belong organisations like NGOs, sustainability thinktanks and foundations. In this category we find the *Ellen MacArthur Foundation*, *Bloxhub*, *Gate 21*, *Concito*, *Realdania*, *Innobyg*, *Rådet* for Grøn *Omstilling*. Architectural firms like *GXN Architects*, *Gehl*, *Lendager Group*, *Vandkunsten Architects*, *Arkitema Architets,* and the construction company *MT Højgaard* can all also be framed in this group for their pioneering works on the sustainability of the buildings.

Another relevant cluster is formed by opportunistic actors from the regime. They are forerunners open enough to understand that being among the first movers can become a competitive advantage for the future that is coming. Here it can be found social housing associations like *Lejerbo* or *FSB*, but also firms like the demolition company *JJensen* or the construction company *Enemærke* & *Petersen*, pioneers in experimenting

new disassembly and construction processes, or engineering companies like *Rambøll* and *COWI*. They are all part of a larger support network for niche-innovation development.

Branches of the government designed to keep a strategic eye on the future of a sector, like *Klima-, Energi- og Bygningsministeriet*, or *Miljø- og Fødevareministeriet og Erhvervsministeriet*, or *Energi-, Forsynings- og Klimaministeriet*, have also an important role and can be seen as translators of the abovementioned groups' negotiations into actionable plans.

Where does *Dansk Byggeri* stand in all of this discussion? There is no doubt they are at the core of the regime, and for obvious reasons they do not act as frontrunners for a sustainability transition. They rather act as lastminute participants. We could say they jump on the bandwagon without deserving it, sure they have not made great contribution in spurring the shift.

5.1.1.2 Drivers

According to Schilling et al (2018) *Drivers* are defined as "*an innovation that causes system state changes and thus affects the transition progress*" (p: 6). There is not exact measurable way to know the actual impact that a driver may or may not have on the overarching transition, especially when the transition is at an early stage on a time frame of several decades. Nevertheless, it is possible through the analysis of Publications and Experiments, and complementary data collected by this research, to empirically identify actions, statements, and initiatives that are supporting a change in the system.

In order to facilitate the task and make the result consistent with the building industry, this research uses the Building-Life-Cycle Phases frame as defined by the European standard for the sustainability of construction works (EN 15978: 2011), and analyses the Drivers in correspondence of each of the 5 stages: Design, Product, Construction, Use, End-of-Life (Fig. CF).

BUILDING LIFE CYCLE PHASES AND INFORMATION

DESIGN	PRODUCT	CONSTRUCTION	USE	END-OF-LIFE
Tasks/Actions	Tasks/Actions	Tasks/Actions	Tasks/Actions	Tasks/Actions
• Pre-design • Development Planning • Building design	• Material Extraction • Manufacturing • Transport	• Transport • Process • Construction Site Machinery	• Use • Maintenance • Repair • Replacement • Refurbishment	• Disassembly • Demolition • Transport • Construction Site Machinery • Waste Treatment/Disposal
Actors	Actors	Actors	Actors	Actors
• Investors • Architects • Designers • Engineers • Consultants	• Manuf. Companies • Extract Companies • Second-hand Mat. • Second-hand Prod. Comp. • Transportation Companies	• Constr. Companies • Install. Companies • Architects • Engineers • Transportation Companies	• Occupants/Users • Owners • Maintenance Comp.	• Demolition Companies • Disassembly Companies • Transportation Companies

Fig. CF Building Life Cycle Phases and Information (inspired by EN 15978: 2011)

Design phase – In this phase we refer to the drivers as coming from the study and the promotion of alternative design processes. A widely accepted approach supporting a sustainable shift in the design phase,

is the so-called Integrated Design Process, where actors and stakeholders are invited to the decision table since the very beginning of the project (Hansen & Knudstrup 2005, Heiselberg 2007, Forgues & Koskela 2009, Landgren 2018). Also, the use of digital tools like Building Information Modelling (BIM) and Virtual Design and Construction (VDC), are nowadays considered essential tools for a design outcome consistent with sustainability constrains (Wu & Issa 2010, Czmoch & Pekala 2014, Carvalho et al 2019). Another important tool that gained strong attention for the design of environmentally sustainable buildings, aimed to assess the environmental impact of a product or a product system through its life cycle, is the Life-Cycle Assessment tool (LCA) (Hauschild 2018). LCA is often evaluated in conjunction with the Life-Cycle Costing LCC, i.e., the total cost of ownership over the life of a building or asset (Swarr et al 2011).

The analysis of the Publications suggests that the Integrated Design Approach, along with BIM and VDC, have been strongly supported and developed since 2013. More specifically the "Hvidbog Om Bæredygtighed I Byggeriet" (Pub4 2013) already advocates for the use of BIM software and Integrated Design Process as necessary tools for the design of sustainable buildings. "Building a Circular Future" (Pub15 2019) and "Circle House" (Exp2 2017) are highly regarded publications, widely recognized as pioneer initiatives in the field of 'circular' construction, also strongly advocating and exemplifying with real cases the use of these tools.

A great example of driver is also represented by the "14 Erhvervsforsker-projekter skal gøre byggebranchen grønnere" (Pub23 2020). A collection of 14 diverse projects focusing on different aspects of sustainability in the building industry. The document highlights the importance of the early design phases for a consistent the attainment of sustainable buildings. Of the 14 projects 3 propose innovation in the design phase.

The strategic relevance of the integration of these solutions in the design phase, is mentioned also in the 2021 "National strategi for bæredygtigt byggeri" (Pub32 2021) suggesting that integration of BIM could help making LCA and LCC calculations easier and more flexible to make.

With reference to the LCA method, it makes one of its first 'official' appearance in the 2013 (Pub4 2013), but it has been formally introduced as a design for sustainability tool by the "Bæredygtigt Byggeri" of 2016 (Pub8 2016). The document, in the form of an elementary visual handbook explains the modalities, the requirements and ultimately the benefits of applying LCA. In 2021, with the approval of the "National strategi for bæredygtigt byggeri" (Pub32 2021) LCA becomes a legal requirement for the design of buildings.

The *Research2025* catalogue can also be considered as a powerful driver since not only it recognises the need for more knowledge around digital solutions for the design process but it actively promotes and sustains research on that field: "*Digitalisation and implementation of new technology - A number of significant research needs are directed towards "Build4.0", i.e. the digital possibilities that will in future encompass all processes by collaborating on production, design, construction and operation of buildings and structures*" (Pub11 2018, p 106).

On the Experiments' side the analysis revealed that all the current projects are dealing with different design aspects from different angles (Table 7). Two in particular stand out for their specificity, the "Circle House" (Exp2 2017) and "Det effective byggeri" (Exp4 2020). The first provide a complete set of macro principles on how to achieve a real circular design in buildings. The second on how digital solutions and tools can

contribute with increased knowledge about the use of digital tools for design can result in a construction with an increased sustainability outcome.

	EXP1 - 2011	EXP2 - 2017	EXP3 - 2019	EXP4 - 2020	EXP5 - 2020	EXP6 - 2020	EXP7 - 2021
	MiniCO2 Husene	*Circle House*	*Mini CO2 etagebyggeriet i træ*	*Det effective byggeri.*	*Bæredygtigheds klasse casebank*	*Reuse and recycling in public tenders - KK*	*Forståelsespapir vedr fossilfri byggepladser*
DESIGN	✓	✓	✓	✓	✓	✓	

Table 7. Experiments working on the Design phase aspect of building projects

Product phase – In this phase we refer to the drivers as coming from the study and the promotion of alternative materials and products for the construction. Alternative refers to sustainable solutions in the form of raw materials from renewable sources, recycled raw materials, and second-hand products. They can be about concrete, insulation materials, wood, windows, doors, pillars, bricks, etc. (Raut et al 2011, Justnes 2015, Leising et al 2018, Eberhardt et al 2019, Vitrone et al 2021)

”Hvidbog Om Bæredygtighed I Byggeriet” (Pub4 2013) stands again as a reference for spreading consistent knowledge about the use of second-hand materials for the construction of new buildings, by illustrating the case of the Upcycle House, part of the larger project from Realdania, the MiniCo2 Houses in Nyborg (Exp1 2011). It also highlights the importance to consider elements of the products like: energy used to extract materials, durability, recycling potential, origin of the material, health issues for the users.

A great example of driver for the product phase, is also represented by the “14 Erhvervsforsker-projekter skal gøre byggebranchen grønnere” (Pub23 2020). The initiative brings the attention on the sustainability relevance of production of preassembled and precast elements in buildings. It also supports and launch 6 product-related projects out of the total 14 of the intitiative.

The use of second-hand materials and components is limited by several factors. From a practitioner point of view, the main obstacle is the access to those solutions with the same degree of availability and reliability of the ‘normal’ products. Regarding the access to viable and reliable data and resources for the use of second-hand materials and products for the design of buildings, two major initiatives are taking place in Denmark, going under the Grand Solutions initiative and sponsored by Realdania Foundation and the Innovation Fund.

The first is called *BusinessReuse* project, a consortium made by DTU, Rambøll, Center for SMV and Gate 21 aimed to identify new methods and processes for the classification of recycled materials and products for construction. The second project goes with the name of *Circle Bank* and part of the consortium made by Teknologisk Institut, Syddansk Universitet, and Danica Ejendomme. Circle Bank “*aims to bring together construction players around a common, digital platform that gathers and integrates new knowledge within e.g., scanning, demolition, material handling and architectural design. Circle Bank's ambition is to create a decision support tool and a market platform that supports circular construction in Denmark as well as internationally*.” (Extract from the website www.circlebank.dk – accessed on 10 05 2021).

The operationalisation of the Circle Bank is directly linked to the advancement on the definition of the so-called Material Passport and of an efficient and reliable reverse logistic Ecosystem. In this perspective, many

of the analysed Publications, stress the importance of these two things in order to be able to manage properly the sustainability transition of the sector. This research found that there are many past and present initiatives informing on the theme (Pub7 2015, Pub9 2017, Pub10 2018, Pub15 2019, Pub30 2021), but also a certain lack of macro initiatives supporting project addressing the material passport challenge.

Later in the journey there are also drivers from Dansk Byggeri. With "Vælg Bæredygtigt" (Pub16 2019) and the question "Why choose sustainable building materials?" it opens the season of discussing the importance of using sustainable products and materials in the new constructions with the member of the regime. It also provides principles on how to do that and where to search for those products and materials. In the same year a more strategic document is also published by Dansk Byggery, the "Bæredygtighedpolitik 2019". Here the materials are treated under one of the main proposals for action, a "*Common Nationwide raw material plan for Denmark*" and whose solution would be "*a joint nationwide and long-term plan to be drawn up for the supply of raw materials in Denmark*." (Pub17 2019).

"Den frivillige bæredygtigheds- klasse" (Pub22 2020) also represents one of the most relevant efforts in the study and support of the use of alternative material and products, mostly because in the wide variety of the proposed experimental projects, these are recurrent elements treated in different forms and strategies.

The already abovementioned ReuseBusiness and Circle Bank initiatives, can undoubtedly be frames in this group too. They are in fact initiatives aimed to support the use of all kind of viable second-hand solutions. In this perspective a company that is pioneering the second-hand business with already remarkable results, is undoubtedly J-Jensen and their already operating digital bank of recycled products (available at: j-jensen.com/kompetencer/genbrugssalg accessed on 10 05 2021).

On the front of raw materials, the Danish Technology Institute is a forerunner in the study of all kind of product/material related solutions. Since 2009 working with a wide range of national and international partners from the private and the public sectors, for the design of a large selection of technological sustainable solutions for buildings: sustainable steel fibre concrete structures, recycling concrete, build-in-wood, infrared coated panels for indoor heating, etc.

From the Experiments perspective (Table 8), Product (and Material) is both a topic of research and testing in 5 out 7 of the analysed projects. It is clearly one of the key issues when dealing with the embodied CO_2 in the buildings. Among the most relevant it should be highlighted the MiniCO2Husene (Exp1 2011) for using a wide range of solutions upcycling materials and products like foundation of recycled steel screw piles, terrain insulation of torn polystyrene from furniture packaging, facade cladding of sheets created from recycled paper and bio-resin, greenhouse windows, which are recycled from a closed school, etc.
A disruptive experiment is certainly the "MiniCO2 etagebyggeriet i træ" (Exp3 2019), engaging in the design and the construction of a multistorey building with wood structure. One of its kind in Denmark and opening the door to sustainable wood buildings.

	EXP1 - 2011	EXP2 - 2017	EXP3 - 2019	EXP4 - 2020	EXP5 - 2020	EXP6 - 2020	EXP7 - 2021
	MiniCO2 Husene	*Circle House*	*Mini CO2 etagebyggeriet i træ*	*Det effective byggeri.*	*Bæredygtigheds klasse casebank*	*Reuse and recycling in public tenders - KK*	*Forståelsespapir vedr fossilfri byggepladser*
PRODUCT	✓	✓	✓		✓	✓	

Table 8. Experiments working on the Product phase aspect of building projects

Construction phase – In this phase we refer to the drivers as coming from the study and the promotion of alternative construction processes, or practices in the construction site.

This is one of the phases where apparently, not much has been done for system change. At least this is what this research concluded. One of the few radical approaches being studied and tested is the 3D printing of buildings or parts of them. Its scalability and sustainability are still under assessment (Hager et al 2016, Sakin & Kiroglu 2017). The process received some attention few years ago between 2016 and 2018, and research and tests were carried out at the Danish Technology Institute. The program's goal was to "*Build a new business area focused on building elements produced with 3D printing technology, strengthening the Danish construction industry's competitiveness*." (Available at www.dti.dk/projects/3d-printed-buildings/36993, accessed on 10 05 21). No further development was found.

An interesting development in the phase, is represented by the prefabricated solutions. In this perspective, a great example of driver is brought by "14 Erhvervsforsker-projekter skal gøre byggebranchen grønnere" (Pub23 2020). The Publication brings the attention on the sustainability relevance of using preassembled and precast elements in the construction process. This is of course on of the presequisites for the implementation of disassembly practices. The initiative supports 3 projects out of the total 14 related to precast solutions

Another interesting front being explored is certainly the "MiniCO2 etagebyggeriet i træ" (Exp3 2019), engaging in the design and the construction of a multistorey building with wood structure. New knowledge about structure and construction process are currently being studied and tested. During the interviews with practitioners was outlined the strategic importance of this project since it is considered as one of the high potential solutions in the search for a more sustainable building industry.

With reference to to the carbon neutrality of the construction-sites, an important initiative has been under experimentation since the beginning of 2021. It regards the possibility of using zero carbon machineries. In this case the aim of the experiment is to test carbon neutral solutions for machineries in, from, and to, the building-site (Heidari & Marr 2015, Nasab et al 2020, Karlsson et al 2020). This is explained in the document "*Forståelsespapir vedr fossilfri byggepladser*" that provides elements about the goals, and the protocol that will be followed in the experimenting phase, and by which officialises the start of the project (Pub31 2021/Exp7 2021).

Interviews with practitioners in charge of the project, confirmed that the experiments are now running and that are divided into two types: electric machines, and bio-fuel machines. In the first case, the biggest limitation is mainly due to technology's limitations and linked to the reduced power currently available for the electric machines. In the second case, two main challenges exist. Frist, the moment a biofuel is

introduced in the tank, is the moment the machine loses its guarantee. The second challenge is related to the very use of a plants-based fuel hence not sustainable on the long run, at least on a large scale (Kralova and Sjoblom 2010). It is currently being study the possibility to use the solution as a phase-out technology, that would allow the electric option to reach a proper technological development.

	EXP1 - 2011	EXP2 - 2017	EXP3 - 2019	EXP4 - 2020	EXP5 - 2020	EXP6 - 2020	EXP7 - 2021
	MiniCO2 Husene	*Circle House*	*Mini CO2 etagebyggeriet i træ*	*Det effective byggeri.*	*Bæredygtigheds klasse casebank*	*Reuse and recycling in public tenders - KK*	*Forståelsespapir vedr fossilfri byggepladser*
CONSTRUCTION	✓	✓	✓	✓			✓

Table 9. Experiments working on the Construction phase aspect of building projects

Use phase – In this phase there are two types of aspects that are reported. First, drivers as coming from the study and the promotion of sustainability matters in the operational and maintenance of a building. Second, more social-oriented elements dealing with the social sustainability of buildings and their surroundings, but also their indoor climate and liveability (Jensen et al 2012, Stender & Walter 2019).

"Research2025" (Pub11 2018) represents undoubtedly a driver. It poses a high focus on the importance of researching the field of social sustainability of buildings. In fact, the research efforts and energies should contribute to their indoor climate optimisation and to the creation of functional and healthy buildings. According to the Publication, those elements can lead to better learning and working environments. Circular resource efficiency, energy efficiency and interaction with the energy system, good physical setting, and good indoor climate, are the macro research themes suggested by the document.

A great example of driver is again represented by "14 Erhvervsforsker-projekter skal gøre byggebranchen grønnere" (Pub23 2020). The initiative brings the attention on the social sustainability aspect of buildings. It also supports 3 projects out of the total 14, whose focus is related to the social dimension.

"Concito og Rådet for Grøn Omstilling: Bæredygtigt byggeri giver også bedre liv" (Pub26 2020), makes the case for including social sustainability in the sustainability transition discourse of the building industry. The document highlight how setting goals for *sociale kvaliteter* (social qualities) could help saving billion of kroner by providing better conditions aimed to alleviate loneliness and poor well-being.

The main Experiments as drivers for this topic are represented by the "Circle House" (Exp2 2017) and "Bæredygtigheds klasse casebank" (Exp5 2020). The first case the 60 units project is about making circularity a reality in social housing. In the perspective they are showing how CE can be applied to the social dimension of building "*Historically in Denmark, the not-for-profit housing sector has assumed a social and societal responsibility with respect to housing design. It is a source of pride for us to help to continue that legacy with a significant and high- profile initiative to create architecture that is eco-aware and resource-efficient – aligned with circularity."* (EXP5 2020 p3) The second case offers a wide selection of 24 projects all around Denmark, and the social sustainability is a goal of at least 8 projects, from better community life to indoor climate, to welcoming social spaces.

From operational and maintenance point of view, it has been already seen in chapter 4 (4.2 A Sustainability transition) that Denmark has been achieving remarkable advancements on the optimisation of energy use in buildings during the last 40 years, becoming a world reference in the field. In this perspective Dansk Byggeri is certainly an important actor for the maintenance of the current high standards in energy matters in buildings (Pub18 2019).

The Publication "Vælg Bæredygtigt – for mennesker, miljø & økonomi" (Pub16 2019) represents a good example of driver for the choice of materials and components that are easy to maintain, replace and repair. In the case of indoor environments, it is suggested to opt for elements that do not lead to extensive renovations, highlighting how low-maintenance materials could be more expensive to purchase, but how they should be framed a good investment.

From the Experiment point of view, "Circle House" (EXP5 2020) represents again a very good example of driver for the achievement of a different state of the system. Through the words of Gerti Axelsen, Head of Construction & Development Lejerbo housing association: "*At the same time we're also expecting our tenants to realise that a circular approach in architecture results in housing of a higher standard. For example, in the way it allows tenants to have influence on their home over time, and the fact that in terms of maintenance tenants will also perceive the housing to be different.*"

	EXP1 - 2011	EXP2 - 2017	EXP3 - 2019	EXP4 - 2020	EXP5 - 2020	EXP6 - 2020	EXP7 - 2021
	MiniCO2 Husene	*Circle House*	*Mini CO2 etagebyggeriet i træ*	*Det effective byggeri.*	*Bæredygtigheds klasse casebank*	*Reuse and recycling in public tenders - KK*	*Forståelsespapir vedr fossilfri byggepladser*
USE	✓	✓			✓	✓	

Table 10. Experiments working on the Use phase aspect of building projects

End-of-Life phase – In this phase we refer to the drivers as coming from the study and the promotion of the End-of-Life practices of a building. Two of the leading sustainability strategies followed by practitioners in different sectors for achieving a more sustainable state of their products and product systems, are the closing- and slowing- loop concepts (Bocken et al 2016). In few words, the aim is to reduce the use of natural resources by extending as much as possible the life of the goods (slowing-loop) and then try to make the most out of what is left at the end of the slowing process through recycling (closing-loop). Clearly, these strategies work at their best if the products are designed accordingly. This is for instance the case of the disassembly and take-back logic in the building industry (Rios et al 2015, Rasmussen et al 2019).

As already notice, Denmark has a consistent background in the reuse and refurbishment of buildings dating way back to the official introduction of the Circular Economy concept in the building industry (4.2.1 Towards a Systemic Approach). Interviews with practitioners also confirmed that way long before the buzz word of Circular Economy started circulating in the field, the extension of buildings' life through refurbishment and reuse of part of them, was already a practice followed by many public offices of Danish municipalities.
In 2013 the "Hvidbog Om Bæredygtighed I Byggeriet" (Pub4 2013) promote this as a good practice, suggesting its use also by practitioners from the private sector.

In “Potential for Denmark as a Circular Economy - A Toolkit For Policy Makers” (Pub7 2015) is also outlined the concept of disassembly, the practice of taking a building a part without destroying the components, that can potentially be used in the construction of ‘new’ buildings.

Successive Publications like “Bæredygtigt byggeri” (Pub8 2016), “The Advisory Board for Circular Economy” (Pub9 2017), and “Strategy for Circular Economy” (Pub10 2018) are also reinforcing the use of these strategies, showing their benefits, and offering guidelines and principles on how to apply them to buildings.

“Building a circular future” (Pub15 2019) and “Circle House Lab” (Pub30 2021) certainly stand out from the crowd for their specificity and for providing real case studies and practical solutions on these strategies.

On the Experiments side, obviously “Circle House” (Exp2 2017) is the most relevant example of real case study offering details and benefits of the disassembly, reuse, and refurbishment concepts. Also, the København Kommune experimental projects from “Reuse and Recycling in public tenders – KK” (Exp6 2020) is good example of drivers for a change of system state. The municipality is working on 9 pilots projects whose focus is reuse, refurbishment, and selected demolition. During interviews with practitioners it was uncovered that 9 more similar projects are on their way for 2022, and that the new set will be focusing on different aspects on the applicability of the Circular Economy concept in the building industry.

	EXP1 - 2011	EXP2 - 2017	EXP3 - 2019	EXP4 - 2020	EXP5 - 2020	EXP6 - 2020	EXP7 - 2021
	MiniCO2 Husene	*Circle House*	*Mini CO2 etagebyggeriet i træ*	*Det effective byggeri.*	*Bæredygtigheds klasse casebank*	*Reuse and recycling in public tenders - KK*	*Forståelsespapir vedr fossilfri byggepladser*
END-OF-LIFE		✓				✓	

Table 11. Experiments working on the End-of-Life phase aspect of building projects

5.1.1.3 Resistance

For the transition progress to advance, it is not only a matter of having effective drivers, but also about framing, containing, and reducing the effects of possible resistances. Resistances can have different forms and influence, they can be related to: A) the expected reaction of the incumbent regime to resist the changes, but also to B) the lack of planning and action from the actors in charge of upholding the transition process (Schilling et al 2018). Drawing on the words of Geels (2014) “*The basic idea is that policymakers and incumbent firms can be conceptualized as often forming a core alliance at the regime level, oriented towards maintaining the status quo*.” (p26).

From the analysis of the Publications and Experiments, this research concluded that the main resistance opposing to the progress of the sustainability transition of the Danish building industry, was mainly due to the reluctance, and the consequent delay, of Dansk Byggeri in joining the debate and in supporting the initiative for a change in the industry. It was purposely used “was” since there is evidence from the last two years of a new phase embraced from the industrial association, showing a higher degree of interest in joining the effort.
Still much must be done for this resistance to be completely taken off. Not only because their presence and involvement is still relatively marginal if compared to the business-as-usual part, but also because their

priorities are still primarily aligned with the current system. Prove of that is the recent test realised by the author in search of specialized courses on the Dansk Byggeri website on themes like 'sustainability' and 'circular economy', has not produced any relevant results[7]. This means that the major industrial association of the building industry still does believe that new educational patterns, despite official declarations, should be explored and nurtured for sustaining the change.

Other aspects that can be framed as Resistance were also identified thanks to the interviews with practitioners. The first and most common is about the margin[8]. All the interviewees questioned on the subject, agreed that the low margin of around 5%[9] of the sector is the biggest obstacle for experimenting new solutions, leaving no space for making mistakes and thus learn from them.

Another outlined challenge during the interviews is the lack of wide availability of data (material passport) on second-hand materials and components in terms of resistance, safety, and usability. As a consequence, there is a lack development of marketplaces and platforms aimed to fill the gap between the necessity and the availability of used materials and components. This also leads to the challenge of being able to plan properly ahead the design and the construction of new structures. Most of the interviewees agree that this also due to the absence of legislation on the topics, and that it is creating a strong sense of uncertainty among the practitioners willing to apply these sustainability solutions.

Finally, this research revealed another potential resistance that could become more relevant ahead in the transition, a systemic lack of educational patterns around sustainability in vocational schools[10]. Ad-hoc courses could help enabling the transition, while a more integrated approach on sustainability in the whole curricula, could help consolidating it (Cedefop 2018).

[7] Based on an online research realised on May 10, 2021, searching the terms "bæredygtighed", "bæredygtig byggeri", "cirkulær økonomi" on the "Kurser og arrangementer" section of the Dansk Byggeri website: https://www.danskindustri.dk/brancher/di-dansk-byggeri/kurser-og-arrangementer/

[8] Margin it is used as a general term in business and can be related to the difference between selling price and the costs supported by the seller of goods or services on sale. It is normally expressed as a percentage of the price.

[9] According to a Deloitte research commissioned by Dansk Byggeri in 2020, the industry margin is 5,5%. (Deloitte 2020)

[10] Based on an online research realised on May 10th, 2021, searching the terms "bæredygtighed", "bæredygtig byggeri", "cirkulær økonomi" on the websites of the following technical-schools: TEC – www.tec.dk (Copenhagen), KEA – www.kea.dk (Copenhagen), AARHUS TECH – www.aarhustech.dk (Aarhus), TECH COLLEGE AALBORG – www.techcollege.dk

5.1.1.4 Sub-conclusions

The above analysis aimed to identify the existence of possible Drivers and Resistance, as defined by Schilling et al (2018), supporting and contrasting respectively a change in the sustainability state of the building industry. The Building Life-Cycle phases approach was used as a reference framework.

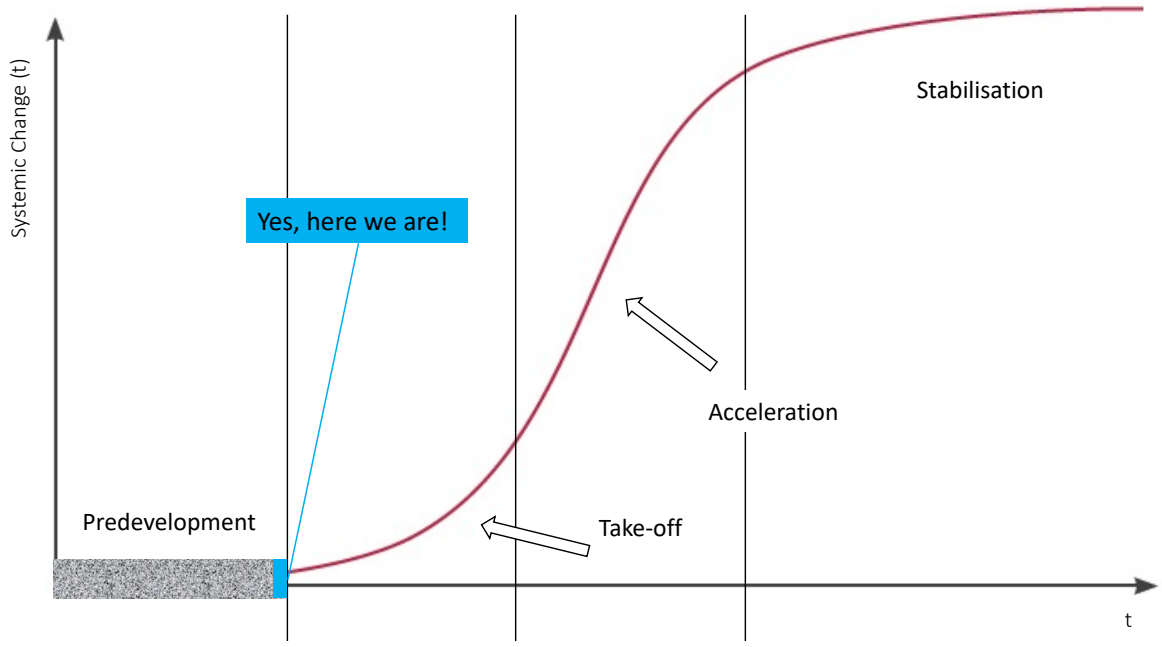

Fig. 9. The current supposed position of the Sustainability transition of the danish building industry (based on Martens and Rotmans 2005)

This research concluded that in Denmark, during the last 20 years, a large number of initiatives, both from public and private organisations, served as drivers for taking the system throughout the *predevelopment* up to the edge of phase 2, the *take-off* phase.
Increased awareness around the issue of sustainability of the industry as a whole, articulation of the concepts, experimentations of solutions, definition of a dominant design concept, outreach of the message, expansion of number of involved actors from the sector and from its fringes, high degree of collaboration among some of the key actors (companies + NGOs + thinktanks + public institutions), increased clarification of targets and available tools, are the key finding that this research has found in support of the abovementioned conclusions.

Resistance is still present and need to be resolved and removed since it could keep the transition stalling in the current position and preventing it entering the next phase. If not properly treated, they could also become more serious problems more ahead in the *take-off* stage.

One last thing that can be extrapolated by this analysis and can result useful in the understanding of the progress of the transition, is the type of transition pathway. Following Geels and Schot (2007) there are two elements to be considered for defining the type of transition pathway: 'timing of the interaction' and 'nature of interaction'. The first element refers to the moment of interaction between the level of landscape pressure and the level of development of niche-innovations. The second element focuses on the nature of the interaction of landscape and niche-innovations with the current regime. In particular, the relationships between niche-innovations and the regime can either be competitive (aiming to replace it) or symbiotic (aiming to improve it).

Elements form the analysis suggest that we are witnessing some sort of a metamorphosis of this relationship. It is true that has started as competitive, but with the transition approaching the take-off phase, it seems to converge towards a more symbiotic relation. This implies that since the dominant design concept (Circular Economy) has been going through a process of refinement and alignment, eventually it is going to be adopted by the regime with the purpose of solving its problems and ultimately improving it. To conclude, learning processes are heading towards stabilization, and powerful actors such as major companies and their industry association have started joining the support network.

5.1.2 Stability

Stability can be seen as "*the system actors' capacity to deal with uncertainty, react to unforeseen events, and recover from shocks, while maintaining the sustainability transition process.*" Schilling et al (2018, p9).
The Stability dimension is composed by the two following elements: A) the Stability of the Sustainability Transition Process, and B) the System Resilience.

5.1.2.1 Stability of the Sustainability Transition Process

The first element can be split into two further sub-dimensions: A.1) Stability of the Envisioned System State with the corresponding Sustainability Goals (SESG), A.2) Stability of the Transition Pathway (STP).

A.1) Stability of the Envisioned System State with the corresponding Sustainability Goals (SESG)
Following Schilling et al (2018), it is possible to identify the elements composing this type of stability. The specificity of the goals set has been progressively more specific. In the 2014 "Energipolitisk redegørelse" the goals were mainly centred around the energy efficiency of buildings and the energy renovation of existing constructions and related to greenhouse gas reduction of at least 40% compared to 1990 (Pub5 2015). During the years they have been progressively challenged, mainly for the need to go beyond the operational energy consumption and considers the emissions during the whole life cycle of buildings.

With the approval of the new Climate Act in 2020 (Pub20 2020), the climate goals become more ambitious and aim to reduce greenhouse gas emissions in 2030 by 70% compared to 1990 level. Plus, it poses the long-term objective of becoming a climate-neutral society by 2050 in line with the Paris Agreement's goals. Finally, the specificity arrives in 2021 with the approval of "Nationale Strategi for Bæredygtig Byggeri" (Pub32 2021). The 2021's law is very specific in the definition of the goals (Table 12), establishing limits of CO2 emissions in new buildings under and over 1000sqm, that will progressively be tightened up until 2029.

2020	Testfase af den frivillige bæredygtighedsklasse, hvor der indgår et krav om LCA-beregning.		
	Nybyggeri over 1000 m²	*Nybyggeri under 1000 m²*	*Frivillig CO_2-klasse*
2023	Krav om LCA-beregning. Krav om CO_2-grænseværdi svarende til 12 kg CO_2-ækv/m²/år.	Krav om LCA-beregning.	Krav om LCA-beregning. Krav om CO_2-grænseværdi svarende til 8 kg CO_2-ækv/m²/år.
Ultimo 2023	Aftaleparterne mødes med henblik på fastsættelse af grænseværdi fra 2025, således at denne kan fastsættes ud fra den nyeste viden og data.		
2025	Krav om CO_2-grænseværdi, der fastsættes ud fra nyeste viden og data. Ved et krav på f.eks. 10,5 kg CO_2-ækv/m²/år vil ca. 1/3 af nybyggeriet skulle præstere bedre klimamæssigt end aktuelt.		Krav om CO_2-grænseværdi svarende til 7 kg CO_2-ækv/m²/år.
Ultimo 2025	Aftaleparterne mødes med henblik på fastsættelse af grænseværdi fra 2027, således at denne kan fastsættes ud fra den nyeste viden og data.		
2027	Krav om CO_2-grænseværdi, der fastsættes ud fra nyeste viden og data. Ved et krav på f.eks. 9 kg CO_2-ækv/m²/år vil ca. 3/4 af nybyggeriet skulle præstere bedre klimamæssigt end aktuelt.		Krav om CO_2-grænseværdi svarende til 6 kg CO_2-ækv/m²/år.
Ultimo 2027	Aftaleparterne mødes med henblik på fastsættelse af grænseværdi fra 2029, således at denne kan fastsættes ud fra den nyeste viden og data.		
2029	Krav om CO_2-grænseværdi, der fastsættes ud fra nyeste viden og data. Ved et krav på f.eks. 7,5 kg CO_2-ækv/m²/år vil ca. 9/10 af nybyggeriet skulle præstere bedre klimamæssigt end aktuelt.		Krav om CO_2-grænseværdi svarende til 5 kg CO_2-ækv/m²/år.
** Defineres som bygninger, der er omfattet af energirammen i bygningsreglementet.*			

Table 12. Step-by-step phasing in and tightening of CO2 requirements for buildings (Pub32 2021)

With reference to the communication of the goals, the analysis of the Publications confirm a clear communication to actors of the regime and an outreach up to those at the fringes. As far as the perceived advantages between the future and the current state, this research showed that these are not still clearly communicated and proved, at least not in the analysed documents. Also, interviews with practitioners confirmed that, even though this is clear from a theoretical point of view, the lack of scale and of real cases, represent the biggest challenge for a fluid adoption of the sustainable solutions.

A.2) Stability of the Transition Pathway (STP)

The STP sub-dimension refers to the ability of the transition pathway to maintain its stability in front of change in the boundary conditions. In this perspective, it is of paramount importance to ensure that the transition pattern is stable, and this is attainable by building large support in the governance system and more in general within industry's relevant actors (Schilling et al 2018).

Before advancing, it is important to define what this research considers as the governance system. In the study case, there is no officially appointed governing body overlooking and directing the sustainability transition. At the same time, it is possible to identify the existence of a governance system whose member belong to the group of system's actors as framed earlier in this chapter (5.1.1.1 The actors). Following, some of these key actors in order of decision-making power.

The national government is clearly the most important actor part of the governance system directly or through its specific branches: "Trafik-, Bygge- og Boligstyrelsens hjemmeside", the "Miljøministeriet", the "Klima, Energi- og Forsyningsministeriet".

Another institutional actor that is clearly part of the governance system, is the sector's industrial association, namely Dansk Byggeri.
Finally, it is fair to admit that, also some of the thinktanks and foundations should be considered as part of the governance system, even though only for consulting and supporting purposes.

Armed with this knowledge and considering the analysed Publications, this research concludes that there is a progressively larger support within the all the spectrum of the governance system.

5.1.2.1 System Resilience

An important element that can help to ensure the System Resilience is the definition of a stable, yet flexible, regulatory framework preserving the ability of the system in providing the expected outcome (buildings), without impeding new solutions to be integrated along the process.

This seems to the be case of the *predevelopment* phase of the sustainability transition of the danish building industry. In fact, the system has not shown any specific sign of disruptiveness, and it has been fully able to produce its core outcome. Worth noticing that the current regulatory framework isn't yet completely welcoming innovations to become part of the system. An example of that is the lack of regulations regarding the use of second-hand materials and components. This implies a low rate of investment for new initiatives in the disassembly and take-back concepts, leaving little space for innovation and learning process to take place on these domains.

5.1.2.2 Sub-Conclusion

The analysed elements confirm that the sustainability transition of the Danish building industry is generally characterised by proper degree of stability, with a balanced distribution of weight among the different components of stability. This allows the system to work while still going through, and almost completing, the predevelopment phase of the transition. More attention, experimentation, and investments should be directed to the collection of data around the use of second-hand material, so that a regulatory framework can be consistently defined.

5.1.3 Adaptability

The third key dimension of the RST concept is Adaptability, and it is about the capacity of the transition process to adapt to new possible circumstances.

In the *predevelopment* phase, the Adaptability dimension is not really important. In fact, in Phase 1 it is too early to look after adaptation issues since the system has not yet reached any relevant change of state, hence, not much to be adapted. This becomes an element of attention in the *take-off* phase and the following *acceleration* phase. What is most important in the *predevelopment* phase, is the capacity of the transition to navigate with a proper level of stability through regime resistance and be sure that it is going to really take-off.

5.1.4 Trade-offs

In order get the most out of the elucidatory property of the RST concept, it is important to analyse and reflect not only on the single dimensions, but also on the relation between them in the *predevelopment* phase. This should lead to the reflection of what trade-offs should be considered in the sustainability transition of the danish building industry. This because, the interplay between different dimensions can affect the resilience of the sustainability transition process itself. Identifying and monitoring the trade-offs of the analysed phase can help to the set the proper balance between the dimensions.

5.1.4.1 Progress vs Stability

This trade-off considers the balance between transition progress and stability of the process.
In other words, it refers to the need for innovation to be allowed and introduced in the system, as drivers for the transition to progress, while at the same time maintaining a proper level of stability in order for the system to be able to produce the expected outcome.

As it has already pointed out, building industry is a system characterised as slow in change and with large inertia. Its sustainability transition too is characterised as slow-pace process. We can fairly agree that the building industry can be framed with a high degree of intrinsic stability, denoting a certain closure to disruptive innovation to happen.

The current phase has been running for at least two decades, and the last 10 years have seen a steep rise in debates and negotiations, with many experiments being carried out, and genuine advancements in the definition of leading design concepts, guiding principles, and regulation frameworks. Stability evolved and shaped accordingly. In the last 7 years, the governance system produced regulation frameworks and goals with higher degree of specificity (Pub5 2014, Pub20 2020, Pub32 2021).

As it has been uncovered in section 5.1.1.2, there are plenty of drivers pushing the system to a change of state. Innovations like new materials and components, can be characterised as incremental and symbiotic with the regime. Other innovations on the contrary, like for instance the design for disassembly approach, can be characterised as more radical and disruptive.

This research reached the conclusion that, at this stage of the transition process, a proper balance between stability and progress exists. This comes with the positive result of minimizing negative effects from potential disruptive change, while still assuring a proper progress of the sustainability transition.

5.1.4.2 System Resilience vs. Bouncing-Back risk

This trade-off regards the balance between the system resilience (5.1.2.3) and the risk for the system to go back to a previous state, reversing the transition direction. Even though this type of trade-off can be much more dangerous in later phases of the process, still in the predevelopment phase is important to assure that system actors are not allured to give up the change and go back to the business-as-usual.

Keeping up the ‘old’ structure can be a plus for the system resilience and stability, but as we have seen, can be a resistance to change if it is kept for too long and too in depth.

Risk of bouncing-back can come from elements like high costs and high efforts of conversion to the new state. This is particularly true for the building industry in Denmark that, as already mentioned is characterised by very low margins (Deloitte 2020).

Even though in the *predevelopment* phase the risk might exist, it is though still very little, mainly because of the still low level of engagement and use of resources when compared to the business-as-usual. In the study case, it is clear that through initiatives like the “Frivillige bæredygtigheds- klasse” (Pub22 2020) or the “Videncenter for Cirkulær Økonomi i Byggeriet (VCØB)” (Pub 25 2020), the governance system is acting for reducing this risk by attracting and involving as many relevant actors as possible in the collective process of debating, negotiating, testing, and learning.

Chapter | 6
Conclusions and Reflections

6.1 Conclusions

Humanity is facing one of its biggest challenges in history. If we do not change the course of our development, we are doomed to extinction. We may in fact be very close to reach dangerous tipping points of no-return. A radical turn in our development is needed so that we can shift toward a more sustainable paradigm in all aspects of human activities (Rockström 2015, Sachs et al 2019).

The building industry is globally responsible for as much as 38% of total CO2 emissions (Unep 2020). As such is required to sustain a radical transformation through a sustainability transition process lasting some decades. For this reason, also in Denmark many strategies and initiatives have been implemented in the last twenty years. The complexity of system, along with the long timespan of the process, make the sustainability transition exposed to many possible unexpected influences. The goal of this research is to evaluate the resilience of the adopted 'general strategy' for the sustainability transition of the Danish building industry, namely the capacity of the transition process to withstand unexpected changes.

Publicly available documents of the last twenty years about strategies, principles, guidelines, recommendations, rules, and experimental projects, along with interviews from practitioners, have been analysed through the lens of the conceptual framework Resilience of Sustainability Transitions (Schilling et al 2018). The analysis focused exclusively on the *predevelopment* phase, corresponding to the phase the transition in passing through, hence where the data exist.

The analysis was carried out on a qualitative basis, using subjective judgement of the author guided by objective elements of relevance (e.g., reported topic, issuing institution, time of publication) of the studied document. The results are built on non-quantifiable information extracted through the reading of those documents.

Armed with this perspective, this research offers the following points with the objective to answer the research question and the related sub-research question.

How resilient is the sustainability transition of the Danish building industry?

Resilience is the "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function*" (Walker et al 2004, p4).
Following the rationale of Schilling et al (2018), the RST analysis of the danish building industry was realised through the study of those key dimensions relevant in the *predevelopment* phase. As a reminder, the *predevelopment* phase is that stage where the status quo is not subject to visible change, niche-innovations

are emerging, but are too fragile to impose on the regime, yet offers the opportunity to consistently reflect on the availability and viability of alternative design options in substitution of the current state.

Empirical finding confirm that the Sustainability Transition of the Danish building industry is steadily progressing and approaching the take-off phase. The advancements are supported by a large number of drivers that overwhelm the inevitable existing resistance. The latter being characterized mainly by the inertia of a large institutional actor at the core of the current regime, the danish association of the building industry, Dansk Byggeri. This is also expected since they represent the majority of the companies of the sector. A change of system state is not naturally aspired by these actors, unless inevitable. This is understandable and justified by the fact that business-as-usual (the current regime) is stable, is predictable, and is reliable. A new state implies uncertainties, possible reshuffle of power settings and positions, and a risk of loss of profit. The 'inevitability' status is increasingly appearing on the agenda and wise first movers from the regime are already taking part to the learning process by which they support the transition.

In this respect, came to help the recently introduced national strategy for sustainable construction. The produced set of targets with high specificity, is regarded as an important aspect of stability. Concurrently, more stability is being produced by an alignment within the governance system on the general goals.

An additional element increasing the stability of the transition process is also the clarity and outreach of communication of goals and of the envisioned state, among the actors and towards at the fringe of the regime. Still a lot of work needs to be done also in terms of perceive advantages, that are not yet seen as clear as they should, partially because of the lack of extensive cases and of scale. This represents a resistance for the new concepts to be safely implemented by the practitioners. The latter represents probably the biggest chance for the system to bounce back, yet this type of risk in the predevelopment stage is very little, since no real change in the system state has been yet achieved.

This research concluded that the Sustainability Transition of the Danish building industry shows proper signs of a resilience process. The right balance of elements of stability and elements of progress, accompanied with a low risk of bounce back and a solid system resilience assuring the proper outcome of the regime during the transition. Another element positively characterising the sustainability transition of the danish building industry is undoubtedly the great deal of collaboration and transparency among different actors, both from inside and outside the regime.

1) *What are the recommendations in support of a more resilient sustainability transition in the case of the Danish building industry?*

As it has already been anticipated in the chapter 5, the transition is also facing some resistance. One of the causes of these resistance is due to the late entry in the arena of the discussion of the biggest actor of the regime, Dansk Byggeri. This has created reluctance from its member to take part in experiments and in participating into the debate. Since 2019 the association joined the conversation and started publishing strategies, goals, and principles, for a more sustainable state.

The weak point in this, at least from a sustainability perspective, is the fact that their reports are almost exclusively produced by its own members. This is a limitation not only because a sustainability transition is achievable as long as a large collaboration is established with different spheres of the society, but also because by quoting Einstein "*We cannot solve our problems with the same thinking we used when we created them*[11]*".* This also leads to the elephant in the room, the lack of real commitment from Dansk Byggeri for the integration of the sustainability discourse in the curricula of technical and vocational educational patterns. Starting from their own line of internal courses. This could create a lack of experienced and skilled workers, necessary for performing properly with new construction processes, new materials, new selective demolition methods, and disassembly processes, just to give few examples.

The first recommendation goes to Dansk Byggeri and call for a more inclusion of alternative voices and perspectives for the production of their strategies.

The second recommendation goes again to Dansk Byggeri but also to the competent authorities (ministries) and it is about the urgence of implementing sustainable 'curricula' in technical and vocational schools, but also in higher educational institutions. A transitioning curriculum, that could help in supporting different phases of the transition (still decades to go), but also a more long-term perspective that could help in fully integrate the sustainability discourse in all the studied subjects, and not just as a side-dish.

The third recommendation, that sounds more like an alert for attention, is about aspects related to Circular Economy in the building industry. Recent studies point to the fact that the mere application of the concept is not a guarantee of sustainability unless a series of limitations and challenges are solved (Korhonen et al 2018, Velenturf & Purnell 2021). That being said, there is also the aspect of the risk of putting all the eggs in one basket. What is the plan B if the approach fails to deliver the expected outcome? By investing all the energies and resources on one main design concept there might be the danger of nurturing path dependence that we could regret of in the future.

The fourth recommendation, coming as insights from interviews with practitioners, is about the involvement in the discourse of all levels of workers, but also of users (occupants of buildings), and owners. It was in fact revealed that this lack of understanding among the 'normal' people (not those specialised on the topic), is a resistance for the investors to believe more in the change. Danks Byggeri, but also government branches, should pay more attention in showing the perceived advantages of a sustainable building, but also informing more pervasively the meaning of the sustainability transition.

The fifth recommendation regards the long-term perspective. It is still very vague the envisioned system of the future, with the too generic goal of a carbon neutral sector in 2050. The high importance of the change should be upheld by inviting more actors from outside the inner core of the regime to take part to the vision and design of the future system.

One last recommendation is about the value proposition of the building industry. Actors of the regime do not discuss possible rethinking of the value proposition. Their Publications do not talk nor debate ideas that

[11] http://icarus-falling.blogspot.com/2009/06/ einstein-enigma.html

could possibly put into discussion the sustainability of the current industry's value proposition. This goes in contrast with the idea that "*in a sustainable business, the value proposition provides measurable ecological or social value together with economic value*" (Aagaard et al 2019, p 9). This might sound obvious, and probably, according to the regime's actors, it is already being addressed, through technological solutions. In this regard, the author disagrees and believes that a reshaping of the current regime without reconsidering the value proposition, will not make the system really sustainable. On the contrary it will make vulnerable to unexpected exogenous attacks. The extended life of the building, the extensive reuse of the materials and components (presumably of very high quality and expensive), and the framing of building as valuable material banks (see previous note), will soon or later and willing or not oblige the system to reconsider its value proposition. The recommendation is to start acting now and dealing with this with an optic of 100+ years of horizon. Waiting for an evolutionary development can be dangerous, especially if and when large global investors will start aggressively moving on this terrain.

6.2 Reflections

From a practical point of view, the RST approach obliges to carry out a pervasive analysis of all the components of a sustainability transition process. The time perspective, but also the in depth of the research of data for each moment ad dimension of the transition, provides a 360 vision of the process. This allows the researcher to better situate possible weak spots and strongholds of the adopted strategies, in the contest of the analysed system.

From a theoretical point of view, the analysis proportionated an interesting reflection about the framing of the sustainability transition. Once studying the elements composing the transition from a time perspective, with the process developing, the transition seems to lose part of its evolutionary trait, to integrate elements of Transition Management, as a governance approach and a policy model. Ultimately, this research would have sometimes found it interesting integrating the two approaches. This seems especially useful when considering the studied sector, building industry, whose inertia and the wide range and variety of actors of its value chain, can require actions of strict planning, but also of free exploring.

Another reflection came as a future Sustainable Design Engineer, from thinking about the acquired knowledge on theories and approaches to sustainability transitions, and how very little attention has been given to their reflexive aspects. In particularly, since we are normally dealing with long term changes, the uncertainty and the chance of thing going in unexpected directions and ending in contrasting states exist. Complex systems with large inertia, are difficult to steer, and it might be too late to change direction once a problem became evident. Studying a transition through the lens of resilience of the process, can help to tune policies and plan intervention at an earlier stage and thus correct possible drifts that could lead the transition far from the envisioned system state.

The biggest limitation of this research is about relying on the use of a conceptual framework entirely based on one single article, The Resilience of Sustainability Transitions, elaborated by Schilling et al (2018). This is not a negative aspect per se, but it comes with obvious limitations in terms of validity and replicability. An

attractive characteristic of the RST framework is undoubtedly its simplicity accompanied with the possibility of becoming a versatile tool for more in-depth analysis.

A major weak point of the framework is the lack of a rigorous process to assess the RST dimensions. The process is mainly empirical and somehow dependent on the subjective interpretation of the researcher. An interesting theme for future research, making a more rigorous process out of the current model, and possibly create a functional dashboard for practitioners interested in monitoring regularly the evolution of the transition process.

A thing that could have been done differently in the study is the search of the data. It was necessary a more systematic and rigorous collection and collation of grey literature along with more interviews with decision makers from the different groups of actors. These two aspects, treated differently, could have led to a better reading of the transition and possibly to a better understanding of its evolution.

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