ZEB Project report 19 – 2014

Jøran Solli and Thomas Berker

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A state-of-the-art report

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1. Introduction

The introduction to a recent report, "Optimal cost – energy rules in the Norwegian building code" (Kostnadsoptimalitet – energiregler in TEK), states:

> To present the cost and energy saving measures taken in existing buildings and new construction is a challenging task. Experience shows that the estimated costs of such measures can vary by several hundred percent depending on who performs the calculation, the assumptions underlying the market and location. Energy savings also depends on "how calculations are performed". We, therefore, warn the readers of the report against devouring raw numbers as they are presented in the figures and tables. We recommend, instead, that the reader have a thorough understanding of the conditions for the assignment, the selection of input data and the limitations that underlie the final figures. Only then will the cost and energy savings figures provide a good basis for use in further assessments and analyses.
> (Multiconsult & SINTEF Byggforsk 2012:4 – our translation).

This warning advises the reader to be careful when using economic knowledge and its calculations, and emphasises the detailed work that goes into the creation of the results. This care for the work that is behind creating bottom lines is also the starting point of many sociological and anthropological studies of economic knowledge. Thus, this report focuses on what has been called "the new studies of economic knowledge", a subject which is mainly located within the academic field of Science and Technology Studies (STS). Wherever possible throughout this report, we draw on the few relevant studies and examples from the construction sector. Where such studies were difficult to find, we refer to examples from other, similar sectors.

To be sure, there exists a host of publications that report on energy- and cost-efficient buildings and present corresponding quantitative measurements and calculations. However, this literature on the energy economics of buildings will not be presented here. While individual studies of the cost-efficiency of a particular building (type) or construction method may prove useful for economists in their work with current, well-known buildings, we argue that the perspectives presented in this report are more useful for the analysis of the development of future buildings – particularly for alternative types of development that go beyond the present economic rationality. The present state-of-the-art report aims to contribute both to an understanding of the possible ways in which economics interferes with the construction of buildings and to a discussion of how such an understanding can create opportunities for dialogue between engineers, economists and social scientists – a dialogue that results in solutions for making zero emission buildings a more economically feasible option.

To answer the question of the economic feasibility of zero emission buildings, another look at the Norwegian debate about the cost of building a passive house, sparked by the report written by SINTEF and Multiconsult (2012)[1] and quoted at the beginning of this report, is instructive. While the additional cost for a 100 m^2 detached family home was estimated to be 80,000 NOK in SINTEF and Multiconsult's report, a representative of the construction industry calculated the additional cost to be 96,000 NOK, by simply changing some underlying assumptions. Given moderate energy prices in Norway, this alternative cost estimate would dramatically extend the time needed to make the investment profitable. In their response, SINTEF and Multiconsult defended their calculations by pointing out that the cost of future buildings will have to be determined by analyses that consider the overall cost of buildings instead of fighting over details that are minor in comparison.[2]

1 http://www.regjeringen.no/upload/KRD/Rapporter/Rapporter2013/Multiconsult_Sintef_Kostnadsoptimalitet_Energiregler.pdf
2 http://www.vvsforum.no/artikkel/6982/lettvinte-konsulentrapporter-versus-lettvinte-innspill.html

Social scientific research on economic calculations more broadly has shown that this type of controversy is actually a very common phenomenon. In every economic calculation, underlying assumptions, which determine what to include and what to exclude from the calculation, frame the outcome – and are therefore prone to become the subject of heated controversies.

Disagreements about what to include in a calculation and what to exclude are usually not part of the calculation when it is presented in its final form. This has led to humanistic critiques of economic reductionism. Critics argue that calculations should include the "real" cost; for example, this argument is used by those who want to include ecological costs – paid by nature, society or both – in the calculations (e.g., Seip & Wenstøp 2006). The hope is that by "assigning values to the environment", sustainability can be made "an underlying principle of business practice" (Gibson 2012:23). As the proponents of this line of thinking are most likely aware, these approaches challenge nothing less than the current economic system, which is based on a rigid legal framework that divides financial liabilities, responsibilities and gains among human – and only human – actors.

In the present report, we challenge existing boundaries drawn around economic calculations (with all their consequences) in a less dramatic and more sociological way: we highlight an approach that directly addresses the very activities around which the boundaries are drawn. Together with the authors quoted below, we claim that the tools, rules, and arguments used to draw boundaries are interesting in their own right. Economic calculations will always include and exclude certain factors, but how these inclusions and exclusions are determined in architects', consulting engineers' and researchers' offices or on the construction site is crucial when it comes to the feasibility of constructing buildings with high environmental ambitions. Therefore, we want to direct the reader's attention to how decisions about inclusions and exclusions used in calculations are made and in so doing lay the groundwork for performing calculations that are more accurate because they are better informed by both their genesis and consequences.

2. Studies of the construction of calculations and calculativeness

Positivist ideals have emphasised the mathematical structures of scientific theories and how they systematise and describe the world. Positivist ideals have traditionally been strong in economics (McCloskey 1986; Mirowski 1989; Louca 2001). Mirowski showed, for example, how neo-classical economics was affected by figures from thermodynamics and how the concept of "value" within economics was connected to thermodynamics without much reflection as to whether such a borrowed metaphor was appropriate at all.

Metaphors build a bridge between theory and reality. The relationship between the methods of economics as a discipline and economic reality has been a long-standing topic of inquiry in economic sociology. Some of the most fundamental contributions to new perspectives on economic practices were provided by Polanyi (1957) and Granovetter (1985). Polanyi was the first to argue that there is a distinction between an abstract, model-oriented understanding of economics (i.e., rational choices as a means to achieve specific goals) and its substantive sense (i.e., economics as an actual practice). A focus on the former, abstract understanding, according to Polanyi, has prevented the study of how economic processes substantively, that is purely practically, take place in different institutional contexts. Furthermore, Polanyi makes the same distinction in his analysis of key economic phenomena such as trade, money and market, to show that, as concrete phenomena, they are not at all as closely intertwined as the formal economic definitions would lead us to believe.

A key theme in economic sociology has been the social embeddedness of rational actors. Granovetter (1985) supports to some degree Polanyi's argument, particularly his critique of the understanding of the rational actor in neoclassical economics, which implies an undersocialised view of economic action. Granovetter parts, however, with Polanyi by also criticising the other extremity: an oversocialised view of economic action. For example, Granovetter argues that other structures, such as the formal rules and norms of a company, determine economically rational action. For Granovetter, there are two complementary mistakes that are made in the social studies of economics: 1) Too much emphasis is placed on social structure and institutional context; and 2) Too much emphasis is placed on an isolated, rational and calculative actor. Instead, he demands a careful study of how economic action is "embedded" in specific social networks (Granovetter 1985:63).

Michel Callon (1998) emphasises that Granovetter's use of the term "social network" does not refer to agents with fixed and stable identities forming a rigid social structure. Rather, he argues that Granovetter sought to emphasise that agents' identities and interests are variables influenced by the dynamics of the relationships between the agents. In this non-essentialist and non-structuralist understanding of a network, it is not then the context within which an agent acts that matters; "both the agent and the network are, in a sense, two sides of the same coin" (ibid.:8). This understanding of networks presents itself as an alternative approach to the study of economic practice. It also forms the basis for Michel Callon's attempt to create a new space for cooperation between economists and sociologists.

Granovetter's approach, as interpreted by Callon, means that we should not assume that a building project's economic aspects are a matter of an isolated architect's or consulting engineer's calculations; neither is it mainly the result of a construction firm's imperative to make a profit. Instead, Granovetter would say that a building project's economic dimension only can be studied by examining the interaction between the calculating architects, consulting engineers, and other involved agents and the contexts that expect them to calculate (e.g., project leaders, customers, managers at the architecture and consulting firms and energy policy institutions).

3. Studies of accounting and other economic practices

Empirical social research has shown that the economic activity of accounting is a multi-faceted social practice (Hopwood and Miller 1994; Power 1996; Porter 1995). These studies have contributed to destabilising traditional perceptions of economic processes as objective and independent from social processes. The main message of these publications is that the lack of contextualisation of economic calculations is caused by the discipline of economics itself: "there can be little doubt that abstract economic models assume away the very contexts of economic calculation that are relevant to science studies" (Power 1996:3).

Several STS studies analysing economic practices have had a particular focus on institutional processes and development. Graeme Thompson (1994) has analysed the historical creation of what we now understand as accounting, with an emphasis on double-entry bookkeeping, and how this method was shaped by the context of institutional development within the church, the education system and the regime of press and publishing in the 15th and 16th centuries. Frédéric Lebaron (2000) has analysed how legitimacy is created around central banks as neutral, independent institutions. Focusing on both the methods used and on the characteristics of the agents embodying this independence, he noted that the assumption that these banks were not political but neutral tools created through science, particularly by the authority of a seemingly socially disembedded economics. Historical studies of the development of calculative methods and tools used in construction projects are missing.

Empirical studies of economic practice have explored the use of economic instruments in different contexts; budgeting in Health Economics (Pinch, Ashmore and Mulkay 1992), the use of spreadsheets in accounting (Law 2002) and the role of economic calculations in technology development projects (Thomas 1994). Henning (2000) has combined STS and a cultural analytical approach to analyse economic argumentation in relation to the use of solar collectors in Sweden. Her analysis shows how perceptions of solar collectors were created; more specifically she describes how appraisals of their material structure, their benefits and uses occurred. One of Henning's main points was describing how cultural considerations, which include economic reasoning, were created. Henning (2000) argued against the understanding of economic considerations as always being "purely economic" ("krasst ekonomiska") by showing that there are cultural classifications based on end users' assessments of profitability.

Referring to these results, it is reasonable to assume that the host of decisions made throughout a construction process will (at the very least) not always follow "krasst" economic reasoning. In a study examining how energy saving features were selected in three construction projects, de Wilde et al. (2002) found that the features were selected without any serious calculative effort and without considering alternatives. The authors also concluded that there is an urgent demand for more studies on actual design processes. More specifically, a study of economic decision-making in construction and the factors that influence these decisions would allow us to show how the seemingly neutral entity "cost" is socially embedded. Neglecting this embeddedness may very well be another major source of the commonly observed disconnect between the expected and actual cost of building construction seen particularly in larger, more complex projects. Moreover, an approach that discusses cultural classifications and sense-making processes may be useful for studies of early/first owners and their investments in passive houses or low-energy buildings.

4. Disentanglement and framing

An important line of inquiry within economic sociology emphasises that conditions for calculativeness and market transactions should be studied as a process of disentanglement. A central question for studies of sustainable innovation is what type of interests is not promoted by the calculations? And, how is the distinction between those elements that are taken into account and made relevant and those that are excluded maintained? Callon (1998; Callon & Muniesa 2003) proposed viewing calculations as a process of disentanglement in three stages:

1. sorting out, detaching and displaying entities in a single space
2. manipulating and transforming these entities
3. extracting a result, a judgment, or a calculation

Central to this perspective is that forms of calculativeness are produced in different ways – by different devices. A task for future studies is to explore how these forms of calculativeness are produced or appropriated in specific sectors, institutions or companies. In these settings, then, what is studied is "the institutional delineation of frames which mark out what is relevant or not to specifically economic calculation" (Barry and Slater 2005:53). More specifically, the actual objects of study can be how market exchanges are performed in practice. Callon emphasise that the limits of these exchanges should be explored by identifying consequences and liabilities. Every economic exchange "cuts off" certain actors and processes (usually represented by "externalities") and imposes limits on obligations. At some point, and thanks to these cut-offs and limits, the economic exchange is recognised as being accomplished by its participants. Callon has shown that these limits and cut-offs are a matter of considerable negotiation. In his economic sociology, in order "to understand the boundaries of markets and market behaviours we need to attend to the fuzziness, instability, negotiability of these limits" (ibid.:55).

The concept of framing refers to the structure of an individual transaction, how it becomes an isolated event and what it formally includes. At the same time, framing allows us to see how social relationships are central to the definition of markets. The implication of Callon's notion of "market instability" is that social actors are just as involved in disputing the boundaries and identities of markets as they are in operating within their boundaries. Slater has formulated this implication in another manner: "an economic actor has to be seen simultaneously as within and without the market frame, as one that is able to calculate in specific ways, but who is also engaged in the framing process itself" (Slater 2005:57). Seen from this perspective, if actors do not take the market boundaries as given frames, then they are never neo-classical economic actors. In Callon's account, this theme is explored further through the concepts of overflowing and reflexivity. These processes are tied to the argument that economics and economists are the main creators of markets. Callon sees markets as a type of technological accomplishment; in his words, calculations have to be "engineered". Callon uses the imagery of laboratories within calculative agencies. Calculations produce a certain rationalisation of social and economic relations, but the actual extent of this rationalisation must, according to Barry and Slater (2005), not be overestimated. One example Callon provides of overflow and reflexivity is the rise of the service economy as an "economy of qualities" that increasingly focuses on the quality, qualification and re-qualification of products. In Barry and Slater's (2005:16) words:

> Although some of the qualities of products may be quantifiable and measureable, this does not mean they are incontestable. Indeed the reverse is true. Actors may become increasingly reflexive and critical about how qualification occurs and what it implies.

In this specific case, Barry and Slater discuss increasing consumer interest in the ways food quality is monitored and guaranteed and the development of "organic" as a brand of quality and purity. Similar

processes are happening in defining "green" and "sustainable", terms which are marketed as qualities of buildings that warrant a certain value. Such framing of "quality products", then, may produce overflows in the sense that new, particular demands from critical consumers exist that producers may have to address or reframe. In the building sector, for instance the quality of being "energy efficient" produces new demands from building owners and occupants that have to be managed by the construction firm. What happens if a certain degree of energy efficiency that was promised by the designers is not achieved? This "overflow" demands new and increasingly clear definitions of liabilities and responsibilities, which are difficult to establish. Naturally, the user of the building will demand that the promises are fulfilled, while the designers can always point to the users and their behaviours as sources of reduced energy efficiency.

These and similar dynamics add to what Barry and Slater describe as a growing sense of the constructedness of markets and the need to ask questions about which particular form new markets are taking. In the context of discussing the relationship between economics and politics, Barry and Slater cite Callon: "The organisation of markets becomes a collective issue and the economy becomes (again) political" (Callon et al 2001:310–313).

Construction of calculative agents and processes of qualification are both themes and approaches that are relevant to energy efficiency and construction. In addition to the question of how the quality of being "green" or "sustainable" is framed, another example of needed research is the exploration of the processes related to the construction of a system of home owners' own reporting of energy standards (Danielsson 2012).

5. Studies of what economics and calculations do

The question of what economics, economic knowledge and calculations do has opened up a whole new field of research. In the following chapter, we examine a number of studies that empirically investigate these concepts and their impact on the relationships between science, politics and technology.

5.1 Economics as rhetoric

The first group of studies of what economics and economists do focuses on language. Economic tropes have always been part of modern language (e.g., "We don't buy it" and "We put in our two cents' worth"). Arguably, economic metaphors have increasingly infused the lives of people who are otherwise little involved with the financial and economic sectors. What is more relevant, within the context of this report, however, is what role economic metaphors play when economists perform calculations.

Thomas (1994) has studied how economic assessments of technologies and solutions were performed in three large industrial companies in the United States. He found that it was important how the projects were promoted internally, because the relationship between economic calculations and economic "realities" was often vague and indefinite. For projects to be implemented, they had to be supported by calculations that demonstrated future profitability. However, because many projects had a long and uncertain time horizon, the act of constructing calculations resembled more guesswork than anything else. Skills in producing optimistic profit projections, according to Thomas, were important for those wishing to gain approval for the implementation of new projects. An essential aspect of the type of expectation management was the linguistic and rhetorical task of positive framing that had to be performed.

To be successful, the task of selling a project with the right words and metaphors has to be understandable for groups of participants with different backgrounds and roles within an organisation. It requires a form of language that can be used across disciplines and different organisational units. Galison (1994) describes how this type of rhetoric often has the character of pidgin – a form of mixed languages. In construction projects, economic calculations are made and assessed in multidisciplinary contexts involving various forms of engineering and architectural expertise. Interdisciplinary collaboration in building-related projects and research has been studied previously (e.g., Moore and Dainty 2001; Berker and Bharathi 2012), however, not in the context of economics as a common language. How is the common language mixed, and to which effect? The understanding and use of concepts emerging from management and business present both opportunities and limitations that need to be examined in the context of the economics of buildings.

In this context, Solli (2004) has argued that arguments for the development and implementation of new renewable technology needed to be formulated in an economic language to be taken into account. Based on an analysis of accounts from central actors involved in wind energy technology development and representatives from central institutions of energy policy, Solli (2004) analysed the rhetoric of calculus. This involved an analysis of how these actors understood central concepts and the rhetoric of these concepts, in particular how their understanding and rhetoric shaped the conditions that determine whether certain projects or developments was deemed something that should be supported or discouraged. When using the economic language, central concepts like "øre/kWh" produced effects that actors had to negotiate, which very often arguments on technology not being cost efficient and also function as a short cut to end a development or project. Solli (2004) described how situations of dealing with certain economic arguments were frustrating for actors working in research and development of new renewable technology. Engineers described difficulties of communicating their interests in this language and experienced this as an economic "pidgin" dominated by a narrow understanding of

economics. Solli (2004) argued that the way we talk about energy technologies to a larger extent should reflect the heterogeneity that characterizes the many practices where technology development and implementation occurs. This could imply to take into account deeper understanding of technological learning through concept of technological learning curve and existing knowledge that is embedded in or employed in technology development and implementation practices.

5.2 Performativity

Obviously, calculations operate on more levels than just the rhetorical. A central concept in many recent studies of economic action is performativity. A performativity approach considers the influence of economic theory on operations of markets and finance (Callon 1998; MacKenzie 2006; Muniesa, Millo and Callon 2007; Beunza, Hardie and MacKenzie 2006; Beunza and Stark 2004). This body of work describes how economic theory helps to transform its objects into something more closely resembling its own theoretical models. In this type of research, analytical techniques, tools, and simplified models used in economic theory become the central objects of research. They are no longer approached as neutral instruments that register reality. Instead, they are seen as the vehicles that help theory perform reality. One example of this approach is a study conducted by MacKenzie (2006) that described how economists at the University of Chicago in the 1960s took their new theories of the correct valuation of company stock prices into the stock market and how they set up trading companies that used these new theories to great effect. Eventually, the stock market started to resemble the ideal model that was the starting point for pricing theory, because traders saw that the theoretical models that the economists used were more efficient than the rules of thumb they had been using at the time. MacKenzie claimed that this effect illustrates how performativity of economic theory can influence economic practice (i.e., how reality is shaped by theory).

The aforementioned studies of accounting practices (i.e., Pinch, Ashmore and Mulkay 1994, and, particularly, Law 2002) offer theoretical accounts of how objects and accounting practices are able to perform realities. An empirical study of this topic has been conducted by Skærbæk and Tryggestad (2010). In a case-based ethnography, the authors analysed the role of accounting devices in corporate strategy. Drawing on the concept of performativity, they showed how accounting shapes strategic options and the external economic conditions of the corporation. Their analysis described how accounting devices rejected, defended, and changed corporate strategy by mobilising lay people and concerned groups. They saw that accounting plays an active role in strategy formulation, the configuration of the identity of the key strategic actor, and strategic change. We know very little about the accounting devices (i.e., software programs) used in construction projects. If they have an active role in the creation of economic calculations they should be analysed with regard to what extent they influence the way we understand the economics of (sustainable) buildings.

The central argument put forward by Callon (1998) (introduced above) is that the economy is not an external object that economists analyse. In its weaker sense, that economists influence economy should hardly be a controversial statement. Market participants, regulators, and other actors regularly draw actively and explicitly upon economists, for example in formulating trading strategies or in designing the "rules" by which economic action will take place. Building on this observation, Caliskan & Callon (2009; 2010) argue that we should study the processes of performativity where spheres of society such as organisations, institutions or simply behaviour are established as being "economical". To study these processes of "economisation", then, implies looking at the ways in which these areas are included in specific sets of concepts that belong in the field of economic discussions. Caliskan and Callon list three key objects to study when examining economisation: the theories of economy, the institutional and technical arrangements that allow for economic action and the objects of value themselves. This is an attempt to define what is at play when rules, regulations and practices evolved in a particular social sphere are drawn into the economic sphere.

Karlstrøm (2012) discusses the economisation thesis in the context of a study of the deregulation of the Norwegian energy system. More specifically, Karlstrøm analyses how economic theory was able to inform the design of a new system for electricity production and distribution. He emphasises that the economisation thesis holds true only for parts of the process:

> The economisation thesis seems to explain fairly well the movement of economic theory into official policy proposals. The work done by leading economists into the design of a new market for electricity was implicitly accepted by those responsible for producing the white papers in advance of the reform. However, when it comes to transforming the proposal into actual legislation and then implementation, the picture is not so clear (Karlstrøm 2012: 66).

Thus, in the further translation of knowledge from policy to actual political practice, the economisation thesis offers less insight than in the formulation of the policies. In the context of zero emission buildings, this means that economisation should be studied as processes of policy formulation instead of as individual construction projects. The report quoted at the beginning of the present report is clearly located in a similar zero emission context as it was explicitly commissioned to inform policy makers about the economic consequences of introducing a new building code.

5.3 Norwegian ENØK: Focus on economy instead of energy

In "How energy efficiency fails in the building industry", Ryghaug and Sørensen (2009) discuss why efforts to integrate energy efficiency into the construction of buildings and sustainable architecture in Norway largely failed in the period from 1975 to 2005. One of the main explanations given by the authors concerns the deficiencies in public policies to stimulate energy efficiency, particularly the so-called "ENØK"-policy. The authors note that the problem with ENØK is mainly that it has proven difficult to translate energy efficiency scenarios into something that attracts and recruits actors into the building industry. A reason for this, they argue, is that ENØK has: "invited a focus on cost efficiency rather than energy efficiency, in addition to making industry actors believe that costs and conservation of energy can be optimised simultaneously" (Ryghaug and Sørensen 2009:990). Further, they emphasise that "the actual translation of ENØK seems to hold the importance of building as cheaply as possible above all else. The strong cost focus in ENØK means that other arguments that could be used to promote better energy standards are rendered less effective."

However, more recent studies indicate that even as ENØK has been appropriated with similar effects described by Ryghaug and Sørensen (2009), a stronger policy focus among some actors in the building sector on the development and implementation of stricter regulations has contributed to an emphasis on energy efficient solutions. However, will stricter regulations necessarily result in more energy efficient buildings? Will not economic concepts and the ways available tools are used by the actors involved in construction projects play formative roles in mediating economic concerns, and if so, how?

Solli (2013) discusses how consulting engineers address energy-related regulations. Solli indicates that there are several ways of dealing with regulations, of which an orientation towards the minimum standard was the most prominent way to handle regulations. An important practice was that dealing with standards contributed to calculating practices that were mainly motivated by concerns over costs and profitable energy efficiency. One engineer cited by Solli (2013) perceived "energy calculations" mainly as a tool for economic calculation: "You start calculating. Was it profitable to do this? Or should you use the same million on something else? Maybe, it isn't profitable to change all the windows? Maybe you would rather add five cm extra insulation?" (Solli, 2013:207).

From this description, we may argue that technical codes promoted a practice where engineers operated as economic optimisers, treating the prescribed minimum energy performance standard as static entity instead of trying to optimise this part of the equation.

5.4 Studies of markets and business models

Markets constitute a key object of both research within economic science and economic practice, therefore it is not surprising that markets are central to studies examining what calculations and economics do. In these studies, the materiality of markets is central. In addition to the usual market descriptions that include supply and demand, the flow of information and the main market actors, Caliskan and Callon (2010:3) give an additional list of factors to be included in the analysis of markets: "rules and conventions; technical devices; metrological systems; logistical infrastructures; texts; discourses and narratives" (Caliskan and Callon 2010:3). These factors may be assembled differently from case to case – the exact assemblage is an empirical question. The material configurations of markets are referred to as socio-technical enactments in the literature. Objects of study are then both these enactments and their results. Applied to the study of zero emission buildings, the creation of a market would have to be studied not only as a relation between producers and customers but also as the creation of rules, definitions, devices, discourses, and logistics.

Another important topic of economic research and practice is business models. Building on a case study of an entrepreneurial venture, Doganova and Eyquem-Renault (2009) investigates the role played by business models in the innovation process. Rather than debating their accuracy and efficiency, the authors adopt a pragmatic approach to business models; they examine business models as market devices, focusing on their materiality, their uses and dynamics. Taking into account the variety of its forms, which range from corporate presentations to business plans, the authors show that the business model is both a narrative and a calculative device that allows entrepreneurs to explore a market and to contribute to the construction of the techno-economic network of an innovation.

Analysing business models as well, Richter (2013) discusses how the German energy transition has created a fundamental challenge for utilities. Richter argues that electric utilities as incumbent actors have faced a massive challenge to find new ways of creating, delivering, and capturing value from renewable energy technologies. Based on a series of in-depth interviews with German utility managers, Richter investigated utilities' business models for renewable energies by analysing two generic approaches. He found that utilities have developed viable models for large-scale, utility-side renewable energy generation, but that they simultaneously lack adequate business models to commercialise small-scale, customer-side renewable energy technologies. Another study describing business models in relation to energy and buildings was published by Okkonen and Suhonen (2010). The authors describe the business models of small-scale heat energy production in Finland, observing the development of "heat entrepreneurship", including the considerable growth of small and medium size enterprises (SMEs) in the last 15 years. According to Okkonen and Suhonen, different business models of this "heat entrepreneurship" exist: public companies/utilities, public-private partnerships, private companies, cooperatives and a network model of large enterprises and franchising. Their paper concludes with a discussion of the applicability of business models in different operational and geographical contexts. A study similar to those conducted by Richter and Okkonen and Suhonen but among construction firms would enable us to examine relevant (future) market participants' perceptions of existing strategies as well as challenges in the commercialisation of zero emission solutions.

The last study presented in this report discusses "integrated solutions" as a particular business model in relation to construction. Brady, Davies and Gann (2005) took as a point of departure suggestions that the future of the construction industry lies in adopting a new business model based on the concept of integrated solutions. Integrated solutions are understood as combinations of products and services that

address a customer's unique requirements throughout the construction life cycle, from development and design to systems integration, operations and decommissioning. The authors discuss research on integrated solutions in other capital goods sectors showing that suppliers had to create new business models, including developing new approaches to adding value and building up new capabilities – especially in systems integration. They suggested the concept of the provision of integrated solutions in the construction environment was still at an early stage in its development. They also suggested that the best opportunity for its introduction is in the context of either private finance initiatives in the public sector or large clients who require repeatable solutions in the private sector. The specific solution described by Brady, Davies and Gann should be investigated in relation to zero emission-related products and services.

6. Concluding remarks

In this report, we chose to focus on research that analyses the role of economics in shaping the construction of buildings. We did not include research that calls for alternative economics promising a more holistic, ecological or "humane" approach; and, we did not include the abundant literature on energy cost-efficiency of buildings that consists of quantitative measurements and calculations. Instead, we explored the space between these two positions that can be found by looking into the black box of economic calculations.

More specifically, we have given an overview of the STS literature that analyses the role that economics plays in shaping how we understand central challenges related to energy and the environment. To lay the groundwork for a more focused treatment of buildings, we have throughout this paper illustrated how concepts and ways of thinking in the STS literature can be usefully applied to studies of the economics of buildings.

In the most basic sense, from a socio-technical approach, analyses of a building projects' economic dimensions are studies of interactions between the calculating architects, consulting engineers, the technological solutions, architectural forms, and the contextual forces that expect them to calculate (e.g., project leaders, customers, managers of architecture and consulting firms and energy policy institutions). We have presented "performativity" as important element in STS-approaches to economy. Moreover, we have presented examples of how economy as a discipline influences practices. Only if we understand how and by which means economic calculations are done, will we be able to substantially alter the way these calculations are performed. As long as economic realities shape themselves with help of black-boxed tools, critiques of their specific rationality will falter immediately when they meet those "realities".

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The main objective of ZEB is to develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition. The Centre will encompass both residential and commercial buildings, as well as public buildings.

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