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Call for a Definition and Paradigm Shift in Energy Performance Gap Research

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Abstract. There is a growing interest in research dealing with energy performance gaps of buildings. Energy performance gaps are usually defined as the difference between energy demand as predicted during the planning phase and energy demand as measured during operation. It is assumed that the research strand, by reducing such gaps, contributes to the United Nations SDGs 7 (clean energy), 11 (sustainable cities) and 13 (climate action). However, in this conceptual article based on literature review we argue that blind spots in the current definition of energy performance gap research (embodied energy, gap between optimal and planned energy performance, greenhouse gas emissions, dynamic character) and weaknesses of frequently used scientific paradigms (techno-economic, psychological) may lead to the fact that the measures identified to eliminate energy-wasting and climate-damaging practices are of limited value. In fact, it is quite possible that conventional energy performance gap research even contributes to perpetuating such practices. The authors therefore call for a definition and paradigm shift in energy performance gap research, suggesting two broader definitions of the research subject (called life cycle energy performance gaps and climate performance gaps) and a promising alternative scientific paradigm (practice theory).

1. Introduction

One of the 17 Sustainable Development Goals (SDGs) of the United Nations [1] is the creation of sustainable cities and communities (SDG 11). As one of several key characteristics of such cities, the UN also promotes a reduced ecological footprint per inhabitant, including the efficient and sufficient use of energy in buildings and the climate-friendly provision of energy (SDGs 7 and 13). Contributing to improved energy efficiency and climate-friendliness is also the aim of many studies dealing with so-called energy performance gaps of buildings (e.g. [2]). The term refers to the observation that the operation of many buildings is associated with a higher energy demand than the planners had predicted during previous new construction or modernisation projects (e.g. [2,3]). Studies on this topic usually deal with one or more of the following 4 topics: defining, quantifying, explaining and overcoming energy performance gaps [4]. The first empirical studies appeared as early as in the 1970s (e.g. [5]) but the term energy performance gap has only become established since around 2011 [6]. Since then, the number of publications per year that explicitly use the term energy performance gap has increased continuously from 11 in 2011 to 240 in 2019, according to Google Scholar. At least 3 reviews of the current state of research have been published by the time this paper was submitted [2–4]. In view of this boom in energy performance gap research, it seems important to us to point out that the way in which energy performance gap research is currently defined and theoretically framed may lead to unintended

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consequences (perpetuation of unsustainable practices of energy demand and supply). Therefore, the authors of this article call for a definition and paradigm shift in energy performance gap research. Chapter 2 describes the methodology. Chapter 3 elaborates on common and alternative definitions and Chapter 4 discusses two frequently used scientific paradigms and one that seems more promising to us. Finally, Chapter 5 concludes with a brief summary and outlook.

2. Method

The criticism of energy performance gap research presented in this article arose between 2015 and 2019 in the context of several applied research projects of the first and second author, which aimed to develop innovative business models to avoid energy performance gaps in professional real estate management [7]. In this context, the first step was to identify and visualize typical causes of energy performance gaps by means of a review of the research literature and own empirical investigations [7]. The visualizations not only revealed the weaknesses of the current definition of energy performance gaps, but also made it intuitively transparent that current explanatory models for energy performance gaps are inadequate. Only an in-depth study of critical sociological literature, which explicitly describes and contrasts different theoretical paradigms (e.g. [8,9]), finally enabled the well-founded writing of this critique.

3. The definition of energy performance gaps, its blind spots and alternative definitions and models

3.1. The common definition of energy performance gaps

In their overview of the state of research on energy performance gaps, Shi et al., p. 4 [4] state: "The most common definition of the performance gap refers to the difference or discrepancy between predicted (or calculated, anticipated, designed, etc.) and measured (or actual, real, achieved, etc.) performance". In addition, the following points are often implicitly assumed in the literature:

- The term 'performance' refers to the *final* energy consumption caused by the *operation* of an entire building or a technical component (e.g. heat pump).
- When predicting the energy demand of entire buildings, all foreseeable sources of consumption should be taken into account (performance modelling). Incomplete predictions of energy demand (as is the case with compliance modelling, for example) are insufficient [2].
- The forecasts from the planning are compared with the actual operating energy requirements a few years after a new building or a major modernisation is put into operation [10].
- Only 'avoidable' wastes constitute energy performance gaps. 'Legitimate' energy demand must be excluded from the definition. ([11], p. 1)

It follows, that in the literature to date, the term energy performance gap of entire buildings is understood at least implicitly as the gap between the following two energy indicators:

- the legitimate demand for final energy in order to operate the building, as predicted by performance modelling
- the actual final energy demand for operating the building determined by measurements 1-2 years after the new building or modernisation is put into operation.

This clarification of the definition of energy performance gaps implies that their extent can only be determined if the issue of what exactly legitimate energy needs should be is addressed. In fact, this important moral issue is never explicitly discussed in energy performance gap research. However, this is only one of the current definition's blind spots. In the following chapter we will deal with these blind spots and the possible consequences of this limited vision.

3.2. The blind spots of energy performance gap research and how they contribute to perpetuating unsustainable practices of energy supply and demand

According to the authors of this article, the common definition of energy performance gaps (see fire-red, non-shaded area in Figure 1) systematically excludes the following crucial aspects of energy performance from investigation: embodied energy, the gap between optimal and planned energy performance, greenhouse gas emissions associated with energy demand (see shaded areas and labels in Figure 1), and the dynamic character of energy performance or climate performance (see Figure 2). In the following, these blind spots are discussed and the extent to which they could lead to energy performance gap research perpetuating unsustainable practices in energy demand and supply.

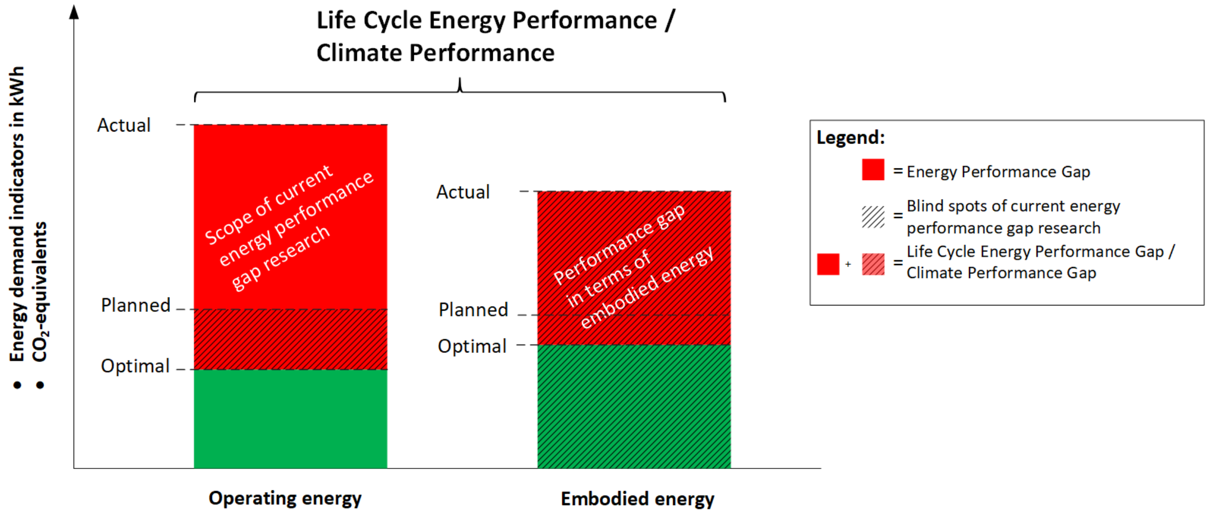

Figure 1: Scope and blind spots of energy performance gap research – Life cycle energy and climate performance gaps as terms to denote the entire field for which performance gap research is needed.

Embodied energy: As is widely known, direct operational final energy demand (left bar in Figure 1) is always associated with embodied energy (right bar in Figure 1). The latter occurs in all phases of the building life cycle. In the sense of a cradle to grave or cradle to cradle approach, embodied energy includes all primary energy demands in connection with resource extraction, production of building materials and components, building construction, maintenance, modification, demolition and disposal or recycling [12]. Furthermore, product storage and transport processes of all kinds as well as energy demand resulting from conversion losses during the provision of final energy for building operation should not be neglected [12]. Since the operating energy consumption of buildings has been significantly reduced in recent years, the relative share of embodied energy in the total energy demand of buildings has risen sharply [13]. In this respect, reducing the demand for embodied energy in construction projects is an important approach to optimise overall energy performance. If this aspect is not taken into account, it is conceivable that buildings could be awarded a "Zero Energy Performance Gap" label, even though large amounts of embodied energy were or are required for their construction and operation (e.g. for energy-intensive manufacture of steel structures and complex technical building installations as well as for the provision of coal-fired operating electricity). This indirect energy consumption or the consumption of primary energy respectively should always to be considered.

Gap between optimal and planned (targeted) energy performance: The commonly used definition of the term energy performance gap suggests that there is one major problem to be solved with regard to the energy performance of buildings: the fact that there is often and unnecessarily a large gap between the energy performance promised in the planning phase (keyword 'planned' in Figure 1) and the energy performance actually achieved (keyword 'actual' in Figure 1). This problem is present in many buildings [2,3] and must be solved if the energy transition is to be accomplished. However, with regard to the energy performance of buildings there is another, perhaps even more serious problem: namely a gap between the optimal energy performance (keyword 'optimal' in Figure 1) and the energy performance that is actually targeted (keyword 'planned' in Figure 1) by the relevant actors in the building life cycle (especially by building owners and planners). By definition, research on energy performance gaps is currently not concerned with this further gap and the processes that lead to its emergence (e.g. the definition of energy-relevant targets for construction projects as well as for operating and utilization processes). Energy performance gap research investigates why existing energy-related goals and plans are often implemented only suboptimally. However, the research strand is silent when it comes to explaining how and why ambitious energy-related goals and plans often do not even come into existence. Yet, from the point of view of reducing energy demand it is key to understand how it could be achieved that more ambitious energy performance targets are set.

Of course, the concept of optimal energy performance is extremely vague, since a definition is only possible if conflicting goals between comfort requirements (e.g. indoor environment quality), economic efficiency and climate friendliness are balanced and, last but not least, unpleasant questions on the necessity of energy sufficiency are answered. The fact that these are ethical and moral questions means that the optimal energy performance of a building inevitably depends on the point of view of the observer. However, the authors argue that the vagueness, controversial nature and metrological inconvenience of the concept are invalid, unscientific and even – in the truest sense of the word – unethical reasons for avoiding it. We argue that from a scientific perspective, the concept has the following two main advantages: On the one hand, it opens up a view of the entire problem to be solved - of entire life cycle energy performance gaps of buildings, including the associated climate impact (see Figure 1). On the other hand, it is a constant reminder that the urgently needed transition to low-energy and zero-emission buildings in some places could also have to do with questioning the legitimacy of other goals (e.g. exaggerated demands for space, comfort and profitability) that are being pursued under the guise of energy efficiency and sustainability [14]. Energy performance gap research currently does not discuss such issues and thereby – at least partially – contributes to the problem it is trying to solve.

Greenhouse gas emissions associated with energy demand: Many studies on energy performance gaps have reported that the elimination of performance gaps is of great importance in overcoming the climate crisis (e.g. [2]). However, the overall energy demand parameters (e.g. kWh/m^2) usually used to quantify energy performance gaps provide only rough indications as to whether limited climate-friendly energy and climate-damaging fossil energy are being used sparingly (e.g. because typically no distinction is made between different primary energy sources). However, if climate-damaging practices in the building sector are to be better understood and prevented in the future, it is of course essential to use greenhouse gas emissions caused (and measured in CO_2-equivalents) as a key performance indicator. Evaluations should include first and foremost all energy-related emissions, but also all emissions caused by other means. However, the current focus on energy rather than on climate performance gaps in principle permits that no energy performance gap is detected for a building even if its construction, operation and use would actually have to be assessed as harmful to the climate by all conceivable standards. Again, it could therefore be argued that in some cases energy performance gap research contributes to the perpetuation rather than the abandonment of unsustainable lifestyles.

The dynamic character of (life cycle) energy performance and climate performance gaps: Case studies and quantifications of energy performance gaps are usually carried out once 1-2 years after a new building or modernisation project is put into operation. Thus, energy performance gaps are implicitly conceptualized as a problem that can occur in construction projects and should therefore be avoided as early as possible in the planning and construction process or at the latest be eliminated in the early phase of operation. Although this view is not wrong, it describes the energy performance of buildings as a comparatively static phenomenon. Obviously, this is not true. Even if a building's energy performance gap has been reduced soon after it has been put into operation, a renewed increase in the energy performance gap is likely without targeted ongoing optimization measures [10]. This is because many buildings and their use and operation are constantly undergoing minor and major changes that are suboptimal in terms of energy efficiency. These include, for example, defects due to aging processes, changes in the use and layout of rooms [15] and suboptimal operation of technical building equipment due to know-how losses when staff are transferred. Energy performance gaps and thus the significance of the various causes therefore fluctuate over the entire life span of buildings and depending on ongoing target-setting, planning, construction, operation and utilisation processes (see also Figure 2). Obviously, the same applies to *life cycle* energy performance and climate performance gaps. All the gaps mentioned

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should therefore be understood as dynamic phenomena and should be continuously evaluated and minimized over the entire life of a building (see also [16]). Defining energy performance gaps exclusively as problems in construction projects maintains the widespread but simply false belief that a sufficient reduction in the energy demand and greenhouse gas emissions of buildings could be achieved just by increasing the rate of modernisation projects.

3.3. Alternative definitions and models: Life cycle energy performance gaps and climate performance gaps

Derived from the above considerations, the authors recommend that more attention be paid to life cycle energy or climate performance gaps in the future and that – in the building sector – these terms be defined as follows: The terms life cycle energy performance gap and climate performance gap refer to the gap between the optimally low and the actual primary energy demand / greenhouse gas emissions of a building (portfolio), considering its entire life cycle. To visualize the essential aspects of these terms, life span models, as exemplified in Figure 2, are proposed here.

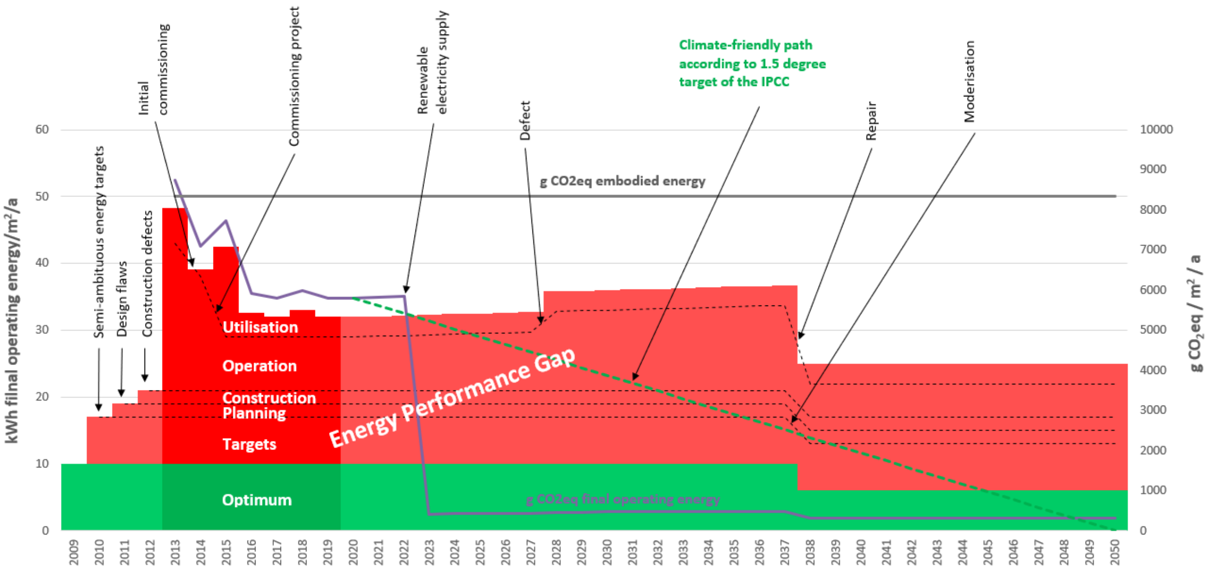

Figure 2: Visualisation and modelling of essential aspects of building's life cycle energy and climate performance (gaps)

The data presented are based on the case of a real university building in Switzerland, but without any claim to perfect accuracy. Obviously, all future developments (between 2020 and 2050; right-hand pastel red and pastel green areas) are purely fictitious. The emergence of the total operational energy performance gap (entire coloured red area, excluding embodied energy) begins even before the building is put into operation for the first time, with the corresponding sub-optimal target-setting, planning and construction processes (left-sided pastel red area). The commissioning process not carried out properly in 2013 was corrected to some extent by a recommissioning project in 2014/2015. During regular operation, energy-related sub-optimal operating, maintenance and utilisation processes also contribute to continuously increasing operating energy consumption. The changeover from non-renewable to renewable electricity supply in 2022 has no effect on this, in contrast to the long unnoticed failure (2027) and later the long overdue repair (2038) of a technical building installation. In addition - also in 2038 - the modernisation of a building services system reduces the energy performance gap. It should be noted that the subdivision of the operational energy performance gap into differently sized, clearly distinguishable causes (targets, planning, construction, operation, use) is purely analytical in nature. In reality, the various 'causes' are closely and dynamically intertwined and even if they were clearly distinguishable, the extent of their contribution to performance gaps would vary from building to building.

However, Figure 2 not only shows the total operational energy performance but also the greenhouse gas emissions associated with the building. The violet line depicts emissions caused by final operating energy demand. For illustration purposes, the greenhouse gas reduction path to be achieved according to the Intergovernmental Panel on Climate Change (dashed green line) is also portrayed for this indicator. The grey line stands for embodied greenhouse gas emissions averaged over a life span of 60 years (according to a benchmark for university buildings [17]). The embodied greenhouse gas emissions also represent the embodied primary energy demand, which is not shown in the figure for the sake of simplicity. In the case of the university building shown, it is evident that embodied energy demands and greenhouse gas emissions account for a significant proportion of the overall energy and climate performance. Please also note that during some of the years, greenhouse gas emissions and energy demand develop in opposite directions.

4. Weaknesses of the techno-economic and the psychological paradigm and a valuable alternative: practice theory

According to Shove [18], drawing on Kuhn [19] different scientific paradigms stand for different, sometimes irreconcilable ideas of what is defined as a problem to be solved (see Chapter 3) and which research agendas, theories and research methods are judged acceptable. In her work [8,9] Shove has identified and criticized two paradigms (or theories of social change) that have been or are shaping research and policy in the thematic cluster of buildings, energy and climate change: firstly, the techno-economic paradigm and secondly the psychological ABC (attitude - behaviour - context) [20] paradigm. In the following, the authors of this paper argue that techno-economic and psychological paradigms underlie most studies in the field of energy performance gap research and, in analogy to Shove [8,9], argue that they are inappropriate to generate plausible explanations and effective 'solutions' for energy performance gaps. The two paradigms are contrasted with practice theory as a valuable alternative.

According to Shove [8], the following assumptions are linked to the prototypical *techno-economic paradigm*: (1) The climate crisis can be solved by climate-friendly technologies, but to do so, researchers must first develop the required technologies and prove their applicability and economic viability in demonstration projects; (2) If an existing potent technology does not spread despite its obvious cost-effectiveness, there is a gap between the technical potential and current practice, which is caused by non-technical barriers or factors (knowledge deficits, lack of information and motivation as well as irrationality among decision-makers, market failures, etc.); (3) To overcome these barriers, social science knowledge of the barriers and drivers as well as appropriate guidelines, training and incentives are needed. According to the authors, the paradigm is strikingly reminiscent of many conceptual and empirical studies on energy performance gaps in buildings. This can be seen, for example, in the strong technology focus when identifying causes and solutions [3] as well as in the attempt to develop an exhaustive list of potential barriers that can occur in the various phases of the building life cycle (e.g. [2]). Following Shove [8], the techno-economic paradigm in energy performance gap research can be criticised for (a) conceptualising technical and social aspects as largely independent of each other and (b) considering, investigating and describing the dynamic socio-institutional contexts in which people have to act and energy performance gaps occur only superficially, if at all.

To describe the *psychological paradigm*, Shove [9] cites Stern's ABC model [20] according to which "behavior (B) is an interactive product of personal-sphere attitudinal variables (A) and contextual factors (C)" (p. 415). According to Shove [9], such models represent the following assumptions: (1) Individuals have very strong agency: they are responsible for climate change, but can always choose to adopt more climate-friendly behaviour. Whether or not actors do so mainly depends on personal variables (e.g. attitudes, values, motives, habits) and can be influenced by behaviour change interventions such as persuasion and consultation; (2) contextual factors (e.g. social situation, history, infrastructure) are considered, if at all, in the form of "catch-all variables" (p. 3) that can be filled arbitrarily with all kinds of determinants. In energy performance gap research, the paradigm described above is mainly applied

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in frequently conducted studies on the behaviour of building occupants [3]. We agree with Shove [9], however, that the psychological perspective conveys a "strikingly limited understanding of the social world and how it changes" (p. 1) in which there exists "no obvious limit to the number of possible determinants and no method of establishing their history, their dynamic qualities, their interdependence or their precise role in promoting or preventing different behaviours" (p.3) and "no scope at all for wondering about how needs and aspirations come to be as they are" (p.5).

An alternative scientific paradigm that distances itself from static, simplistic and over-generalizing barrier-driver or factor models while offering a more fruitful theory of all forms of social change is the *practice paradigm*. Practice Theories [21] conceptualize social phenomena of all sizes as the simultaneous performance of a multitude of practices. According to practice theories, the social phenomena of our world - whether they be temporary clothing fashions, energy performance gaps in building stocks, or seemingly irrefutable forms of government and institutions - must not be taken for granted, since they only continue to exist if we continually reproduce them through our practices [21]. For this reason, social states and transformations (e.g. practices of energy supply and demand) can be explained most precisely if the course of specific practices and their emergence, diffusion, perpetuation, modification or disappearance is chosen as the central object of investigation. Practice theories position themselves between the two extremes of agency and structure and assume that agents act neither completely free nor predetermined by mysterious social structures [21,22]. Instead, actions always take place amid unique assemblages of preceding, simultaneous and subsequent socio-material practices and are therefore strongly conditioned by them. Within this context, however, it is quite possible for individuals to strive to no longer be "carriers" [9] of certain practices and, if applicable, to establish new practices. According to practice theory, an effective, comprehensive promotion of climate-friendly practices in the building sector is therefore at least theoretically possible - but it can only succeed if interventions are repeatedly adapted to the site-specific history, current situation and dynamics of the systems of practices to be changed. The authors argue with Gleeson ([23], p.1) that the practice paradigm has the potential to finally disrupt the "simplistic 'need for skills and knowledge' dialogue" that has been held for far too long and to "open a discussion where failure in technical performance [as shown in Figure 2, author's note] is addressed as a social phenomenon".

5. Conclusion

Current energy performance gap research has several blind spots and researchers would probably be better advised to investigate how climate performance gaps emerge or may be minimized. The practice paradigm offers a promising set of theoretical concepts and methods that allow us to question traditional, widespread, but hardly plausible technology-centred or individualistic notions of the emergence of unnecessarily high energy demand and greenhouse gas emissions. Instead practice theory allows us to view performance gaps - despite the originally techno-economic gap concept [8] - as the result of large systems of situated, interrelated, on-going social (e.g. professional, organizational, policy) practices. The authors therefore call for a definition and paradigm shift in energy performance gap research. Since around 2013, several empirical studies have already been conducted under the practice paradigm. However, this research is still in its infancy with regard to various aspects (e.g. range and prioritisation of examined climate-relevant practices, methodological competence for a sophisticated investigation of these practices, technical understanding, internationality). If future climate performance gap research develops well elaborated conceptual frameworks on such aspects, builds on them and receives substantial funding, it might soon make a valuable contribution to the climate-friendliness of buildings, cities and perhaps even other thematic areas (e.g. mobility, industry, agriculture).

References

[1] United Nations 2020 United Nations Sustainable Development Goals - Time for Global Action for People and Planet *About the Sustainable Development Goals*

[2] van Dronkelaar C, Dowson M, Spataru C and Mumovic D 2016 A Review of the Regulatory Energy Performance Gap and Its Underlying Causes in Non-domestic Buildings *Frontiers in Mechanical Engineering* **1**
[3] Zou P X W, Xu X, Sanjayan J and Wang J 2018 Review of 10 years research on building energy performance gap: Life-cycle and stakeholder perspectives *Energy and Buildings* **178** 165–81
[4] Shi X, Si B, Zhao J, Tian Z, Wang C, Jin X and Zhou X 2019 Magnitude, Causes, and Solutions of the Performance Gap of Buildings: A Review *Sustainability* **11** 937
[5] Socolow R H 1978 The twin rivers program on energy conservation in housing: Highlights and conclusions *Energy and Buildings* **1** 207–42
[6] Wingfield J, Bell M, Miles-Shenton D, South T and Lowe R J 2011 *Evaluating the impact of an enhanced energy performance standard on load-bearing masonry domestic construction: Understanding the gap between designed and real performance: lessons from Stamford Brook.* (Department for Communities and Local Government)
[7] Janser M, Hubbuch M, Vecsei P and Pfenninger M (in preparation) *Bringing Real Estate Portfolios on a Climate-Friendly Track - Recommendations for Profitable Procurement Practices and Innovative Services for Energy Optimization and Modernisation of Existing Buildings.* (Wädenswil: Institute of Facility Management)
[8] Shove E Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings 8
[9] Shove E 2010 Beyond the ABC: Climate Change Policy and Theories of Social Change *Environment and Planning A: Economy and Space* **42** 1273–85
[10] Min Z, Morgenstern P and Marjanovic-Halburd L 2016 Facilities management added value in closing the energy performance gap *International Journal of Sustainable Built Environment* **5** 197–209
[11] Bordass B, Associates W B, Cohen R and Field J 2004 Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap *Proceedings of the 3rd International Conference on Improving Energy Efficiency of Commercial Buildings* 3rd International Conference on Improving Energy Efficiency of Commercial Buildings pp 1–10
[12] EN 15978: 2011 *Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method* (European Committee for Standardisation (CEN))
[13] Azari R and Abbasabadi N 2018 Embodied energy of buildings: A review of data, methods, challenges, and research trends *Energy and Buildings* **168** 225–35
[14] Shove E 2018 What is wrong with energy efficiency? *Building Research & Information* **46** 779–89
[15] Haasl T and Heinemeier K 2006 *California Commissioning Guide: Existing Buildings* (Califormia Commissioning Collaborative)
[16] Preiser W F E, Hardy A E and Schramm U 2017 *Building Performance Evaluation: From Delivery Process to Life Cycle Phases* (Springer)
[17] Simonen K, Rodriguez B X and De Wolf C Benchmarking the Embodied Carbon of Buildings *Technology | Architecture + Design* **1** 208–18
[18] Shove E 2011 On the Difference between Chalk and Cheese—A Response to Whitmarsh et al's Comments on "beyond the ABC: Climate Change Policy and Theories of Social Change" *Environ Plan A* **43** 262–4
[19] Kuhn T S 1970 *The structure of scientific revolutions* (Chicago: University of Chicago Press)
[20] Stern P C 2000 New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior *Journal of Social Issues* **56** 407–24
[21] Nicolini D 2013 *Practice Theory, Work, and Organization: An Introduction* (Oxford: Oxford University Press)
[22] Schatzki T 2016 Practice theory as flat ontology *Practice Theory and Research*
[23] Gleeson C P 2016 Labour and Low Energy Buildings: the energy performance gap as Social Practice 34th International Labour Process Conference Berlin, 04 to 06 Apr 2016