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REPUBLISHED ARTICLE

Resistance against zero-emission neighbourhood infrastructuring: key lessons from Norway

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Collections · **Demos** · **Metabole**

ABSTRACT

This article analyses non-trivial resistances encountered in the implementation of zero emission neighborhoods in Norway, based on eight years of living lab experiments and interviews with key stakeholders. Drawing on a socio-material approach to infrastructuring, the study identifies three distinct categories of resistance: tensions between professional groups – particularly between energy and construction sectors, resistance ‘from above’ through lack of political and regulatory support, and resistance ‘from below’ by local stakeholders and future users. The analysis reveals that these resistances go beyond simple opposition to change, instead reflecting deep-seated professional practices, shifting political priorities, and local social contexts that compete with or contradict zero emission planning goals.

Keywords · infrastructure · change management · overcoming resistance · net zero carbon · decarbonisation · cities · neighbourhood · socio-material · climate mitigation · Norway

PRACTICE RELEVANCE

For practitioners and policymakers, this study demonstrates that successful implementation of zero emission neighborhoods requires more than technical solutions and regulatory frameworks. The findings suggest that – at least in the Norwegian context – future zero emission planning must better integrate diverse professional expertise, particularly from energy and building experts but also from local planners and user groups, while developing strategies that can succeed with minimal state support. The study also highlights the importance of making climate change impacts on infrastructure more visible to generate public support. These insights can help practitioners design more inclusive and effective approaches to neighborhood-scale decarbonisation efforts.

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Introduction

In the literature, resistance against science-led sustainability interventions – e.g., the implementation of energy efficiency innovations – has predominantly been framed as barriers preventing a benevolent and rational change (van Soest and Bulte 2001). Inspired by scathing critiques of such simplistic approaches (Shove 2010), this article leaves a simple conception of unreasonable resistance against rational change behind. A more elaborate analysis of resistances demands caution in relation to reductionist approaches that assume resistances against rational, science-based technological innovation can only be guided by a lack of knowledge, particular interests or irrational fear.

In this article, we present a theoretically grounded and empirically informed analysis of resistances against science-led change in the Norwegian context. We focus on those resistances against solutions developed to make zero emission neighbourhoods possible that do not amount to a denial of the need for action, but that rather formulate alternative pathways to achieve sustainable change. Thus, instead of dismissing any kind of disagreement and resistance against science as misguided from the outset, our focus aims to provide space for the performance of “a broader ethic of responsibility” (Janda and Topouzi 2015, 530), which is aware of the socio-material entanglements, which enable or prevent science-led sustainability change and through which urban planning produces long-term effects on citizens’ everyday lives (Westerhoff 2016).

A change towards less or even zero CO₂ emissions in the built environment represents an explicit and measurable goal but – like all comprehensive changes – it also creates unintended side-effects, which must be anticipated, reflected on, and responded to (Owen, Macnaghten, and Stilgoe 2012). Resistances encountered in the process of implementation and experimentation with new solutions in this sense are an indication for deficits in zero emission planning and the present study of these resistances intends to inform more responsive and responsible approaches. Consequently, the research question posed is not only what the non-trivial resistances encountered in the implementation of zero emission neighbourhoods are, but also what are the consequences and what can be done to avoid resistance or at least reduce levels of resistance.

In terms of theory, socio-material approaches are mobilised, above all perspectives that frame the decarbonisation of the built environment as socio-material infrastructuring. In terms of empirical research, the article draws on eight years of work in a large research centre, which was tasked to produce world-leading research on how to design and implement zero emission neighbourhoods. More specifically, the authors have established living labs at five of the research centre’s pilot neighbourhoods, in which resistances were encountered against zero-emission transformations. In addition, eleven key stakeholders directly involved in the centre’s work were interviewed about their experiences with resistances.

In the next section, we describe and justify our theoretical framework, which leads to a more precise formulation of the research question. We then present the context of the research and its methods. The presentation of empirical findings is organised along three categories of resistance encountered empirically. A discussion of consequences for future decarbonisation of groups of buildings derived from the interviews and living lab case studies concludes the text.

An infrastructural perspective on zero emission planning

The intricacies of engendering change in the built environment are well reflected in planning theory, where complexity, contested norms, and uncertainty have led to the development of the now widely used term ‘wicked problem’ (Rittel and Webber 1973). There is no reason to believe that decarbonising the built environment will escape these problems. If anything, zero emission planning might be more ‘wicked problem’ than

other forms of planning since the change must comprise existing and new structures, reaches far into the future, and transcends the usual geographical and temporal limitations of planning processes' focus on individual projects. While the transition may involve a large number of smaller decarbonisation projects, calling for a rapid and ambitious decarbonisation demands a more comprehensive rethinking of how the built environment is developed.

Socio-material infrastructuring

The built environment consists of material structures, e.g., buildings, streets, and bridges, but its environmental performance depends in addition to how these structures are designed and implemented on how the structures are used. Moreover, seen from the perspective of its inhabitants, the built environment provides an infrastructure, which in routine operation remains in the background while supporting the inhabitants' daily practices. A well-established theoretical approach, which is able to capture both the interactions between material structures and their use and the infrastructural character of the built environment is the relational perspective on socio-material infrastructures introduced by Susan Leigh Star, Geoff Bowker, and colleagues in the 1990s. Here, infrastructures are seen as relational entities, which are performed in the interplay between the material and the social and which support the performance of everyday routines. According to Star and Ruhleder (1996) such relational, socio-material infrastructures

- support social practices,
- have a reach beyond one type of activity or place,
- are invisible to their users unless they break down,
- are transparent to use, i.e., they can be used without being assembled first,
- are learned as part of membership in a community of practice,
- are embedded in other social and material structures,
- are heavily standardised, and
- are built on an existing base.

These characteristics explain why infrastructures have a tendency to resist change and why changes – if they happen – are usually incremental. Since everyone depends on infrastructures working in a robust and predictable way, radical changes, unless they are accompanied by a larger transformation of practices, lead to costly disruptions in the fabric of daily life of a potentially large number of individuals.

The act of creating, changing, operating, and maintaining socio-material infrastructures, is called *infrastructuring* (Karasti and Syrjänen 2004; Karasti and Blomberg 2018). Infrastructuring is the creation and stabilisation of infrastructural relations, which includes work on the material side of the socio-material relation as well as on the social. Infrastructuring is a special socio-material practice, which produces the conditions for other socio-material practices to be stabilised and performed. Despite the prevalence of heroic stories of infrastructural mega-projects that are told in the context of nation building and the 'conquest of nature' (Larkin 2013), it is important to remember that almost all infrastructuring today is in fact re-infrastructuring, in which "existing infrastructure is further developed according to new logics and directions" (Grisot and Vassilakopoulou 2017, 8).

Who does the (re-)infrastructuring is an empirical question (Karasti and Blomberg 2018). More recently, drawing on ethnographic and "designerly" uses of the term, "infrastructuring from below" has been described, reminding us that roles in relation to infrastructures are context-specific and that studies of infrastructuring should be agnostic in relation to where and by whom driven infrastructuring takes place (Berker 2023a).

Returning to the question of decarbonisation and reframing this process as zero-carbon infrastructuring, walking through the list of infrastructural characteristics reproduced above makes clear that decarbonisation must make sure that the results continue to support routine activities, that it should do so invisibly and transparently, that it may mean the establishment of new standards, etc. The list of characteristics can also be read

negatively as factors which motivate resistances when they lack, e.g., when an infrastructure fails to support everyday activities, or when it does not work transparently and has to be assembled each time to be used, etc.

Two implications for the study of resistances to science-based decarbonisation of the built environment stand out. First, since – true to the agnosticism of an infrastructuring approach – it cannot be taken for granted who is doing the zero-carbon infrastructuring, the identification of actual participants in a specific decarbonisation effort should be part of the empirical investigation. Since several groups may be involved with different agendas, conflicts between different ways of zero-carbon infrastructuring can be expected, and it is not always clear who is the one infrastructuring and who is resisting. Second, zero-carbon re-infrastructuring, competes with existing ways of infrastructuring. This implies that in addition to potentially conflicting visions of new, zero-carbon infrastructuring there are established ones that will add their powerful voice to negotiations of how infrastructuring should be conducted. It is reasonable to assume that these tensions, between infrastructuring actors and between the new and the existing, are involved in what we have called non-trivial resistances.

From trivial to non-trivial resistances

Resistance to sustainable change has been framed in terms of active exercise of power driven by ‘incumbent’ actors (Geels 2014). Evidence for these concerted interventions against sustainable change that encompass the silencing of critical voices, spreading of uncertainty, and active lobbying is by now abundant (Oreskes 2015; Miller and Dinan 2015). The success of populist parties that invariably include climate denial in their political message shows that this kind of active resistance can be harnessed to appeal to broader audiences. Both explicit and hidden acts of resistance that actively obstruct climate change mitigation efforts will be called **trivial resistance** in the following. Apart from the fact that these efforts sometimes are hidden from plain view and need active investigation to be brought to light, this kind of resistance is trivial in the sense that it follows simple political or material interests. While it may be useful to learn *about* the tactics and strategies of these opponents, science-based decarbonisation of the built environment can learn little from these resistances. With the focus on infrastructuring, however, without ignoring trivial resistances, other forms of resistance become visible, for lack of a better word called **non-trivial** here, that are not rooted in an explicit or implicit denial of the necessity to address climate change. What the non-trivial forms of resistance have in common, thus, is that they accept the need for emissions reductions, but resist specific proposals, in our case the recommendations derived from building research, while proposing alternative forms of low or zero carbon infrastructuring. The implicit assumption on which this article is built, then, is that learning from these alternatives should be considered by science-led decarbonisation efforts, and treated as potential source of knowledge instead of adversary.

The distinction between trivial and non-trivial resistance, as it is proposed here, is at best still only a first step in the formulation of a more comprehensive heuristic of resistances against science-led sustainable change. It is meant to enable critical self-reflection for scientists in light of them meeting resistance. A more comprehensive heuristic will be presented at the end of the article.

Background and method

The starting point of the case discussed here can be situated around 2008 when all parties in the Norwegian national parliament (stortinget) – except the climate-change denying right-wing populist party – agreed on what would be called the climate-compromise (klimaforliket). An important part of this was the commitment to prioritise research on environmentally friendly solutions up to a point that the funding would match and overtake the considerable resources provided to research supporting Norway’s all-important oil and gas sectors. In 2009, a first group of nine research centres on environmentally friendly energy was created, which received around 30 million Euro each distributed over a period of eight years. These centres were conceived as

‘national teams’, comprising industry, research, and authorities who were supposed to work together to start a sustainable transition in their respective sectors. One of these centres was the Research Centre on Zero Emission Buildings (ZEB), active from 2009 to 2017, followed by the Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN), which operated between 2017 and 2024. Both centres included regulators, companies from the whole value chain, and the central relevant research milieus in Norway. The step from ZEB to ZEN was marked by the inclusion of actors from the energy sector and mobility into the centre’s personnel and by the extension of definitions established in relation to individual buildings to groups of buildings. A logic of emissions-balance was central to both centres where in various ways renewable energy production on-site was calculated against CO₂ emissions related to the buildings and other infrastructures. Both centres included dedicated activities related to pilots, buildings or neighbourhoods, which were supposed to act as demonstrators and test sites.

The authors of this article were involved in both the ZEB and ZEN centres from the beginning (TB) and in various roles, e.g. as researchers (TB, RW), as interim centre manager (RW), and as ZEB work package leader (TB). Here, we focus on our work done in relation to the ZEN centre’s living labs, experiments conducted at pilot sites aiming at probing resistances and exploring possibilities for inclusion (Woods et al. 2019). The passages in the present text which describe local actors’ relation to ZEN research, i.e., prospective users, pilot owners, etc., are based on the work done in these living labs, which has been described in detail elsewhere (Berker and Woods 2020; Woods and Berker 2021, 2022; Berker et al. 2024).

In addition, and to fill gaps in our understanding of the resistances ZEN has met against its proposed changes, between 2022 and 2024, we conducted eleven interviews with key stakeholders in ZEN research where we encouraged the interviewees to reflect on resistances encountered when working with and within the ZEN centre. There were representatives from both the energy and construction sector, building researchers, work package leaders, pilot owners, and other experts directly involved in the centre’s work. All but four interviews were conducted online. The analysis was based on extensive notes taken by the interviewers during the interviews and which were then coded along the characteristics of infrastructures presented in the previous section. Since the topic of resistances was perceived by some interviewees as politically sensitive, great emphasis was placed on creating a safe space for the respondents. Part of this was that we were not recording the interviews. This is also the reason why we refrain from describing the interviewees beyond in the most general terms here. In one instance, the interviewee, despite these measures, felt still uncomfortable to talk about resistances. The interview ended early, and based on the wishes of the interviewee the collected data was discarded.

Resistances, if they are framed as non-trivial, i.e., resulting from conflicting ideas about how the decarbonisation of the built environment should be performed, are not about which definition of zero emission buildings is right and which is wrong. Being involved in the research themselves, the authors are convinced that both ZEB and ZEN have produced sound and in many cases world leading research. However, this is not in contradiction with the goal of this article, which is critical reflection of the research’s impact and its focus on instances of lack of interest and resistance.

Three resistances

The material reveals three dimensions on which the interviewees and participants in the living labs have described resistances. Using a spatial metaphor, they can be grouped in resistances “sideways” with professional groups as opponents, “from above” with public authorities as main actors, and “from below” relating to the local populations affected by zero emission planning. These ‘dimensions’, thus, describe three forms of resistance that draw on different kinds of knowledge, are embedded in different institutional contexts, and are driven by different actors.

Resistance sideways: Energy vs construction?

As described in the previous section, the story of zero emission neighbourhoods in Norway starts with zero emission buildings. The work done in ZEN's precursor ZEB was not without internal tensions and critics from the construction sector (for an in-depth account, see Kvellheim 2017; Berker 2023b), but particularly through its nine pilot buildings that were spread all over the country it played a significant role in moving the Norwegian construction sector in a more sustainable direction (Nykamp 2017). In terms of technology, the strategy of the centre was heavily influenced by passive house energy conservation, which was paired with renewable energy production on-site, expected to make up for the emissions connected to construction, operation, and demolition (Mamo Fufa et al. 2016).

To calculate a CO₂ emissions balance between CO₂ equivalents related to construction, operation, and demolition of a building and the CO₂ equivalents related to production of renewable energy on-site, ZEB had to find a CO₂ factor for energy, which would remain valid during a building's lifetime. However, CO₂ factors depend heavily on energy systems that in turn depend on political and technological developments. The solution to this problem found by ZEB researchers after years of discussion and research was to base the factor that was eventually proposed, 132 gCO₂e/kWh, on the – at this time – most likely future scenario, which assumed the continuation of efforts to both decarbonise European energy systems and to interconnect European grids. Contesting ZEB's argumentation for this specific CO₂ factor especially proponents from the Norwegian energy sector argued that since Norway's massive domestic electricity demand is predominantly served by renewable hydro-power, all electricity use related to buildings is practically emissions free. This would obviously render the whole point of the research centre moot as renewable energy production on-site cannot compete with cheap and well-established hydro power. Against this, the majority of the centre's researchers argued that electricity demand would rise – in Norway and beyond – and that the use of electricity for space heating was a waste of this valuable resource, which, moreover, could become a source of future export revenues.

Another manifestation of a similar disagreement was debates around district heating development. Here, proponents of the centre warned against costly investments that are not needed given the possibility of reducing energy demand radically through passive house technology. District heating proponents argued that it would be much easier to make a larger system energy efficient than every house one by one. This argument, in which larger, more efficient energy systems and the piecemeal approach of a building-centred approach were set against each other, was also connected to the question whether renewable energy production on-site was meaningful at all. Representatives from the energy sector did not only reject the notion of a need for decarbonisation of the current Norwegian energy system, they also pointed towards large-scale renewable energy development, e.g., in wind farms, to fulfil future energy needs. In their view, intermittent, small-scale renewable energy production connected to buildings would be inefficient and only destabilise existing grids.

ZEN, the successor of the ZEB centre, moved the system boundary from individual buildings to groups of buildings, responding to some of the critics' demands. Moreover, the new centre was required by its main source of funding, the Research Council of Norway, to include energy researchers and representatives from the energy sector as equal partners. After the establishment of the centre in 2017, the different approaches clashed despite repeated efforts to negotiate a common view. To create common ground, it was argued that even in the special Norwegian situation, local renewable energy production has a role because it can prevent costly upgrading and extension of energy infrastructures through shaving of peak loads and provision of energy to remote settlements. Also, considerable resources were used to make building services and envelopes a source of energy flexibility, which would serve the same goals. (Taveres-Cachat et al. 2019; Clauß et al. 2019).

Despite considerable efforts to find a compromise, the interviews with ZEN researchers and partners conducted for this article towards the end of the centre's lifetime showed the persistence of the antagonism, which one interviewee, a building researcher, called "the elephant in the room". Asked about resistance against ZEN solutions another building researcher described opposition from the energy sector, both within and from outside the centre, as one of the major forms of resistance encountered. Expressing frustration about

the ‘immunity of energy actors to sound calculations’, another informant framed this kind of resistance as a disagreement over which side of the argument has the better case in terms of cost efficiency. Within the centre, this informant saw this resistance, for instance, among representatives from the district heating industry, which echoes discussions, already going on during the times of ZEN’s predecessor, ZEB (Kvellheim 2017; Berker 2023b). Notably, the same informant described another longstanding form of resistance from architects that reject decarbonisation because of its aesthetic consequences. This interviewee expressed frustration about the persistence of this opposition from both energy sector and architects, “despite all the good examples that by now are out there”.

The persistence of resistance encountered from individuals working in and related to the energy sector and architects can be interpreted as trivial resistance related to incumbent actors defending their privileges. However, this interpretation ignores that the opponents of ZEB’s approach did have a pronounced alternative vision of how decarbonising infrastructuring should look like. Indeed, the accusation of self-interested opposition against ‘sound’ decarbonisation solutions was well-known by an informant who represented the energy sector. This interviewee conceded that some of their colleagues certainly did not ‘dare or want to face this discussion’. However, almost from the beginning of the interview, they defended the perspective that in ‘many cases’, particularly when ‘society has already invested in district heating infrastructure’, there is just no way a case for building-centred decarbonisation could be made. Moreover, they defended these investments as reasonable since ‘collective’ solutions are ‘always’ more efficient than individual ones.

Comparing the arguments brought forward in the interviews and contextualising them in the history of the debate described at the beginning of this section, the different frames of reference are conspicuous. Where the representative from the energy sector talked about ‘collective’ solutions on the level of district heating networks, the two interviewed building researchers tended to refer to groups of individual buildings. According to Star and Ruhleder (1996), infrastructures are intrinsically relational entities connecting potentially a large number of heterogeneous elements. Taking such a relational perspective seriously, it is clear that energy infrastructures and the built environment are connected and should be treated as connected entities when CO₂ emissions are at stake, hence the need for coordination and collaboration. But it is not only the relations between these infrastructures that are at stake. How the relational networks of social processes and technologies should be sliced and cut in order to arrive at a notion of which elements have to be accounted for (Callon and Law 2005) and which are outside the scope of a zero emission neighbourhood, will greatly affect whether offset- and balance-oriented approaches (Lützkendorf and Frischknecht 2020) can succeed in a given project (Pan 2014). If, for instance, district heating is assumed to be reasonable because of its collective nature, if feasible it will be necessarily included in calculations, whereas a more building-centred approach will contest this inclusion to keep alternatives on the table.

It is reasonable to assume that the professionals on each side of the divide not only differ in which material frame they address, what they focus on and what they disregard, but also in their professional training and the meanings they attribute to decarbonising a neighbourhood. If we add architects, their training, and what a building means to them, a triangle of distinct professional practices emerges, where each side pulls in a different direction.

Summarising this kind of non-trivial resistance, we have found evidence for the persistence of disagreements about the best way to decarbonise the built environment, particularly between energy and construction researchers but potentially also architects. Active and passive resistance through self-interested defense of the status quo may play a role here, but an infrastructural perspective nuances this interpretation by directing attention to effects of professional practices on how system boundaries – here used in the broadest sense of which elements are seen as necessary to include – are defined and defended.

Resistance from above: Enforcing change through regulation?

Six of the eleven interviews were conducted right after a consequential political decision, which eliminated one of ZEN's pilot sites. Given this timing, it is not surprising that these six respondents took this event as the basis for more comprehensive reflections on the erosion of political support for the centre.

The decision in question was to halve the budget of an ambitious plan to move parts of NTNU, Norway's largest university and the centre's host institution, to the city of Trondheim's city centre. This move, which implied comprehensive construction activity, was supposed to result in a zero emission campus, which could demonstrate and be used to test solutions developed by ZEN. After the dramatic cuts in 2022, however, these environmental ambitions were completely abandoned (for more details, see Berker et al. 2024). Confronted with the consequences of the cuts, the responsible politician, Ola Borten Moe, referred to existing Norwegian building regulations, which, according to him, were strict enough.

This specific story of withheld funding can be interpreted as a result of the actions of a populist politician or the consequences of fraught negotiations and party politics within a government coalition. However, an infrastructural perspective adds non-trivial nuances to this story of trivial resistance.

The politician's deflection of responsibility by pointing at existing building regulations was echoed by the interviewees, although in a different way: they unanimously complained about what they perceived as the complete lack of political support for ambitious changes to building regulations which could support a transition towards CO₂ reduction in the built environment. Instead, as one of the already mentioned building researchers said, the politicians were now 'terrified' of making construction more expensive.

Studies of infrastructural change have shown that because of its impact on a potentially large number of interrelated entities – other infrastructures, social processes and technologies – change is usually incremental (Loorbach, Frantzeskaki, and Thissen 2010). It is obvious that radical changes risk disruption of the lives of a potentially large number of people, as is demonstrated abundantly in situations of infrastructural shock (Castán Broto et al. 2014). Given this background, the researchers' complaints about 'timid politicians', who were not willing to enforce far-reaching changes by law may appear somewhat surprising. To understand why the interviewed researchers would expect their government to enforce implementation of results of their research by law, it is useful to introduce a historical dimension. The situation in 2022 is in strong contrast to the context in which these researchers worked around 2009, when the Norwegian government through a white paper just had announced upcoming stricter regulations for energy demand in new buildings. Then, the establishment of the research centre ZEB and eight years later its continuation as ZEN gave a strong signal of the importance of zero emission buildings and neighbourhoods in Norway's overall decarbonisation efforts. ZEB researchers supported the government's goals, e.g. through the formulation of Norwegian passive house standards, and demonstrating the technical feasibility of stricter rules (Berker and Kvellheim 2018). Judging from the frustrated statements given by the interviewees, the researchers in ZEN continued this work assuming this to be what was expected from them, but they found themselves in a changed political context which made an infrastructural transition through regulatory support from above very unlikely.

That the research centres ZEB and ZEN, in the 16 years of their existence were not able to decarbonise the Norwegian built environment is as obvious as unsurprising. Seen from an infrastructural perspective, the initial idea to collect all relevant actors across different forms of expertise in a centre and to provide them with funding to 'solve' climate change, has the appeal to take seriously the heterogeneity of materials and practices that are involved in infrastructural change. Together with strong political support this approach has delivered considerable energy savings as a result of the support from research done in the ZEB centre. However, with the extension to neighbourhoods and in a changed political climate, these 'changes in the direction of infrastructuring' (Grisot and Vassilakopoulou 2017) could not be repeated and the incremental business-as-usual of infrastructural change became dominant again – as the case of the unlucky zero emission campus shows. In light of this, it makes sense that in 2024 an application for research funding to continue the work for eight more years in a new research centre lost against competitors that had more plausible claims to be a necessary

part of Norway's climate mitigation efforts (for the list of successful initiatives, see <https://www.forskningsradet.no/en/financing/what/fme/>).

Resistance from below: No need for ZEN?

In addition to resistance and lack of support from the 'side' and 'above', ZEN did not manage to create popular support among (future) users and local stakeholders around the pilot neighbourhoods. The gradual shift between active and passive resistance became particularly visible in the story of one of the pilot projects in which future users, initially only cautiously skeptical, organised and lobbied against the pilot which consequently was cancelled before it could be realised (Woods and Berker 2021). In other cases, the pilot carried on even though there was popular resistance, which, for example, was expressed in local newspapers (Woods and Berker 2022).

As with the previous two kinds of resistances, a trivial version of popular resistance would assume that the resisting groups prioritise their immediate interests against environmental concerns. However, a closer look at episodes of popular resistances – performed in both passive and active ways – two different forms of non-trivial resistances can be distinguished: first, based on ideas of good professional practice among future users and second, in cases in which future inhabitants were resisting, based on ideals of good domestic life.

We start with two examples of professional resistances, both emerging during the planning process. As documented elsewhere (Woods and Berker 2021), a refurbishment project, which was planned in the neighbourhood of Lø, was rejected by its future users, kindergarten teachers. In terms of CO₂ emissions the plan to convert an unused existing building to a kindergarten made sense: the original building was a broadcast production facility from the 1980s with massive concrete walls that embodied large amounts of CO₂ emissions. However, the kindergarten teachers included in the planning process through the municipality had for many years waited for getting a new kindergarten building and were hostile to the thought that this building would rather resemble a concrete bunker than a new building purpose-built to house children. Their resistance relied heavily on ideas of good professional practice, where natural light, visibility between indoor and outdoor areas, and flexible use of spaces featured prominently. The kindergarten teachers sent a letter to a local politician warning that this project would be a costly mistake, which weakened political support in the municipality to the point that the project's environmental ambitions were abandoned and the original building was demolished to make space for a new kindergarten. The second example (Gohari and Larssæther 2019) concerned a residential development project outside of Bergen, Norway's second largest city. From the beginning, the project was opposed by local politicians and administrative staff from the county council and the municipality because of its location. If the overall goal was climate change mitigation, they argued, placing a residential development far outside the city was nonsensical. Again, professional expertise was at the basis of these resistances, the professional judgment that densification would be sound environmental planning instead of contributing to urban sprawl.

In two other cases neither the planners nor specific future user groups rebelled against the zero emission plans. Instead, hostility became manifest in public opinion as expressed in newspaper articles and in interviews and group discussions conducted by the authors of this article. In the first case, Ydalir, a brownfield development just outside the centre of the small town of Elverum, car-based mobility became a central issue. To achieve an overall CO₂ emission balance, in the small-town context of this pilot project, ZEN researchers had provided evidence for an urgent need to reduce car-based mobility (Lund, Lausset, and Brattebø 2019). However, plans to keep cars outside the planned residential area met fierce resistance in local newspapers. As Woods and Berker (2021) argue based on interviews with locals, here – and in many other rural areas – the car was deeply embedded in the social fabric of everyday life so that it not only played utilitarian roles but also became a medium of highly valued care relations. The resistance never manifested in political pressure against the pilot as such, as it did in the case of the kindergarten teachers, but at the time of writing this article, there

were strong concerns whether the newly built houses and flats in the neighbourhood would attract enough buyers.

Another case did not result in open resistance but exemplifies the consequences of lack of local support. This project was located in Furuset, a socially strained neighbourhood within Norway's capital Oslo. Different from other local settings in Norway, in Oslo a fourth governance level (the local district) is a relevant actor in addition to the municipal, regional (county), and national level. The pilot was supported by the municipality of Oslo but, as became clear when the authors of this article tried to enroll local support for a citizen participation project in 2023, it had no support on the local level. Both a representative of the neighbourhood and inhabitants interviewed clearly expressed that **social** sustainability was high on the local agenda whereas infrastructural CO₂ emission reductions were seen as a distraction. These priorities – which competed with ZEN's agenda – made perfect sense given the local context of social problems, just as the priority for car-based mobility made sense for a rural setting.

Taken together, resistances from below in the cases presented here were mainly fuelled by local characteristics that ZEN had not taken seriously enough to make them part of its pilot project planning. The kindergarten teachers' professional priorities were not respected, the local urban planners' environmental precedence for density was ignored, the small-town citizens' need for cars was contested and social sustainability was no priority for ZEN, even in the case of a socially disadvantaged neighbourhood.

Discussion: Worst case scenarios and their consequences

We have sorted the empirical material into three different forms of non-trivial resistance, which represented different contexts and different actor groups. This answers the first part of the research question. While not every instance of resistance mentioned in the interviews or encountered in the living labs and pilots found its way into this section, we claim that the three categories are exhaustive. Admittedly, the topological metaphor covers all cardinal points and directions in this metaphorical space of resistances. However, the categories are different enough to yield different answers to the second and third parts of the research question, regarding the consequences and possible ways of dealing with resistances. In the following discussion of findings, we first speculate about possible worst-case scenarios and what they would mean for zero emission infrastructuring.

Both the ZEB and ZEN centres' claim to contribute to a rapid decarbonisation of the built environment rested on the combination of interdisciplinary research-based expertise with professional expertise from the relevant sectors. As demonstrated, however, the involved experts performed boundary work, i.e., the active work of defending one's own expertise against competing groups (Gieryn 1983). In this context, the differences in how system boundaries were drawn are more than just methodological decisions that can be adapted from case to case. Instead, when routinised and institutionalised in a discipline or sector, decisions about what matters and what does not form and are formed by professional discourses (Gunnarsson 2009) that underlie professional socialisation, identity formation, reflexivity, and performativity (Irimiea 2017, 115). As the interviews showed, the six years of collaboration in the ZEN centre had not contributed to the formation of a new boundary-crossing community of practice between building and energy research, despite frequent contact in meetings and workshops. The "professional narratives that maintain ritualized ways of working" (White and Featherstone 2005, 207) have persisted, preventing the formulation of a common enterprise and repertoire, which besides frequent contact are the two other factors that Wenger (1999) describes as constitutive for such communities. This explains why the negotiations did not lead to a stable compromise. The professional perspectives were too different producing two directly competing visions of decarbonisation. Here the worst case for ZEN would be to lose against the energy sector's vision, which would severely reduce the need for building-based decarbonisation – as all efforts would be directed towards decarbonisation of energy production.

Moving on to the resistance from above, the Norwegian state, despite considerable liberalisation since the 1990s, still acts within the basic framework of a strong Nordic welfare state, partly enabled by considerable in-

come from the export of oil and gas. Whether these developments indicate the end of support for research based decarbonisation of the built environment, which started around 2009, will only become clear in hindsight. A new government may bring new priorities and reverse decisions, just as the current government has scrapped promises made by the previous government. In light of the theoretical perspective used here, and despite this uncertainty, this particular kind of resistance is of special importance. Withholding further political and material support for zero emission regulations in the built environment, research, and implementation in favour of other forms of climate policies, such as those related to more centralised renewable energy production and carbon capture and storage (CCS), would make the realisation of the particular vision of ZEN highly unlikely. In terms of infrastructural change, states have both the resources and legal means to realise large-scale infrastructural projects. However, if a specific infrastructural vision loses political support, it will have to resort to other sources for funding and conflict resolution. Private investment is one of these, but also bottom-up initiatives could step in (Heiskanen et al. 2010).

As the living labs have revealed, popular support for zero emission infrastructuring was largely absent. Alternative, better infrastructures were imagined by the citizens who lived in and around the pilots, but these improvements were either unrelated to the work of ZEN or even potentially in conflict with the aim of reducing CO₂ emissions. To look at ZEN and its solutions in the context of socio-material infrastructures presents an explanation for the lack of popular interest. One of the central characteristics of infrastructures introduced above (Star and Ruhleder 1996) is that they are invisible unless and until they break down. However, climate change, the reason for the infrastructuring efforts we are discussing here, is not an occasion which leads to infrastructures becoming visible in this way. Climate change may make natural disasters more likely, but the events are still too sporadic and geographically dispersed, and causal links are difficult to establish for laypeople. This structural disinterest in ZEN's infrastructuring initiatives may be complemented by climate-skeptical attitudes or not. The worst case for ZEN is obviously if both elements – denial (which falls into the category of trivial resistances here) and structurally produced ignorance – appear together and reinforce each other.

Finally, within this third group of resistances from 'below', we found critiques of ZEN pilots and concepts based on professional expertise. Kindergarten teachers, urban planners, and local governments protested against having their perspectives on sustainable infrastructures disregarded by ZEN's work. For these local experts, ZEN infrastructuring was threatening central professional standards. In the worst case, ZEN and its zero emission balance becomes impossible to reach when the professional norms are preserved. However, an earlier and more serious dialogue with these groups may very well have made a difference, for instance by focusing on daylight in the planning of the kindergarten case. Also, the local government at Furuset might have been easy to enrol by adding aspects that address social sustainability in the zero emission pilot project. However, it is quite possible that finding a compromise would have been difficult in the case of reduced car-based mobility (Ydalir) and the development project outside the city (Bergen). In these cases, earlier and more serious negotiations may just as well have resulted in these two pilots not being built at all, which, after all, is not necessarily in itself a problem for the decarbonisation of the built environment.

Learning from resistance

The worst case scenarios discussed in the previous section are concerning: If the arguments of the energy sector win the argument, if state backing disappears, and if climate change mitigation turns out to be incompatible with the preservation of many professional norms in society, then there is no reason to believe that research-based zero emission infrastructuring in the built environment has any chance to make a difference in the future. The typical resistance against change and preference for careful, incremental changes, which the theory ascribes to socio-material, relational infrastructures (Star and Ruhleder 1996), will then prevent the kind of change that is needed if the built environment is to be a meaningful contributor to climate change mitigation. To avoid these scenarios, the resistances prompt questions that research on zero emission infrastructuring in the built environment should address if it is based on lessons learned in ZEN.

First, we will have to ask how the expertise of energy system experts, planners, but also of other professionals representing building users, can be better incorporated in zero emission infrastructuring of the built environment. These negotiations are likely to result in different solutions for different scenarios involving different stakeholders. The ability of these groups to contribute positively to infrastructuring, i.e., their participation in design and implementation of buildings and neighbourhoods, is an old topic in building research and planning. Participation from a socio-material and relational infrastructural perspective amounts to the synchronisation of material and social change, which needed to turn resistance into contribution. Second, there is the question of how to perform zero emissions infrastructuring without – or with minimal – state support. In the built environment, private sector and bottom-up initiatives to achieve radical sustainable change have existed since the beginnings of sustainable architecture. Questions of economic feasibility will be central for market-driven change, whereas bottom-up efforts will have to address their inherent difficulties when trying to scale up.

It is plausible that the forms of resistance described here can be found against science-led sustainability efforts in other sectors, e.g., food and food production, as well. Disagreements among different professional groups about the right direction for decarbonisation efforts, and lack of state and popular support are sufficiently general to describe dimensions in a heuristic of non-trivial resistances.

In this article, a one-sided focus on frictions and resistances was presented, which probably is guilty of masking the successes and progress made in the ZEN centre. By framing the research centre's work as instance of a much larger endeavour which amounts to a change in how the built environment is designed, implemented and used, the article sought to divert the focus from blaming to learning. In Norway, research and practice of zero emission infrastructuring in the built environment, after a period of generous support, finds itself in a changed, much less favourable context. This article presents possible ways forward.

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