



A matter of time: Explicating temporality in science and technology studies and Bergen's car-free zone development

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ABSTRACT

In their article on 'sociotechnical matters', Hess and Sovacool (2020) draw on extant STS scholarship to unpack 'the black box' of sociotechnical contributions to social science studies of energy. Notably absent in their synthesis is explicit attention to temporality and to the impact of temporal dimensions on the politics of material change. We argue that temporality is a key analytical entry point to unpack how energy infrastructure changes. Using the case of transitions to low-carbon mobility in urban transport in Bergen, Norway, we highlight how attention to temporality enables us to not only understand and explain, but also engage with and influence, changes in sociotechnical matters. Empirically, we deconstruct the ongoing development of car-free zones in Bergen's suburban spaces, and show how the temporal organisation of events is a key constraint in the project. Car-free zone planning occurs within a continuously evolving context, with trade-offs between requisite time to build sufficient knowledge, fast-approaching project deadlines, and the timing of parallel synergistic processes. An analytical appreciation of the significance of time in setting and swaying the politics of material change is, we argue, instrumental to both unpacking the black box of sociotechnical matters and to informing and impacting change.

1. Introduction: STS and the temporality of sociotechnical transitions

In their review of Science and Technology Studies (STS) and its potential impact on energy studies in social science, Hess and Sovacool [1] argue that STS-informed analytical processes can lead to work that is theoretically grounded and empirically descriptive, as well as socially impactful in terms of influencing policy actors and other important decision makers. Nevertheless, their rich and otherwise comprehensive synthesis of thematic STS scholarship overlooks the importance of temporality in the politics of material of change. The authors refer to space and time, but much remains to be said of what STS does at their intersection. In opening up "the black box of sociotechnical matters" [1, p.14], a key question is, "what's not in the box?" Apparently, temporality is not in that box. Yet STS has deep insights on temporality, at least implicitly, and failure to recognise this would be a missed opportunity for the ERSS community. Therefore, we want to argue for, and to empirically illustrate, how consequential temporality is to the analysis of sociotechnical interventions.

The lack of attention to temporality is also somewhat surprising,

given that temporality seems to be increasingly drawn into studies of transitions in energy systems and the broader sustainability discourse ([2,3]). Recent scholarship on energy flexibility and sociotechnical practices shows how temporality is a key element to grasp the changing nature of energy infrastructure. Blue et al. [4, p.923] point out that "matters of time and timing are routinely abstracted from the social practices and forms of provision on which the rhythms of supply and demand depend." Moss [5] uses the case of politically fluctuating Berlin over the past century to show how energy infrastructure and urban politics are co-constitutive over time. This line of thinking construes sociotechnical change as an emergent, relational phenomenon, where sociotechnical practices are understood as intimately interlinked, rather than the social or the technical driving the other.

In this article, we will illustrate how temporality is a key analytical entry point to unpack how energy infrastructure changes. Looking at transitions to low-carbon mobility in urban transport in Bergen, Norway, we show how attention to temporality enables us to not only understand and explain, but also engage with and influence, changes in sociotechnical matters. In the STS tradition of placing a single material intervention in focus and thickening contextual analysis around it [6],

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we deconstruct the ongoing development of car-free zones in Bergen's suburban spaces. This is intended as a corrective to the broader literature on energy studies and STS [7], which arguably prioritises a focus on infrastructure over deep engagement with temporality.

Long-term emergent trends have opened up for a 'sustainable mobility paradigm' [8], and in turn a political space for low-carbon logics that view cars as the technological embodiment of past mistakes. Creating car-free zones, then, entails a struggle with the historical layers of planning paradigms that have become materialised in the urban environment [9]. Struggling with this material history, municipal planners are tasked with making sense of and materialising emergent political visions of the green and people-centric city. Car-free zone planning occurs within a continuously evolving context, with trade-offs between requisite time to build sufficient knowledge, impending project deadlines, and the timing of parallel synergistic processes. For example, street works underway for sewage infrastructure present opportunities for layered interventions, yet such competing urgencies imply lower bars for evidence-based action, introducing uncertainties characteristic of navigating complex systems [10,11]. Time also sets the larger frame through high-level time-bound targets such as reduced car parking spaces, concomitant with municipal rapid decarbonisation goals.

In other words, advancing this energy transition in urban mobility entails temporally contingent renegotiation of everyday socio-materialities to mobilise situated imaginaries of a car-free future in a present characterised by persistent automotive dominance. Without attention to temporality as an analytical dimension, analyses of the development of car-free zones might easily miss these constraints and complexities, and in doing so, would fail to apprehend a nuanced set of interactions and concerns that co-shape infrastructure through a process of 'undefined becoming' [12]. We would overlook the 'memory of practice' that Bissell [13, p.1946] describes as shaping "the complex temporal folds through which the past inheres in the present, transforming its course". An overt appreciation of the significance of time in setting and swaying the politics of material change is, we argue, instrumental to both unpacking the black box of sociotechnical matters and to informing and impacting change.

Our empirically informed theorisation at the intersection of research on sociotechnical change and temporality at the urban scale is summed up in this coinage of 'changeography': *the engaged study of emergent sociotechnical futures*. This is sensitive to the fact that each urban context, each neighbourhood, has an embodied memory of practice, and that implementing sociotechnical change requires engagement with these urban spaces as particular kinds of places within and across cities.

We proceed as follows. Below, we source concepts from STS and related energy research on temporality and explicate four temporal frames: (i) *temporal residues*, (ii) *the durability of change*, (iii) *target-based timing*, and (iv) *multiple simultaneous timeframes*. Next, we illustrate these frames empirically using the urban mobility transitions case of Bergen's car-free zone development. Finally, we reflect on how drawing on insights on temporality as we pack this black box of sociotechnical matters is helpful both in reference to our engaged study of the Bergen case and in order to understand the co-evolution of sociotechnical practices and energy infrastructure, notably in relation to urban mobility transitions.

2. Temporality and sociotechnical change at the urban scale

Time is central to cities and to efforts to change them. Technological and infrastructure arrangements of cities embody past politics and historical forms of social order, and these material forms influence and shape the politics and social orders that make use of them. History acts as a plane of reference for situating ourselves within ongoing processes and assigning meaning to the world around us. This has effects for how we move forward, and in particular, how we advance energy transitions in the urban context. Temporality encompasses both materiality – such as the timeframes embodied in different urban infrastructures – and relational affect – for instance the urgency to act invoked by climate

change. Drawing on a range of scholarship not limited to but cognate to STS, we highlight some key insights that sensitivity to temporality instigates.

First, urban energy transitions are always struggles with the *residues of time*. Scholars in the STS tradition have significantly informed understanding of how *sociotechnical matter* conditions and slows down change. STS scholarship has, for instance, pointed to the politics of infrastructural design and how design choices shape practices over time. As Hommels [14, p.324] puts it, "urban artefacts are remnants of earlier planning decisions, the logic of which is no longer applicable, [and which] may prove to be annoying obstacles for those who aspire to bring about urban innovation". Advancing transitions and change in urban contexts is always a process of restoring, reconfiguring and reworking layers and fragments of existing materials, and struggles with existing artefacts, models and standards [15,16]. The way we understand the past through history and imagine potential futures sets up timeframes which structure the potential for action. For energy transitions, this implies that change is often slow. We have less understanding of the socio-material basis for *rapid* change. Rapid urban change is typically framed in simpler technological or economic terms [17], which overlooks the way social, political or infrastructural aspects condition the speed of change.

Second, *durability* is a key aspect of how impactful sustainability interventions are. Asking "What sticks?", Grandin and Sareen [2] review scholarship on the durability of urban scaled sustainability transitions. They identify a range from transient interventions that *catalyse*, to iterative initiatives that *revamp and reconfigure*, to more lasting transition measures that become *institutionalised and endure*. Their review identifies limited scholarship on infrastructural aspects of transitions, notably featuring work on generative urban experimentation (e.g. [18]), grassroots technological innovation to ramp up local material endeavours (e.g. [19]), and collaborative maintenance and repair spaces and economies (e.g. [20,21]). These contributions suggest that a temporal approach to sociotechnical change focuses on multiple practices of place-making that span a wide range from transience to durability. This conceptualisation is more analytically pointed than the theorisation of social time as 'pluritemporalism' [22], as it attends to the ephemeral or lasting nature of temporal change.

Third, in the policy realm, time already provides a key framing for action towards sustainability. In policy-making for sustainability and climate change, *target-based timing* is a predominant way we make sense of the pace and scope of change. While climate related targets are often presented as direct reflections of scientific facts, they are always embedded in politics and negotiation, illustrating the socially constructed nature of climate action temporality [23]. Setting future targets can be a way to delay action in the present. But as Haarstad [24] argues, future targets may also work themselves into present processes of governance with a similar type of carrying power as other metrics have done in our governance of nature. That is to say, target-based timing can serve as temporal boundary objects to determine action [25]. At the same time, there is also a question of how well universal targets correspond to the varying temporalities of change processes in different contexts. Delina and Sovacool [26] emphasise the tension between the urgency induced by target-setting for decarbonisation and the need for pluralism to avoid treating real-world messiness in unjustly reductive ways. Attention to the correspondence between timeframes of policy-determined targets, the temporalities of ecological change, and the pace of change in different contexts is key for how well we manage sustainable transitions.

Fourth, we need energy transitions to reflect "thinking, fast and slow" [27]. The research that foregrounds temporality illustrates that processes of change at multiple *timeframes* are happening simultaneously. While urban governance increasingly appears geared towards shorter-term experimentation [28] and 'projectification' [29], change is also occurring at 'infrastructure time' [30]. Karasti et al. [30, p. 377] argue that the long-term material commitments embodied by

infrastructure necessitate a ‘continuing design’ approach “towards longer time scales and more diversified temporal hybrids in collaborative infrastructure development”. Degen [31, p.1075] distinguishes between “the temporalities of planning, the temporalities of the environment and the temporalities of everyday life”. This means that there is a need to learn from the past [32], as well as to construct powerful future sociotechnical imaginaries [33] to act upon multiple timeframes in the present.

This thinking through timeframes can be further informed by Lefebvre’s [34] celebrated work on rhythmanalysis, which regards multiple temporal rhythms to be constitutive of place. Lefebvre thinks of different rhythms as embodying the sedimentation of historical and geographical characteristics. Lefebvrian notions such as eurhythmia (synchronic rhythms), arrhythmia (discordant rhythms) and polyrhythmia (multiple rhythms) can be moulded into reading various ways change operates through time. Applying rhythmanalysis to socio-technical change specifically in energy infrastructures, Walker [35, p.2] observes that “A rhythmanalytic view makes clear that time and temporalities matter [...] in the very substance of how energy systems work and how they are integral to the ongoing structure and order of societies. This means that it is rhythms *in transition* that matter to low carbon futures, not just the temporalities and rhythms *of transition*.” This resonates with Blue [36, p.922] who applies rhythmanalysis to “articulate the ways in which practices *become* connected through [...] processes of institutionalisation.”

In our paper, the separation into four frames broadly coheres with temporal rhythms, and is specified more concretely to allow for empirical study to identify place-specific effects and interventions. To examine time and temporality in the rhythms *in* sociotechnical transitions, we hold that the four-part framing elaborated below is a valuable heuristic and analytical tool. Explicating temporal frames of changing urban energy infrastructure can improve our understanding of changes in sociotechnical matters. In the next section, we put the four temporal frames discussed above – residues of time, temporalities, timing and timeframes – to work on a specific urban case of sociotechnical change: mobility transitions in Bergen. The purpose here is not to bring all the ideas introduced above into play on a single case, but to illustrate the difference that temporal frames make in the analysis of a specific urban intervention with relevance for energy transitions.

3. Residues, durability, timing and timeframes in urban mobility transitions in Bergen

As with other cities, Bergen’s green shift is a struggle against time. The city has adopted a number of targets that are projected years into the future, but are close enough in time that they warrant substantial action in the present. The current Climate and Energy Action Plan sets the target of 20 percent decrease in private car use by 2030 (compared to a 2015 baseline). There are fast and slow measures that help the city move towards that target. The key intervention, according to politicians across the political spectrum, is the building of the Light Rail or Bybanen – a slow measure that has been subject to intense political debate for more than two decades, despite which only one line has been completed to date. Bybanen is central to the plan to structure the city’s growth around compact nodes and to shift mobility from cars to public transport. But planning and building it takes time. So politicians eager to put their stamp on the city’s development on a shorter timescale are also considering other measures.

Car-free zoning is a measure that can be implemented on a much shorter timescale. If done right, car-free zones can be implemented with few changes in regulations or physical infrastructure. In 2018, the city launched a project of turning the central neighbourhood Møhlenpris into a car-free zone. As an already pedestrianised neighbourhood which was undergoing street-level upgrades unrelated to the car-free zone project, and with resident groups who had already mobilised for better walkability, it can be considered an easy place to have started. In 2020, the

city took the project to a new phase of planning car-free zones in suburban areas, where car driving has a much higher share of mobility.

This section considers the different ways in which temporal frames condition the project. We sequentially look at (i) *residues of time*, and how they impact the terms of car-free zoning, (ii) *the durability of change*, in terms of how transient or durable the interventions for car-free zone development are, (iii) *target-based timing*, both national and local, and how this drives the pace and nature of change, and (iv) *timeframes*, or the multiple temporal scales at which action unfolds. The discussion is based on data generated through citizen focus groups, a public seminar and two small-scale surveys on mobility transitions in Bergen, and focused expert interviews and a cross-sectoral workshop with municipal practitioners where we chiefly discussed the car-free zones project.

3.1. Residues of time

When examining a specific project, such as the car-free zones project in Bergen, it is evident that the planning and infrastructural legacies – the residues of time – have consequences for its implementation. In Norway, as elsewhere, suburban planning and development relied on the premise of automobility (Eriksen 2020). In the city centre, planners could rely on historical precedent to support the project of a car-free zone, because the urban form in these areas took shape before cars became ubiquitous. The Møhlenpris neighbourhood has a history of resistance to car-based development from the 1980s when residents organised civil action against expansion of a highway overpass that would remove buildings and increase traffic. This went counter to public urban renewal projects already underway, which had rallied residents in favour of improved livelihoods in their community. The highway overpass expansion went ahead nonetheless. This infrastructural intervention did cause house demolitions, but also reinforced a physical barrier on one side of the neighbourhood, with a hill, a park and a lake constituting barriers on the other sides. In turn, the material artefact of the road has created a relatively coherent physical demarcation of the neighbourhood, which has possibly engendered a stronger sense of identity and sense of community [37]. In this sense, the road provides a residue of time, an example of “remnants of earlier planning decisions” [14, p.324], that condition possibilities in the present.

Similarly, the current citizen mobilisation for the car-free zone has been about reclaiming the space occupied by the highway overpass. The car-free zone created in the central neighbourhood of Møhlenpris had organised neighbourhood groups who wanted the change. Using Figs. 1a and 1b, a planner speaking at our seminar showed a street festival in the neighbourhood that represents urban revival and reclaimed use of public space away from car parking for convivial activities. Fig. 2 is a poster from the same ‘Under the Bridge’ festival.

While the success of the pilot project in Møhlenpris in the city centre served as a major justification for expanding the policy to the suburbs, planners expected that the situated synergies, historical materialities and social practices that supported the project in the centre would by contrast present significant challenges in the suburbs. The bottom-up demand was lacking in the envisaged suburban zones. As one planner put it, “In Møhlenpris, we got a lot for free. I don’t know how it will work with public participation in the suburbs.” Through setting up participation processes, the planners will essentially be creating a public with which to consult.

In a workshop our research team co-convened with the cross-sectoral team of planners responsible for the suburban car-free zones, two experienced urban mobility researchers recommended explaining to citizens that car-free zoning is a common intervention in cities around the world and not something novel. One of the lead planners on the project repeated this assertion, noting the importance of emphasising historical precedent because “people are afraid of change”. She recognised that the spatial layout of the suburbs reflects a car-centric planning legacy in which housing is segregated from other functions such as shops and schools. Simply removing cars will not erase the “memory of



Fig. 1. (a) and (b). A planner highlighted the ‘Under the Bridge’ festival in Møhlenpris as reclaiming public space for people, showing these ‘before’ and ‘after’ photos. Source: Lars Ove Kvalbein.

practice” [13, p.1946] embodied in the place.

Thus, the residue of time – spatial planning, car-centric infrastructure and embedded mobility practices – shapes the societal contexts in which change projects such as car-free zoning intervene. Contemporary citizen mobilisation in Møhlenpris marks struggles over and against residues of time – remnants such as the highway overpass. Consequently, these interventions must be sensitive to the long arc of mobility practices and imaginaries over time. This diverges significantly even within Bergen, at the sub-urban scale of contrasting neighbourhoods.

3.2. The durability of change

The sociotechnical change project of car-free zoning exhibited multiple degrees of durability. Some forms were fleeting: ‘urban cafés’ for public consultation on car-free zones, such as at the popular Møllaren café on Møhlenpris. Others were less ephemeral but nonetheless transient, for instance a car-free experiment during summer 2020 on the

popular downtown stretch of Bergen’s pier, Bryggen, a world heritage site and popular touristic and entertainment haunt. Yet others were informed by more enduring intent: the installation of mobility hubs – ‘mobilpunkt’ – at central junctions such as Danmarksplass with a view to facilitating smooth multi-modal connections.

Distinct logics drove interventions across this range of durability: cross-fertilisation from practices in other European cities, national policy pushes, long-running urban planning visions. When asked to reflect on what they had learned from working on the first car-free zone, two planners centrally involved in the pilot project brought up multiple temporal issues. They began with one explaining that the project “was a bit special because there was a political position which took a long time to become operational”. The project had been discussed for many years but it was a confluence of political will and opportunistic synergy with unrelated projects that made it possible. A recent city election had shaken things up and put the Green Party (*Miljøpartiet De Grønne*) in the seat of the City Councillor for Urban Development. Part of the political

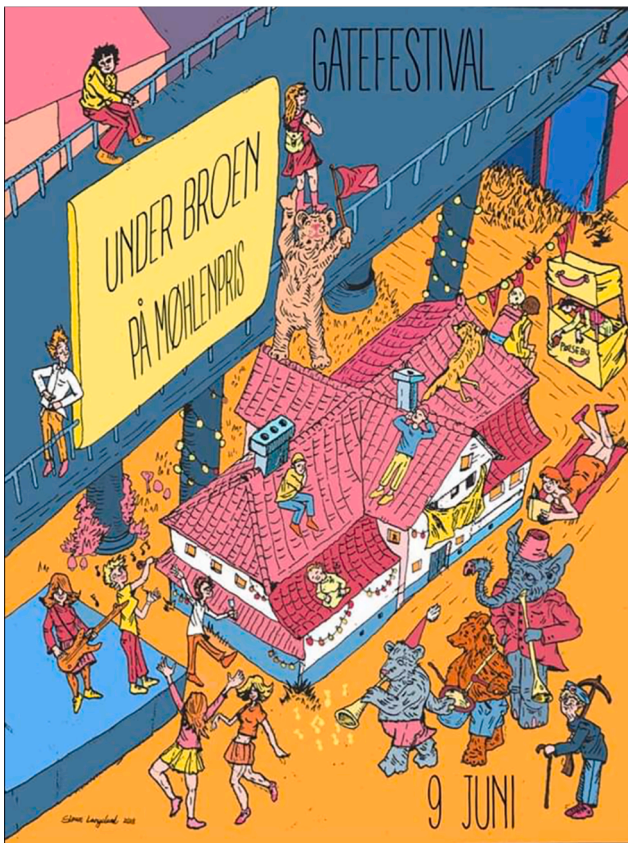


Fig. 2. A poster from the ‘Under the Bridge’ (‘Under Broen’) street festival, 2018.

platform of the Green Party was to create car-free zones and generally restrict automobility in the city in a lasting way within an electoral timeframe.

Thus, the implementation of the first of the suburban car-free zones represented and materialised an enduring shift in the power constellations of urban governance. Cars as a mode of transportation, a signifier of class and a driver of particular spatial arrangements were identified as a major site for intervention. The mobility planners explained that they simultaneously became aware that “the whole area was being dug up due to water and sewerage upgrades. We could use the opportunity but we didn’t have time for long planning processes. We needed to do

something that could be done without asking too much permission.” The planners’ sensitivity to a fleeting political pulse and windows of opportunity due to infrastructural upgrades thus allowed them to undertake an intervention that had previously met with many political barriers, converting a transient window for intervention into lasting change. The resultant sociotechnical change constitutes an enduring materialisation of a new kind of urban mobility; by 2020, the streets of Møhlenpris had benches, planters, an urban beach and food trucks that had become firmly implanted as new imaginaries of urban street life and symbols of car-free zoning. Fig. 3 shows a snippet of this neighbourhood street life.

3.3. Target-based timing

The car-free zones project is articulated in relation to several time-sensitive targets, both national agreements and locally mandated ones. These targets have diffused into policy-making and funding streams, and shape municipal-level interventions. Targets define a temporal horizon for interventions to have effects, making it important to think about both the speed and effect of local policies.

Bergen is subject to the national Zero Growth Objective (ZGO), which limits all growth in traffic to walking, cycling and public transport. Originating in the national Parliament, the ZGO has been built into the Urban Growth Agreements (UGAs) between cities, regions and the state: meeting the target impacts the funding cities receives. Bergen’s UGA highlights the ZGO up front as its core principle. These agreements set specific temporal and spatial boundaries to measure the ZGO, within which measures are “prioritised according to an evaluation of their total effect on the ZGO”, making consideration of the ZGO integral to urban planning.

The Zero Growth Objective exercises agency beyond the incentive of securing funding – Bergen has sharpened the target in its Climate and Energy Action Plan, which aims for a 20 percent *reduction* in automobile traffic by 2030. When interviewed, three senior planners responsible for the municipal spatial plan – one of the city’s chief tools to steer development – explained that the ZGO is “a very useful tool for us. It sets the premise for the municipal spatial plan and lays the foundation for other guidelines”. Asked if the target should be changed to zero emissions instead of zero growth in the number of private vehicle miles as some actors at the national scale have proposed, they responded “that would be catastrophic”, anticipating that rapid growth in electric automobiles would crowd out public space. A representative of Bergen’s Agency for Urban Environment expressed frustration that while the Norwegian Public Roads Administration took part in UGA negotiations, their large road projects into Bergen undermined the city’s efforts.



Fig. 3. Residents enjoy the street life offerings of Møhlenpris. Source: Per Gunnar Sakseid.

Over time, the national ZGO has become implicated in planning discourses in Bergen, as a baseline goal for planning and mobility interventions. As an integral part of how urban decision-makers plan and strategise future interventions, the target enables them to evaluate whether the totality of interventions and projects cohere to steer overall developments in the desired direction. An interviewed mobility planner from Bergen’s Department for Climate, Environment and Urban Development lamented that a major road expansion project and the increased traffic it was likely to generate would cancel out the positive effects of the car-free zones and undermine the ZGO: “based on current trends, they predict more traffic in the future, so they design roads with increased capacity today. But the new roads make the targets impossible”.

In short, Bergen is currently setting mobility targets based on sustainability-related issues. These targets usually have a clear temporal implication – they set a deadline or a time horizon for when they have to be met. In the case of car-free zones, they provide politicians with a measure that may help towards targets in the short run. The targets set parameters – sometimes conflictual – for decisions made in the present. Not all targets effectively influence decisions in the present – some remain inconsequential. But well-defined ones that are worked into concrete plans create temporal horizons for policy-making.

3.4. Timeframes

Car-free zoning is subject to the timeframes of annual budget cycles, electoral cycles, related projects, as well as the timeframes of participation processes and bureaucratic procedures. The most important timeframes appear to be related to election cycles, and the typically four-year elected term of each City Council. This incentivises each City Councillor to plan using timeframes based on their period in office, both to ensure that the project is implemented and to accrue credit for its completion. The current City Councillor’s ambitious target for reduction in car traffic corresponds to the electoral cycle (30 percent reduction by 2023), and the milestones for car-free zoning are also set within that timeframe (i.e., start a suburban pilot in autumn 2021, implement it by 2022, and complete a report by December 2022 that identifies all suburban car-free zones).

These temporalities, which we may call *political timeframes*, are potentially at odds with the practical realities of creating car-free zones in the city. It discounts important contextual differences between neighbourhoods, which means that it is simpler and quicker to implement car-free zones in some than in others. In the pilot area of Møhlenpris, where a project of car-free zones had been initiated in the previous political cycle, conditions were ripe. A central and walkable neighbourhood, with short distances to public transportation and places of work, with residents mobilised in favour of reducing car traffic, and with ongoing infrastructure projects that made sidewalk expansion relatively low-cost, made car-free zones easier to implement. As mentioned, a neighbourhood group there pressured the municipality to speed up the implementation. In 2019, the neighbourhood group held a public forum on car-free zoning, and invited the municipality (as well as one of the authors of this paper) to attend. Residents spoke about the need to secure the school area for children, and few voices were in favour of cars.

The social, cultural and spatial context, and hence the *timeframes of implementation*, may be very different in other neighbourhoods. For the next phase of car-free zoning, the municipality has turned its attention to the suburban area of Åsane – an area which grew into its current spatial configuration under the car-centric planning paradigms of the 1970 s. Here the physical make-up is characterised by shopping centres and stores like IKEA, detached homes, and car-based commuting. This is also an area where the anti-road toll, pro-car party received strong support in the 2019 local elections – as opposed to Møhlenpris, which is part of the electoral district that favoured the Green Party. These political divisions are indicative of the bifurcation of politics associated with the rise of

populism in recent years, with increasing polarisation between urban and non-urban areas [38]. This phase of the car-free zone project is moving into a very different material environment and political culture. This will likely have significant effects on the timeframe of implementation, since the project has to work against the legacies of car-based planning. Reconciling the constraints of this context with the political timeframes of election cycles, budget processes and the like presents a substantial challenge to the future of the car-free zoning.

Table 1 summarises the four frames in our analysis of temporality in Bergen’s car-free zone development.

4. Changeography as the engaged study of emergent sociotechnical futures

By pointing to the importance of temporality, this Perspective aims to contribute to the debate on what STS has to offer social science energy research. In their review of the literature, Hess and Sovacool [1] mention but do not highlight the importance of time, which convinced us of the need to show how consequential temporality is to analysis of sociotechnical interventions. Historians of technology have convincingly demonstrated this relevance, e.g. Schipper et al. [39] highlight the importance of drawing on decentred alternatives from the ‘usable past’ for present mobility transitions, and Moss [5] traces the agency of temporal residues through a century of shifting political regimes in shaping urban infrastructures of present-day Berlin. Key insights in STS, for instance that artefacts and design have politics [15], or that technologies operate through sociotechnical systems assembled through people, norms, practices and infrastructures, deeply implicate temporality. Artefacts and technologies become systems as they are layered and interwoven over time (as Latour [40] acutely captures in the title “Technology is society made durable”). Temporality must be central to the contribution of STS to energy research, not least because so much of social scientists’ work on energy concerns change over time – how to advance a transition to more sustainable energy systems. Indeed, a *meta*-study draws on 36 past transitions to understand drivers of regime destabilisation [32].

In our analysis of an intervention to shift mobility practices away from private cars in Bergen, we have highlighted four frames of temporality that matter to analysis.

First, *temporal residues* determine the framing of urban interventions and bound the scope for action. Remnants of legacy infrastructure exercise agency in the routines of the present, inflecting visions of progress [14–16]. This frame resonates with STS work on large technical systems and the politics of design, specifically path dependence, emphasised in [1]. But *temporal residues* further underscore how change agents struggle

Table 1
Definitions of frames of temporality instantiated with Bergen’s car-free zone case study.

Frames of temporality	Definition	Car-free zoning case examples
Residues of time	Socio-material continuities of past planning legacies that condition possibilities of change in the present	Suburban spatial layout; car-centric road infrastructure; embedded mobility practices
The durability of change	Multiple practices of place-making ranging from transient interventions to more lasting measures that become institutionalised	Urban café consultations (transient); summertime car-free pier (iterative); multi-modal hubs (durable)
Target-based timing	Target-based construction of temporal horizons that structure policy-making and implementation	Automobile traffic volume reduction targets; car-free zone development deadlines
Timeframes	Simultaneous changes in multiple timeframes wherein political and implementation processes play out	Electoral and budget cycles; participation process timeframes; project implementation periods

against historically layered remnants of past action.

Second, change occurs along a range of *durability*, where some interventions are easy to undo whereas others embody a logic of ratcheting up and layering into existing infrastructures and practices over time. Sociotechnical change is thus varyingly institutionalised: some is ephemeral, some is composted and revamped, and some becomes institutionalised as enduring infrastructure [2]. Hess and Sovacool [1] note that this graduated understanding of temporality is reflected in STS work on themes of experimentation among and mobilisation of publics, and Aiken [21] interrogates the issue closely. Yet intensified attention to time shows how this mobilisation is enacted through different temporalities.

Third, *timing* is critical for initiatives to succeed, as actors (planners, citizens, politicians) act strategically within the overarching limits fixed by local and national targets. For instance, privileged actors can strategically deploy their temporal resources to leverage long-term plans to their advantage [41]. There are overlaps with STS work on cultural and policy analysis since the 1980s and 1990s highlighted in [1], in terms of the construction of symbolic meanings, expertise, risks and standards. But what we illustrate here is how the power of symbolic meanings depends on critical timing – as symbolic meanings are highly contextual in time and space.

And finally, *timeframes* of the institutions and infrastructures in the mobility sector, from planning cycles to project timescales and municipal elections, modulate the nature of sociotechnical interventions. This frame is evident in the analysis of participatory planning process timeframes that serve to legitimate decisions [42], and in the social construction of visions and planning horizons through infrastructure time [30,33]. These elements overlap with the Latourian work on actor networks and performativity in STS acknowledged in [1]. Yet what we illustrate more fully is how these actor networks are structured by the timeframes of institutions.

As we have shown by operationalising the specificity of these particular frames, our stance is that the unpacking of sociotechnical matters can make considerable gains by grasping the importance of temporality as an analytical lens for sense-making of and engagement with emergent sociotechnical futures. Our coinage of the term '*changeography*' is meant to remind scholars at the intersection of STS and sociotechnical transitions that change in sociotechnical systems is always conditioned in particular times and particular places. Our analyses must be sensitive to the fact that each urban context, each neighbourhood, has an embodied memory of practice, and set of interlocking cultures, artefacts and infrastructures layered over time, that have enduring effects on the possibilities for and pace of future change. Implementing sociotechnical change requires engagement with these urban spaces as particular kinds of places within and across cities. From a rhythm-analytic perspective, socio-technical change in any place is a function of shifting institutional rhythms that manifest as "self-organising, open, spatiotemporal practices [that] emerge, endure, and evolve" [36, p.923]. Accordingly, we define changeography as the engaged study of emergent sociotechnical futures: engaged because unpacking sociotechnical matters must be timely in order to matter for real-world change, and emergent because sociotechnical change is a creative and contested act. Thus, we call for scholars at the intersection of STS and energy social science to embody the spirit of changeography by explicitly grappling with temporal frames in their engaged analyses of emergent sociotechnical futures.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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