Scaling theories of change in REINVENT case studies

Deliverable 6.1

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1. Introduction / Executive summary

This report brings together a collection of case studies conducted as part of the REINVENT project, and attempts **a synthesis of the findings** gathered thereby **with regard to the conceptualisation of scale and scaling as phenomena pertaining to innovations** of various types.

The complete aims and objectives can be found in Section 2, which refers back to the original project outline to identify the **overarching focus on the heretofore overlooked political, geographical, economical, and material dimensions of decarbonisation transformations**. This is to be achieved through the **application of a multifaceted analytical framework** which emphasises the materiality of the carbon-intensive society as currently constituted, so as to **seek new pathways for decarbonisation**, and **open up the more indeterminate narratives of transformation to be found beyond the usual sites and domains of study** in this field.

The **four theoretical frameworks** "in play" in this analytical exercise are introduced in Section 3: the **Multi-Level Perspective (MLP), Multi-Level Governance (MLG), Material Politics (MP), and Cultural Politics (CP)**. For each framework, a short literature review is conducted which focuses on answering four questions about how it conceptualises scale. This is followed by a matrix which compares and contrasts the frameworks with reference to these four questions, and condenses the frameworks to a set of heuristics from which replicable and comparable analyses of cases might begin.

Section 4 discusses the results of the analyses with an eye to **surfacing findings that shed light on the different ways scale and scaling are conceptualised in transformation studies**, drawing generously on the most illuminating cases. (The case studies themselves are collected in full in the appendix, Section 7.)

Then Section 5 draws out three succinct findings from the discussion, which may be further summarised as follows:

Scaling as a concept in innovations—for decarbonisation, in this particular study, but plausibly also for transformations of other types—turns out to be far more contested than might be assumed at first. The use of multiple theoretical perspectives for the analysis of any one case study, and the taking of a hybrid 'toolbox' approach rather than the rigid dogmatism of "frameworks", offer the possibility of broadening understandings of transformation dynamics.

A largely unquestioned conflation of "scaling" with "change" obscures important aspects of transformation processes. Upscaling, the dominant understanding in hierarchical theories, tends to focus on temporal processes in which scaling is seen as an end in itself, while rescaling, which is more important in relative theories, tends to focus more on spatial and material conditions of already-ongoing change in which scaling is seen as one means (among many) to a broader strategic end.

Thus, the two "sets" of theories deployed within this project should be seen not as antagonistic but complementary, each providing analytical tools with which different sorts of cases might be "gripped". However, all four frameworks share in common a bias toward a top-down envisioning of the sociotechnical landscape, which might be balanced by the introduction of perspectives from the "demand-side" end of the value chains under study.

This report thus provides **a review of the current "state of the art" in understanding transformations** from the conceptual standpoint of scale and scaling, and **suggests routes forward** through the deployment of new concepts and theoretical perspectives.

2. Aims and objectives

REINVENT was originally conceived to focus on the heretofore overlooked 'political, geographical, economical and material dimensions of decarbonisation', on the premise that 'such factors help us understand the "lock-in" of existing sectors and the "inertia" facing innovations'. This perspective is critical to the aim of 'advanc[ing] understanding [of the] non-technological factors and drivers and innovative solutions' implicit in any significant decarbonisation reconfigurations (REINVENT, 2016).

The dominant model of sociotechnical change in policy-facing research is the Multi-Level Perspective (MLP), along with its more instrumentalised progeny, such as "transition management" and "strategic niche management". The narrow definition of "success" in the MLP model—which might be summed up as the viral uptake of a challenger technology that goes on to conquer the incumbent market "regime" for a particular product or service—leaves it less able to explain instabilities, or more partial (unevenly distributed or heterogeneous) forms of transformation. Furthermore, its bias toward institutions and firms, in combination with a narrow conceptualisation of the "change agent", serves to exclude socio-cultural factors in favour of techno-economic ones, while also overlooking the more subtle strata of materiality. This broad approach produces strong accounts of successful transitions in retrospect, but it tends to downplay the influence of social and cultural factors on transformation processes. REINVENT has sought to address this gap.

This is not to dismiss the MLP outright. As the project brief makes clear, the MLP's three-level model provides a "distinction between niches and regimes [which] has been proven to be a useful heuristic to capture processes of new path creation in the emergence of radically new sustainable technologies while at the same time accounting for processes of path-dependence and lock-in" (REINVENT, 2016). Indeed, one might argue for the MLP's necessity by using its own terms of reference: over the past two decades, its core heuristic has successfully conquered the regime of sociotechnical transformation scholarship, to the extent that it has had significant and lasting effects upon the contextual landscape in which that regime is embedded. Nonetheless, the MLP's monopoly on the study of sociotechnical change is limited by 'a degree of methodological myopia', which 'partly explains why transition studies have not been able to find systematic evidence for which countries and regions have been successful in initiating and accelerating transition pathways, and why' (ibid.).

The overarching aim of REINVENT (and of this report) is to understand the ways in which the materialities of the carbon-intensive society as currently constituted shape both the potentialities and the limitations of decarbonisation. This is to be achieved by 'pay[ing] particular attention to innovations that enable configurations of decarbonisation to establish new pathways through which new sites, elements and agencies are enrolled', a perspective which then 'opens up contemporary narratives of decarbonisation pathways that may be more indeterminate, emerging as new connections and junctures are formed through innovations, and finding expression in new sites and domains' (ibid.).

The specific objectives of WP6.1, of which this report is the primary deliverable, are 'to better understand the challenges involved in scaling-up and mainstreaming innovation for decarbonisation' through the application of the REINVENT analytical framework ('which emphasize[s] political,

geographical, economical and material dimensions of decarbonisation') to the mappings and case studies of innovations collected as part of WP3, with a particular focus on 'implications for managing low carbon transitions in terms of agency, timing and accountability' (ibid.).

In more concrete terms, then, the objectives of this report are:

- to present succinct summaries of the MLP and three alternative theoretical frameworks—Multi-Level Governance, Material Politics, and Cultural Politics—for the analysis of sociotechnical change;
- to explore how each of those four frameworks approaches the question of how the phenomenon of scaling might be understood in the context of the decarbonisation of supply chains;
- to derive a simple and repeatable (if necessarily reductive) analytical heuristic from each of the four frameworks;
- to apply the four heuristics to the lion's share of the case studies from WP3; and
- to draw conclusions about the suitability of the four frameworks for the understanding (and possibly the nurturing) of different types of as-yet unrealised and/or incomplete decarbonisation transitions.

3. Four theories of change

3.1 The Multi-Level Perspective (MLP)

Originally introduced in 2004, the veteran status of the Multi-Level Perspective (MLP) has resulted in considerable mutation and conceptual "spread", as a succession of scholars (including its founders) have expanded, altered, tweaked, and critiqued its first formulations. As such, it is difficult to provide a truly definitive outline of the MLP, as so many variations and applications now exist. What follows may thus be best thought of as a depiction of the perspective as it exists somewhere close to the centre of the bell curve of its expressions.

Scaling with regards to what?

While notionally developed for the study of "sociotechnical innovations", in practice the MLP has tended to be applied to novel "challenger" technologies introduced into a market regime dominated by an older, established technology.

How does scaling occur?

The MLP's central heuristic (see figure 1) posits three levels of activity. Innovations are assumed to be developed or nurtured within a "niche"—a protected or otherwise isolated site embedded in a sociotechnical "regime". The regime features an established incumbent technology which is put to the same use as the innovation, but whose fulfilment of that purpose is somehow deficient, even if not necessarily perceived as being so by its users. (In the case of decarbonisation transitions, then, it is implicitly assumed that the innovation's most important advantage is its greater "sustainability".)

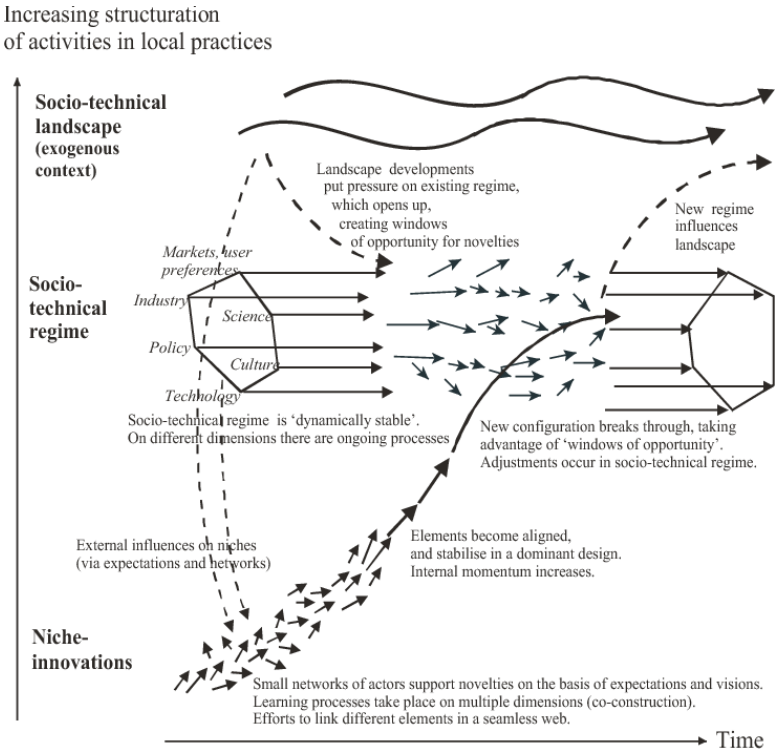


Figure 1 *Multi-Level Perspective on socio-technical transitions (Geels & Schoot 2007, p. 401.)*

The regime may harbour multiple niches within which innovations are developing (though there is little or no literature dealing with the dynamics of competition between such niches). The regime

itself may be one of a number of such which are in turn embedded within a contextual "landscape", where a variety of extrinsic factors—social, cultural, political, economic, environmental—combine to hold the configurations of the regime(s) in a situation of relative stability. However, the landscape is in turn influenced by changes in the regimes embedded within it.

Across many interpretations, then, there is a tendency for the MLP to view scale as being synonymous with these three "levels". Despite the use of explicitly spatial terms, the levels also imply a broader analytical dimensionality which also includes concepts such as temporality and structuration. Scaling up—which is the only "direction" of scaling that the MLP sees—is thus understood to happen when, through various interactions with their political and economic surroundings, innovations developed in protected niches achieve sufficient uptake (and thus market share) to dominate their native regime, and/or the landscape level beyond. The regime and landscape levels are thus assumed to be "higher": for example, Hodson and Marvin (2010) discuss levels in terms of *micro*, *meso*, and *macro*, and the ways in which innovations emerging from a niche (*micro*) can be scaled up from the city (regime / *meso*) to the national (landscape / *macro*) level (i.e. "vertical" scaling). However, scaling can also take place within the protected niche in various processes (i.e. growing, replication, and accumulation) (Naber et al. 2017; Hamilton et al. 2014).

Who shapes scaling?

Scaling is generally seen as emerging through the interaction between niche and regime actors and processes—although the MLP literature has predominantly tended to prioritise the analysis of niche actors over that of regime/landscape dynamics in its narratives of transformation.

The material dimensionality of innovation uptake is often reduced to natural resource availability, or otherwise under-conceptualised; furthermore, actors at a certain scale or level are predominately assumed to hold a certain power/agency (Späth & Rohracher 2012), but the framework does not elaborate upon how such agencies are formed, constructed or challenged.

Regions and cities are deemed to be crucial sites for niche innovation, but also active catalysts or nurturers of innovation processes (Hodson & Marvin 2010; Späth & Rohracher 2012), while national governments (i.e. states, which often implicitly take the role of the "landscape") are deemed important in providing the financial backing necessary for significant scaling to occur. Recent work (see Hamilton et al. 2014; Hodson & Marvin 2012; Kivimaa et al. 2019) also stresses the importance of intermediaries or "middle-men" actors in mediating between different levels of action, and hence facilitating the scaling process. Intermediaries may refer to a variety of organizations with different functions (see Kivimaa et al. 2019). In MLP, intermediaries are seen as important within niches, for connecting similar projects, and for supporting local niches to be accumulated by a global niche (Kivimaa et al. 2019; Naber et al. 2016; Späth & Rohracher 2012).

Scaling occurs to what effect?

The effect of upscaling is the successful and widespread incorporation of the challenger innovation at a "higher" level (e.g. regime or landscape), resulting in the acceptance and/or support of the innovation by actors at an (inter)national level. This in turn implies the obsolescence of an incumbent technology, though the (sometimes protracted) lingering and obduracy of legacy technologies and systems falls outside of the MLP's narrative scope: successful transitions at scale are assumed to be both total and fairly fast, despite plentiful evidence to the contrary for even the most canonical of the MLP's foundational case studies.

3.2 Multi-Level Governance (MLG)

While there exist a number of similarities between it and the MLP model—most notably the three tiers or strata of action—the Multi-Level Governance perspective is sufficiently distinct from the MLP to merit being treated separately. Foremost amongst their differences is the way experimentation is assumed to occur: where the MLP sees a lone innovation developing in protected isolation (see e.g. Späth & Rohracher 2012), the MLG model sees them as (at least potentially) happening simultaneously in multiple urban sites across polycentric and/or transnational networks (such as the C40 network, see Kern 2019).

We can distinguish two types of MLG approaches. Within the first (Type I), governance levels are highly formalised and hierarchical with non-intersecting jurisdictions, usually exemplified by federal governance systems. The second (Type II) is instead characterised by fluidity, network-type governance, and a heterogenous set of actors simultaneously involved in different levels (Betsill & Bulkeley 2005; Späth & Rohracher 2012; Kern 2019).

Scaling with regards to what?

In another significant point of difference from the MLP, MLG takes a broader view of "innovation" as extending to practices and protocols. The "experiments" with which it is concerned might thus also include social-entrepreneurial activities, regulations, tax codes, planning approaches, or hybrid combinations thereof.

How does scaling occur?

Multi-Level Governance understands scaling to take a number of potential forms (e.g. vertical, horizontal, hierarchical, embedded) and to manifest through different processes over time (e.g. expansion, diffusion, transformation; see Kern 2019). Crucial to this perspective is the recognition that these different manifestations of scaling are given form through the interaction between an innovation and its implementation in a new context. Through experimentation across a number of sites, each of which will be unique, the innovation is "tested" against a greater number of contexts than the niche singularity supposed by the MLP; as a result, the innovation has a greater chance of mutating in a manner conducive to its survival and propagation, thus resulting in some form of scaling.

Much of the MLG literature explicitly counters the hierarchical nature of scaling as proposed in the MLP, drawing instead upon theories of polycentric governance (e.g. Bernstein & Hoffman 2018; Kern 2019; Peng et al. 2019) to understand how scaling takes place through the realisation of connections between actors, the coordination/orchestration of those connections, and the functions that the resulting emergent networks perform.

Who shapes scaling?

The MLG decentres the nation state as the key actor, instead highlighting the role of subnational actors (in particular cities) and non-state actors in polycentric systems. This does not mean that states are viewed as diminished; instead they are seen to adopt a new role within governance (Markantoni 2016). Kern (2019) notes that polycentric systems with multiple governing authorities at different scales are at an advantage due to established mechanisms for learning, adaptation, and mutual monitoring. However, subnational actors and/or actors within polycentric systems might have differentiated capacities for scaling: for example, while much early research focused on world cities that participate in transnational initiatives, Kern (2019) has noted that smaller cities or towns

("followers" and "laggards") may have lacked those big-city capacities to support experiments and the scaling thereof. The regional and the local are crucial; for instance, demonstration projects in regions may 'lend legitimacy' and thus build the credibility of deviations developing within a regime (Späth & Rohracher 2012).

In common with the MLP, MLG highlights the importance of intermediary actors to foster the capacity for scale—but rather than seeing intermediaries as a bridge between "lower" and "higher" levels, they might be seen as connective between "inner" and "periphery" actors (Markantoni 2016). The focus on horizontal scaling also takes local/subnational actors seriously (not as mere precursors to national- or international-level action, see e.g. Hamilton et al. 2014; van der Ven et al. 2017), and addresses the matter of geographical embeddedness by highlighting the ways local conditions may shape the embedding of innovations into new contexts (Peng et al. 2019).

Scaling occurs to what effect?

The MLG highlights the variety of forms in which scaling may manifest, with emphasis placed on the embedding and spread of experimentation across networks (e.g. of cities). This embedding may then result in changes in the structure and dynamics of the networks themselves. In other words, it is not just the results of the experiments themselves that matter, but also the expansion of the capacity for successful experimentation—which may be strengthened just as much by a failed experiment as by a successful one.

Bernstein and Hoffman (2018) warn that the upscaling of an experiment does not necessarily lead to entrenchment, and may even end up indirectly reaffirming carbon lock-in through unintentional entrenchment(s) in other sectors. This is exemplified by an energy project in Colorado which was intended to promote renewable energy, but ended up replacing coal with natural gas, thus establishing a new, less carbon-intensive, but nevertheless fossil lock-in (Bernstein & Hoffman 2018). However, van der Ven et al. (2017) demonstrate how unintended consequences may lead to decarbonising practices, using the example of product carbon foot printing. This failed to take off in the UK, but the idea nevertheless spread and inspired similar concepts for quantifying GHG emissions elsewhere. Thus, it becomes clear that the indirect consequences of scaling must be examined alongside the direct ones when considering an intervention's overall impact.

3.3 Material Politics (MP)

From the perspective of Material Politics (MP), scale is conceptualised as being fundamentally relational. Building on the scale debate in Geography (Swyngedouw 1997), MP understands scales not as naturally discrete "levels" or strata but rather as interconnected systems that are socially, materially, and discursively constructed (Haarstad 2014; Bouzarovski & Haarstad 2018). Rejecting the structural assumptions of nested hierarchies, MP thus emphasises the messiness of scales. This results in a greater assumption of interrelationship and interaction: what happens at one scale affects other scales (Bouzarovski & Haarstad 2018). This dynamic undermines the notion of innovations cultured in a "protected niche" by demonstrating that such a niche, cut off from all external pressures and influences, is in effect a fantasy of entrepreneurial genius.

Scaling with regards to what?

Scaling is here understood as affecting not only innovations themselves, but also the broader socio-material relations in which they are embedded. In other words, the successful scaling of a decarbonising innovation decarbonises not just the practice in question, but the sociotechnical and political networks in which it is embedded.

How does scaling occur?

As its name implies, Material Politics takes materiality seriously, by paying close attention to the way in which it enacts—and is enacted through—social, political, and economic relations. This results in a core critique of the "one size fits all" approach of, for example, the MLP, on the grounds that such an approach obscures the material politics of low-carbon interventions. MP thus teaches us something of how materialities—in particular the infrastructural systems upon which an innovation may or may not depend—might be overlooked when conceptualising scaling as a simple replication or diffusion. Seen from this position, then, successful innovations are not simply transferred (scaled), but co-constructed (rescaled) with the sociomaterialities of the context within which they are reconstructed/reproduced: to borrow the language of earlier frameworks, we might say that in a process of rescaling, a (sociomaterial) regime and an innovation engage in a simultaneous and perpetual reconstruction of one another.

Rescaling is not achieved by simply replicating policy ideas or moving them into a higher political arena; rather, '[l]ow-carbon initiatives immanently require some form of disruption of established power relations and ideological systems beyond their immediate territorial location' (Bouzarovski & Haarstad 2018, p261). Central to the MP perspective is the idea that such power is not pre-given nor held, but 'generated through the ways in which different entities are bought into relation with each other' (Stripple & Bulkeley 2019, p56) in order to 'disorder, rearticulate and undermine political structures that maintain a fossil economy' (Bouzarovski & Haarstad, 2018, p262). The following processes are essential: politicisation (i.e. the challenging of established power relations), enrolment (i.e. knowledge exchange and engagement with cross-sectoral actors). and the dynamics of hybridisation (i.e. the construction of agencies).

Who shapes scaling?

Scaling is given shape through the interaction of nodes—human and non-human—within sociotechnical networks; given this embeddedness of innovations in their sociotechnical contexts, rescaling is thus deeply intertwined with sociomaterialities of infrastructure systems (e.g. Bulkeley

2016; Bouzarovski & Haarstad 2018), and therefore necessitates various forms of material engagement with technical infrastructures (Bouzarovski & Haarstad 2018). Materialities also shape the making of markets (Mouat & Prince 2018), which in turn provide another shaping influence on scaling processes.

Scaling occurs to what effect?

As understood in MP, scaling is ultimately a political act. Thus, effective forms of scaling result not only in the propagation of the policies themselves, but also in the reconfiguration and transformation of sociotechnical power structures (Bouzarovski & Haarstad 2018). At the risk of being reductive, the most obvious expression of this sort of transformation would be a shift from a reliance upon a carbon-intensive infrastructural system or supply chain to a reliance upon a less carbon-intensive system, or (in less radical manifestations of scaling) to a more hybrid, multi-systemic arrangement.

3.4 Cultural Politics/Cultural Political Economy (CP)

As a framework for analysing sociotechnical change, Cultural Politics draws upon a larger body of literature known as Cultural Political Economy. Since it draws on the same scale debate as MP does, its reading of scale is, unsurprisingly, similar. Many articles that take the CP position describe scale as being socially and discursively constructed (González 2006, Allen 2017; Dannestam 2008; Tucker & Rose-Redwood 2015; Seivanen et. al. 2012). They tend to emphasise the ways in which the politics of scale itself are created through (and/or used as strategies in) struggles between different actors (Allen 2017; Sievanen et. al., 2013), or in order to (de)legitimise a political project (González 2006). Thus, discourses acquire power through mobilising scale to frame how the world should be observed (Chung & Xu 2015).

Scaling with regards to what?

The object of scaling in CP might be said to be a particular set of values or ideals. The innovations with which it is concerned are discursive rather than technical, though the discourse or imaginaries in question may be centred upon (or, perhaps just as likely, set against) a more material or technical innovation. As such, concepts of scale may themselves be subject to scaling: a particular notion of the appropriate or acceptable scale for a given mode of production or action, for instance, may well be bundled up within an imaginary focused upon that mode of production or action.

This recursiveness adds to the challenge of applying this framework—as does the potential disjunction between an imaginary and the innovation with which it is associated: an imaginary might well assume capacities or capabilities in an innovation which it simply does not have. (As such, CP might be best considered as a supplemental understanding to more materially oriented accounts: while the other frameworks may overlook the narrative aspects of sociotechnical change, CP used alone may go too far in the other direction.)

How does scaling occur?

In common with MP, CP tends to talk not about upscaling, but rescaling. Central to the rescaling process is contestation over the framings of a problem, over its proposed solution, and over the scales at which these should be enacted (Delaney & Leitner 1997). For example, rescaling is deemed to take place through 'scalar narratives' in which actors tell 'stories about changes in the spatial patterns of socio-political processes' (González 2006, p840), thus opening up the idea that particular scales are appropriate for particular actions.

This rescaling is thus dependent upon narratives and imaginaries, the 'shared socio-semiotic systems that structure a field around a set of shared understandings of the climate' (Levy & Spicer 2013, p659). These are important because they propagate and support certain stories about social, political, and technological structures, and thus, if successful, have the power to challenge and shift the dominant narratives with which they compete.

Perhaps uniquely among the frameworks discussed here, CP also takes obduracy and counter-innovation seriously, asking how discursive hegemonies (or hegemonic scalar narratives, or dominant imaginaries) need to be unmade, and how this might be resisted. For example, in the case of meat and dairy, the politics of naming innovations in this sector (e.g. "synthetic milk", "cultured" or "lab-grown meat") and the narratives constructed around them (e.g. "created in 'unnatural' labs") are a key aspect of resistance from incumbents to the introduction of new innovations into the market (Mouat & Prince 2018). However, Cultural Politics should not be understood in solely

semiotic terms. The perspective also needs to attend to materialities in order to understand how meaning becomes embodied (Bulkeley, Paterson & Stripple 2016).

Who shapes scaling?

CP proposes a diverse set of actors as potential agents of change. Not only (state) institutions, but also scientists, NGOs, communities and social movements, and perhaps even influential individuals, might have roles to play in shaping scaling through the introduction (or modification) of new discourses, narratives, imaginaries, and visions for the future (Brown & Spiegel 2019; Dannestam 2008; Delaney & Leitner 1997; González 2006; Levy & Spicer 2013; Tucker & Rose-Redwood 2015; Sievanen et al. 2013). In order to scale, imaginaries need to connect with wider popular interests and identities, and also to align with economic and technological aspects of the energy system to constitute "value regimes" (Levy & Spicer 2013). As such, materialities and their linkages to discourses have an important role to play in shaping scaling, albeit one which is not necessarily reflective of their actual capabilities or capacities.

Scaling occurs to what effect?

The effect of scaling would be to successfully challenge—perhaps even to displace—a dominant discourse or "value regime" by strengthening the competitiveness of a new "challenger" imaginary. Whether the actual manifest scale of any given process is changed is immaterial to the CP perspective; rather, the goal is to change assumptions about the appropriate scale for a given process.

3.5 Analytical Heuristic Matrix /Typology

	MLP	MLG	MP	CPE
With regards to what?	Innovations (usually technologies) developed in protected (isolated) niches. Experimentation for the sake of variation, which subsequently leads to selection in regime.	Experiments developed in polycentric systems for the purpose of learning, become (locally, regionally) embedded, and spread.	Rather than attending to the innovations themselves, the MP considers the ways these challenge current power systems and material configurations, for instance infrastructural or value chains.	Rather than attending to the innovations themselves, the CP considers how narratives and imaginaries challenge or align with dominant narratives and climate imaginaries.
How?	Upscaling as reaching "higher" levels; replication and growing within niches, then reaching and transforming the	Upscaling as becoming far-reaching; horizontally, vertically, or embedded through processes of time;	Rescaling as a political act; disrupting power and ideology systems through politicisation (enrolment,	Rescaling as a discursive act; contesting meanings and challenging dominant narrative

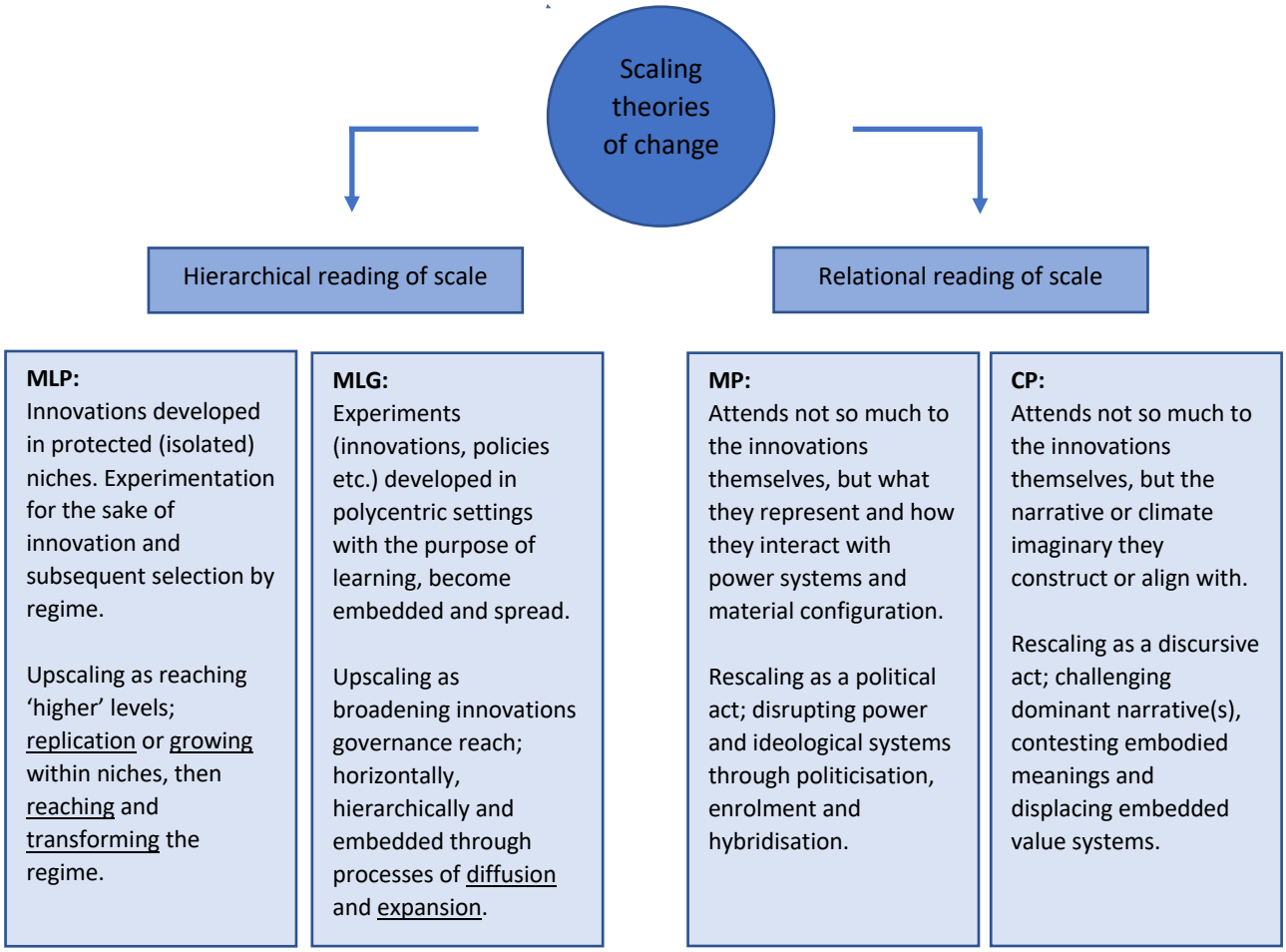
	regime.	diffusion, expansion, and transformation.	hybridisation).	and value system.
Who shapes?	Intermediaries within niches or to foster niche-regime interaction.	Subnational and non-state actors. State still relevant and may mediate transitions.	Scaling is given shape through the interaction of nodes—human and non-human—within sociotechnical networks and their embedded socio-materialities.	A large diversity of actors; state and non-state institutions, scientists, NGOs, communities, and social movements.
To what effect?	Incorporation of new technology. Ultimately, to bring about regime shift and transformation.	Learning, adaptation. Innovations becoming far-reaching.	Disruption of power systems and ideologies.	Successful challenging (or displacement) of dominant narrative, climate imaginary, and the value system in which it is embedded.

3.6 Typology of scaling

Theory	Form of scaling	Conceptualisation	Exemplified in cases
MLP **Upscaling**	*Growing* *Replication* *Accumulation* *Transformation (upscaling)*	More actors participating in experiment (Naber et al. 2017). Increased number of initiatives within niche, or experiment used in another context (Hamilton et al. 2014; Naber et al. 2017). Experiments linked to each other. Local niches aggregated to a more stable global niche (Naber et al. 2017). Niche innovation reaching regime to transform regime rules.	Oatly Although no full transformation of dairy regime has taken place, indications of this happening in Oatly.
MLG	*Expansion* (horizontal	Rolling out of place-based experiments	N/A in studies (could

Upscaling	upscaling) *Diffusion* (horizontal upscaling) *Transformation* (akin to vertical upscaling (van der Doren et al. 2016) and mainstreaming (Bai 2000))	(Kern 2019). Upscaling of experiments between cities, on voluntarily basis, through networking. Diffusion of best practices, voluntarily governance (Kern 2019). Upscaling leading to transformational change within a territory, e.g. region, nation state (Kern 2019).	potentially be seen in the future of HYBRIT). BREEAM adopted in new countries. Opening of new zero-waste store in other cities.
Material Politics **Rescaling**	Politicisation	Questioning power structures by making them visible.	Zero-waste supermarkets' politicisation of package plastics.
Cultural Politics **Rescaling**	Discursive contestation	Challenging of dominant narrative, climate imaginary, and value system.	Zero-waste on packaging as "waste" instead of "protection". GPA of plant-based protein: "plant-based" instead of "synthetic" and "lab-grown". Oatly on dairy milk: "high-carbon", "unhealthy", "unnatural" instead of "natural", "environmentally friendly".

3.7 Two pairs of theories



4. Discussion

4.1 Varying conceptualisations of scaling (and why we need more than one)

While the question of how scaling takes place might seem at first glance easy to get a grip on, it is evidently deeply contested. While each of the four perspectives provide a different conceptualisation of scaling, they can be seen as two related pairs of theories of scaling (see section 3.6), as they build on two significantly different ontological assumptions of scale. These related pairs can be categorised as *hierarchical* (MLP and MLG) and *relational* (MP and CP) readings of scale, in which scaling is broadly conceptualised as *upscaling* and *rescaling* respectively.

From the starting point of seeing scale as a set of nested, hierarchical levels of activity and connection, the MLP identifies two types of scaling. The first is understood to take place within protected niches, through the replication and growth of innovations or initiatives (e.g. LCUIs; see e.g. Hamilton et al. 2014; Naber et al. 2017; see also table 3.7). However, what is most commonly referred to here is *up*scaling; the process of radical niche innovations ascending to the (higher) regime to either replace earlier techniques or technologies, and/or to transform regime rules and thus bring about a transformation (Geels 2002; Geels & Schot 2007). Relying on similar scalar assumptions, the MLG tends to understand scaling as a process involved in expanding the reach of interventions' governance efforts (van der Ven et al. 2017). Upscaling is understood to take place either vertically, horizontally, or hierarchically, through temporal processes of expansion, diffusion, and transformation (Kern 2019). Scaling is thus no longer solely a matter of reaching 'higher levels'; it is also a matter of expanding horizontal reach.

In contrast to the hierarchical theories, the relational perspectives of MP and CP draw on the long-standing scale debate in geography (Swyngedouw 1997), which has called for the rejection of ontological assumptions that treat scale(s) as natural, separable, and nested units. Scale is instead deemed to be socially constructed (Chung & Xu 2015; Haarstad 2014; Bouzawski and Haarstad 2018). Thus, rather than innovations being scaled "up" to "higher" levels, scalar structures—through which decarbonisation is governed—are constantly in contestation, and continuously reconfigured materially and discursively by processes of rescaling. While relying on the same relational assumptions, Material Politics and Cultural Politics differ with regard to exactly what it is that is being rescaled, and through what processes. According to Material Politics, rescaling is ultimately a political act that seeks to challenge and dismantle power structures and suggest alternative configurations. From the Cultural Politics perspective, rescaling refers to the 'reconfiguration of a particular scalar structure of environmental governance [which] is the outcome of the discursive contest among various political actors, whose discourses acquire persuasive power through employing scale to frame how the world should be observed' (Chung & Xu 2015, p1404).

Applying the contrasting conceptualisations of scaling to the case of zero-waste supermarkets highlights how they capture different processes. The innovation of the zero-waste supermarket is characterised by its social nature, which derives from—and remains a part of—the zero-waste movement. There is no technological replacement offered; instead, the "innovation" consists of a reconfiguration of an existing concept (the supermarket) by shifting grocery shopping practices to remove the need for packaging. This absence of technological novelty is one of many reasons the MLP struggles to make sense of the case; the fact that the initiative is developed in a polycentric

setting rather than a protected space is another, as it is hard to identify a "niche", and without a clear fix on this central concept of the MLP, it is hard to identify an ongoing scaling into the "regime". Zero-waste supermarkets are unlikely to transform the regime of traditional, high-waste supermarkets by replacing the old hegemonic business model with a new one, precisely because zero-waste rejects the growth economics imperative of expansion as an end in itself. What *can* be observed is the taking up of zero-waste concepts by conventional retail, with the appearance of packaging-free departments and product lines. However, it is doubtful that this can be read as an upscaling of the zero-waste supermarkets to the regime level.

If we instead adopt an MLG approach, the context in which zero-waste operates is more easily understood: it resembles the MLG's polycentric governance structures, and it is a predominantly urban phenomenon. In terms of upscaling, we can identify a horizontal spread of the concept to other cities (the opening of new stores), as well as to regional waste management policies. We can also consider the ways further plastic regulation by policy makers might continue to foster the initiative.

However, what both of the hierarchical perspectives fail to capture are the wider political implications of the zero-waste phenomenon. Applying an MP reading of rescaling reveals the ongoing politicisation of plastics, and the interrogation of the infrastructural organisation that supports their production and use. This challenge is affected by demonstrating the possibility of reducing reliance on packaging, and on the global supply chains that distribute it. Through Cultural Politics, meanwhile, we can examine the ways zero-waste is contested by incumbent actors, and how this plays out as a discursive contestation of the meaning of packaging (that is, "waste" versus "protection").

We could compare this with the case of Oatly, an innovation that begins in the realm of the technological—with a new, patented enzyme process for making oat milk—but which gradually acquires a more distinctly sociotechnical character as it is introduced to the regime beyond its (academic) "niche". Oatly is notable for its disruptive potential with respect to value chains and political-economic relations (e.g. the dairy-state complex). But as a business proposition it conforms to and sustains capitalist market logic. Oatly is thus deviant and disruptive in some respects, but nonetheless follows and exploits some rules of the regime. The MLP permits us to understand the emergence of the innovation: Oatly was developed in a protected niche, nurtured by research institutions and incumbent actors; only after growing and expanding within this niche was it able to reach the regime level, by taking advantage of a window of opportunity created by increased criticism of the non-sustainability of prevailing dairy production. We thus identify a typical (albeit as yet incomplete) upscaling process, whereby a deviant niche innovation gains internal momentum, propagates in to the market, and subsequently reaches the regime (Gaels 2002; Geels & Schot 2007). The MLG, meanwhile, provides almost no traction on the Oatly case, because it lacks the characteristic features—polycentric urban sites of experimentation, and the influence of actors in systems of governance—upon which that theory tends to focus.

Although the deviant character of the Oatly innovation is captured by previous perspectives, its disruptive dynamics may be more thoroughly understood by attending to the relational perspectives. MP highlights how Oatly achieves rescaling through the politicisation of cow's milk: by highlighting its significant carbon footprint and its reliance upon state subsidies, the "naturalness" of consuming cow's milk can be brought into question, revealing the political processes of which it is an

outcome. Thus an MP approach can reveal Oatly's challenges to both chains of value production (as cows are cut out of the process), and long-lived power structures (e.g. the relationship between the dairy industry and the state). Cultural Politics is also essential to understanding the Oatly case as it highlights how the company successfully challenged the dominant narrative (on cow's milk) and established a contesting climate imaginary. It also helps explain how such a narrative has managed to scale (through alignment with an emergent alternative value system), even as it launches an exposing attack upon the power structures of the dairy regime. CP also illustrates that, although Oatly has challenged the power of *some* actors, it nonetheless aligns well with dominant political and economic structures (e.g. market logic, economic growth). By examining the case through the analytical tools of CP, we see how contestation plays out between incumbents and Oatly. While the hierarchical perspectives acknowledge the ways Oatly is met with the hegemonic inertia of the regime, such dynamics cannot be fully understood without applying these more relational perspectives.

These cases suggest that applying only a single notion of scaling risks missing other types of scaling that may be happening. While zero-waste supermarkets might appear to be failing to scale from a hierarchical viewpoint, they are *already* rescaling according to MP and CP. And while Oatly seems to be disrupting the regime from the hierarchical perspective, its alignment with capitalist market logic is revealed through a CP lens. This points out how "scale" is a *floating signifier*—a term which has a particular and specific meaning within a given discipline or field, but which may not be understood the same way in an adjacent field, despite bearing the same name. Contestation and broadening notions of scaling are thus not merely issues of a practical nature; they also have wider political implications. If scaling reproduces capitalist assumptions regarding what "successful innovation" looks like—namely, products or services able to completely replace a fossil counterpart on a market—then other disruptive initiatives might be deemed failures, even though they may already be involved in the contestation and reconfiguration of systems of power. Hegemonic notions of scale thus lead to the normalisation of particular understandings of how change can be understood to take place; contesting such understandings can open up a space for alternative decarbonisation paths to be imagined.

Taking a more abstracted view of the two sets of theories, it seems apparent that the matter of scale differs in the extent to which it is considered to be either a means to an end, or an end in itself. There is considerable variation across actual applications of each model to empirical cases—a function of their interpretability that is manifest even within the relatively contained scope of this project. But we might advance the rule of thumb that hierarchical conceptualisations of (up)scaling tend to see scaling as an unquestioned end in itself, while relativist conceptualisations of (re)scaling tend to see scaling as one among a number of means to a much more nebulous (if perhaps more significant) end—one that reaches beyond the initial context in which an innovation emerges. This dichotomy can be seen to haunt the surprisingly fraught relationship between "scale" and change itself.

4.2 Change as a multi-scalar process (scaling, change, and momentum)

As shown above, scaling takes many different forms depending upon not only the specificities of a particular case, but also upon the perspectives from which that case is analysed; as a result, it could be said that "scaling" ceases to be a usefully comparable measure of change. Or, to put it another way: "scaling" and "change" are not necessarily equivalents, even though they are often used

synonymously. In the context of decarbonisation, significant change must surely mean structural change, whereby carbon emissions are reduced to an impactful extent: this is change as *transformation*. As suggested by these analyses above, then, *up*scaling appears to describe a process potentially leading to transformation, while *re*scaling would seem to refer to transformative change that is already happening, in which a given innovation may or may not turn out to be a significant actant.

Looking at the case of BREEAM, we see how significant scaling has been identified according to the MLP (diffused into the regime) and the MLG (expansion and diffusion). However, BREEAM is not considered to challenge the incumbent rules prevailing within the regime of construction practices, and neither is any significant reconfiguration of practices (e.g. tech replacement, transformation of regime) that might result in transformation understood to be taking place. If we instead apply a Material Politics perspective, we see how BREEAM reinforces prevailing power structures, which promote sustainability as being governed by voluntary processes of (self-)assessment rather than by regulation, thus aligning with current neoliberal laissez-faire political structures in the UK (where BREEAM originated). Thus, while the MLP acknowledges a form of upscaling without wider transformation to have taken place, an MP perspective recognises neither rescaling nor transformation to have taken place.

This could be compared to the case of the zero-waste supermarkets, where, from an MLP perspective, neither upscaling nor transformation is understood to have happened; the zero-waste supermarkets instead appear as a societal pressure group leading to some limited reorientation of regime actors around the "disruption" they enact (see transformation pathways, Geels & Schot 2007). Seen from the perspective of Material and Cultural politics, however, we can identify an ongoing *re*scaling through the politicisation of packaging plastics, and a challenge to the dominant narrative on the circular economy (e.g. recycled plastics). This process is simultaneously the means of transformation as well as the means *and* the end of scaling. In much the same way, from the Cultural Politics perspective, challenging and contesting dominant narratives and imaginaries on plastics is simultaneously the means and the end of rescaling. This reveals transformation to be an always-already ongoing process when seen from a relational perspective—a process in which a given innovation may or may not succeed in accelerating said transformation.

This suggests that, within Material Politics, (re)scaling is seen as a constant transformative process, as opposed to the more linear views of scale-as-an-end-in-itself apparent within the MLP. Thus while upscaling appears to be a means to achieve "change", rescaling might more easily be translated to "change" already taking place. While this proposed relationship between scaling and transformation is far from conclusive (based as it is on a limited number of empirical cases), what becomes fairly clear is that scaling is only one of various processes involved in transformation(s). As well as the scaling processes already discussed, which Kern (2019) identifies as being temporal processes, we also observe *spatial* processes of *momentum*, which is also viewed in different ways by the four theories in play.

Within the MLP, momentum manifests in the process of a new technology becoming a part of a new stabilised regime (Geels 2007). Momentum is, according to the perspective, also understood to drive (up)scaling, since building up internal momentum within niches is seen as crucial for an innovation to scale (Geels & Schot 2007). Momentum thus becomes the condition which allows scaling to "take off", but it is also implicated in the process of "landing" the scaling of innovation into a new stable

dynamic. Within the MLG, momentum is referred to as *entrenchment*; scaling thus means 'expanding the reach of governance efforts', which then (assuming momentum is established) leads to 'substantive effects that are durable and difficult to reverse' (van der Ven et al. 2017, p8). Like MLP, MLG see momentum and scaling as two fairly separated processes. However, in the latter perspective's approach to scaling, spatiality is considered a part of scaling, since all such activities are considered to 'amplify the impacts of an intervention across space' (van der Ven et al. 2017, p9). Within MP, momentum is established through actors' engagements with material objects, and is thus 'generated through the ways in which entities become configured in relation with one another' (Stripple and Bulkeley 2019, p54). And within Cultural Politics, momentum is seen to be enacted through the transformation of the meanings we give to social life, to material objects, and to the practices they depend on and enable (Bulkeley, Paterson and Stripple 2016).

The different ways spatiality and momentum are understood within the four perspectives seems to emphasise the difference in how they read "change". In the MLP, momentum seems to be the spatial *effect* of change, while scaling seems to be a predominantly temporal process or *means* by which to achieve change, even though the two terms are often treated as synonyms. Within MP and CP, by contrast, rescaling is instead temporally and spatially co-constructed, and momentum is thus continuously considered: any "beginning" or "end" to the dynamics are an artefact of the scope of the analysis itself. To reiterate, the understandings of how processes of scaling and momentum interact is illustrative of each perspective's view of transformation: while the MLP employs a linear ends-oriented view of change, the relative perspectives (CP and MP) have a more process-based view of transformations (with the MLG sitting somewhere in between the relativist positions and the "purer" temporality of the MLP).

Momentum thus appears as a *spatial* process of perpetual transformation referring to a broad variety of concepts, which may be understood either as an effect, or as a co-constructive force. Momentum thus resembles "spatial embeddedness" and the path-dependency of high-carbon systems (Bridge et al. 2013), as well as the entrenchment of lock-ins (van der Ven et al. 2017). Bridge et al. (2013) argue that while thinking transitions through their temporal processes may allow us to understand rates of mainstreaming of new technologies, an examination of their *spatial* processes teaches us something about the consequences and/or political implications of policies, thus highlighting the importance of understanding transitions as "spatially constituted". While they do not refer specifically to the terms scaling and momentum, these concepts may nonetheless provide analytical tools to understand the temporal and spatial processes with which they are concerned.

In the analysis of the case studies, the need to take spatiality seriously is striking. To return to the example of BREEAM, we see how upscaling of the certifications has led neither to significant decarbonising effects, nor to disruptive change of power structures. Similar patterns are identified in the case of Friesland Campina, where green bonds have upscaled remarkably, while the extent of the "greenness" resulting from that "success" is largely unknown. The same case also illustrates how although the FC Green Schuldschein has *not* scaled in terms of significant transformations manifest as measurable decarbonisation, it *has* led to new governance structures. This calls for a thorough examination of spatial effects, which is fairly absent in the concept *up*scaling, though a crucial part of *re*scaling.

The discussion of spatiality can be contextualised by the existing debate on its absence, for which the MLP in particular has come under scrutiny. For instance, Bridge et al. (2013) call for an increased

acknowledgement of spatial configuration within transition studies: this is compared to path-dependency, and exemplified by the *durability* of national energy systems, and thus lies close to the concept of momentum-as-entrenchment.

It bears noting the extent to which these qualities may be seen as value judgements, and thus as subjective and contextual. Bridge et. al.'s (2013) connection of path-dependency and durability is emblematic of the issue, as is the MLG's use of the term of entrenchment, a word with martial connotations that bring to mind a protracted (and destructive) resistance to external forces. Entrenchment and durability are also viable synonyms for resilience, a term often used in the context of sociotechnical transformation—and all of these terms could equally be rephrased as obduracy. Without wishing in any way to undermine the goals of decarbonisation (or other manifestations of sociotechnical transformation), it should be pointed out that obduracy, such as that of the fossil-fuelled supply chains with which REINVENT is concerned, may be seen as a resilience or durability which is no longer desired. As such, we may wish to reconsider the framing of desirable transformations in such terms, lest our efforts result in replacing one obdurate and no-longer-suitable system-of-systems with another one which, in time, is revealed to be equally unsustainable in some dimension as yet to be considered urgent. Ongoing research into the resource footprint of grid-balancing batteries and electric vehicles hints strongly at this possibility, and suggests that, rather than being tools for defeating the fossil-fuel hegemony, ideals such as durability, entrenchment, and resilience may be the root hazards from which our current destructive dependence upon fossil fuels has emerged. The relation of durabilities and entrenchments, both conceptually and empirically, to the spatial distributions of practices and the infrastructures which enable and sustain them, is thus revealed as crucial not only to decarbonisation transformations, but to a more generally adaptive and adaptable manner of living within the limits of the biosphere of Earth.

As such, this report hopes to extend and deepen this debate by emphasising the need to acknowledge spatiality in change processes, which we would rephrase as *the importance of taking spatial processes of momentum seriously*. To reiterate a metaphor used above, it is dangerously short-sighted to focus our understanding upon the take-off without sparing any consideration for the landing.

4.3 Utility and limitations of the theories of change

This exploration of different conceptualisations of scaling—how it occurs, and to what effect—is by no means intended as a judgement on which perspectives are universally "better" or "worse". Instead, we seek to understand the circumstances in which each theory of change works at its best, and also at its worst. This involves understanding what kind of innovation each of the theories best "fits" with, but also the different aspects of transformation which each is best suited to analyse.

The analyses of the zero-waste supermarkets and Oatly suggest that the MLP will be helpful in understanding the scaling of (predominantly) technological innovations, which are deviant in their immediate implementations without being "too" deviant from regime rules. That is, innovations which feature a focus on technological products and/or services, but which also align well with classical liberal market ideology, as in the case of Oatly. However, the MLP struggles to identify scaling in innovations of a more social nature that depart significantly from this ideal, as illustrated by zero-waste supermarkets and the Green Protein Alliance (see case study in appendix).

This limitation of the MLP is not solely the result of a narrow definition of innovation. It gestures toward a conservatism in the very narrative of transformation that underpins this analytical model. The generic form of the MLP bears a marked resemblance to the "hero's journey" template so beloved of Hollywood: the plucky little innovation grows up on an isolated farm, where it is mentored by forward-looking change agents who will train up the chosen one for the task of unseating the prevailing regime; once it has developed its skills and courage sufficiently, it heads out into the world beyond the niche to gather a band of loyal supporters and, eventually, take on the incumbent system and instigate regime change. This is a caricature, of course—but it allows us to identify the crucial elements of the innovation narrative which, if absent or changed, render the template useless. If, for instance, the innovation and its protected niche are themselves nurtured by a regime that seeks to change itself (as in the case of HYBRIT), the essential dynamic of contestation against hegemonic resistance is removed, and the story fails to flow: the MLP thus cannot tell us what would have to happen for hydrogen-reduction steel-making to "scale up", because the theory's notion of what scaling means is tied up in the David-and-Goliath mythology of technological entrepreneurialism.

Multi-Level Governance has a similar problem of overdetermination, in that it is a vast literature with a fairly narrow set of core assumptions about the meaning of innovation. MLG's focus on experiments in urban contexts, along with its preoccupation with actors inside systems of civic or regional governance, make it difficult to apply to experiments which have taken hold without any significant intervention from policymakers. Therefore, innovations such as Tierra is hard to analyse through this theory; although the innovation is an experiment in one sense, it is detached from the urban. However, the results of being an unfit match seems to be less "severe" than the MLP, as cases deviating from the theory's notion of innovation still can make use of the MLG's analytical concepts. Of particular value is the MLG's broadening of the upscaling concept through the addition of horizonal and hierarchical modes of scaling to the MLP's one-note repertoire of vertical "growth". As such, the MLP is especially helpful in mapping how scaling of innovations such as zero-waste supermarkets takes place, as the theory is able to identify how these have spread geographically to new sites.

The relative theories (MP and CP) attend less to the innovations themselves, taking instead a broader view of what the innovations represent: that is, the narrative which the innovations enact, the value chains on which they depend, and the ways in which they reconfigure or (align with) current political and cultural practices. As addressed above (see 4.1), few of the innovations "fail" to fit the relational models, while the hierarchical perspectives are much more "hit and miss"; therefore, MP and CP can more easily be applied to a broader variety of innovations, regardless of their dominant character (e.g. technological, social). For instance, MP and CP are able to identify critical political mechanisms of both Oatly and zero-waste supermarkets, despite the innovations' fairly different characters. As attended to in the previous sections, the relative perspectives are especially successful in revealing disruptive potential (e.g. zero-waste), but also the lack thereof (e.g. BREEAM, FC). However, a different issue arises: through their refusal to adopt an overarching narrative of change (i.e. seeing change pathways as continuously co-constructed rather than predetermined) the relative perspectives undermine their own chances of suggesting ways in which other innovations might be nurtured or supported.

This can be understood by referring to the case of Oatly. While its initial phase of development, growth, and take-off can be understood through analytical tools of the MLP, MLG becomes useful in developing an understanding of how such an initiative may spread within polycentric settings, and thus how similar innovations may be further fostered. Adding CP to the analysis helps us understand how contestation with incumbent actors plays out as a discursive battle over the meaning of dairy milk, rather than appearing as a static inertia or "brick-wall" resistance to change. Indeed, one could go so far as to claim that such perspective-switching is a vital part of the process of (to borrow the MLP's own terminology) the rules of a prevailing regime of transformations research. As such it makes visible not only the possibility of bringing about significant change, but also the ways in which change is *always-already* happening.

To make an admittedly reductive generalisation, where one pair of theories fails, the other often succeeds, or expands into the gaps left unexplored. This suggests the possibility, and the potential usefulness, of a multi-model approach: rather than forcing a case into the generic narrative of one particular framework, those generic forms might instead be broken down into fragments or "moments" of narrative, from which new hybrid narratives might be assembled in order to better explain each given case. Any hybrid framework constructed through this approach to address a particular case might happen to prove useful in the analysis of certain other cases, but it could of course become rigid and illegible in its own way if inappropriately applied. What we propose is not the proliferation of new frameworks in a vain search for universal utility; as any framework will be limited and partial, adopting any one framework will require considering its limitations and weakness. Thus, we rather suggest the shift to a "toolkit" approach: treating the frameworks we have as a grab-bag of analytical grips and probes from which one might retrieve and assemble a suitable selection on a case-by-case basis. As such, each theory and its analytical tools can be helpful in different contexts, depending on what is aimed at achieving. Moreover, this approach can serve to highlight the other perspectives' limitations and strengths. Our approach does not preclude the possibility of creating a new integrated theory encompassing all four theories of change. However, it is our understanding that moving away from framework-thinking to a 'toolbox' approach to a larger degree allows reflecting the circumstances in which each theory is more favourably employed. Moreover, building such new framework would need a broader set of cases than applied here, and is thus subject for further research.

Finally, it should be noted that all four frameworks herein deployed share what we might describe as a bias toward a top-down vision of the sociotechnical landscape. The picture remains incomplete without a view from the "demand side" of the value chain to complement the "supply side" vision that the four frameworks combine to provide. To put it another way, the addition of MP and CP to the analytical toolkit gives the study of transformations a geography which it has often lacked—but while transformations may be acquiring a geography, they still lack a sense of place, a problem at least in part due to the lack of end-user voices in the chorus of opinion and imagination. We thus suggest that theoretical positions such as Haraway's "situated knowledges" (1988), and analytical heuristics with a demand-side focus such as those developed in the field of social practice theory (see e.g. Shove et al. 2007), might serve to balance the top-down envisionings of sociotechnicality endemic to transformations research with a view from "closer to the ground". Opening this other analytical eye might serve to give a greater depth to the object(s) under study, in a manner analogous to binocular vision; as well as putting the researcher and their activities "back on the

map” as a participant in processes of transformation, changing and changed by that which they seek to understand.

5. Conclusions

The phenomenon of scaling in innovations—for decarbonisation, but plausibly for transformations of other types—turns out to be a far more contested concept than might be assumed at first. As suggested by the conducted analysis of the case studies, applying a single theoretic approach to scaling risks failing to identify the many ways in which scaling take place. This is evident in the case of the thriving zero-waste supermarkets, which are not seen as scaling in the most commonly applied sense of reaching a higher organisational level, precisely because they reject hegemonic ideas that equate success with infinite growth. Instead, the stores are involved in rescaling high-carbon value chains, politicising plastic use, and contesting the embodied meaning of such practices. As such, the use of multiple theoretical perspectives for the analysis of case studies, and the taking of a hybrid 'toolbox' approach rather than the rigid dogmatism of "frameworks", offers better odds for broadening understandings of transformation dynamics. This approach does not preclude the possibility of creating a new integrated theory encompassing the four theories of change. However, it is our understanding, through this work, that a 'toolbox' approach more thoroughly can reflect limitations and strengths of each theory of change, and in which circumstances their set of analytical tools are most favourably employed.

A largely unquestioned conflation of "scaling" with "change" serves to obscure important aspects of transformation processes. Upscaling, the dominant understanding in hierarchical theories, tends to focus on temporal processes in which scaling is seen as an end in itself, while rescaling, which is more important in relational theories, tends to focus more on spatial and material conditions of already-ongoing change in which scaling is seen as one means (among many) to a broader strategic end. The voluntary certification schemes of BREEAM have been upscaled *although* this has led to little disruptive and decarbonising effect. Meanwhile, no rescaling can be understood to take place, *just because* BREEAM reinforces rather than challenges prevailing power structures. This highlights how scaling is one of many processes involved in change, alongside spatial processes of momentum. This also suggests that the latter needs to be attended to if we want to fully grasp how decarbonising change take place.

Thus, the two "sets" of theories of change deployed within this project should be seen not as antagonistic but as complementary, each providing analytical tools with which different sorts of cases and their transformational dynamics might be "gripped". Even in cases like Oatly, which fit the MLP model of innovation like a glove, some interesting findings are still left out. MLP may allow us to map the emergence of Oatly and its diffusion into the regime, but we struggle to fully understand how contestation with incumbents plays out unless we attend to this discursively through a Cultural Politics lens. However, all four frameworks share in common a bias toward a top-down envisioning of the sociotechnical landscape, which might be enhanced and deepened through the addition of another complementary perspective from the "demand-side" end of the value chains under study. Adding this to our hybrid 'toolbox' might serve to bring a greater depth to the object(s) under study, examining not solely how transformations can be fostered and reimagined, but also how agency of subjects shapes such processes.

6. Appendix: Analysis of case studies

6.1 Zero-waste supermarkets

Zero-waste grocery stores depart radically from the standard practices of conventional supermarkets by offering their range of goods without any plastic packaging whatsoever. They rely on shoppers to bring their own bags, jars, and containers from home and fill them up at the store, buying only as much as they need.

In contrast to the more technoeconomic innovations further up the plastic value chain (such as new types of plastics or new ways of producing them) or further down (innovations in recycling and waste management), zero-waste supermarkets stand out for representing innovations of a more social nature. There is no complicated technology or infrastructure that enables them. Neither is the organisational and business model of the zero-waste store overly innovative in comparison to supermarkets. These are not novel forms of arranging the sale of groceries, as they very closely resemble the small-scale grocers that used to exist in abundance before the advent of the modern supermarket with its economies of scale, efficient logistics, and extensive range of product offerings.

According to Bepakt.com, an online register of zero-waste grocery stores, the first zero-waste store to open was Unpackaged in London, and they were followed by a number of other store openings in the following years, mainly in Italy, the United Kingdom, and the United States. From 2011 onwards, stores started opening in France, Spain, and other countries. Each of the years following that saw exponential growth in the number of new stores opening. More than half of the stores on the index opened in 2016 or later. The vast majority of stores are in EU countries, with Germany and Italy featuring heavily, followed by France, Spain, and Belgium. Despite the rapid growth, zero-waste retail still makes up a minuscule niche of overall retail, catering primarily to affluent, urban neighbourhoods.

6.1.1 Multi-Level Perspective

Instead of being born in a technological niche (Smith & Raven 2012; Geels & Schot 2007), zero-waste supermarkets, being of a social nature, were born out of the zero-waste movement. Identifying the niche in this case is a bit tricky, mainly due to the lack of a protective space in which the stores operate. The social movement could be seen as the niche itself, but also as crucial in nurturing and protecting a niche consisting of the stores themselves (Smith & Raven 2012). The stores are embedded within the broader regime, which raises the question: to what extent will zero-waste replace conventional retail or, conversely, will conventional retail take on elements of the zero-waste innovation into its regime?

According to the case study we conducted, zero-waste supermarkets are very closely linked to the local environments in which they operate, and few of the owners show aspirations towards scaling up their own operation—in terms of increasing the scale of their organisation—as this would entail a decoupling from the local environment. Zero-waste supermarkets are highly reliant on being tightly embedded in local communities, both for labour (volunteer employees) and financing (crowdsourced loans). The niche of zero-waste is thus empowered and nurtured by members, and by the community in which stores are embedded. Although other actors are also represented by the

MLP (political actors, scientists, etc.), scaling depends primarily on the interaction between niches and incumbents.

It is hard to imagine these steps being taken if it had not been for the massive politicisation of plastic use and pollution in Europe in recent years. The zero-waste movement played an important part in this politicisation, both through direct lobbying by organisations such as Zero Waste Europe and through a growing movement of social media influencers who are popularising zero-waste as an attractive lifestyle through blogs, Instagram, and best-selling books such as Bea Johnson's *Zero Waste Home* (2013). The MLP would understand such interventions as efforts to destabilise the existing sociotechnical regime in order to open windows of opportunity for zero-waste supermarkets to establish themselves.

The zero-waste business model has indeed been replicated in many locations. Since individual stores refuse to seek growth by becoming large scale, scale can instead be measured by how many neighbourhoods are served by a locally embedded zero-waste store. This is a growth model that some zero-waste storeowners do employ—for example, Løs Market opened a second store in a different neighbourhood in Copenhagen two years after opening their first store. Thus, instead of replacing one technology (virgin plastics) with another, zero-waste is challenging the regime's set of rules by suggesting a reorganisation of retail. However, due to its radical deviation from the regime rules, it is hard to imagine the innovation of zero-waste ever scaling by an MLP definition of the term. What is already happening, though, is that most retailers are now taking steps to re-evaluate their use of disposable and plastic packaging, simplifying packaging in order to use less, using bioplastics or recycled materials, making more packaging recyclable. Retailers are also incorporating elements of the zero-waste grocery store into their own operations, for example, introducing packaging-free sections into some stores. This tendencies indicate a market take-up of the zero-waste innovation.

However, it is crucial to highlight that the use of MLP's analytical tools of scaling is not straightforward in the case of zero-waste. Scaling through replication is understood to take place within a niche. Although we identify replication of zero-waste, this does not take place within the protected space required within the MLP. It is thus doubtful if the spread of the zero-waste supermarkets should be considered scaling. It is also questionable if the incorporation of zero-waste elements could be viewed as scaling. This more closely resembles incumbents adjusting after a destabilisation of the regime (Geels & Schot 2007), which in this case is partly driven by pressure from the zero-waste movement that the zero-waste supermarkets are one part of.

6.1.2 Multi-Level Governance

While the MLP approach relies on the agency of niche or incumbent actors to do the work of actually scaling the innovation, the MLG approach shifts the emphasis towards institutions and policies at different levels (local, national, international, etc.) and how these interact (Kern 2019). According to this perspective, scaling is achieved through policies that support the expansion and diffusion of the zero-waste grocery store, for example through business and knowledge support, financing, experimentation, and so on. Alternatively, policymakers may seek to make zero-waste a more embedded element in conventional retail by adjusting or introducing regulation on the use of plastic or disposable packaging in general.

The MLG perspective especially emphasises the importance of sub-national actors, which accords with zero-waste grocery stores' focus on the local community. We have seen how the concept of zero-waste has been expanded to engage waste management targets and practices at the municipal and national levels. It is easy to imagine possible further policy developments that could make cities and towns more hospitable to entrepreneurs seeking to operate zero-waste grocery stores, and how this may feed in to political priorities, especially in regional areas: creating jobs, avoiding depopulation, supporting small businesses, supporting local agriculture, and keeping money in the community. Local governments and cities could serve as important intermediaries between local producers, consumers, entrepreneurs, and other actors.

Scaling could be further fostered by increased experimentation with policies in order to identify best practices (policy instruments, governance models, or regulatory frameworks), and then diffusing these best practices laterally through city networks or vertically to the national or international levels. The task for policymakers is to identify the levers that best "orchestrate" (Hale & Roger 2014) the wider proliferation and multiplication of zero-waste supermarkets.

6.1.3 Material politics

Both of the previous perspectives (the MLP and MLG) miss an important avenue through which the zero-waste innovation might scale, which is captured by the material politics perspective. According to this perspective, the power of farmers, small producers, and small stores is circumscribed by the power of large, incumbent retailers, who are able to dictate prices and quantities and shift suppliers at their whim. It follows that reconfiguring relations of scale also reconfigures relations of power.

In this regard, zero-waste supermarkets challenge the arrangements that characterise the world of modern, industrial, global retail especially: global supply chains, cheap products, convenience, disposability, and powerful intermediaries. Zero-waste is oriented towards rebuilding relationships between customers and suppliers through a process of disintermediation, in other words, cutting out the middleman. Zero-wasters want a fairer system that provides better prices for farmers while contesting the 'distancing' between consumers and food. Scale, according to this perspective, means a re-orientation of retail supply chains away from global links that emphasise low prices and large quantities towards a multiplication of local supply chains that emphasise higher prices and higher quality.

Zero-waste supermarkets provide socio-material spaces that enable the kinds of interactions that allow such rescaling to occur. They also show what a system with different value chains could look like. A proliferation of zero-waste supermarkets would entail a proliferation of local supply chains and a gradually intensifying process of disintermediation.

However, it is important to note that, although zero-waste supermarkets question how the value chain is organised, and thus put pressure on conventional retail, they also align well with the neo-liberal individualisation of responsibility which places the burden of climate action on individuals rather than governments, and encourages people to use consumer demand to shift unsustainable practices in retail (Seyfang 2005; Maniates 2002).

It is also important to note that, since plastics are a by-product of the fossil fuel industry, the production of plastics is subsidised by upstream oil and gas revenues. We therefore do not expect a lowered demand for plastic packaging to translate into a lower demand for fossil fuels, because fossil fuel demand is much more sensitive to demand from the transportation sector than it is to

demand for plastic packaging. Thus, the intervention has a disruptive potential in retail, but not necessarily cross-sectoral decarbonising effects.

6.1.4 Cultural Politics

The perspective of cultural politics aligns closely with material politics when it comes to rescaling. There is a difference in what is emphasised, however, and what scales. The politics of scale are primarily understood as a discursive battleground through which political projects are legitimated (Allen 2017; González 2006). Rescaling is therefore pursued through discursive as well as material means, and there is more focus on how actors argue for or present the pros and cons of local versus global food networks. Scale is achieved by engaging in these politics in order to mobilise a critical mass of people around a different 'climate imaginary' that promotes alternative visions of a desirable future—in this case, one defined by local and fair food networks that minimise waste and plastic usage (Levy and Spicer 2013).

Applying a Cultural Politics perspective on zero-waste supermarkets illustrates contrasting narratives on packaging and plastics, and by extension competing perceptions of how sustainability is achieved within the food sector. In conventional retail, packaging is seen as "protection", which is most evident in the Swedish packaging company Tetra Pak's slogan, 'Protects what's good'. It is seen to enable the safe transportation food and goods across distances, so as to conveniently gather everything one may need or want in the same store.

By contrast, zero-waste regards packaging as "waste", unnecessary since goods that are heavily packaged and transported over long distances can be substituted with locally produced and lightly packaged ones. This view of packaging mostly originates in discussions of downstream plastics issues such as marine litter, but it is also relevant to packaging's fossil origins and its carbon-intensity. Furthermore, zero-waste challenges the modularity of conventional supermarket consumption: instead of buying whatever sized pack the manufacturer chooses to offer, one is encouraged to buy only what one needs to consume. Zero-waste supermarkets also question the need to be able to choose between many competing versions of the same product, which is one of the raisons d'être of conventional supermarkets' extensive value chains. Thus, zero-waste supermarkets become entangled with a bigger narrative about ideal food production. Instead of the currently dominant business model of multinational, outsourced food, zero-waste imagines food production and consumption on a small and local scale.

The key actors in this perspective are the activists, influencers, and organisations that promote and mobilise zero-waste discourses, for example through lobbying politicians, engaging with the press, or working through social media or blogs. They also rely on spreading the messages of zero waste to potential allies, such as more general environmental NGOs, scientific experts, other social movements, and so on. The increasing attention to global plastic pollution (especially marine litter) is certainly due in part to the influence of the zero-waste movement, but is also simultaneously an important driver of the movement's own growth and support.

However, zero-waste discourses are also encountering resistance from incumbent or otherwise opposed coalitions of actors, who seek to defend themselves and promote alternate discourses by positing other climate imaginaries. Conventional retail actors stress the need for packaging to avoid food spoilage, suggesting that food (rather than packaging) is the more pressing environmental

issue. Instead of promoting zero packaging, they emphasise the need for recycling and making packaging more sustainable, and thus draw on a circular economy approach.

The key contention at this stage is thus between zero-waste on the one hand and circular economy on the other. European policymakers and large sectors of industry and commerce are aligning behind the circular economy narrative, which promotes a different set of goals than that behind zero-waste. Where zero-waste speaks in tones of minimalism, restraint, and limits, the circular economy is more closely aligned to ideas of green growth and ecological modernisation, where decoupling economic growth from environmental degradation is the goal. The circular economy turns waste into a resource, which can be recycled and reused in industrial processes. Waste is viewed in terms of lost earnings potential. By and large, retail giants take the circular economy to mean initiatives to promote closed-loop packaging systems, recyclability of packaging, and more recycled content in their packaging.

The Cultural Politics perspective thus reveals questions of rescaling as ideological battle grounds between circular economy and zero-waste thinking. The circular economy narrative defends existing business models and scalar relations in the retail sector from the challenge posed by zero waste. It thus aligns well with the current dominant value system, which can explain its rescaling (Levy & Spicer 2013). Zero-waste, on the other hand, bears many similarities to the "sustainable lifestyles" climate imaginary (Levy & Spicer 2013), in that it experiments with alternative economic structures based on small-scale production and strong community. This imaginary implies more substantial change and is thus seen as threatening to business as we know it. Scaling zero-waste necessitates capturing some of the will that is expressed through the idea of "sustainable lifestyles": support must be gathered around remaking economic structures so as to shift global, abstracted concerns about efficiency and productivity towards local, situated concerns about fairness and limits. It comes as no surprise that the zero-waste narrative is struggling to establish itself against the circular economy narrative. However, zero-waste supermarkets appeal to notions of ecological citizenship (Seyfang 2005) and, to some extent, the neoliberal individualisation of responsibility (Maniates 2002), which might explain the ongoing rescaling.

6.2 Tierra

Fossil-based synthetic fibres such as polyester, elastane, and polyamide constitute an increasingly large part of the fibres produced to make our clothes. The production of oil-based fibres is estimated to consume 342 million barrels of oil annually, and the industry's emissions add up to more than those of international flights and maritime shipping combined. Microplastic ocean pollution from the laundering of synthetic materials is a growing concern (Ellen MacArthur Foundation 2017). However, while there has been some legislative action to address other sources of microplastic pollution, such as in cosmetics, the garment industry has not so far been significantly affected (Greenpeace, 2017).

Tierra are a Swedish outdoor clothing manufacturer who have made a 100% bio-based jacket called Deterra (meaning "of the earth"). The development of the jacket began at the time of COP21, and was intended as an example of a 100% fossil-free outerwear garment. The use of bio-based plastics is not new, but they are most commonly blended with fossil plastic in a 30/70 blend. There have also been some efforts to recycle clothing plastics. But there are few companies to date producing clothing made of 100% fossil-free fabrics. The innovation of Deterra is thus the exclusion of fossil fuels altogether in the choice of textiles. Since the launch, the jacket has received various sustainability awards and significant attention within the outdoor clothing sector.

6.2.1 Multi-Level Perspective

The Deterra innovation was born in the niche of sustainable outdoor clothing, within which many niche innovations are developed. The fabric producer FOV and the yarn manufacturer Fulgar, who produce the materials for the jacket, had worked on previous bio-based projects. This may suggest that sustainable clothing technologies are circulated and replicated within the niche to foster new innovations. State-owned research institutions such as RISE, Sverea IVF, and the independent research foundation MISTRA (see MLG) may have helped nurturing the niche by conducting and funding research on sustainable clothing materials. A group of actors in the Swedish outdoor industry, including Haglöfs, Tierra, Houdini, and Peak Performance, have formed an industry collaboration group known as the Breakfast Club, in which they discuss issues of sustainability in the industry. Although hard to tie directly to the case of Deterra, this initiative may have helped protect the niche by sharing knowledge and developing visions on how to make the clothing sector more sustainable.

The regime within which the niche is embedded constitutes the extensive set of producers and retailers that primarily use fossil fabrics to sell outdoor products on a global scale. These companies are usually closely associated, through ownership, production lines, or distribution, to big clothing brands like H&M and Zara. This regime is heavily dependent on the use of virgin plastics, which Tierra, being 100% bio-based, clearly challenge regime rules. Scaling of Deterra would entail either an uptake of bio-based fabrics into the regime's product lines, or the displacement of fossil fabrics in the regime.

The Deterra jacket was designed as a proof of concept, not necessarily to sell on the mass market. This is one reason for accepting the high costs involved with using bio-based materials. However, the signing of the Paris Agreement also played an important role. The PA was a landscape pressure that destabilised the clothing regime and created a window of opportunity for Tierra to justify cost-ineffective investments. Increasing general sustainability concerns have also put pressure on the regime. Although there are few regulations forcing regime actors to rethink, a sense of incoming regulations motivated action. Thus, *perceived* landscape pressures (Smith et al. 2005) have been shown to be crucial in initiating collaborative action within the industry.

We also see niche-regime interaction, which is, according to the MLP, deemed crucial in the scaling of innovation. The industry association Textile Exchange has created a working group to deal specifically with these issues, in which Tierra play a leading role along with regime actors such as H&M and Patagonia. Textile Exchange is thus a managerial actor, fostering interaction between niche and regime actors. However, no signs indicate that these activities have led to scaling to date.

Since work started on the jacket, bio-based synthetic fibres have become more commonplace both in the outdoor sector and in conventional clothing. These materials can now be found in everything from shoes to evening wear. Although more 100% bio-based clothing items have not been seen on the market, there has been some mainstreaming of the use of fossil-free component parts. However, this remains a miniscule niche in a global clothing market in which recycled polyester has become the primary 'renewable' fabric of choice.

6.2.2 Multi-Level Governance

At its core, the Deterra jacket is an experiment. It was made, not to sell at scale, but to answer the question: is it possible to produce a 100% fossil-free jacket? Fitting fossil-free materials to the strict

functional requirements of outdoor garments took the designers into uncharted waters. Zippers had to be replaced with buttons, for example, as only the later could be provided in bio-based materials. Furthermore, the process of choosing materials required time-consuming research into every prospective material's origin, production conditions, and social impact. This research is now are available to other producers. Thus, the project has developed new knowledge on bio-based materials ready to be diffused and used by other actors within the clothing sector.

The Sustainable Apparel Coalition (SAC) has developed a set of standardised supply chain measurement tools for the footwear, apparel, and textile industry, with the aim of standardising the process of improving sustainability. The membership of the coalition is vast and gathers actors across the entire value chain. However, the organisation's sustainability measure, the Higgs Index, is not evaluated by a third party, and could easily be manipulated. Rather than being intended for customers, it is designed to be an internal guide for companies. The global non-profit organisation Textile Exchange focuses on collecting and disseminating best practices regarding farming, materials, processing, traceability, and product end of life. They provide standards for evaluating sustainability claims about materials (e.g. recycled materials, organic cotton). Both initiatives exemplify how crucial intermediaries are, as they foster interaction and knowledge-sharing across the value chain and between niche and regime actors.

Compared to other emissions-intensive industries, clothing has been relatively unregulated. However, there have been governmental efforts to promote sustainable fashion. An inquiry into producer responsibility for textile waste is underway, and the Swedish government have launched a cooperative platform on sustainable textiles at the Borås School of Textiles, located in a city that has a long industrial history of textile manufacturing and has recently become a technologically advanced innovation cluster. The Swedish EPA have also hosted dialogues with civil society, industry, and academia on how to create a sustainable textile industry. The fabric manufacturer FOV, which made the fabric for the Deterra jacket, is based in Borås and is deeply connected to the local textile school. Additionally, the Swedish state-owned MISTRA funded a research program called Future Fashion, in order to "close the loops" in sustainable clothing manufacture and spark system transformation. The program was active until 2019, and involved partners from the industry (such as Kappahl, H&M, and Houdini) and from academia and research institutes.

In the case study we conducted we did not see any sign that these governmental initiatives have led to the scaling up of the innovation in question. However, such interventions may foster and nurture further experimenting on sustainable clothing. To further scale outdoor clothing niche innovations, government regulation is necessary. For instance, regulation of the price of plastic might help shift the demand for fossil-free materials and foster innovations in the development of such materials.

Although an experiment, Tierra does not fit closely the MLG narrative on innovation. There is no polycentric setting—it operates in a protected space—and it is detached from the urban. It is thus hard to fully understand the scaling dynamics of Deterra through the lens of MLG. However, this perspective is very useful in understanding how the initiative could be further fostered by governmental and non-state actors.

6.2.3 Material Politics

The clothing industry depends on large value chains, within which materials are sourced wherever the price is lowest, and vast demand is required in order for manufacturing to be economical. Thus

smaller companies such as Tierra are heavily constrained by the industry demands of larger clothing companies such as H&M and Patagonia. Looking at the value chain within the industry, there is a deeply entrenched oil dependence that is being perpetuated by the interests of these large, powerful companies. This dependence is sustained by oil subsidies and demand, since plastic production is a by-product of oil revenue.

The Deterra jacket in itself does not challenge these power structures, as it is possible to imagine the sector with all the same structures, but with fossil-based materials replacing the bio-based ones. However, it does challenge the traditional value chain, since taken-for-granted fossil materials are left out. Also, Tierra as a company is involved with creating networks such as the Breakfast Club and Textile Exchange, which further the goal of increasing the sustainability of the sector. Such networks might have a hard time disrupting power structures, but by coming together they can influence demand and push it away from fossil-based materials.

Outdoor clothing has strict requirements for material properties, given the harsh conditions it is used in. In the design of the Deterra jacket, fossil materials could not simply be translated to bio-based counterparts. Zippers needed to be replaced with buttons and stoppers with knots. This shows the socio-materialities at work in the bringing into being of the Deterra jacket.

The garment industry has been politicised to some extent: sweat-shops, working conditions in cotton fields, a general reaction against over-consumption and fast fashion. What has not been politicised is the fossil-fuel origins of the fabric from which most of our clothes are made. Plastics themselves have been questioned, but that critique has primarily focused on packaging and downstream plastics, especially marine litter. When fabrics are criticised, it is typically due to their shredding of microplastics, not their feedstock. By advertising the jacket as ‘fossil-free’ and ‘bio-based’, Tierra makes the oil in the clothing industry visible, along with its consequences, not just downstream but upstream. Furthermore, the Deterra jacket materialises in miniature a vision of a decarbonised clothing industry. However, we need to keep in mind that as is seen in the case of zero-waste supermarkets, less demand for plastics does not necessary affect demand on fossil fuel oil.

6.2.4 Cultural Politics

A dominant narrative in the clothing sector is one of so-called “fast fashion”, including trends that are rapidly invented and discarded to sustain clothing mass consumption. However, increased scrutiny has forced the sector to move toward sustainable fashion. Increasingly we see incumbents such as H&M and Patagonia making sustainable and conscious collections from either partly recycled or 100% recycled plastics. Such narratives fit well into a circular economy imaginary, within which pointing to closing material loops is seen as the one-stop-shop solution to sustainability problems. Since it does not question the political economic structures within which it is embedded, it allows producers to maintain the fast fashion narrative and business model, only replacing virgin plastics with recycled ones. (It bears noting that in reality using recycled plastics will not create a closed materials loop—due to the limited recyclability of the material, further use of virgin plastics will always be necessary.) This explains why circular-economy-compatible narratives building on recycled plastics have rescaled: they make the clothing sector appear sustainable, but enable consumption patterns and economic models to remain the same.

Tierra, on the other hand, represents another imaginary of clothing production, one within which we move away from fossil-based plastics towards a bio economy. What's interesting is that we may imagine two different pathways to removing fossil-based plastics in clothing. One is a "sustainable lifestyle" climate imaginary (Levy & Spicer 2013), within which simpler lifestyles and restructuring of the economic system are promoted. We can envision long-lasting bio-based clothing enabling reduced consumption and the remaking of economic market logics. The other possible pathway is a "techno-market" climate imaginary (Levy & Spicer 2013), where biomass materials simply replace virgin fossil, but the production and the market remains the same. Of these two, the techno-market has the biggest potential to become a dominant narrative as it more closely aligned with the wider value regime of the garment industry. However, as the "sustainable lifestyle" imaginary is in close alignment with established cultural values within the outdoor clothing—long-lasting products, purity (no oil), leather care, and so on—this imaginary is more feasible to rescale in that specific part of the market. What both imaginaries will have to face is the challenging discourse on food insecurity, as bio-based materials could be viewed as a threat to food supply and food security.

6.3 Voluntary Certification Schemes (BREEAM)

Steel production currently accounts for approximately 7% of global anthropogenic CO_2 emissions, a figure which is expected to increase to 10% by 2050 (IEA 2017). The construction industry is one of the main users of steel, accounting for more than 50% of steel consumption, of which almost two thirds is used for buildings (D´Amico & Pomponi 2018; WSA 2017; Moynihan & Allwood 2012). Steel-as-buildings accounts for approximately 2.5% of global CO_2 emissions and is thus of great significance in the project of reducing emissions globally. Of special interest are embodied emissions (emissions involved in acquiring raw materials, processing, transporting materials etc.), which are estimated to make up approximately 30% of all emissions from buildings (UKGBC 2017). Structural steel, specifically, can contribute over 80% of a building's total embodied emissions, but could potentially be reduced to 20% (Gan et al. 2017). This illustrates the relevance of cutting embodied emissions in steel construction.

In response to increasing demands for sustainable buildings, an abundance of environmental assessment and voluntary green certification schemes have been created in the construction industry to identify best practices in green building construction. Such voluntary schemes set sustainability standards that go beyond the stipulations of mandatory building codes and regulations (CBI, n.d.) and thus intend to distinguish between "shades of green".

The first certificate of its kind was the UK Building Research Establishment Environmental Assessment Method (BREEAM), established in 1990 by the UK Building Research Establishment (BRE). Shortly afterwards, the UK government adopted BREEAM as a measure of best practice in environmental design and management. This was followed by a variety of similar assessments schemes (e.g. LEED in the US, Green Star in Australia) which are now used all over the world. BREEAM is still a leading voluntary sustainability assessment for the built environment and has been used to certify over 590 000 assessments of buildings across the building life circle, and is applied in over 78 countries. Its latest assessment, the BREEAM New Construction certification scheme 2018 (hereafter referred to as BREEAM NC 2018), is a voluntary scheme that especially assesses the environmental impact of non-residential buildings. While many environmental assessment schemes have focused on operational emissions and impact, BREEAM NC 2018 includes more extensive assessments of embedded emissions. However, as the scheme in its current form came into

operation only in 2018, only the most preliminary impact assessment was possible in our 2019 case study.

7.3.1 Multi-Level Perspective

BRE was, at the first assessment scheme's inception, a governmental research body, and thus an incumbent actor. As such it is quite an unusual case to which to apply the MLP model, as it is hard to conceptualise a pre-existing niche in which BREEAM was born. Furthermore, while MLP usually assesses technological innovations, BREEAM NC 2018 is primarily social and procedural in its nature, emphasising change in assessment and design decision-making.

The regime, in which the innovation is embedded, consists of different actors on the production side: architects, developers, contractors, and suppliers, among others. Sustainable construction has been on the agenda for some time within the sector. There has been a big recent drive toward net-zero carbon building from the industry itself, in response to a perceived failure of national policy. Around 2006 a number of policies were introduced around sustainable building, such as the Code for Sustainability homes and Zero Homes regulations. These, however, were withdrawn due to the financial crisis. In this light, BREEAM appears more a means to implement the regime's articulated sustainability ambitions than a challenge to its set of rules.

The UK government adopted BREEAM as a measure of best practice in environmental design and management shortly after its introduction. It is notable that the voluntary schemes following BREEAM have generally been introduced at national level in a similar fashion, some as the national benchmark for green building practice (e.g. LEED in the US). This illustrates the importance of governmental intermediary action in the uptake of such schemes. It is also an indication of the mainstreaming of certifications in the regime.

We can identify scaling up of the innovation by the growing number of certification schemes in different countries and the growing number of certified buildings. This bears similarities to replication and growing, however it is difficult to conceptualise a niche within which such scaling practices would originate. Although the scheme has been mainstreamed, a full incorporation of the schemes would mean standardising them within the construction sector. The varied methodologies for evaluation and assessments (e.g. LCAs, EPDs) within the regime illustrate that such a comprehensive scaling up has not taken place.

It is possible to get an overview of how BREEAM as an innovation has diffused into the regime with the help of the MLP. However, the theory turns out to be unfit for capturing the details of this process, chiefly because it is not possible to identify the protected niche from which the innovation should have originated. This raises questions as to whether the identified spread of the innovation could be considered scaling or not, when it goes against the fairly narrow scaling dynamics the theory develops.

7.3.2 Multi-Level Governance

Governmental bodies at various levels have been shown to be important in fostering the innovations of BREEAM. The UK government adopting BREEAM as best practice, and their approval of BREEAM certification bodies was crucial to the significant scaling of the innovation. This is also the case with various other voluntarily evaluation schemes, such as LEED in the US, most of which were applied at national level. Although hard to link directly to the scaling of BREEAM, we see different efforts made by subnational actors to support the case for net-zero carbon ambitions within the construction

sector. For instance, the London Mayor wants the city to become net-zero carbon by 2050. Part of the draft plan to achieve this is a set of guidelines for sustainable construction. We also see efforts made by such actors directly leading to the uptake of BREEAM. A 2012 study found the largest driver for using BREEAM is planning requirements. Such requirements are part of the local development frameworks in more than half of local authorities in England. Although it somewhat goes against the concept of the evolutions being voluntary, this certainly leads to the scaling of BREEAM's practices. Where national-level policies on sustainable building have failed, the necessary action is increasingly taking place at the subnational level.

The MLG allows us to identify scaling in the case of BREEAM by looking at the growing number of certifications schemes introduced after the first BREEAM scheme. However, instead of being replicated in a protected and isolated space (as explained in MLP), the schemes are diffused into new contexts, leading to different versions of the standards. The certifications vary when it comes to theme (e.g. environmental or health assessment) and also methodology, leading to different results. Furthermore, the evaluations are locally adapted. For instance, BREEAM have national versions for each of the countries outside the UK in which they operate.

Although there are stipulations that BREEAM will continue to spread, the mechanism struggles with credibility. This is due to severe uncertainty as to how sustainability is accounted for and how credits are received, leading to overblown claims for green buildings. As stated by one interviewee in the case study we conducted, for those who aim at making building 'truly' sustainable, BREEAM may prevent rather than incentivise this effort. There are also severe doubts in the measurement methods used in the LCAs and EDPs on which BREEAM builds, which may pose a significant obstacle to further scaling of the schemes.

There is evidence of ongoing experimentation with the schemes, with efforts to identify best practices and reshape and improve the BREEAM scheme occurring every four years (although information on *how* criteria are updated has been hard to find). Despite (or because of) credibility issues with measurement methodology, the schemes encourage a process of trial and error that results in increased learning regarding LCA and EPD methodology in construction. Methodologies and data have improved remarkably of late, and although it is hard to attribute this to BREEAM, these changes are certainly important in the process of identifying best practices.

Intermediary action is crucial in the spread of the schemes, exemplified in government action to adopt schemes at national levels (Kivima et al. 2018). Looking at the involvement of local authorities, this could be seen as intermediary action between BREEAM and contractors. We can also understand the assessment schemes themselves as intermediaries, since they foster greater coordination between different actors across the value chain, which may lead to scaling of decarbonisation practices such as recycling steel, lightweight (steel) construction, or the uptake of sustainable and innovative niche materials.

6.3.3 Material Politics

Looking at the current power configurations within the UK, there is a general tendency to lean on the market for regulation. As BREEAM is a voluntary mechanism, it reaffirms such power structures rather than questioning them. It is deemed crucial that schemes 'move with the market'; if they are too far from the market they will simply not be used. The schemes have helped put sustainability on the agenda within construction and thus make decarbonisation visible. They also have the potential

to politicise the issue of emissions in construction, which is of especial importance for widely overlooked *embedded* emissions (included in BREEAM NC 2018). However, it is hard to claim that BREEAM disrupts power structures, or even seeks to do so. In this sense, it cannot be said to have led to rescaling.

The value chain of construction has a constellation of a variety of actors (architects, developers, owners, tenants, contractors, and suppliers). BREEAM itself does not lead to decarbonisation, but its assessment encourages decarbonisation decision-making across the construction phase. It encourages less consumption of steel (e.g. by material substitution or design optimisation) and thus affects the steel value chain downstream. Although the construction sector has the necessary competences to decarbonise, there seems to be a major issue with implementation. BREEAM may help incentive such implementation, as it can foster coordination across the value chain. However, since there is neither control nor follow up on the actual choice of material—and hence actual impact—there is a tendency to measure intent rather than effect. Unless this is adjusted, the actual impact on the value chain may be low.

6.3.4 Cultural Politics

Following increased criticism of the sustainability of the construction sector, a net-zero carbon narrative has arisen which, at least in the UK, is driven by the industry itself. For instance, it has been promoted by the London Energy Transformation initiative (a network consisting of over 250 built environment professionals), and through the UK Green Building Council's Advancing Net Zero Carbon Programme. Although an environmental rather than a low-carbon sustainability assessment, BREEAM mostly aligns with the net-zero carbon narrative. BREEAM could also be seen to be aligned to the circular economy, which is gaining increasing traction. This narrative is especially prominent at the EU level, with ecodesign in regulation and circularity in buildings being heavily promoted.

Looking at other certification schemes beyond BREEAM, we see how "sustainability" is deeply contested, and does not necessarily align with either net-zero carbon or circular economy thinking. Some certification schemes are increasingly situated within a health narrative, rather than focusing on environmental impact. The timber industry seeks to couple the health discourse with "wellbeing" and "naturalness", leading to the importance of buildings being (perceived as) "natural". Such imaginaries lead to contestation of materials based on their "naturalness" rather than their low-carbon credentials. For instance, buildings made by steel are perceived as "unnatural", making them undesirable according to a "health and wellbeing" narrative, even if they are built with less carbon-intensive steel. Thus, instead of use of less carbon-intensive steel, other materials such as timber become desirable.

The health discourse is also closely coupled with "safety". Timber, specifically cross-laminated timber, has been promoted as a low-carbon material, but concerns linger about its possible combustibility. These fears date back at least to the Great Fire of London, but the Grenfell blaze of 2017 has given fresh urgency to public fears about building safety. The fire led to a ban on combustible cladding for residential buildings over 18 meters, but studies of the fire have found that many experts had previously tried to raise the alarm over the fire risk posed by the cladding on Grenfell Tower, and many hundreds of other residential buildings across the UK have been found to have the same hazardous cladding in place. These findings have caused a crisis of public trust in the building industry and its regulators that will take a long time to repair. Although the cladding that fueled the Grenfell blaze was not timber but plastic insulation with an aluminium coating, public

fears around any building material perceived as flammable remain high. The actual fire hazard posed by timber buildings is a matter of debate, but the widespread perception that it is unsafe has certainly hindered its potential to break through as a low-carbon material. The re-use of steel has similarly been contested on safety grounds. With significantly lower CO_2 emissions than new steel, re-used steel has great potential for decarbonising the building industry. However, as mentioned by one interviewee, re-used steel lacks CE markings. It is clear, then, that concerns about health and safety are not always easy to square with the quest for less carbon-intensive materials.

Many certifications emphasise and assess health rather than environmental impact (e.g. the WELL standard and certification scheme), which seems to indicate a shift in the meaning of "sustainability". BREEAM has multiple sustainability dimensions but its main focus is on the environmental sustainability of building, rather than specifically being a low-carbon certification scheme. The contestation of the meaning and key elements of sustainability may influence what is included and what is assessed within the schemes in future. This illustrates how the shaping of voluntarily schemes is a political process, rather than a technical issue: it results from contestations of, and struggles for, meaning. It is probable that a rescaling of a "health & wellbeing" perception of sustainability could lead to the obscuring of environmental and climate impact in construction, or at least to there being less of a focus on environmental impact and low-carbon construction.

6.4 HYBRIT

The steel industry is the single biggest emitter of greenhouse gases across all of industry, mainly due to the production of primary steel, for which coke in particular, but also natural gas, coal, and sometimes oil, are used (D2.2). In Sweden, steelmaking accounted for 11% of national emissions in 2016. Innovation in the steel sector in the past has focused on productivity gains on energy use and material efficiency, but in recent years research on decarbonising primary steel production has emerged.

HYBRIT, acronym for Hydrogen Breakthrough Ironmaking Technology, is a development project with the aim of implementing fossil-free primary steelmaking through direct reduction of iron ore. It uses hydrogen as reductant (H-DR) and the fossil-free mining and pelletisation of iron ore. The project consists of two parts: Hybrit Development AB, which is a joint venture by Swedish companies SSAB (a steel company), LKAB (a state-owned mining company), and Vattenfall (a state-owned energy company). HYBRIT RP1 is a research project that includes academia, research institutes, and industry, with financial support from the Swedish Energy Agency. The initiative was publicly announced in April 2016. The pilot phase will last from 2018 to 2024, which includes having the pilot plant in Luleå (north Sweden) built by 2020. The demonstration phase will last from 2025 to 2030, leading to the production and commercialisation of fossil-free steel by 2030.

6.4.1 Multi-Level Perspective

HYBRIT is a demonstration and research project. Since it was initiated by regime actors (SSAB, LKAB, Vattenfall), it does not fulfil the MLP conditions of being a niche. Still, HYBRIT is being developed in a protected space: it is financially protected as a joint venture heavily supported by public funds. Additionally, two of the three companies owning the joint venture are state-owned.

The idea of hydrogen steelmaking existed before HYBRIT, but HYBRIT was first to take the innovation on from the R&D stage and show that it is possible to do at a larger scale. Furthermore, all the

energy consumed in setting up the scheme is envisioned to be fossil-free, which has not been tried before. Ambitious climate targets, such as the Paris Agreement and Sweden's goal of having net-zero emissions by 2045, were drivers for the initiation of the HYBRIT project. The Paris Agreement helped destabilise the energy regime, forcing incumbent actors to respond. We can understand this pressure as having created a window of opportunity; however, these usually describe how niche innovations break through into the regime. As HYBRIT operates within a niche created by incumbents, it is questionable whether 'window of opportunity' describes the dynamics of the case.

The goal of HYBRIT Development AB and HYBRIT RP1 is to scale into a demo plant, which is where most of the public funding for the project is directed. From here, scaling would be achieved when the steel is commercialised and sold, thus being mainstreamed into the market. The idea of hydrogen steelmaking has already scaled by spreading to regime actors globally, but the innovation is not yet a sociotechnical practice that can be scaled. HYBRIT may encounter obstacles when entering the global market, as it will probably be a lot more expensive. However, most Swedish steel companies already compete on the global steel market by developing market niches (Jernkontoret 2019). There is thus a slight, but still highly uncertain, possibility that HYBRIT may account for a more expensive but sustainable market niche product.

6.4.2 Multi-Level Governance

The MLG perspective emphasises the role of policy and public actors in upscaling. Political support is deemed crucial for HYBRIT to succeed, both through setting ambitious climate targets (see MLP) and through financial support from the Swedish Energy Agency. The European Commission released their Industry Strategy in March 2020, which included a "Clean Hydrogen Alliance". Although it might not be completely clear how this will affect HYBRIT, this suggests that there is high-level political support for clean hydrogen technology as a means to move towards a fossil-free society.

Jernkontoret, the Swedish steel producers' association, was an important intermediary at an early stage in establishing a sustainability vision for the Swedish steel industry. This was titled "Steel shapes a better future". The early work they put in with politicians paved the way for the development of HYBRIT. The Swedish Energy Agency has, besides funding, been an important networking actor, allowing actors to come together. Intermediary technology providers also play an important role in providing knowledge, since most of the HYBRIT technology is bought from external actors.

Since HYBRIT is still at the pilot project stage, it is not yet possible to scale. However, as HYBRIT has come to symbolise a solution for the heavily emitting steel industry, diffusion to other sites can be expected if the demo project succeeds. Sweden offers uniquely hospitable conditions for this project, given its good access to fossil-free electricity. As such, replication might be hindered in other countries that don't have this condition. Since fossil-free steel risks being a lot more expensive than fossil steel, and thus has a problem with competing on the market, it might be necessary to combine with governmental regulatory measures such as fossil fuel taxes. Such initiatives may help HYBRIT steel to mainstream into the market.

6.4.3 Material politics

The global steel market is characterised by large fixed costs and high barriers of entry. Unsurprisingly, the market consists of large companies, which means power is fairly centralised (D 2.2). The case of HYBRIT does not challenge such systems of power, as the project has been

developed and introduced by established actors. Instead we see incumbent actors reinventing themselves and using HYBRIT to reconfirm their agency and position in the future of the industry. HYBRIT is thus an example of an industry-driven low-carbon innovation that can be instated without shifting power relations. However, we might see some impacts on the value chain. As fossil energy sources are intended to be cut out of the steel production process, to be replaced with electricity generated in Sweden, HYBRIT could signify a shift to more local value chains. Furthermore, it could lead to more decentralised steel making at smaller scales, since shaft furnaces for hydrogen steel making are smaller in scale. It could signify major effects on the coke and coal industry, since today about 13% of coke and coal goes to the steel industry.

A challenge for HYBRIT is to secure access to fossil-free energy, which is one of the innovative parts of the project. The transition is estimated to require 10% of Sweden's current electricity production(Svt, 2019). While the supply of fossil free electricity is not estimated to be an issue—the estimated future capacity of wind power is critical here (see Svensk Vindenergi 2020)—, the distribution thereof is. Expanding the grid is deemed necessary to satisfy the demand, and doing so is (in Sweden) encountered by obstacles in lengthy permissions processes.

HYBRIT, whose goal is to have fossil-free steel production by 2035, is a central part of SSAB reaching its goal of becoming 100 % fossil free by 2045. As a part of reducing their GHG emissions, SSAB plans to replace their two active blast furnaces in Oxelösund with an arc furnace. The long-term goal is use either electricity or biofuel at the production site. (SSAB, n.d; Hybrit Development AB 2020) However, as transition fuel, Oxelösund will use Liquid Natural Gas (LNG). Investments are now being made by SSAB and the municipality of Oxelösund to rebuild the harbour to include an LNG terminal. Although it is possible to replace natural gas with renewable energy at a later stage, building the LNG-terminal might risk create incentives to keep with natural gas, as the terminal provides a stable supply thereof. Although the LNG terminal is not a part of the HYBRIT project–LNG will not be used in the HYBRIT steelmaking–it is a part of SSAB, and may affect their possibility to reach their climate goal. Thus, establishing the terminal might also affect HYBRIT's long-term prospect of making Swedish steelmaking 100 % fossil-free, however if and how remains to be seen.

A key element of HYBRIT is providing a socio-material space to make decarbonisation legible and visible. By building a demonstration plant, a vision is created of how Swedish steelmaking may look at large scale.

6.4.4 Cultural Politics

According to the current dominant narrative, steel is seen as a hard-to-abate sector because it is responsible for generating a large amount of GHG emissions. SSAB has been identified as a top emitter for many years, accounting for 10% of Sweden's emissions, and is usually regarded as a "climate villain". Thus, rescaling the narrative and story of the steel industry and some of its key actors is one of the merits of HYBRIT. HYBRIT is now part of Sweden's story for going fossil-free, building on the government aim of net-zero emissions by 2045 and on Jernkontoret's vision, 'Steel shapes a better future'. Communication of HYBRIT is aligned with these visions, but has 'fossil-free' as their key word instead of 'zero emissions'. Core to the narrative on HYBRIT is that this is a 'breakthrough' technology which will address the problem 'at its root', rejecting business-as-usual-narratives.

Just a few years ago, hydrogen steelmaking was not considered a possibility for decarbonising the steel industry, and was barely discussed. Instead, Carbon Capture and Storage (CCS) technology was seen as the way to go to limit the steel industry's emissions. Since HYBRIT was launched in 2016, actors globally are picking up the narrative of hydrogen steelmaking, among them the World Steel Association, Eurofer, and a number of researchers and companies. Much of the steel industry outside Sweden has distanced itself from the Swedish steel industry because other countries do not have the same preconditions (government support, lower electricity prices, potential for fossil-free electricity, etc.). The international steel industry now talking about hydrogen steelmaking indicates discursive alignment.

As an imaginary, HYBRIT signifies a completely different way of producing steel. However, since it leans toward a tech-fix/technological replacement, it does not deeply question current economic structures, nor compromise the pursuit of infinite growth. Thus, HYBRIT fits the description of a Keynesian techno-market imaginary (Levy & Spicer 2013), within which the state takes a crucial role in supporting clean energy to decouple economic growth from GHG emissions. This might explain the significant rescaling and the broad appeal of the HYBRIT narrative.

6.5 Biofuelled lime kiln

The intervention consists of an investment made by SCA (a Swedish timber, pulp, and paper manufacturer) to replace two oil-fired lime kilns with wood-powder-fired lime kilns at the kraft pulp mill in Östrand. The project was announced in 2009 and went into operation in 2011. Andritz, an Austrian plant engineering group, supplied the equipment. The lime kiln is primarily fuelled by wood powder from ground pellets, supplied by SCA's wood pellet factory only 40km away.

The Swedish pulp and paper industry has undergone a long transition into becoming fossil free and self-sufficient, beginning in the 80s and 90s following the oil crisis in 1973. Going from oil to biofuelled lime kilns is one of the final steps for the industry in reaching this goal of self-sufficiency and breaking fossil dependency.

6.5.1 Multi-Level Perspective

Lime kilns partly fuelled by wood powder had been researched for many years prior, but initiating a 100% wood-powder-fired kiln was made possible with SCA's investment in 2009. The high oil price at the time was a landscape factor and a driver.

Since the biofuelled lime kiln is a technical innovation at the final stage of the transition of the pulp and paper industry, initiated and developed by regime actors, it doesn't fit as a sociotechnical niche according to the MLP. It came at a time when the pulp and paper regime had already united around a vision of being self-sufficient and fossil-free, and therefore is more the result of regime change than a cause of that change. Furthermore, it was developed and introduced by incumbents.

Still, we can look to the innovation being scaled globally through market uptake. The innovation was developed by the incumbent actors Andritz and Valmet, two of the biggest actors in supplying systems for the pulp and paper industry. The innovation builds on previous skills in SCA (e.g. in producing and handling pellets) and in Andritz and Valmet, but also required new skills to be developed. The technology is now being offered by these two suppliers on the market. However, rather than being a niche taken up on the market, the new technology was directly introduced by incumbents.

There are a few issues when applying the MLP to the case of the biofuelled lime kiln. First, and as identified in many previous cases, it is difficult to identify a niche because the innovation is introduced by incumbents. Second, the case illustrates issues of interpretability regarding one of the core concepts of the theory, 'regime'. If we operationalise the Swedish pulp and paper industry as the regime, we see how a complete shift has taken place and the biofuelled lime kiln becomes the last fix. However, seeing the regime as the global pulp and paper industry, such a shift is not evident. Instead, the Swedish industry seems to be a small niche challenging the wider regime. Difficulties with how apply these concepts thus lead to issues with identifying transformations, which is what the theory sets out to do.

6.5.2 Multi-Level Governance

In this case study, no specific support or policies were identified as crucial; neither were intermediaries identified. Scaling of the biofuelled lime kiln is thus mainly determined by companies being willing to invest in the technology.

From a wider perspective, the pulp and paper industry is one of Sweden's most important export industries, and has received governmental support through the years for working on, for instance, energy efficiency. Both the Swedish and Finnish governments also actively support the idea of a sustainable, bio-based, and almost fossil-free industry (see Cultural Perspective). There are also examples of regional initiatives supporting innovations, such as Paper Province around Karlstad and Processum in Örnsköldsvik, but none to mention in this case.

Apart from the vertical scaling identified under MLP, we can identify horizontal replication of the innovation in kraft pulp mills at other sites. The innovation, starting at Östrand mill, has been replicated by SCA at their Munksund pulp mill and by Södra (a Swedish forest owner association and pulp producer) in their Värö pulp mill, both in 2012. SCA has planned an upgrade of their pulp mill in Obbola for 2021 (Pulpapernews 2019).

The innovation in this project built on previous knowledge. However, although Andritz had good theoretical knowledge of wood burners, they had no previous practical experience. Thus, an effect of the innovation was learning and developing new knowledge. This is now a technology which might be used to scale the innovation further.

6.5.3 Material politics

Looking at Material Politics, we can consider how and whether the biofuelled lime kiln has led to rescaling of socio-material relations and power structures in the paper and pulp industry. Since the transition of the pulp and paper industry began in the 80s and 90s, there has been a power shift away from the oil industry toward self-sufficiency. Innovating and switching to biofuelled lime kilns has therefore been an easy step to take with few disruptive effects, being initiated by industry actors who possess the agency. Thus, there are no major shifts in power structures or in value chains.

Socio-materialities as well as geographical aspects have played a major part when shifting from oil-fired to wood-powder-fuelled lime kilns, and more local supply chains have been established. Östrand, Munksund and Värö, where this technology has been installed, fuel their lime kilns with ground pellets, and all have access to pellet or sawdust production nearby. At Östrand the logistics for transporting pellets were already in place, with trucks delivering sawdust to the pellet factory from a sawmill near Östrand. Considering socio-material relations and power structures in the Material Politics perspective, it can be seen that switching to a wood-powder-fuelled lime kiln

provided a stable demand for wood pellets from the wood pellet factory and created new supply chains between sister companies in the SCA group.

At the moment there appears to be greater interest in biogas-fired lime kilns that produce biogas via thermal gasification, because these can often make use of by-products of kraft pulp production, such as bark. Gasification is preferred for pulp mills that aren't in proximity to a sawmill or pellets factory, since making wood powder is an energy-intensive process in itself.

6.5.4 Cultural Politics

The pulp and paper industry has worked towards rescaling their narrative into being a sustainable and almost fossil-free industry over a long time. This narrative has actively been promoted both by individual firms and the forestry industry, as well as by the Swedish and Finnish national governments. Additionally, they have promoted themselves as being core to the bioeconomy through regenerative forestry, paper as a natural material, environmentally friendly bleaching, pulp mills as bioenergy providers, and so on. SCA, who installed the first biofuelled lime kiln, has a corporate strategy to maintain and strengthen their green profile and be an environmental leader in the pulp and paper industry.

The general idea of pulp mills and the Swedish forest industry as sustainable and fossil-free is well accepted among the public, so the rescaling of the narrative has been successful. The lime kiln is more or less the final fix to reach fossil independence for most pulp mills, and as such is in alignment with the dominant narrative rather than challenging it.

6.6 DuraSense

Almost all plastics in current use are based on fossil resources, and it is estimated that 4–8% of European demand for petroleum goes into the production of plastics. Innovative materials that are able to reduce dependency on fossil resources and yet comply with the high demand for advanced products are thus likely to be important in reducing the carbon footprint of society in future. For plastics, different pathways that address this challenge have been identified: reduced use of plastics, bio-based plastics, recycled plastics, biodegradable plastics, and fewer types of plastics (Nielsen et al. 2018). DuraSense, developed by Stora Enso (a Finnish-Swedish manufacturer of pulp, paper, and other forest products), is an innovation that partially follows the bioplastics pathway, although it is not in itself a bioplastic, but a biocomposite: it aims to substitute a part of the plastic material with a bio-based one.

Composite materials are well known and often consist of a stiff, strong material (wood fibres) embedded in a matrix of a continuous, softer material (plastic). This gives the new material properties that cannot be achieved with any of the individual components. Biocomposites are composite materials comprising one or more phase(s) derived from a biological origin (Fowler et al. 2006). Biocomposites are already used in a range of applications, such as automobile panels and upholstery, noise insulating panels, and indoor furniture (La Mantia & Morreale 2011).

The global demand for wood-plastic composites was estimated to be around 900 000 tonnes per annum in 2008, with around 70% of the demand located in North America and 20% in Europe. The main demand came from decking. An annual demand growth of more than 20% was seen in the early 2000s (Markarian 2008). This growth was accompanied by increased activity in patenting in the area post 2006 (Gardner et al. 2015), indicating that demand growth most likely incentivised innovation. Recent estimates for Europe are that more than 30 compounders are active in the area

of biocomposites, who together produced more than 100 000 tonnes in 2018 (Holmes 2019). How should we assess the potential for this innovation to scale further?

6.6.1 Multi-Level Perspective

According to the niche-regime dynamics of the MLP, biocomposites such as DuraSense exist in a niche of the broader petroplastic (that is, plastic from fossil fuel feedstock) regime. Stora Enso, as a manufacturer of wood and biomass products, is not directly in competition with the petrochemical companies and plastic converters who work with fossil feedstock in the production of polymers and plastic products. They exist in different value chains (biomass versus fossil) but offer a range of products that partially overlap. Biocomposites are one such example, as they are able to replace conventional plastics in applications such as furniture, packaging, toys, storage, and logistics. Stora Enso is therefore a niche actor in the petrochemical regime, seeking to take market share from conventional plastic companies in the areas where biocomposites can compete.

They may be helped in this endeavour by developments in the broader regime and landscape levels of the MLP. Fossil resource dependency and use is increasingly becoming politicised and linked to decarbonisation and climate change efforts. Though the focus has previously been on fossil fuels, it is increasingly extending to fossil materials. There is increasing interest in green materials. Coupled with mounting pressure on Stora Enso from decreased demand for traditional paper products, biocomposites are an innovation that might help them diversify and exploit the window of opportunity.

An MLP analysis would place most emphasis on the actions available to Stora Enso in order to scale up their innovation. They are currently trying to establish biocomposites in different plastic product categories, as mentioned above. To increase production, they are currently investing 12 million EUR in a production facility and 7 million EUR in a biocomposite competence centre. They are hiring new research engineers with experience in the pulp and paper industry. Collaboration and networking with other actors in the value chain is also important. To that end, Stora Enso has established contacts with downstream actors such as household plastic products group Orthex and local SMEs that possess expertise in compounding, injection moulding, and plastic converting. Some of these collaborations and partnership may take the form of innovation clusters, as in Hyltebruk, Tingsryd, and Gnosjö, where there are Orthex production facilities and a high density of small manufacturing SMEs.

6.6.2 Multi-Level Governance

The MLG perspective emphasises the role of policy actors in facilitating innovative activities and supporting their upscaling. According to our analysis, policy actors at any level are not currently playing any significant role in the innovation dynamics of biocomposites. The initiative is still fairly new for Stora Enso, and the business case for this kind of materials and their applications is still being demonstrated. As such, the scaling of biocomposites currently is very much determined by the level of private business investment and the market demand for and performance of the products. According to interviews, existing policy packages do not directly support biocomposites, and neither is there government support available.

Having said that, there is, especially in Sweden and Finland, increasing interest in promoting the idea of the bioeconomy. This is also supported at the EU level, with high-level policy discussion on the bioeconomy dating back at least twenty years. The exact shape of the bioeconomy and the role of

biocomposites therein are still open questions, however. An MLG perspective on the potential for scaling biocomposites might bring up the possibility of running policy experimentation with supporting the establishment and operation of innovation clusters that may drive further knowledge sharing and interaction on biocomposites. These kinds of experiments could feed into higher-level policy discussions about the bioeconomy in general.

6.6.3 Material Politics

The material politics perspective focuses on the implications of shifting from petroleum and fossil-based materials to bio-based, renewable wood, and biomass. This would entail a massive rescaling of resource extraction and production networks. Bio-based plastics still make up a very small percentage of total plastic production, and it is difficult to see how any rapid shift from petroleum infrastructure to biomass infrastructure would be feasible in the short run, especially taking into consideration the impact on land use that a rapid demand for biomass would entail. Biocomposites do not seek to completely replace plastic production, but are currently targeting innovative use cases where their material properties endow them with unique characteristics that are difficult to replicate with other materials. Because Stora Enso is also located in a different value chain than fossil plastic companies, scaling of biocomposites would in all likelihood not entail large-scale disruptions to petrochemical infrastructure.

However, depending on how successful biocomposites become and how widespread their possible applications may be, it is possible that a reorganisation of scalar relations between users and producers of materials takes place. An emphasis on local materials made from renewable resources will almost certainly become more pressing in light of global environmental and climate breakdown. The idea of materials made from fossil sources from distant parts of the globe may encounter mounting resistance. Under such a scenario, plastic converting companies in Europe will be pressured to build relationships based on trust and proximity to local, renewable feedstock suppliers rather than rely on global markets for plastic pellets.

Questions remain as to how plastics companies much larger and more powerful than Stora Enso would respond to such developments. There are ample opportunities to contest bio-based innovation through recycling. Demand for more biocomposites depends both on their sustainability credentials becoming more sufficiently established (an open question, in comparison to recycling of existing plastic material), as well as their carbon reduction properties being made legible in the material and products, for example through labelling or certification.

6.6.4 Cultural Politics

The growing politicisation of plastics and the imagined place of plastics in society are issues of interest to the cultural politics perspective. Attention to the problematic uses and properties of plastics are helpful for spurring support for initiatives such as biocomposites. However, the political debate around plastics can also be criticised for drawing attention to solutions, such as banning plastic straws, cup lids, and cotton buds, that only marginally address sustainability problems. Other parts of the debate, especially relating to the circular economy, are very focused on packaging and recycling, where biocomposites or Stora Enso are not likely to play any significant role.

DuraSense is promoted to potential customers, partners, and other stakeholders with a strong emphasis on the material's low-carbon qualities. This aligns it with broader visions about the need to decarbonise society, as presented in climate imaginaries of the bioeconomy. As such, a cultural

politics perspective pits the climate imaginaries of the bioeconomy and the circular economy against each other in the case of biocomposites. Progress towards one may come at the cost of progress to the other, and vice versa. For example, it may be difficult to recycle bio-based plastics and biocomposites, and conversely, a growing market for recycled plastic content may crowd out biocomposites. However, they may be compatible with each other in the more distant future.

According to cultural politics, the power of one imaginary vis-à-vis another depends on how these are situated in discourses, and how both powerful and everyday actors connect to them. The characterisation of plastics as a problematic material in the eyes of many citizens may afford an opportunity to reshape our cultural relationship to material use in general, but it is unclear whether turning forests into materials is going to sit much better with the sentiments of a public that is becoming climate hyper-aware. As biocomposites are such novel entities, cultural relationships are still in the process of being formed. Cultural politics directs our attention to the importance of following the emerging sentiments and desires that citizens will attach to green materials, as this sets important boundaries within which the innovation will be forced to operate.

6.7 Oatly

The negative environmental impact of livestock farming has been increasingly understood and documented during the past two decades, leading to a questioning of the dairy industry. According to oatly (2019), livestock industries represents 14.5% of all anthropogenic GHG emissions. Although GHG emissions per gallon of milk have fallen due to increased productivity, dairy emissions still increased by 18% between 2005 and 2015 (FAO & GDP 2019). A recent publication by the RISE Foundation stated that livestock in EU member states has to be reduced by 74% by 2050 to meet climate mitigation goals (Buckwell, et al. 2018).

One way to reduce GHG emissions is to substitute dairy products with plant-based counterparts. The Swedish food brand Oatly produces oat-based dairy analogues for an international market. Through a patented enzyme process, they manufacture an oat base which is then processed into a diverse set of products (milks, yoghurts, cream, etc.). The innovation came about in the early 90s, but it was not until 2012 that Oatly really took off.

6.7.1 Multi-Level Perspective

Oatly's innovation originally started in a niche of milk alternatives for those who could not consume cow's milk. The initial experimentation was funded by the Swedish Grain Association, who needed to come up with an oat milk to make use of their non-exportable oats. Along with the Swedish Grain Association, the niche was shielded in its early innovation phase (Smith & Raven 2012) by LU research on lactose intolerance, justifying the need for oat milk. Later on, it was also nurtured by the regime actors and dairy company Skånemejerier (Dairy of Skåne, a region in southern Sweden), who let them produce in their factories. This helped Oatly establish connections to the food cluster of southern Sweden, and allowed them to grow. With knowledge from LU research and with capacity and infrastructure from Skånemejerier, Oatly's oat milk could be produced and brought to the market. Today, Oatly's oat milk has grown to be a part of a market niche of plant-based food, mostly directed towards people choosing not to eat dairy or meat.

The regime in which the niche is situated is the heavily subsidised dairy industry. By promoting their (according to some, very simplified) 'Oatly Way'—making oat milk directly from oats instead of oats

feeding cows to make cow milk—the innovation challenges the very existence of dairy farms. Thus, they also challenge the EU and national milk quota systems that are important and long-lived rules of the dairy regime.

Dairy grew increasingly questioned following landmark publications by the FAO in 2006 on the climate impact of meat and dairy. This could be seen as a landscape pressure, which created a window of opportunity that allowed Oatly to diffuse into the regime. As the popularity of non-milks such as Oatly grew, they diffused more and more into the regime. Large dairy companies such as Danone bought plant-milk producers and the big Swedish retailers produced generic oat milks. Oatly was acquired by a Belgian-Chinese brewery consortium (which now owns a majority of shares), which enabled an international launch complete with foreign production facilities. Oatly scaled remarkably, thanks to financial support from influential groups and dairy regime actors.

There are more indicators of Oatly scaling. It is now sold refrigerated next to cow's milk. In late 2019 the Scandinavian multi-national dairy cooperative Arla released a milk beverage composed of 50% plant-based and 50% dairy milks. Recently—after years of publicly opposing oat milk—the company have announced that they will release their own line of oat milk, JÖRD, as they can see a growing market demand (Arla 2020). When even its dairy competitors are producing oat milk, the innovation must be seen to be incorporated in the regime. However, plant milks are still a niche product, holding roughly 4% of the EU market for milk in 2018 (MMO Economic Board 2018). It is thus hard to claim that the dairy regime has shifted.

6.7.2 Multi-Level Governance

Technological experimentation was crucial during the early phase of Oatly, since laboratory experiments were how they came up with the now-patented production process. Once the technical innovation was in place, they needed to turn to social innovation, so as to turn oat milk into a product for everyone, not solely vegans and the lactose intolerant. This illustrates how Oatly's oat milk isn't a purely technical innovation, but a sociotechnical one.

Oatly was able to cooperate with Lund University as well as the Swedish Agricultural University on several research projects on plant milk. Since we know more about the production of dairy than the production of plant milk, such endeavours were important in order to catch up on the research on plant-based milk. Oatly have also cooperated with schools to complement dairy milk in school lunches, and trained school staff to cook with plant-based ingredients, which has been aimed at establishing new plant-based consumption practices.

Scaling from the MLG perspective, in this case, comes down to how policy hinders scaling from occurring. In its marketing, Oatly has put significant emphasis on the school milk subsidies distributed by the EU as well as the lack of support from the policy community for plant-based products. To amend this, the Swedish plant-based sector established its own lobby organisation, *Växtbaserat Sverige,* together with three other actors: Food for Future, Simris Alg, and Astrid & Aporna.

Oatly has scaled up in several ways. Firstly, it is possible to see a rise in the production of oat milk by other producers. Although it might be hard giving the full credit to Oatly, this can clearly be seen as diffusion of the innovation of oat milk. Since the rebranding of Oatly in 2014, the initiative has continuously expanded and grown, enabled by enormous market demand and by selling shares and accumulating capital. However, the latter has also led to people questioning Oatly's role. From being

an underdog, a rebel and a (self-styled) “good company”, their majority share is now owned by Chinese and Belgian investment companies.

7.7.3 Material Politics

Historically in Sweden milk and dairy have been highly subsidised, both at state and EU level. The dairy industry has been deeply interlinked with them both economically and culturally, forming a state-dairy complex. By drawing on research and sustainability measures, Oatly not only made the high carbon impact of dairy visible but also highlighted the dissonance between Sweden’s climate goals and its subsidisation of the dairy industry. In this way Oatly challenged the naturalised state-dairy power relation and questioned the Swedish dairy sector’s hegemonic position.

In many countries the production of milk depends on a complex production and distribution system. In order to get fresh milk to the stores on a daily basis, there needs to be geographical distribution of dairy farms, ample refrigeration, and steady consumption of milk. Plant milk production requires parts of the chain (transport, processing, packaging) but, importantly, replaces the cow with industrial processing. Thus oat milk production questions the necessity of one of the world’s most entrenched farming practices: the rearing of cattle. By implication, Oatly promotes a very different value chain.

In various ways, Oatly has used socio-material spaces as an argument for, and demonstration of, decarbonisation. They are present in schools with so called oat-stations—refrigerators that dispense oat milk—to offer an alternative to cow’s milk (Oatly n.d.). They also collaborated with Way Out West to make the festival milk-free in 2015. The festival area thus came to represent a minimal version of what a dairy milk-free world might look like. By these means, decarbonising dairy (by replacing it with plant-based products) becomes highly visible and feasible.

6.7.4 Cultural Politics

The production of dairy milk is deeply culturally embedded. A central part of the (formerly?) dominant dairy narrative is picturing the production of milk made in symbiosis with cows. This narrative is reaffirmed by producing campaigns (directed at children) in which cows are personified, and arranging the yearly “kosläpp”, where overjoyed cows are released to pasture after spending a long winter inside the barns. Arranging school excursions to dairy farms and serving milk at schools is crucial in making dairy seem a natural and nutritious part of a meal. The state has been a crucial actor in sustaining this narrative, among other things by funding school milk campaigns and issuing dietary advice that promotes drinking milk.

This hegemonic narrative on milk and dairy production has been deeply challenged by Oatly and their campaigns. Through the slogan, ‘the Oatly way’ (see MLG), dairy milk is recast as “inefficient”. The slogan, ‘It’s like milk, but made for humans’ makes the human consumption of cow’s milk “unnatural”; and through campaigns alluding to alcohol consumption, such as ‘Spola mjölken’ (‘Flush milk’, referring to a successful Swedish anti-alcohol campaign initiated in the 70s) (Resumé 2019), dairy milk comes to signify “unhealthy”. Their latest campaign, which rolled out in 2019, encourages the food industry to ‘show their numbers’, referring to revealing LCAs on dairy milk. In this way, Oatly stress the higher GHG emissions involved in milk production and thus emphases cow’s milk as high-carbon.

This has been widely contested by incumbent actors such as the Scandinavian dairy company Arla. Claiming environmental benefits to cows grazing pasture lands, the dairy cooperative have intended to reaffirm dairy milk as environmentally and culturally important. Arla's 'Only milk tastes like milk' campaign identifies milk drinking as a comforting cultural habit. However, the wide use of oat milk amongst non-vegans (even to the point of using it in their coffee) shows how Oatly have managed to break through dairy's cultural embeddedness, reducing its "stickiness" and aligning their own product with cultural habits (for example, making an oat milk which blends seamlessly with coffee).

The cultural jockeying for position between diary and plant-based milks perhaps reaches its apogee in the debate over the actual meaning of "milk". Oat milk's status as milk has been vehemently questioned: does any white liquid with milk-like properties qualify? What is the *functional unit* that makes milk milk? In some countries and regions, the legal definition of milk requires an animal. In these markets, Oatly has resorted to calling itself an "oat beverage". The politics of naming products illustrates how the material "milk" is embodied with meaning, which is always up for contestation.

The ongoing contestation of the meaning of milk, which intensified with a legal dispute in 2015, has now come to be known as the "Milk War". Important actors in rescaling Oatly's narrative on milk have been social activists taking to social media to argue Oatly's case, especially during the lawsuit. Another crucial actor has been the plant-based lobby organisation Växtbaserat Sverige (Plant-based Sweden). Since the narrative draws heavily on sustainability research, research partners were also important for rescaling of the narrative.

With their 100% plant-based products, Oatly have created an imaginary of a world in which dairy has been seamlessly replaced, expressed in their slogan, 'Post-milk generation'. This imaginary bears many similarities to the tech-market imaginary (Levy & Spicer 2013), in which technology is replaced without questioning endless economic growth. The Oatly imaginary's close alignment with current economic structures may explain why it has been rescaled significantly.

6.8 Friesland Campina

Globally, livestock production accounts for 14.5% (2013), while the dairy sector accounts for approximately 5% (2010). Friesland Campina (a multinational, but Netherlands-based, dairy cooperative) controls 75–80% of the Dutch dairy market. As such, reducing the GHG emissions within its value chain would have a significant effect on the GHG emissions of the entire Dutch dairy sector. The Dutch dairy industry is the fourth-largest dairy producer in the world.

A transition to a low-carbon society will require a significant investment in 'green' sectors, a small but fast-growing area of financial activity. Financial instruments like green bonds and green Schuldscheins might be a means to increase such investments and finance decarbonisation. Although still a market niche, green bonds are rapidly increasing, with 51% growth from 2018 to 2019.

The first *green* Schuldschein was released in 2016 by the renewable energy company Nordex. With the release of their green Schuldschein, Friesland Campina were the very first dairy company to issue a green debt instrument, which are more commonly issued by renewable energy companies. The green Schuldschein is akin to a green bond, but not identical: the latter is traded in a market and listed on a stock exchange. To issue a green Schuldschein is to undertake that the money raised will be used for sustainability projects.

6.8.1 Multi-Level Perspective

The green Schuldschein is a green finance initiative situated within both the dairy and the finance regimes. With its approximately 80% dairy market share in the Netherlands, Friesland Campina is to be viewed as a regime actor within the dairy regime. Other crucial actors in the FC green Schuldschein, such as banks and second opinion providers, are also incumbent actors in the finance sector. Thus, it is not obvious how the niche would be conceptualised in this case. One way to see it is that financial instruments like the green Schuldschein are developed within the niche of green bonds, a regime niche created by incumbents in the financial regime. The innovation which scales is thus a financial instrument rather than a technology. Within the dairy regime it is harder to identify a niche; Friesland Campina appears here more like an incumbent actor intending to pre-empt industry regulation.

The FC case is interesting as it ties together two otherwise not necessarily close sectors, dairy and finance. Green bonds are still relatively new, and their characteristic features are still being determined. The logic of ruling by price has not been challenged; instead, green bonds increased when they became profitable. Thus, within the finance sector FC's green Schuldschein does not challenge regime rules (e.g. market logic), although it does have decarbonising potential. Within dairy there has been an increasing focus on sustainability, driven by criticism of the climate impact of livestock industries (e.g. FAO report 2006). Such pressures, together with the withdrawal of the EU milk quota in 2014 and the signing of the Paris Agreement, can be seen as important in destabilising the regime. Additionally, there is an agreement between the Dutch government and the dairy industry, by which the latter is required to improve its energy efficiency by 2% annually. Thus, regulation and the pre-empting of incoming regulations were crucial in motivating the incumbent dairy company to release a green Schuldschein.

Looking at the increase in the number of green financial instruments, we can see how this niche has scaled by replication and growing. Although it is hard to identify scaling of the FC green Schuldschein, we may see it as a scaling of Nordex's green Schuldschein. However, this assumes that green bonds can be considered a niche, which is not certain. Although green bonds are no longer solely the domain of so-called socially responsible investors, the green economy is still relatively small, and green bonds remain a market niche. We can, however, envision a transformation process driven by "green" instruments: a financial system where climate change and "sustainability" are considered in all financial practices. There seems to be an emerging interest in issuing green bonds, from both banks and actors within the dairy industry, and thus a potential for such further scaling. This could be empowered by inter-sector knowledge networks, through which knowledge and best practice could be shared.

6.8.2 Multi-Level Governance

Looking at the innovativeness of the FC green Schuldschein from an MLG perspective, it is less about a carbon-reduction technology and more about exploring and experimenting with climate governance within dairy. A crucial part of the use of a green financial instrument is, as stated by interviewees, how the green Schuldschein brought together different parts of an organisation—the sustainability and finance departments—and thus aligned finance and sustainable dairy. Except for the dairy company Meggle's issuing of a green Schuldschein, not much scaling in terms of diffusion and replication can be identified in the case study. However, the innovation of the green Schuldschein has led to new practices in governing decarbonisation, which may spread.

One big concern is the true "greenness" of these new financial instruments. There is a particular credibility gap involved in developing methodologies to distinguish green from non-green investments. While some green bonds are assessed and certified by a second party (by 2017, 14% of green bonds in the green bond market), there are still many bonds that are self-labelled "green" with no external assessment of certification. Among those that are certified, there is no agreed definition of what constitutes "green". Some argue that too many restrictions will hinder the market growth of green financial instruments. There are also indications that whether bonds are green or not seems to be of markedly little interest to investors. Thus, a scaling up in the form of a larger number of "green" bonds could be fostered by absence of regulation. However, if scaling of green bonds is to be seen as scaling governing decarbonisation, the difficulty of determining "greenness" is a significant hindrance to scaling.

Policy makers and intermediaries could play a crucial role in building credibility for green bonds. The intermediary and second party assessor Vigeo Eiris played a crucial role in the case of the FC green Schuldschein by providing a second opinion on the sustainability of the project chosen to invest in; the project must be chosen and named before issuing the green Schuldschein. To combat the issue of the lack of credibility of green bonds, policy makers could seek to regulate the green finance market further by introducing restrictions and requiring certifications of "greenness", and help with knowledge-sharing to support standardisation of best practice. We can also envision (sub-)governmental steering aimed at regulating the financial market as a whole, making sustainable consideration mandatory.

6.8.3 Material Politics

The dairy industry has a very dispersed asset base. There are institutionalised rules in the finance market on how to issue financial instruments. The cost of issuing a Schuldschein means significantly lower issuance. Thus, a green bond is primarily suited to actors further up the dairy value chain, who may have a substantial asset base. FC is such an actor. Issuing a green Schuldschein is in compliance with power structures within finance, however within dairy introducing a financial instrument amounts to reconfiguring scale at which decarbonisation is governed.

The potential for decarbonisation varies across the different parts of the dairy production process. Most of the emissions involved in dairy are farm-based, which are also deemed the hardest to reduce. As stated by an interviewee, some farm-based emissions, for instance methane, are even unavoidable. More broadly, materiality plays a crucial role in establishing green bond criteria for certification. The Climate Bond Initiative has a certification scheme for green bonds, but this is currently only available for certain sectors, where carbon has been deemed more easily calculable. Sectors where carbon is less easily measured, or in which high-carbon cannot be as easily distinguished from low-carbon, do not have yet the option of certification.

FC admits that the projects that were financed by the green Schuldschein were going to be implemented anyway, thus no additional sustainability projects were carried through. Moreover, the money raised from the green Schuldschein is claimed to be used for sustainable projects aimed at making post-farm production more efficient, rather than addressing farm-based GHG emissions. This suggests that, although new governance arrangements have been established, FC's green Schuldschein is not leading to substantial decarbonisation effects. Instead, it seems to be obscuring decarbonisation action where it is needed most: at farms.

6.8.4 Cultural Politics

In recent years, the dairy industry has increasingly been criticised for its GHG emissions and climate impact. The issuing of this financial instrument was a clear means to improve FC's green credentials, a move made within a wider context of changing the narrative around the dairy industry's sustainability. There is thus a focus on replacing the view of the dairy industry as a heavy emitter with one in which the industry is "green" and "natural". To be precise, there is an evident focus on positioning Dutch dairy as "sustainable" rather than "low-carbon". The problem with the latter (as discussed under Material Politics) is the technological difficulty of avoiding farm-based emissions. These are deemed more difficult to decarbonise, partly due to technological limitations and partly because such efforts are contested by farmers. Thus the decarbonisation of dairy is made visible in their factories, but not at their farms. Since a majority of GHG emissions are farm-related, this might be an obstacle in rescaling sustainable practises.

FC's strategy is framed as one of achieving climate-neutral growth. Within this narrative it is possible for FC to frame themselves as green while sustaining their underlying economic model of continued demand and growth. Because the climate-neutral growth narrative aligns itself with current economic structures (e.g. economic growth) there is a potential for it to rescale. However, since it was issued only in 2016 it is not yet certain that the Schuldschein will come to be seen as low-carbon, green, or sustainable.

However, there is some contestation surrounding the narrative of dairy going "green"; the imagined "sustainable" dairy industry. One of the possible pathways to reducing emissions within dairy is reducing demand, which is (not surprisingly) explicitly resisted by farmers. At one conference one attendee stated, 'In Sweden they are being told to drink less milk to reduce emissions. Let's not do that here [in the Netherlands]!'. While sustainability through reduced production requires significant changes in the way business is done, climate-neutral growth does not. Climate-neutral growth thus aligns well with the circular economy approach. This speaks for a potential rescaling of climate-neutral growth.

6.9 Green Protein Alliance

Based in the Netherlands, the Green Protein Alliance (GPA) is a broad social movement that envisions a more sustainable food system by accelerating the protein transition towards a society that depends mainly on sustainable vegetable sources for its protein needs. The GPA is thematically placed within food transition, with a focus on restoring the protein balance in dietary supply and consumption by increasing the adoption of plant-based protein (PBP) products among consumers. Through its Green Protein Growth Plan, the organisation aims for a 50/50 diet split between conventional (meat and dairy) and plant-based protein sources. The alliance is formed between supermarkets, manufacturers, scientists, NGOs, and government institutions.

6.9.1 Multi-Level Perspective

From the multi-level perspective, the GPA can be viewed as an actor nurturing the niche of protein alternatives, operating within the wider regime of agri-food systems. The GPA does not itself produce any PBP products, but aims to create a favourable climate for structural change within the agri-food industry by aligning with policy makers, education institutions, and supply chains actors. This niche increases to greater shares of adaptation once consumers value PBP products for their taste and ease of preparation, along with their environmental benefits. Studies into the agri-food

system have shown that niche activities, and the enrolment of new actors, lead to a gradual reconfiguration of the regime.

Scaling in this case is shaped by the entrepreneurs, NGOs, governments, and research institutes aligned with the GPA, who will play a role in promoting PBP. This change is achieved through the construction of shared visions of agri-food issues by the associated network of relevant actors, and through embedding these visions in local policies and public action. These visions are outlined in the GPA's Green Protein Growth Plan, which was developed in line with the Biomass and Food Transition Agenda by the Ministry of Agriculture, Nature, and Food Quality. Additionally, the movement provides educational products such as the Friendly Future for Plants programme offered to lecturers and bachelor students, which covers plant-based innovations and new revenue models to reduce carbon footprints.

The introduction and successful implementation of the initiative was highly dependent on the national political context of the Netherlands, as well as the already established visions and goals of the government towards the protein transition. Together these factors created a window of opportunity for the GPA. If legislation were reformed, it would be much easier to communicate the advantages and pitfalls more clearly—which would allow for easier market introduction of green proteins. The GPA aims to promote the consumer acceptance of green proteins and rebalance diets. Ultimately, these effects will ripple into further sustainability issues pertaining to land use, water use, and CO_2 emissions.

6.9.2 Multi-Level Governance (MLG)

Policies aimed at scaling the success of PBP products in the protein transition are key to the success of the GPA. These can include placing additional taxes on non-PBP products, subsidising the production of PBP products, and introducing regulations, such as limiting the amount of nitrogen and phosphate from manure and artificial fertiliser that can be put on agricultural land.

The initiative takes an embedded approach to scaling, using a number of experiments such as educational packages, national campaigns, and anchoring to the governments' Biomass and Food Transition Agenda. The GPA creates a network of suppliers, educators, and policy makers—connecting sector actors to share knowledge co-creation, accelerate initiatives, and create a central platform for a PBP transition. Doing this promotes further transparency and collaboration between businesses and governments in guiding the development of legislation and policies. For example, on the national level GPA collaborates with the Dutch Cuisine foundation to make sustainable, tasty, healthy food more attractive and available to local audiences. Internationally, the alliance worked with Het Planeet (a founding member of the GPA) to develop the International Corporate Social Responsibility covenant for vegetable proteins, which focuses on legislation related to the protein balance between plant and non-plant sources in developing countries. Thus, the GPA operates as an intermediary whose experimentation leads to new governance arrangements to govern decarbonisation in dairy.

6.9.3 Material Politics

Power shifts are a particular challenge in agri-food, a sector characterised by high levels of government rationality. Transitions here are shaped by the sanctions, regulations, and styles of governance specific to the sociotechnical system. The GPA's approach here is to rescale the legislation currently hampering the introduction of green proteins on the market. However, there is

no knowledge about how to manage risks in the supply chain. Through its blog and organisational activity, the GPA frequently creates the narrative that the protein transition is not one hinging on consumer choice, but rather on political activity. While educational products and informative platforms are offered to consumers, the alliance campaigns for action by politicians to support and facilitate the protein transition.

By reforming legislation, businesses gain agency over the supply chain as they now know how to manage and participate in these structures. This will empower PBP businesses, leading to the setting up of industry initiatives and voluntary standards to transform legislation and the supply chain, and to streamline processes to favour PBP products over non-plant sources.

However, the wider material impacts of this social movement will be seen in the land use, water use, and CO_2 emissions in the Netherlands in the coming years. Land use systems can be considered an example of a complex adaptive system resulting from human efforts to sustain ourselves on the biophysical environment through, for example, cultivating land for food production, creating buildings and infrastructure, and distributing and consuming goods and services. Though the proportion of land in the Netherlands dedicated to agriculture has steadily declined in recent decades, in 2016 more than half the total available land (53.31%) was still devoted to farming—with a third of this total being occupied by dairy farms. As they require less land and water use, PBP products can therefore be means of reclaiming land that is currently devoted to rearing livestock and growing its feed. Shifting from traditional protein sources such as meat and dairy to PBP implies a massive rescaling of the production networks supporting these industries (such as water and animal feed), as they move from agricultural land into capital-funded laboratories.

6.9.4 Cultural Politics

The GPA is itself a social movement comprised of industrial and governmental actors, promoting a vision of more sustainable eating practices. Key actors in this perspective are influencers, smart marketing, and the zokanhetook campaign—the main driver informing and educating people about plant-based alternatives to traditional protein sources.

Particularly challenging to rescaling of the GPA narrative is the politics of naming meat substitutes (e.g. “lab-grown”, “synthetic”, “cultured”, etc.) and the narratives constructed around them that give the impression they are “unnatural”. These are key aspects of resistance from incumbents to the introductions of new innovations into the market. GPA thus seeks to rescale narratives of “artificially” made food towards the health and environmental benefits of these products, to make them more desirable. To this end, GPA seeks to shift the narrative on plant-based foods by referring to all partner products simply as “vegetable products”, alluding to their basis in plants and avoiding imagery associated with meat and dairy products and with industrial processes.

One may consider that social media platforms may play a role as scaling tools for social movements such as the GPA, strengthening the movement by facilitating collective meaning-making, and expanding the movement by allowing members to amplify and disseminate non-dominant discourses about the benefits of PBP products (Mundt et al. 2018).

Narratives and imaginaries connected with climate action only become dominant when they connect with popular interests and identities and align with economic and technological aspects of the energy system to constitute “value regimes” (Levy & Spicer 2013). The GPA’s imaginary links up with the “sustainable lifestyle” imaginary presented by Levy and Spicer (2013) by constructing its

narrative around the “health” of four elements of society: (1) the consumer, drawing attention to the health benefits of rebalancing one’s protein consumption; (2) the climate, by stating the reductions in carbon emissions that can be achieved; (3) the economy, highlighting that vegetable proteins will create commercial opportunities throughout the entire supply chain; and (4) the supply chain itself, which will benefit from heightened circular activity in agricultural and retail spheres.

Finally, the GPA’s discourse aligns closely with that of the Dutch government, which recognises the disproportionate land and water resources needed for meat production as opposed to vegetables, and aims at shifting the food pattern to more vegetable and less animal products, and a more efficient production of animal proteins through the Biomass and Food Transition Agenda.

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