

# Transforming Imaginations?

Multiple dimensionalities and  
temporalities in transformations  
to sustainability

# TRANSFORMING IMAGINATIONS?

## Multiple dimensionalities and temporalities in transformations to sustainability

emerging ideas & evidence on imaginaries of energy & urban change in Kenya, Germany & the UK

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A work-in-progress paper for the T2S project on Governance of Sociotechnical Transformations (GOST)  
*final draft – 22<sup>nd</sup> February 2021*

***"Es aventurado pensar que una coordinación de palabras ... pueda parecerse mucho al universe"***  
*(It is hazardous [venturesome] to think a coordination of words, can have much resemblance to the universe)*  
Jorge Luis Borges, *Other Inquisitions*, 1952<sup>1</sup>

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## EXECUTIVE SUMMARY

This paper examines some key issues around the core roles played by ‘sociotechnical imaginaries’ in the shaping of ‘sustainability transformations’. As part of a wider project on ‘the governance of sociotechnical transformations’ (GOST), this research examines prospective transformations and associated imaginaries of cities in Kenya and energy infrastructures in the UK (and, less so, Germany). Although currently only interim, these developing ideas and findings may hold significant implications for onward research and policy actions.

In keeping with important themes highlighted in the original proposal<sup>2</sup>, what this strand of the GOST project involves, is a focus on neglected challenges of ‘*multiple dimensionalities*’ and ‘*multiple temporalities*’.

‘**Multiple dimensionalities**’ relate to a point well made by the writer Jorge Luis Borges (and quoted in the epigram for this paper): “*it is hazardous to think a coordination of words, can have much resemblance to the universe*”<sup>3</sup>. The numbers of dimensions encompassed in language and ideas are typically radically smaller than those that constitute the world itself. If practice and research concerning sustainability transformations (and the many diverse ways these might variously be imagined and enacted) are shaped by categories that are too expediently simplistic, then some serious vulnerabilities can arise, both to error and to manipulation.

In these terms, mainstream ways to imagine, enact – and research – transformation tend to be ‘*monothetic*’ (envisaging a necessary set of dimensions). This can neglect alternative ‘*polythetic*’ views (recognising more plurality and fluidity in the dimensions that constitute social processes and actions). Drawing especially on empirical research conducted over the past two years concerning key ‘smart city’ initiatives around Nairobi, this challenge of addressing multiple dimensionalities in polythetic ways is undertaken here by using Q method: a technique specifically developed over many decades to interrogate this kind of social complexity.

Instead of treating transforming imaginaries as monothetic categories (each in its setting), Q method allows more explicit exploration of how ostensibly discrete imaginaries or transformations can overlap, entangle, co-exist and co-constitute. At this stage, results are still emerging. But findings do support a picture in which multiple imaginaries of urban transformations can be discerned in the Kenyan setting, variously sharing some features in common with each other and wider international formations, whilst differing in others. It is early days, but this may offer a way to interrogate interactions and ‘ecological’ patterns among these imaginaries.

For its part, ‘**multiple temporalities**’ is about the straightforward point that the world can change – and transformations unfold or not – in many ways. Some relevant processes are not well described as changes that unfold only in one direction, albeit sometimes varying in pace. Alternative kinds of change can involve many forms of more wrangling, erratic, arrhythmic or turbulent dynamic. Just because a particular direction for change is of interest or desired, does not make it the only frame of reference. Where processes of change are complex and uncertain, with diverse values, interests and understandings in play, then it is important that imaginaries of transformation escape confinement by simple models aligned with powerful interests.

With respect to this issue of temporalities, mainstream ways to imagine, enact (and research) transformation likewise tend to be ‘*monotonic*’ (envisaging a single steadily unfolding direction of change). This can neglect alternative ‘*nonmonotonic*’ processes (which undulate in different directions over time and contrasting contexts). It is in seeking also to address these latter kinds of phenomena, that this paper draws on empirical comparative interpretive research undertaken over many years concerning the inter-related dynamics of nuclear power and renewable resources in the energy policies unfolding since 1960 in the UK and Germany.

Although also provisional, emerging results again suggest that neglected kinds of non-monotonic temporality are more important than conventionally conceded. Likewise, it appears that imaginaries and associated wider processes of ‘energy transformation’ are driven by dynamics entangled well beyond the energy sector – driven in the UK by hidden military imperatives and deeply colonial commitments in national political culture. Hitherto undocumented in research, a ‘*drumbeat*’ temporality emerges that interlinks supposedly separate civil and military infrastructures. This materially-driven nonmonotonic rhythm is privately recognised in elite policy making. That a contrasting non-monotonic temporality of ‘*nuclear renaissance*’ is projected in more public policy imaginaries, again points to concurrence and complex interlinkage among multiple dimensions.

# 1 INTRODUCTION

## 1.1 Initial grounding

Funded by the International Science Council ‘Transformations to Sustainability’ (T2S) Programme since 2018<sup>4</sup>, the ‘Governance of Sociotechnical Transformations’ (GOST) project is a collaboration between researchers in Leipzig, Harvard, Nairobi, Bangalore and Sussex<sup>5</sup>. As a core focus, the GOST Project applies the well-established, conceptually subtle and empirically rich ‘socio-technical imaginaries framework’ to the forming of deeper understandings of transformations to sustainability across different sectors and geographical settings<sup>6</sup>. This builds on wider insights in the co-productionist tradition of constructivist science and technology studies<sup>7</sup>. Although many others are discussing this conceptual lens for exploring aspects of this important topic<sup>8</sup>, none have yet posed the distinctive series of practical and conceptual questions identified in the original GOST Project bid<sup>9</sup>, which promised (with emphasis added in bold for present purposes) that:

*“Our study goes beyond previous work on transformation in four ways:*

- *First, it applies **sociotechnical imaginaries** for the first time specifically to **sustainable transformation** and inflects this concept with established policy experiences, thus enabling a more **complex, multidimensional** analysis of hoped-for futures.*
- *Second, by addressing two key general parameters of transformations: **dimensionality** and **temporality**, the project unpacks in analytically tractable ways the **complexity** of transformation.*
- *Third, our **comparative** research design explores the varieties of transformation pathways, as embedded in local **social and material practices**, in ways that lay the groundwork for broad stakeholder engagement. ...*
- *Fourth, our proposal pays specific attention to the **governance implications** of transformations, which have traditionally received relatively little attention in transformation studies. It thus contributes to the design of choices and alternative pathways for achieving prospective global transformations to sustainability in three crucial policy areas: food, energy, and urban digital governance.”*

Each of the highlighted key conceptual terms emphasised in the quote above, were discussed in some depth in the bid materials themselves – and even more, in the detailed background communications exchanged between members of the research team at the time of writing and in the various subsequent discussions<sup>10</sup>.

## 1.2 Aims of this paper

As requested by other members of the GOST Project team, it is the purpose of the present document to review (up until this still-interim, but now near-final stage of the project) how the particular strand of work undertaken in the UK and Kenya settings has focused on operationalizing the above key framing concepts highlighted in the bid – and on eliciting (and beginning to deliver) findings relating to associated questions. As such, this paper is weighted more to conceptual aspects of analysis, than previous outputs have been<sup>11</sup>.

Against a background of the core focus in the GOST project on sociotechnical imaginaries of transformations to sustainability, then, this in-depth discussion paper will focus particularly on thinking around ideas of multidimensionality and temporality highlighted in the remit of the project workshop of 28<sup>th</sup> January 2021:

- 1) how detailed concepts behind the prioritisation in the bid of **multidimensionality** and **temporality** have been implemented in work undertaken up until now by the Sussex and Nairobi teams;
- 2) what kinds of more **complex** patterns we’re looking to distinguish beyond the simplified categories sometimes used in the study of **sociotechnical imaginaries** and **sustainability transformations**;
- 3) what initial findings are emerging (slowed somewhat by the COVID-19 crisis), that relate equally to the **social and material** aspects of **practices** associated with transformations to sustainability;

- 4) how prospective findings bear on **comparative** GOST Project research – and the broad shape of some associated **governance implications** emerging across contrasting national and sectoral settings.

Our emphasis in this present document will centre on each of these four points, focusing in particular on exploring the contribution we might make around the core terms in the bid highlighted above in bold. We hope this helps contribute to wider discussions concerning how these same issues are addressed in other strands of GOST project work. And it is on this basis that we hope to assist coordination of work across the whole team, to integrate broader results concerning these initially-prioritised themes of the original bid.

### 1.3 Summary of discussion

To this end, each section of the paper will take one topic in turn. Section 2 that follows, will show how thinking about imaginations and transformations present challenges of *multidimensionality*. Mainstream ways to imagine and enact transformation are '*monothetic*' in these terms – seen as comprised by a fixed set of dimensions. This neglects alternative '*polythetic*' views – recognising more plurality and fluidity. On this basis, it will be argued that the challenges on which the GOST project focuses. Go beyond mere '*multi-dimensionality*' to encompass the more intractable and turbulent dynamics of '*multiple dimensionalities*'.

Next, Section 3 will start by exploring how the existence of *multiple temporalities* adds to these challenges. In particular, it will explore the importance of going beyond conventional imaginations of processes of transformation that are '*monotonic*' – involving a single steadily unfolding direction of change. This side-lines alternative understandings of 'non-monotonic' processes of change – which undulate in different directions over time. Each of these sections will end with a series of practical implications for research.

Section 4 will then outline a distinctive approach to research called *Q-method*, which is specifically tailored to interrogate *multiple dimensionalities* – whether such plurality emerges in imaginations of transformations or transformations of imaginations. It will describe how research based around Nairobi, is currently exploring in an interactive way with a diversity of stakeholders, the implications of a plurality of different imaginaries concerning what might be meant by contending visions of 'smart cities' and 'urban transformations'. This will show how imaginaries of urban transformation can be empirically elicited in interactive ways that allow researchers' interpretations to be tested concerning how multiple dimensions relate to each other within particular imaginaries – and how potentially multiple imaginaries relate to each other in a specific setting.

After this, Section 5 will interrogate key issues around *multiple temporalities* through a comparative analysis of unfolding events around nuclear power and renewable generation in the UK and Germany – two radically contrasting imaginations of 'sustainable energy'. Looking comparatively at historical patterns of change in UK and German energy systems and associated policy imaginaries over the past sixty years, discussion will focus on the adequacy of conventional monothetic accounts of energy transformations. It will ask to what extent the empirical picture warrants moves beyond conventional imaginaries of change in order to also engage with potentially multiple temporalities in processes of energy transformation. A new idea will be illuminated, concerning the importance of a dynamic referred to as a 'nuclear drumbeat'.

The final discussion of conclusions and possible implications will be rather brief in this note, since these will be heavily informed, *inert alia*, by discussions at the upcoming GOST project workshop on 28<sup>th</sup> January.

## 2 MULTIPLE DIMENSIONALITIES

### 2.1 Framing in the bid

In our original bid to the T2S Programme in 2018<sup>12</sup>, the GOST project team stated (with emphasis added in bold for present purposes) that:

*“Dimensionality refers to the assemblages of dimensions or attributes that are understood as constituting states of transformation. These involve aspects of social phenomena such as institutions, interests, infrastructures, practices, cultures or discourses. The hypothesis is that transformative efforts often fail because ex ante imaginations of past and prospective transformation tend to be essentially **monothetic (unidimensional)** in the ways they conceptualize inputs, flows, drivers, and change itself. Examples in the three focal areas might include: carbon emissions as a sole criterion for sustainable energy transformations; protein and carbohydrate productivity as sole measures of the green revolution; and IT-centric definitions of smart cities. This is associated with the single narratives and privileged framings of many sustainability approaches, as well as the use of fixed categories and deterministic algorithms in conventional quantitative assessment methods used to rationalize projects. Ex post imaginations, by contrast, will in this analysis tend to be **polythetic (multidimensional)**, in that they will resist these expedient academic and policy simplifications.”*

### 2.2 Unpacking dimensionality

From this, it is clear that dimensionality (in the sense we are using this term), applies equally (insofar as such a distinction can be made) to understandings of sustainability transformations themselves, as well as of the sociotechnical imaginaries with which these transformations are co-produced. In short, **dimensionality refers to arrays of variously-distinguishable attributes, kinds and contexts of social and material phenomena, by reference to which, categories and instances equally of ‘sociotechnical imaginaries’ and ‘sustainability transformations’ are constituted as salient constructs**. As such, issues of dimensionality are crucial to identifying, characterising, aggregating, partitioning and associating concepts of imaginaries and transformations in general, and of the particular ways in which different manifestations relate to each other.

As shown in Figure 1 below, this point raises a key issue for all social research that involves any mode of **categorisation** of different kinds and degrees of phenomena using any sort of analytical **construct** (like ‘imaginaries’ or ‘transformations’). This is, that all associated constructs can be expected to be constituted in relation to a variety of apprehended **dimensions** of kinds described by the above definition of dimensionality. For example, such ‘constituting’ dimensions might include variously parallel, interlinked, or diversely-nesting ‘economic’, ‘jurisdictional’, ‘institutional’, ‘cognitive’ or ‘legal’ aspects of the transformations or imaginaries in question.

Depending on the distribution of observed **attributes** across different candidate empirical **instances** in contrasting **settings**, then, the constituting **dimensions** of any **constructs** (like imaginaries or transformations) can therefore be identified, characterised, aggregated, partitioned or associated in radically-different but equally-reasonable ways<sup>13</sup>. For example, moving from left to right in Figure 1 below shows that no salient distinctions between attributes can be made under dimension **H** across the relevant settings (**m** to **z**). Adding dimension **J** allows discrimination between attributes **j-i**, **j-ii** and **j-iii**, yielding a threefold partitioning of the constructs in focus. In other words, the number of kinds of imaginaries or transformations that are resolved in any such analysis depends not only on observed empirical attributes in different settings, but on the ways and details in which constituting dimensions are apprehended.

**Figure 1: apprehending distinguishable attributes of multidimensional constructs in contrasting settings**

Here: ‘**constructs**’ = various resolved kinds of transformations or imaginaries; ‘**dimensions**’ = broad aspects of society held to constitute these; ‘**attributes**’ = basis for making distinctions relevant to constructs under these dimensions; ‘**instances**’ = specific empirical examples of these constructs; ‘**settings**’ = social, geographical, institutional, jurisdictional or temporal contexts with which instances associate; ‘**partitioning**’ = the number of resolved kinds of construct.

CONSTRUCTS	DIMENSIONS				INSTANCES in different settings
	Dimension H	Dimension J	Dimension K	Dimension L	
Construct A	attribute h-i	attribute j-i	attribute k-i	attribute l-i	settings m – n
Construct B			attribute l-ii	settings o – p	
Construct C		attribute k-ii	attribute l-iii	settings q – r	
Construct D		attribute j-ii	attribute k-iii	attribute l-iv	settings s – t
Construct E			attribute k-iv	attribute l-v	settings u – v
Construct F		attribute l-vi	settings w – x		
Construct G		attribute j-iii	attribute k-v	attribute l-vii	settings y – z
<b>PARTITIONING</b>	unitary	threefold	fivefold	sevenfold	

Moving further to the right in Figure 1, wider attention to dimensions H, J and K together, results in a fivefold partitioning of the focal constructs (imaginaries or transformations) – resolving attributes associated with dimensions C, D and G, with (A & B) and (E & F) conflated. Attention to dimension K yields further more nuanced distinctions (between attributes k-i/k-ii and k-v/k-vi), allowing separable resolutions of A, B, E and F – a sevenfold categorisation of the focal constructs. Whether there are seen to be one, three, five or seven distinct kinds of imagination or transformation in play will obviously be crucial to the interpreted ‘empirical’ picture that is obtained. So, both the analytic and the practical implications for action can be significant.

**2.3 Monothetic approaches**

The above implications are quite obvious under constructivist epistemologies in science and technology studies<sup>14</sup> – and a co-productionist perspective in particular<sup>15</sup>. But they are important to set out here, because they are often neglected in positivist approaches to social research<sup>16</sup>. These sometimes tend to assert subjective analytic constructs in ‘essentialised’ ways – as if intrinsic and synonymous with the phenomena they describe<sup>17</sup>. In wider study of sustainability transformations, for instance, simplistic assumptions can be adopted in relation to analytic constructs like ‘regimes’, ‘niches’, ‘transitions’, ‘systems’ or ‘sectors’– both of instances and of these categories themselves. In effect, it is often taken for granted that the constructs correspond in expedient one-to-one ways with the more complex and dynamic patterns in how the empirical phenomena themselves are constituted, instantiated, and mutually associated in different contexts<sup>18</sup>.

The co-productionist epistemology underpinning sociotechnical imaginaries offers an important opportunity to avoid this syndrome and derive results that are correspondingly more robust<sup>19</sup>. However, this potential can be compromised, if co-productionist understandings conflate the relatively straightforward and well-recognised dilemmas in the constituting of constructs that have been discussed so far, with the deeper and less tractable challenges on which the GOST project bid also crucially (and distinctively) set out to focus. These more complex and intractable challenges relate to the distinction in the bid between *monothetic* and *polythetic* approaches to understanding imaginaries and transformations. This refers to more fundamental implications of how analytic constructs relate to the turbulent empirical phenomena they aim to describe<sup>20</sup>.

In ways elaborated later, then, a *monothetic* category is definable by a set of attributes seen collectively as both necessary and sufficient<sup>21</sup>. A *polythetic* category, by contrast, is definable in terms of ‘family resemblances’ involving a wider set of attributes, no one subset of which is seen as necessary or sufficient<sup>22</sup>.

Associated distinctions between monothetic and polythetic styles in analysis apply to all kinds of social constructs (whether positivist or constructivist) – and, indeed, to all analytic categories more generally<sup>23</sup>. But the contrast is even less well attended to in conventional analysis of social transformations, than are the more basic dilemmas in categorising social constructs discussed above. Again, some of the key underlying issues are particularly well explored in constructivist science and technology studies<sup>24</sup> – as well as in some more relationally-aware branches of interpretive social research<sup>25</sup>. But just as critical distance can confound these two analytic problems, it is also notable that some of the crucial repercussions that arise can also be somewhat neglected even in relation to constructs developed in constructivist epistemologies<sup>26</sup>. The practical implications for analysis and policy are all the more important for remaining so relatively hidden.

To pick up in turn on each side of the monothetic/polythetic distinction we emphasise in our bid, then, the first is the idea of '**monothetic**' analysis. Again applying equally to either 'imaginaries' or 'transformations' as constructs, this involves a tendency to represent focal categories as if these each unambiguously and exclusively bound and partition an associated set of identified instances or distinguishable kinds.

In these terms, diagnosing the presence of a particular kind or instance of imaginary or transformation (as a focal construct) in any given setting can all-too-easily reduce to little more than an interpretive performance. The constituting of the construct in question is often conveyed simply in the narrative that communicates empirical findings. Typically little attention is given to specification in advance of what might count as being salient to a diagnosed presence or absence of this construct. Likewise, rather scant scrutiny tends to be given to interpretive latitude in the characterising of different attributes, or the validating of presence or absence. It is not usually noted whether any attribute that might be considered salient is absent, nor any non-salient attribute is present. As a result, the overall background of potentially relevant attributes can remain tacit, with those that are held (either negatively or positively) to constitute the constructs in play, effectively being performed as if they are both necessary and sufficient. Albeit inadvertently, then – and despite other forms of rigour and insightfulness – what can sometimes emerge is an effectively 'essentialised' representation of the focal constructs, as if they are unambiguously intrinsic to – and distinctive of – the setting in question.

Examples of the kinds of constructs in this regard, that are of relevance to the GOST project, might include different recognised kinds of sociotechnical imaginaries variously concerning institutional and material formations like 'smart cities'<sup>27</sup>, 'ecological farming'<sup>28</sup> or 'renewable energy'<sup>29</sup>. Also relevant are the contrasting envisaged endpoints for associated 'urban'<sup>30</sup>, 'energy'<sup>31</sup> or 'agricultural'<sup>32</sup> 'transformations to sustainability'<sup>33</sup>. And diverse constructs are also used in describing understandings of general processes of social transformation, for instance distinguishing 'structural', 'systemic' and 'enabling' approaches<sup>34</sup>. As categories, each of these constructs can be framed in analysis in varyingly monothetic or polythetic ways.

Although well-recognised to invoke many dimensions of social phenomena, these and many other named constructs relating to sociotechnical imaginaries bearing on transformations to sustainability are typically framed monothetically – in the sense that they are held to be constituted by an array of dimensions spanning all kinds and instances in congruent ways. As shown by the ways all rows intersect all columns in Figure 1, all constructs are held to be constituted and distinguishable in relation to contrasting attributes under the same set of dimensions. Through neglect of greater complexity then, recognised categories tend to be monothetic, in that they are treated as internally homogeneous and exclusively bounded and clearly distinguishable from other similarly notionally homogenous kinds. A pictorial representation of this is given in Figure 2 below.



**Figure 2: A stylised picture of monothetic categories – constructs are homogenous and mutually discrete**

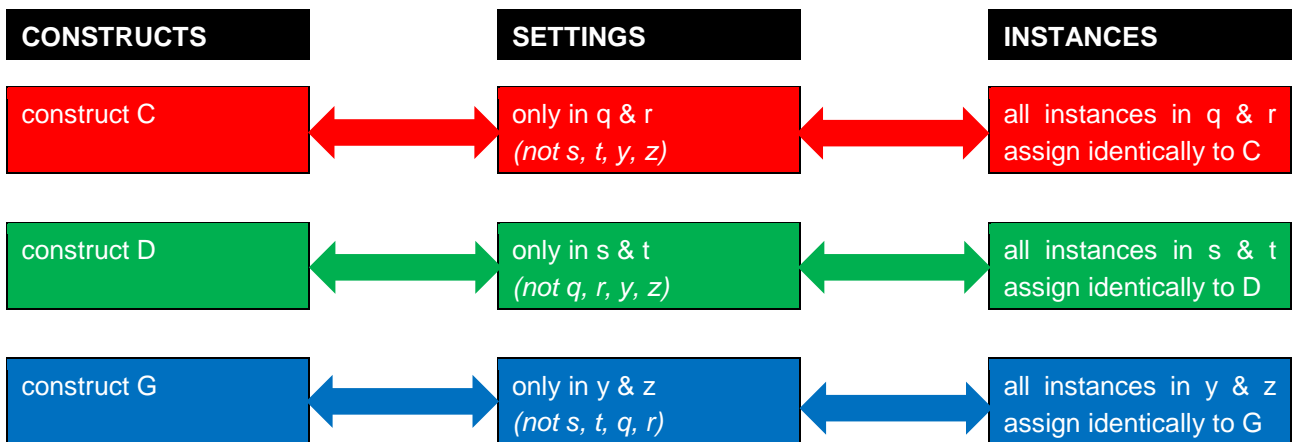
Constructs from Fig.1 with attributes exactly as defined there under dimensions J, K & L: ‘**constructs**’ = various resolved kinds of transformations or imaginaries; ‘**dimensions**’ = broad aspects of society held to constitute these; ‘**attributes**’ = basis for distinguishing constructs; ‘**settings**’ = social, geographical, jurisdictional or temporal contexts of instances.

Dimensions			Construct C	Construct D	Construct G			
Attributes			setting q	setting r	setting s	setting t	setting y	setting z
J		attribute j-i	present	present	absent	absent	absent	absent
	K	attribute k-i	present	present	absent	absent	absent	absent
		L	attribute l-i	present	present	absent	absent	absent
		attribute j-ii	absent	absent	present	present	absent	absent
		attribute k-iii	absent	absent	present	present	absent	absent
		attribute l-iv	absent	absent	present	present	absent	absent
		attribute j-iii	absent	absent	absent	absent	present	present
		attribute k-v	absent	absent	absent	absent	present	present
		attribute l-vii	absent	absent	absent	absent	present	Present

It follows from this that adoption of a monothetic approach in comparative research, may tend to foster assumptions that these kinds of relatively fixed category of sustainability transformation or socio-technical imaginary will correspond in one-to-one relation with other similarly expediently congruent categories. For instance, this monothetic style of comparative research might definitely associate notionally discrete national jurisdictions or temporal periods (as ‘settings’), each with a particular singular kind of ‘imaginary’ or ‘transformation’. In this way, comparisons set out to take the form of an array of correspondences structured as a simple table, in which all kinds and instances of the constructs in focus are defined in terms of the same rows and columns (with distinct entries in each cell representing orderly variations within a given set of notionally common constituting dimensions – as shown in Figure 1). The consequence is shown in Figure 3.

**Figure 3: A stylised picture of one-to-one relations between monothetic constructs, settings and instances**

Constructs from Fig.1 with attributes as defined there under dimensions J, K & L: ‘**constructs**’ = various resolved kinds of transformations or imaginaries; ‘**dimensions**’ = broad aspects of society held to constitute these; ‘**instances**’ = specific empirical examples of these constructs; ‘**settings**’ = social, geographical, jurisdictional or temporal contexts of instances.



Accordingly, pictures like those given in Figures 1, 2 and 3 of relations between constructs, instances and settings are, of course, not in themselves self-evidently – nor in any way necessarily – problematic. Indeed, as a heuristic to inform further research *questions*, this kind of monothetic style can be fruitful. But it can be seen in relation to the wider array of constructs hinted at in Figure 1, that patterns characterised in Figures 2 and 3

give an impression of individual distinctiveness, internal homogeneity and mutual separability that may not be justified by underlying empirical pictures. So, whilst monothetic constructs can be useful in posing research questions, any implication (or, worse, assumption) that these can be *answered* in such monothetic ways, risks yielding pictures that are partly artefacts of the analytical processes used.

For instance, where comparative method employs a pre-fixed template of settings (eg: jurisdictions) merely requiring filling with instances, then any resulting picture of one-to-one correspondences is hardwired in advance. Agency in the analytic process is restricted effectively to assignments of instances and correspondences and modulating the ways these are described. Such a process may inadvertently detract from – or actively side-line – deeper analysis that seeks to ask about the underlying one-to-one template itself. Even if such reductive tendencies are present only to a small degree, they can simplify a resulting overall picture of relations within and between imaginaries and transformations. This would be especially problematic for any analysis which – like that proposed by the GOST project bid – sets out in particular to avoid simply assuming monothetic categories and illuminate often-obscured *complexities* of transformation.

So, whilst such monothetic forms of comparison may yield characterisations of instances that are in themselves heuristically informative and conceptually fertile to some degree, associated ostensibly empirical patterns of notionally distinct instances and one-to-one correspondences may largely be an artefact of the method. This matters, because such a structure may obscure recognition for crucially more nuanced relations within and between real-world instances of sociotechnical imaginary or transformation to sustainability.

The only way in which there can be real confidence in any empirically-based picture of ostensible one-to-one monothetic correspondences like those shown in Figures 2 and 3, is if the method that is used in analysis, is as open to falsifying such a picture as it is to validating it. This is where the importance arises (as emphasised in the original GOST project bid), of testing more polythetic methods for the interrogation of constructs like sociotechnical imaginaries and sustainability transitions. Commitment and respect for the value of empirical comparison arguably intensifies this importance of scrutinising whether polythetic methods may help raise confidence that key attributes of resulting pictures are not avoidable methodological artefacts.

## 2.4 Polythetic approaches

It is fortunate that there exists a family of more '**polythetic**' approaches to analysis, that offer practical and effective means to address serious problems presented by simple presumptions of monothetic categories<sup>35</sup>. With resulting enhancements in social research characterised as a difference between a "*monothetic glance*" and "*polythetic flux*"<sup>36</sup>, polythetic constructs can be seen as "*macrometaphors*"<sup>37</sup> that help address relations of "*affinity*" or "*resemblance*"<sup>38</sup> in more nuanced and systematic ways. Accordingly, these more explicitly relational and transparently interpretive frameworks for understanding have long been well established in fields like linguistics<sup>39</sup>, archaeology<sup>40</sup>, social anthropology<sup>41</sup>, psychology<sup>42</sup> and evolutionary studies<sup>43</sup>.

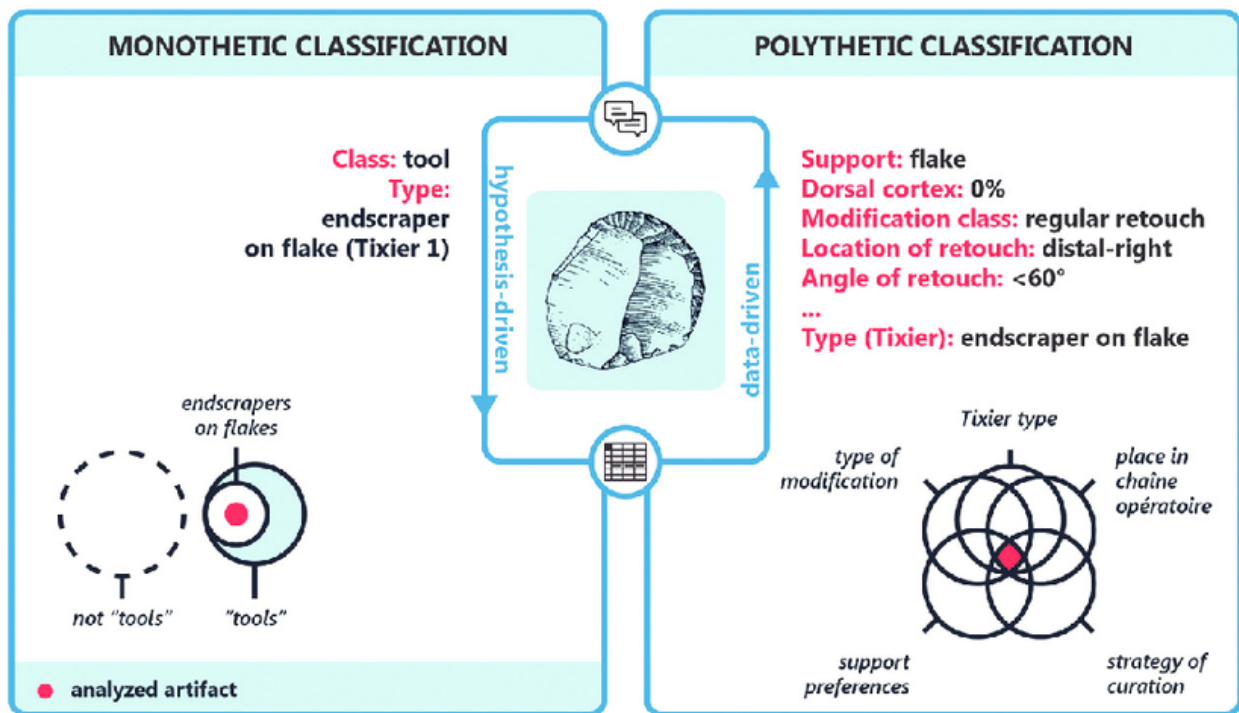
Whilst sometimes addressed in quantitative – occasionally complex statistical<sup>44</sup> – ways, a polythetic approach is arguably even more consistent with a straightforward – and more open and subtle – qualitative interpretive style<sup>45</sup>. Where (as across science and technology studies and the GOST project) this is associated with a broadly co-productionist perspective that is more reflexive about researchers' own commitments in analysis, polythetic methods offer particular advantages<sup>46</sup>. More explicit questioning and reflexivity around the characterising and partitioning of key constructs offers, greater sensitivity and rigour on possible relations between analytical lenses and the associated pictures of empirical phenomena which they variously yield.

Taken together, these attributes of a polythetic approach hold out the possibility of recognising more complex diversities in – and pluralities of perspectives on – relational patterns of 'family resemblances' between kinds and instances of the constructs in focus (like sociotechnical imaginaries or sustainability transitions)<sup>47</sup>. This is achieved by avoiding starting with a presumptively monothetic taxonomic structure of fixed categories (as held to be manifest in contrasting empirical settings), each then populated with kinds and instances. Instead, a polythetic approach starts with a finer-grain set of attributes elicited in empirical scrutiny of candidate

instances<sup>48</sup>. Analysis then allows instances to be assignable in varying ways and degrees to kinds. Likewise categories themselves can emerge (or not) in varyingly differentiated, nested, overlapping or dependent ways – as a function of observable patterns of association between attributes.

It is this quality of polythetic (rather than monothetic) approaches that the GOST Project bid refers to in expressing a commitment to “resist ... expedient academic and policy simplifications”. Figure 4 (below) shows these contrasts with a monothetic approach in a stylised example drawn from archaeology<sup>49</sup>.

**Figure 4: a stylised contrast between polythetic and monothetic categorisation of constructs and instances**  
 An archaeological example: where ‘tools’ is an analytical construct (like ‘imaginary’ or ‘transformation’) and ‘Tixier 1’ is an instance (like ‘Kenyan imaginary’ or ‘German transformation’) distributed across contrasting settings (Kiraly, 2018).



**2.5 Contrasting monothetic and polythetic approaches**

Unlike monothetic approaches, then, polythetic methods do not simply assume into being, a template of neatly-ordered, notionally internally-homogeneous categories, defined by means of supposedly necessary and sufficient diagnostic attributes by which they are named. Nor do they require that more nuanced analysis (if undertaken at all) be disciplined such as to constitute any other potential new categories, simply as ‘hybrids’ between existing constructs<sup>50</sup>. This may accommodate permissible variations along single-axis spectra running between the notionally fixed nominal categories. But the results are restricted to rigid one-to-one combinations between categories taken as a whole. By contrast with such restrictive fixed-category hybridising, a polythetic approach allows more flexible and systematic exploration of a wider diversity of complex and nuanced possible permutations, not between constructs as a whole, but their finer-grain constituting attributes. Figure 5 below shows how these more complex associations between attributes and constructs recognisable in a polythetic approach, contrast with the monothetic picture shown in Figure 2.

**Figure 5: A stylised picture of polythetic categories – constructs are diverse, ambiguous and entangled**

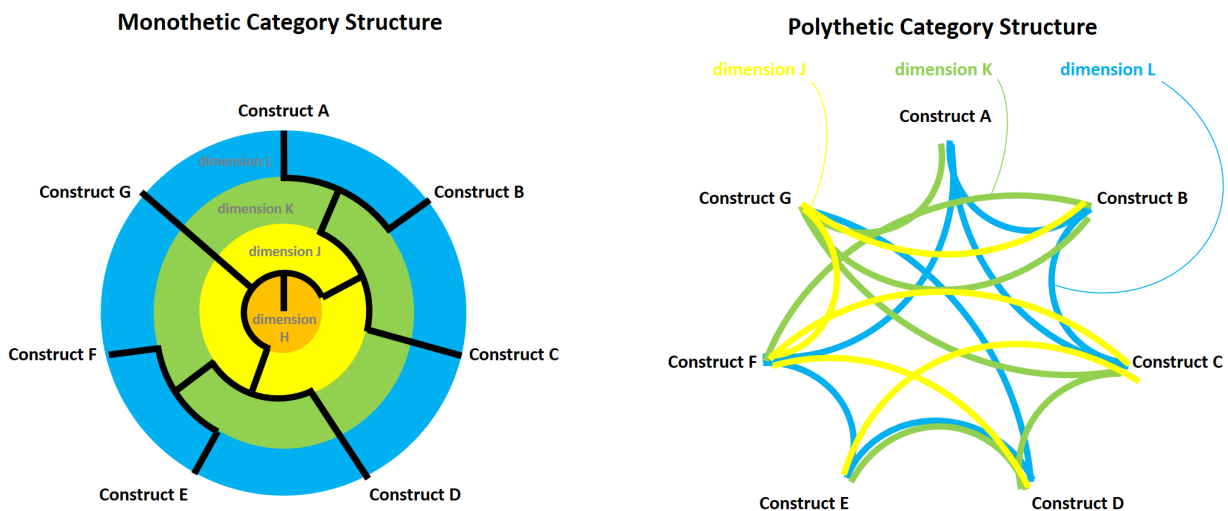
Also with constructs from Fig.1 and with the same format as Fig. 2 this shows a modified attribute set under dimensions J, K & L to illuminate a contrast between monothetic and polythetic categorisation. ‘**Constructs**’ = various resolved kinds of transformations or imaginaries; ‘**dimensions**’ = broad aspects of society held to constitute these; ‘**attributes**’ = basis for distinguishing constructs; ‘**settings**’ = social, geographical, jurisdictional or temporal contexts of instances. Rather than depending monothetically on full presence of all and only the designated attributes, recognition of a construct might be triggered instead by presence of just two of the three associated attributes, with only one nonsalient attribute.

Dimensions			Construct C	Construct D	Construct G			
Attributes			setting q	setting r	setting s	setting t	setting y	setting z
J		attribute j-i	Present	absent	Present	absent	absent	Absent
	K	attribute k-i	Absent	present	absent	absent	absent	Absent
		L	Present	present	absent	absent	present	Absent
		attribute j-ii	Absent	absent	present	absent	absent	Present
		attribute k-iii	Absent	present	present	present	absent	Absent
		attribute l-iv	Absent	absent	absent	present	absent	Absent
		attribute j-iii	Present	absent	absent	absent	absent	Present
		attribute k-v	Absent	absent	absent	present	present	Present
		attribute l-vii	Absent	absent	absent	absent	present	Absent

Beyond such monothetic constructs, then, polythetic styles of analysis are able to grasp more contingent (and challengeable) relational patterns and more ambiguous entanglements of underlying attributes. Constructs are recognised to merge and cross-relate as well as nest or subsume. Instances can relate in particular ways to a multiplicity of ostensibly contrasting categories, without compelling classification merely as ‘hybrids’ in a more coarse-grain categorical fashion. Rather than being disciplined in one-to-one correspondences, relations among categories of phenomena can be recognised to be more plural<sup>51</sup>. Rather than being restricted to relatively simple ‘arborescent’ branching structures<sup>52</sup>, associations across both categories and constructs can be clearly seen in more nuanced ‘rhizomically’ interconnected ways<sup>53</sup>. Reflecting the more complex picture in Figure 5, these features are shown differently in Figure 6 below.

**Figure 6: key differences between mono- and polythetic pictures of possible relations between constructs**

Constructs and dimensions from Figs.1-3. This is another way to think about the contrast also shown between Figs. 2 and 4. ‘**Constructs**’ = various resolved kinds of transformations or imaginaries; ‘**dimensions**’ = broad aspects of society held to constitute these. Less rigidly-constrained patterns of association in polythetic attributes allow relations between constructs to be more nuanced, flexible and context-sensitive, than monothetic categories can be.



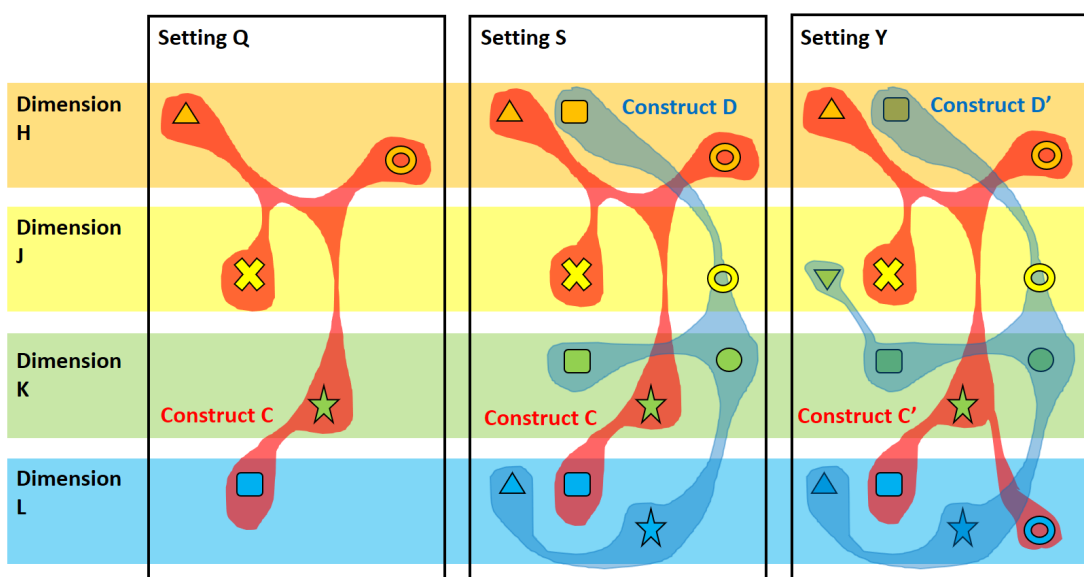
One practical consequence of moving from monothetic to polythetic categories in analysis of sociotechnical imaginaries concerning transformations to sustainability, then, is that there is more to method than simply resolving and articulating notionally discrete instances of either. Phenomena in focus can also be addressed in more transparent, systematic and fine-grain ways. This requires the nuancing of analysis beyond a focus just on different candidate definitions for categories and instances. Attention can be prioritised instead, to direct, systematic empirical exploration of the kinds of finer-grain attributes that might in principle variously be seen to constitute, distinguish and associate relevant categories and their constituting empirical instances.

In other words, a polythetic style of analysis is a way more rigorously to interrogate different possible forms and patterns equally involving ‘imaginaries’ and/or ‘transformations’ – and more respectfully address both empirical evidence and the richness of associated conceptual literatures. Although of course not without their own shaping conditions, polythetic methods can allow constructs to be developed in more subtle and reflexive ways to allow pictures of salient focal phenomena to emerge more from research, than from notionally fixed constructs asserted in advance. And in this way, the precise forms in which recognised kinds of sociotechnical imaginaries or sustainability transformations may actually emerge from analysis, can be more readily be critically scrutinised – and robustly accountable across contrasting analytic perspectives.

One final further potentiality that is strengthened (but not determined) by use of polythetic methods relates to the granularity of the pictures that can be derived of particular settings. By relaxing the tendency of monothetic categories to emphasize one-to-one mappings (as illustrated in Figure 3), polythetic methods not only allow more nuanced characterisations of variabilities in relations and instances of individual constructs (as in Figure 6), they also allow a picture to emerge (where warranted), of multiple constructs coexisting in particular settings. This alternative possible picture is illustrated in a stylised way in Figure 7 below. What this might mean in relation to sociotechnical imaginaries and sustainability transformations, is that it can be easier than is often currently the case, to avoid drifting into a simplistic ‘monoculture’ shorthand, in which particular settings (social, geographical, institutional, jurisdictional or temporal contexts) become disproportionately associated with just a single construct (a specific kind of ‘transformation’ or ‘imaginary’).

**Figure 7: key additional potentialities in a polythetic picture of possible relations between constructs**

Dimensions, constructs and settings broadly relate to those in Figs.1-3. ‘**Constructs**’ = various resolved kinds of transformations or imaginaries; ‘**dimensions**’ = broad aspects of society held to constitute these; ‘**attributes**’ (small shapes) = basis for distinguishing constructs; ‘**settings**’ = social, geographical, jurisdictional or temporal contexts of instances. In **Setting Q**: just one instance of a focal construct is resolved (Construct C) – as is routinely conditioned by any monothetic approach. In **Setting S**: a polythetic approach can also resolve less prominent instances of contrasting kinds of construct in the same setting (Constructs C & D). In **Setting Y**: a polythetic approach is more readily able than a monothetic approach, to resolve subtle variations around an established construct characterisation (Constructs C’ & D’)



Without forcing such a picture, can emerges in an empirically grounded polythetic approach of the kind stylised in Figure 7, are interpretations in which multiple kinds of imaginary or transformation can coexist, associate, interact, complement, aggregate, fractionate, synergise or contend together in potentially significant ways. This possibility to recognise more ‘ecosystemic’ engagements of imaginaries or transformations (or both) – within (rather than just between) particular sectors, jurisdictions or periods – adds an important form and degree of further subtlety to analysis of sociotechnical imaginaries and sustainability transformations.

## 2.6 From multidimensionality to multiple dimensionalities

It is for reasons that hinge on the above discussion of the key differences between monothetic and polythetic approaches to analysis, that the present discussion paper is titled by reference to *multiple dimensionalities*, rather than in less discerning terms of *multi-dimensionality*. This is because the difference between these analytic approaches underscores that monothetic category structures are quite readily recognised merely to be ‘*multidimensional*’. This refers simply to the property of categories being constituted (and instances distinguishable) in an array of different dimensions. This is why comparative work structured according to templates of such categories, can be represented as simple tables, with instances in columns (for instance, differentiated kinds of socio-technical imaginary or sustainability transformation) and whatever are held to be distinguishing features of these instances in rows (eg: institutional, cognitive or jurisdictional settings)

What the contrasting term ‘*multiple dimensionalities*’ adds to this, is an acknowledgement that what is at issue in analysis is not merely the monothetic differentiation or grouping of constructs and assignment of instances according to notionally given dimensions. Attention moves first and foremost, to the populations of fine-grain empirical attributes that might potentially constitute the dimensions through which both instances and encompassing constructs are understood. In this sense, it is not so much constructs that comprise subordinate dimensions. Instead, it is the dimensions of observed empirical variation themselves, that are recognised as ontologically prior to any categorical constructs that analysis may seek to impose.

It therefore follows that the multiple dimensionalities envisaged in the GOST project bid differ from merely multidimensional analysis, in going beyond simplified orderings of categories and neatly nested, mutually-exclusive instances according to a few specially-prioritised dimensions. What is highlighted instead, is that:

- (a) a far **more diverse multiplicity of dimensions than is normal** may be relevant to resolving categories;
- (b) what is **salient** then, may be the **dimensions themselves**, not just attributes on given dimensions;
- (c) **no category is assumed to be necessarily or sufficiently definable** by any subset of such attributes;
- (d) categories are thus not just grouped and nested, but **overlap and inter-relate in complex ways**;
- (e) **instances are not definitively or exclusively assignable** to one fixed category rather than another;
- (f) defining and bounding of construct is therefore acknowledged as **contingent and conditional**;
- (g) in other words, categories are **co-produced in different ways** with social orders bearing on analysis.

Such a polythetic approach is arguably especially consistent with co-productionist styles of understanding, because what are under scrutiny are not just the supposedly discrete phenomena in focus. Attention also extends to processes of scrutiny themselves, being reflexive (explicit, transparent, accountable and rigorous), about the attributes that distinguish the constituting of dimensions of variability and associated categories. So, by using a more polythetic approach in interrogating and comparing socio-technical imaginaries and sustainability transformations, analysis may become more consistent with the insights of social construction.

## 2.7 Practical implications

It follows from all this, that the phenomena of interest that may arise in research concerning kinds or instances of either sociotechnical imaginaries or associated sustainability transformations may prove:

- (i) to be **less easily separable** from each other than might otherwise be expected or assumed;
- (ii) to depend more obviously than may appear, on **subjective prioritising of attributes** for analysis;
- (iii) to display in ways worthy of attention, **variable degrees in how they might be distinguished**;
- (iv) to be **concurrently co-located collectively together** to contrasting extents in any given setting;
- (v) to be less independent than dependent, in their **mutually constituting relations** with one other;
- (vi) to thereby **defy simple one-to-one correspondences** in comparison with other kinds of construct (eg: in settings notionally defined around on national jurisdictions or temporal periods);
- (vii) to display regularities not only at the level of particular constructs of variously-clustered attributes, but also more **'ecological' patterns in diverse relations** between concurrent and/or co-located (perhaps also more deeply co-constituting) kinds of imaginaries or transformations.

In simpler terms, sociotechnical imaginaries and sustainability transformations can (more than is usually acknowledged) be seen (in turn) as: (i) not easily distinguished; (ii) in the eye of the beholder; (iii) ambiguous in their presence or absence; (iv) found together more than individually; (v) interdependent more than separate; (vi) resistant to simplistic comparisons; (vii) important more in their relations than their identities.

The point here is not these kinds of more complex pattern are not in principle already sometimes acknowledged in relevant literatures concerning sociotechnical imaginaries or sustainability transformations. Nor is the point that they are somehow necessarily of greater relevance or interest than those patterns that are more routinely identified in either field. In line with the highlighting of **complexity** at the centre of the GOST project (see above), the key point instead, is that it is only by framing analysis in this way, that it might emerge (in ways that can be readily interrogated), whether these more complex kinds of pattern are salient.

### 3 MULTIPLE TEMPORALITIES

#### 3.1 Framing in the bid

In the original GOST project bid to the Belmont-Norface Transformations to Sustainability research programme in 2018<sup>54</sup>, the project team stated (with emphasis added in bold for present purposes) that:

*“The **temporality** of change refers to the imagined dynamics of change by which transformation is understood to occur. The hypothesis here is that ex ante imaginations of transformation can be expected to be **monotonic** in nature (i.e., the dynamics in question are understood as proceeding in a consistently positive direction – albeit at changing rates – through time). Such a view is inherent, for instance, in conventional understandings of social transformations which are broadly characterised by a classic logistic function or s-curve, running through an orderly sequence of notionally discrete stages, running from ‘take-off’, through ‘uptake’, to ‘saturation’. Correspondingly, ex post characterisations are hypothesized to be more **non-monotonic** (i.e., dynamics in the constituting **dimensions of transformation** will unfold in contrasting directions during different episodes and loci of change, sometimes aligned with, at other times proceeding in diametrically opposite to the expected orientation, not in pre-determined sequences but in more contingent, disorderly ways”*

#### 3.2 The significance of temporality

Questions over temporality in the above sense, are as crucial to the GOST Project as issues of dimensionality. Likewise, they apply equally to understandings of sustainability transformations themselves, as well as to understandings of the sociotechnical imaginaries with which these transformations are co-produced. And here again, the purpose of analysing this further aspect of potentially greater complexity than is normally attended to, is not to be ‘critical’, but constructively to reinforce and make more robust the comparative analysis across countries and sectors of sociotechnical imaginaries concerning sustainability transformations.

#### 3.3 Contrasting approaches to monotonic and non-monotonic temporalities

A process is describable as ‘**monotonic**’ if the parameters of interest – for instance the unfolding of a specific socio-technical imaginary or sustainability transformation – are understood in a particular frame, to proceed consistently in whatever is the defined direction (albeit at possibly changing rates) over time<sup>55</sup>.

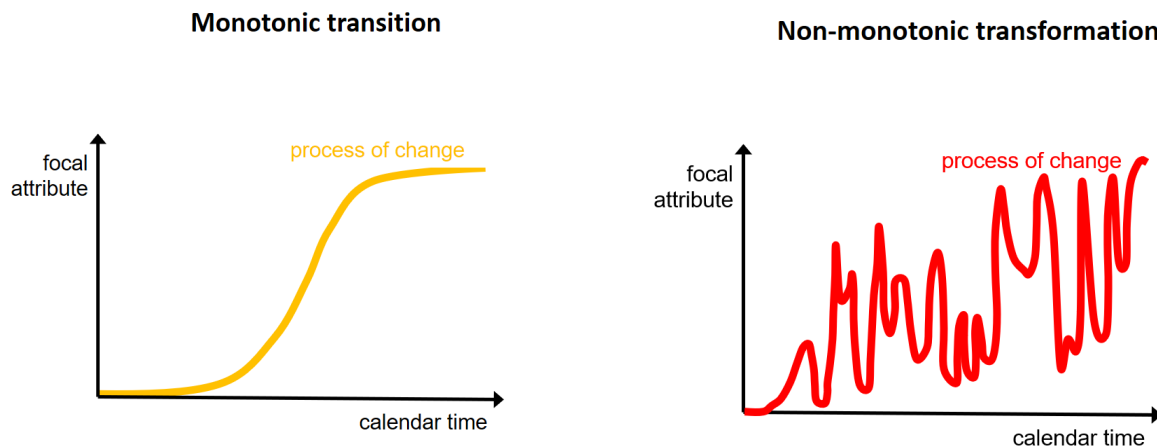
A ‘**non-monotonic**’ process, on the other hand, is where the dynamics in question are seen to unfold in more undulating ways (regular or disorderly), across different episodes or loci of change, in some intervals aligning and in others opposing, whatever is the notional overall orientation of change<sup>56</sup>.

Building on this picture (as shown in Figure 8 below), a further array of qualities tend to be associated with this monotonic / non-monotonic distinction, even though they are not necessarily entailed by it. First, there are tendencies (albeit with exceptions) for monotonic frameworks to be more common than non-monotonic understandings in high-level policy debates<sup>57</sup>. This is evident in a multiplicity of ‘*theories of change*’<sup>58</sup> that arise (for instance), across disciplines variously concerned with innovation<sup>59</sup>, development<sup>60</sup>, revolution<sup>61</sup>, disruption<sup>62</sup>, transition<sup>63</sup> and transformation<sup>64</sup> – and as exemplified in prominent international initiatives like the research programme of which the present project is part<sup>65</sup>.



**Figure 8: a stylised picture of the contrast between monotonic and non-monotonic processes of change**

Monotonic change consistently follows in each period, the overall direction of change; non-monotonic change does not.



Second, it tends to be assumed in the study of ostensibly monotonic forms of change, that the overall orientation of the dynamics in play is somehow axiomatically given *ex ante* – as a factor that is effectively external to analysis (perhaps reflecting prior normative or disciplinary commitments)<sup>66</sup>. There are tendencies (at least implicitly) to adopt a generalising approach across different contexts, in which this assumed common orientation remains relatively under-interrogated<sup>67</sup>.

Third, it is also often the case (especially in studies of large-scale socio-technical transformation) that specific monotonic frameworks take the form of regular sequences of change across what are often pre-determined phases<sup>68</sup>. Examples include the variously-named stages in the classic mathematical ‘logistic function’<sup>69</sup> or ‘s-curve’<sup>70</sup>, so often adopted as a basic model for this kind of change<sup>71</sup>. This entails an orderly sequence of notionally discrete stages, proceeding (for instance) from ‘predevelopment’<sup>72</sup>, through ‘take-off’<sup>73</sup>, then ‘acceleration’<sup>74</sup>, to ‘stabilization’<sup>75</sup>.

Fourth – in order to operationalise analysis of these stylised phases – it is typically necessary to privilege particular parameters of change (for instance, those that are most expediently measurable<sup>76</sup>) among the multitude of dimensions in play<sup>77</sup>. This in turn entails that (though they can differ from each other quite radically), these monotonic models, tend (despite disavowals<sup>78</sup>) to adopt a similar deterministic idiom<sup>79</sup>.

Fifth, it is often tacitly implied<sup>80</sup> – even actively claimed<sup>81</sup> – that these attributes make it possible to predict emerging events and prescribe policy interventions<sup>82</sup>. In this regard, it is typical that crucial characteristics of the monotonic model (like the durations of phases, or the magnitudes of associated shifts) are highly ambiguous<sup>83</sup>. This in turn entails, that resulting interpretive flexibilities, routinely leave these frameworks (despite a frequent positive idiom) as effectively unfalsifiable in practice<sup>84</sup>.

### 3.4 Interrogating the monotonic / non-monotonic distinction

It follows from discussion of polythetic relations in the preceding section, that constructs involving a simple consistent set of necessary and sufficient attributes across multiple dimensions are not likely to be highly epistemically justifiable or empirically reliable as comprehensive generalisations<sup>85</sup>. Nevertheless, some kind of first-order pattern is practically discernible (albeit with exceptions (Prigogine and Stengers, 1984)), in which non-monotonic understandings of change over time can be seen to display the opposite characteristics in respect of each of the above five broad generalisations of what generally tend to be features of monotonic frameworks<sup>86</sup>.

Perhaps related to this, is that non-monotonic understandings tend on balance (despite exceptions) to be seen as less prominent in contemporary high-level policy making. By comparison with the above prevalent kinds monotonic models, non-monotonic frameworks for understanding change can sometimes tend to be treated, furthermore, as: less deterministic; less axiomatic; less assertive in their phasing; less predictive and less generalizable across contexts<sup>87</sup>. Maybe it is these perceivable erosions of utility as means to policy justification, that explain why non-monotonic temporalities may be seen to be less prominent in politics?

This said, however, it is also an illustration of the points made in the last section concerning the perils of simplistic categorisation, that this essentially monothetic picture of the difference between monotonic and non-monotonic approaches to change does in fact exhibit many exceptions. For instance (especially as attention moves away from the highest levels of policy making, to areas of academic discourse where the stakes may be lower and justificatory pressures less intense), a plethora of non-monotonic frameworks indisputably come to the fore<sup>88</sup>. And here it also defies the general picture summarised above, that these non-monotonic frameworks can be as deterministic in style as monotonic models<sup>89</sup>.

For instance, large literatures exist across disparate areas of economics<sup>90</sup>; as well as political, institutional and social movement theory<sup>91</sup>; and policy, management and innovation studies<sup>92</sup>; that are variously concerned with phenomena like 'long waves'<sup>93</sup>, 'Kondratieff surges'<sup>94</sup> and 'Kuznets swings'<sup>95</sup>. Other potentially relevant supposedly quasi-regular 'cycles' come in forms including: 'attention cycles'<sup>96</sup>, 'business cycles'<sup>97</sup>; 'hype cycles'<sup>98</sup>; 'product cycles'<sup>99</sup> and 'policy cycles'<sup>100</sup>. Drawn from ecology, ideas around the 'adaptive renewal cycle'<sup>101</sup> are notably prominent in social studies of sustainability transformations<sup>102</sup>.

Although less prevalent than the ubiquitous array of disciplines concerning supposedly monotonic change, all of these frameworks tend in at least some ways, to defy the generalisation above, that non-monotonic temporalities tend to be associated with less positivist and deterministic approaches than monotonic temporalities<sup>103</sup>. Many of the above frameworks are actually sometimes quite prescriptive in their idiom, for instance being highly assertive about the supposed phasing of change<sup>104</sup>. It is of course as much a condition for survival here as elsewhere, that the ambiguities and interpretive flexibilities preclude ready falsification.

Crucially, however, a feature often shared by all these frameworks asserting non-monotonic temporalities, is that dynamics in play are treated as relatively regular – such as to permit the orderly metaphor of the 'cycle' or 'wave'<sup>105</sup>. What tends in these approaches to remain just as unaddressed as in frameworks emphasising monotonic temporalities<sup>106</sup>, are crucially more complex, undulating forms of change described above as 'disorderly' – including various kinds wrangling, erratic, arrhythmic and turbulent dynamic<sup>107</sup>.

Being less amenable to asserting justificatory stories for incumbent interests, these kinds of more messy<sup>108</sup> models of change may be less likely to attract policy – or wider political – patronage<sup>109</sup>. Yet it is an insight well-established in co-productionist analysis<sup>110</sup>, that 'inconvenience' of this kind may inhibit the uptake of an idea like non-monotonic temporalities, but this need in no way lessen salience to the actual unfolding of "events, dear boy, events"<sup>111</sup>.

### 3.5 Relations between temporality and dimensionality

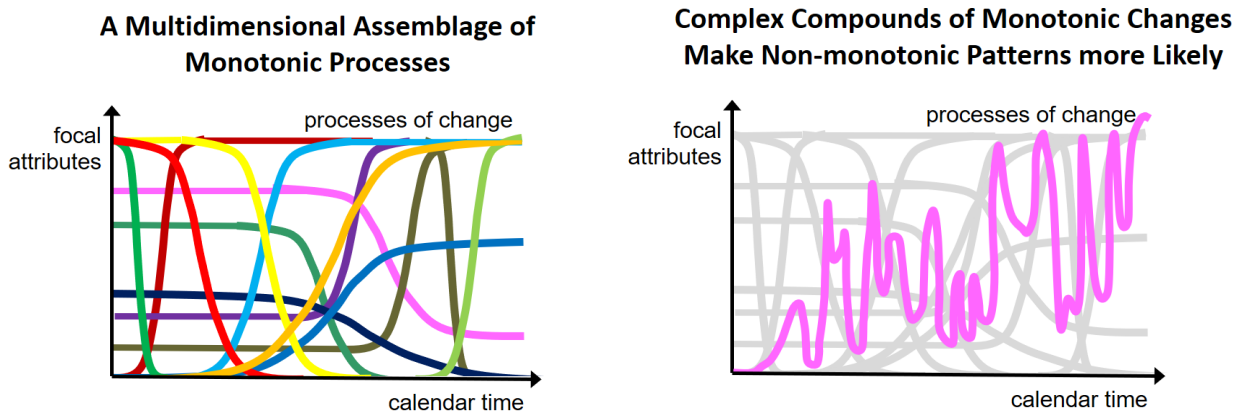
In this regard, the rationale for attending to non-monotonic as well as monotonic temporalities, may be more intuitive than that associated with discussion in the last section of this paper, of needs to move from monothetic to more polythetic approaches to categorisation? But the two themes are deeply related. For instance (as mentioned in the above quote from the bid), it is partly the possibility of there existing multiple complex dimensionalities through which to distinguish conditions before and after a notional transformation (either in imaginaries or encompassing societies), that raises issues of temporality in the first place.

If a process of transformation is imagined as a transition between two monothetically-defined categories, then issues of temporality may appear rather simple. This is true equally of changes seen relatively directly and positively in relation to a given 'sustainability transition' or understood in a more co-productionist way as change in associated 'socio-technical imaginaries'. Either way, the main structure of analysis is framed around implicitly essentialised states, one *ex ante* and one *ex post* in relation to the notional process of change. So, whatever detailed empirical complexities may be encountered in time or space in relation to this transformation, the framing is essentially one-dimensional between what went before and what comes after.

But this expediency destabilises when more multidimensional analysis is undertaken in the sense discussed in the last section. Here, either sociotechnical imaginaries and/or associated sustainability transformations may be treated in a more polythetic style (as summarised, for instance, in Figures 5 and 6). Then, the practical possibility emerges more strongly, that processes of change may themselves also be far more complex than is suggested in this kind of frame. In this case, what the GOST bid called "*contingent, disorderly ways*" in which change can unfold, may not so easily be dismissed as ephemeral 'noise' around a central process where one clear category is replaced by another. A stylised view of this point is illustrated in Figure 9 below.

**Figure 9: a stylised picture of relations between complexities in dimensionalities and temporalities**

Compounded one-dimensional monotonic changes yield non-monotonic change in the multidimensional assemblage.



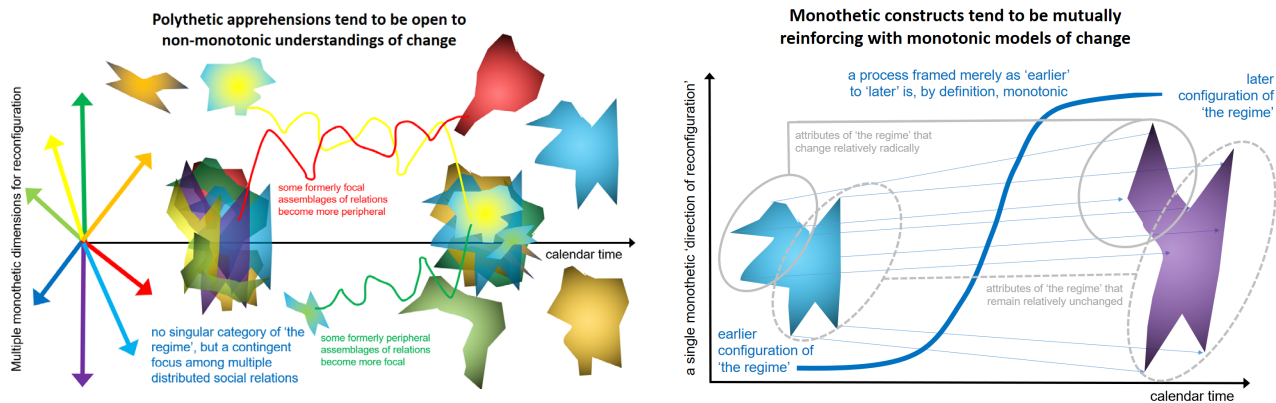
What Figure 9 shows about this relation between dimensionality and temporality, is that the greater complexity of higher dimensionalities might (in and of itself) be expected (all else being equal), to result in more complex forms of temporality. It may of course, also be that the kinds of change characterised by single dimensions can also be non-monotonic. In this event, the point being made here about the importance of complexity, will apply even more strongly. But Figure 9 shows how the likelihood of empirically recognising non-monotonicity can be expected generally to rise with capacities to attend to multiple dimensionalities.

This is because a polythetic view of either imaginaries or transformations will allow that each among many dimensions in understandings of focal processes, may implicate not only its own distinctive direction of change, but also its own modality of temporality. Just as connotations of multiple dimensionality may transcend those of more disciplined notions of multi-dimensionality, so too can the wider implications of multiple temporalities be distinguished more deeply than the circumscribed (non-)monotonicity divide alone. Figure 10 (below) shows

how these complex polythetic non-monotonic associations between dimensionality and temporality (on the left) are simplified under conventional monothetic monotonic views (on the right).

**Figure 10: simplifying polythetic non-monotonic transformations to monothetic monotonic transitions**

Shown on the left, multiple dimensionalities of polythetic constructs of phenomena undergoing change (imaginaries or transformations) enable apprehension in more fine-grain ways of more non-monotonic temporalities. Both before and after, focal phenomena are framed in a more complex and conditional manner – fluid and relational more than rigid and categorical. Shown on the right, the simpler storylines of this complexity that are favoured for purposes of policy justification assert monothetic constructs both ‘before’ and ‘after’ ‘the transition’, as well as on processes of transformation themselves. Transformation is thus represented simplistically as singular and temporality as monotonic.



Under instrumental pressures noted above for disciplinary ‘impact’ and political patronage, inconveniently complex wranglings between dimensionalities and temporalities on the right of Figure 10 typically become lost in the constructing of expediently simplistic policy narratives of transformation as shown on the left hand side. It is routine, for example, to focus attention simply on one selected (ostensibly singular) dimension running from ‘before’ to ‘after’ some specific idiosyncratically-imagined transition process. Analysis adopts a specific characterisation of an earlier (current) configuration of a notionally unitary focus of interest (eg: ‘the regime’; ‘the system’) and then frames the process of change according to circumscribed notions of what counts as salient. By combining monothetic constructs of what it is that is changing and monotonic framings of processes of change themselves, appreciation is side-lined for more messy or unruly dynamics of transformation. It is to help resist these forms of potentially highly misleading expediency (summarised in Figure 10), that it has been suggested that a distinction be made between simplistic models of ‘transition’ and more realistically complex processes of ‘transformation’<sup>112</sup>.

It is even more important to appreciate this particular dimension of hidden complexity in representations of temporality, because behind this picture there hide many further kinds of complexity that further intensify the point being made here about the dangers of expedient policy simplifications. Beyond these interlinked issues of polythety and non-monotonicity, many different disciplines show how temporalities may vary not just in their undulating directions, but also in more fundamental features of their ontologies<sup>113</sup>. In ways that it is not necessary for present purposes fully to explore here, radical implications arise from temporalities being variously characterised as:

- ‘cyclical’, ‘linear’, ‘epidemic’ or ‘chaotic’ in their patterns<sup>114</sup>;
- ‘endogenous’ or ‘exogenous’; ‘mundane’ or ‘exotic’ in their provenance<sup>115</sup>;
- ‘geometric’, ‘exponential’ or ‘hyperbolic’ in their dynamics<sup>116</sup>;
- ‘closed’, ‘open’ or ‘recursive’ in their topologies<sup>117</sup>;
- ‘scaled’, ‘fractal’ or ‘rhizomic’ in their nestings<sup>118</sup>;
- ‘evolutionary’, ‘dialectical’ or ‘teleological’ in their drivers<sup>119</sup>;
- ‘deterministic’, ‘immanent’ or ‘emergent’ in their processes<sup>120</sup>;

- 'arrhythmic', 'polyrhythmic', or 'isorhythmic' in their periodicities<sup>121</sup>;
- 'continuous' or 'discrete'; 'vertical' or 'horizontal' in their relations<sup>122</sup>;

Far beyond the particular notionally constituting attributes of presumptively discrete *ex ante* or *ex post* states, then, issues of temporality emerge in much more profound forms than simply the possibility that directions of change may go in entirely different – even opposite – directions in different respects over the same period. Just as dimensions may vary in their underlying ontologies as well as their partitioned attributes, so too may contrasting temporalities contrast with each in more radically disparate ways than merely whether they are characterisable as 'monotonic' or 'non-monotonic'.

So, this simply underscores even more strongly, the central point argued here about multiple temporalities and their relationship with multiple dimensionalities. If other implicated categories are recognised to be characterisable in polythetic ways, then so too may processes of change be recognised as similarly unruly. Under such circumstances, what this means in practice, is that a conventional view of transformative change is even more manifestly invalid than at first appears. The idea referred to in the bid, of a classic logistic function or s-curve, running through an orderly sequence of notionally discrete stages (eg: 'predevelopment', 'take-off', 'acceleration', 'stabilization'), is clearly recognisable as a potentially damaging artefact of method.

### 3.6 Analytical neglect of non-monotonicity

It need not be seen as a sign of ignorance, that academic research and policy appraisal concerning processes of social transformation are so routinely neglectful of these inconveniently messy and undisciplined wider implications of multiple temporalities. That attention so often fixates on an ostensibly simple monotonic storyline (or sometimes on a presumptively highly regular form of non-monotonicity) may actually be a reflection of the relatively expedient functionality of this kind of storyline.

This again becomes clear when it is taken seriously that understandings of temporality are co-produced with the encompassing social orders in which such knowledges are produced and used. In this sense, it can be seen as a reflection of more subtle, knowing – and worldly – qualities in understanding, that such relatively simply ontologies are propounded as 'necessary fictions'. For – as is shown in Figure 10 – it is arguably the rigidly monothetic categorical assertions associated with monotonic narratives of change, that make such stories effective as political interventions in their own right. Interests that associate with simplifying frames are thereby reinforced, whilst potentially threatening alternatives are conveniently foreshortened and side-lined. Either way, in whatever hands, a simple monotonic storyline does not need to be true to be effective.

Ironically, however, a similar pattern of neglect can also arise for less obviously instrumental reasons. This can apply, for instance, even to self-consciously critical perspectives, of kinds that define themselves in contrast with the conventional policy cultures where such instrumental syndromes are most pronounced. These too can display pressures and resulting tendencies to side-line attention to non-monotonic dynamics.

What is arguably operational here, are the tendencies noted above, for attention to undulating, arrhythmic, turbulent – and generally more 'messy' – dynamics to associate with a natural scientific idiom around 'cycles', 'fluctuations' and supposedly regularised 'waves'. For self-consciously 'critical' sensibilities or disciplinary commitments formed in opposition to such a natural science idiom, this can add its own dis-incentivising implications. This can be so, especially where identities are as formative as substance in the shaping of style. Either way, it is the instrumental value of a positive deterministic idiom to incumbent policy interests, that can deter those wishing to challenge these interests from becoming associated with the same kind of idiom.

Whilst analytic language and style are of course always context-dependent, sticky and never innocent, it does not therefore follow that they are irrevocably determining of associated politics. It is precisely an insight of polythetic understandings, that contrasts and correspondences can be recognised as overdrawn between 'critical' or 'instrumental' perspectives; 'qualitative' or 'quantitative' methods; 'constructivist' or 'positive' understandings and 'humanities' or 'natural science' idiom<sup>123</sup>. Such distinctions can be acknowledged as salient, whilst at the same time recognising that each may also – in particular settings and perspectives – associate substantively and authentically with supposedly opposing attributes in other respects.

In this way, then, it is perfectly possible and legitimate for 'interpretive' analysis to attribute 'positive' understandings<sup>124</sup>; for constructivist insights to be expressed in quantitative methods<sup>125</sup> and for 'critical' research to deploy 'instrumental' approaches attuned to its own ends<sup>126</sup>. Likewise, a prevalence in some fields of a natural scientific idiom in addressing phenomena like non-monotonicity, need not be taken as a reason to deter other perspectives from attending to the same phenomena in a different register. Otherwise, there might follow a rather ironic outcome, in which 'constructivist' communities become unreflexive about their own conditionalities – and 'critical' nondeterministic perspectives find themselves uncritically determined by precisely the positive instrumental approaches they disassociate from most substantively.

In all these ways, then, there is no reason why critical, constructivist, interpretive attention to non-monotonic dynamics over time, should be deterred by the frequent descriptions of such phenomena in the positive language of 'fluctuations', 'oscillations' and 'waves'. It would be strange indeed, if historical processes as evidently important in their possible salience as undulation, turbulence and incipient rhythmicity were to be side-lined for such essentially parochial disciplinary reasons. It would be even more odd, that a corollary of such a syndrome (even to a small degree), would be a tendency for critical constructivist perspectives to confine themselves to the generally more simplistic, deterministic, instrumental ontology of monotonicity.

### 3.7 Practical implications

As with dimensionalities, then, it follows from all this, that the kinds of temporalities that may emerge in research concerning sociotechnical imaginaries and associated sustainability transformations may prove:

- (i) to be **less easily separable** from each other than might otherwise be expected or assumed;
- (ii) to depend more obviously than may appear, on **subjective prioritising of attributes** for analysis;
- (iii) to display in ways worthy of attention, **variable degrees in how they might be distinguished**;
- (iv) to be **concurrently co-located collectively together** to contrasting extents in any given setting;
- (v) to be less independent than dependent, in their **mutually constituting relations** with one other;
- (vi) to thereby **defy simple one-to-one correspondences** in comparison with other aspects in focus (for instance, such as those notionally based on national jurisdictions or temporal periods);
- (vii) to display regularities not only at the level of ostensibly singular temporalities in any specific context, but also more **'ecological' patterns in diverse relations** between temporalities of change and other aspects associated with contrasting views of imaginaries or transformations.

In simpler terms, then both sociotechnical imaginaries and sustainability transformations may – more than is usually acknowledged – be seen to evoke sometimes radically contrasting temporalities of change that are: (i) not easily distinguished; (ii) in the eye of the beholder; (iii) ambiguous in their presence or absence; (iv) found together, not individually; (v) interdependent more than separate; (vi) resistant to simplistic comparisons; and (vii) important more for their relations than their identities.

Again, the point here is not these kinds of more complex pattern are not in principle already sometimes acknowledged in relevant literatures concerning sociotechnical imaginaries or sustainability transformations. Nor is the point that they are somehow necessarily of greater relevance or interest than those patterns that are more routinely identified in either field. In line with the highlighting of **complexity** at the centre of the GOST project (see above), the key point instead, is that it is only by framing analysis in this way, that it might emerge (in ways that can be readily interrogated), whether these more complex kinds of pattern are salient.

## 4 MULTIPLE DIMENSIONALITIES IN KENYAN IMAGINARIES OF URBAN TRANSFORMATIONS

### 4.1 Q Method: an approach to engaging with multiple dimensionalities

A Q study follows a fairly standardised methodological protocol whereby a ‘concourse’ is first developed, involving the gathering together of diverse statements about the focal topic. From this, a subset of statements is selected (the ‘Q set’) which are presented to participants as the stimuli for their active representation of their views. Participants in a study are purposively selected to maximise the diversity of views, and hence the potential dimensions of difference between these. During a Q sort interview, participants are asked to rank-order the statements from ‘most like’ to least like’ their viewpoint into a grid distribution. In ‘Q parlance’, participants imbue statements with different degrees of ‘psychological significance’ through the process of doing a sort. The resulting Q sort patterns are subject to factor analysis, which reveals clusterings of similarly performed sorts. These ‘factors’ represent idealised views shared among two or more participants, and enables the researcher to understand the dimensions along which factors/views can be distinguished from one another, as well as to gain insight into the relationships between factors/views (which will frequently be correlated with one another to a greater or lesser extent). The incorporation of quantitative, statistical elements in Q methodology, and the fact that the method requires the researcher to work through a standard protocol in a fairly prescribed way arguably puts the method into productive tension with much constructivist STS research, in which the (largely interpretive) research methods used, are often held to become intuitive over the course of carrying out research of this type. However, despite the quantitative underpinnings and standardised protocol, Q method is fundamentally an *interpretive* method<sup>127</sup>, and even apparently statistically determined elements of the process such as factor selection, ultimately derive ‘from an understanding of what factors mean’<sup>128</sup>.

Importantly for the present discussion of dimensionalities, although a researcher might hypothesize about the kinds of patternings of viewpoints that might be expected to exist in a given study context, the diversity, structure and relationship to one another of the emergent ‘factors’ or imaginaries (i.e. the number and nature of the dimensions along which differences between views can be distinguished) is an emergent property of the study itself. This is not to imply that views or imaginaries are simply ‘scientifically determined’<sup>129</sup> in a Q study, awaiting the discovery by the researcher, but rather, these elements are not fixed at the outset by the researcher alone. Respondents in a Q study actively shape these constructs themselves, creating a representation of their ‘whole’ view by bringing discursive fragments into conversation with one another in the process of doing a Q sort. This provides a window – from the inside (individual) out – into the shifting processes of negotiation of collective imaginaries, the meanings of which are neither singular nor fixed, but rather emergent as individuals engage with existing texts, and weave these into changing, sometime contradictory narratives in particular contexts, cultures and moments in time.

Although no method can, nor should, remove entirely the subjectivity and biases of the researcher (and in a Q study it should be readily apparent that researcher subjectivity infuses all stages of the research process, from the framing of the study; the selection of statements; the number and rotation of factors, and ultimately the interpretation of the results), however, Q method represents an attempt on the part of the researchers, to ‘surrender the monopoly of control in their relationship with the researched and so contribute to more democratic research design and implementation’<sup>130</sup>.

The following paragraph provides a brief outline of the discursive context of urban futures in Kenya, while section 4.3 describes the specific research process undertaken in Kenya.

### 4.2 Imagining urban futures in Kenya

Urban futures in Kenya are currently being imagined into being through a number of high level official ‘Master Plans’, ‘visions’ and ‘strategies’, most notably, Kenya’s long term national planning strategy or ‘development blueprint’: Kenya Vision 2030<sup>131</sup>. Kenya Vision 2030 shapes a range of urban development policies, including the Nairobi Metro 2030 Strategy (launched in 2008) and the Nairobi Integrated Urban Development Master

Plan (NIUPLAN)<sup>132</sup>; as well as raft of ICT policies and Master Plans<sup>133</sup>. The common threads linking these policies are the belief in power of top-down holistic urban master-planning, and (in line with a 'digital turn' in development<sup>134</sup> a belief in the transformative power of ICT for development.

The explicit imperative as outlined in these incumbent policies is that Kenya become an 'industrialised information society and knowledge economy' in the coming decade. ICT is framed as the key to helping Kenya benefit from the 'fourth industrial revolution' in order to 'leapfrog into a transformed society where every citizen will have better access to opportunities to improve their livelihoods and harness the benefits of a digital economy'<sup>135</sup>. The publication of Kenya Vision 2030 follows a development trend that has been witnessed across sub-Saharan Africa, from donor-driven development policies framed around reducing poverty, toward state-led 'visions' and Master Plans, often with a focus on large scale infrastructure projects, frequently financed by Chinese investment and loans<sup>136</sup>.

The influence of models of 'Chinese urbanism'<sup>137</sup> and expertise in mega-projects<sup>138</sup>, mean that over the past decade China has become the 'epicentre of the neo-urbanization process that is being strongly promoted in Africa'<sup>139</sup>. While there has been much rhetoric around South-South cooperation arguing that these new configurations represent a fundamental rupture from colonial-era relations and dynamics, others have been critical of this notion, and there has been some push back by African governments against what has been critiqued as 'debt-trap diplomacy'<sup>140</sup>.

While there is a degree of novelty in that the countries to be emulated in urban development are no longer in Europe or the US, but rather Malaysia, Singapore, South Korea, China, India among others, Kimari and Ernston argue that the new model replicates colonial and racist relations, practices and structures, despite the language of 'partnership' and 'friendship' that accompanies such development. They suggest that contemporary large scale infrastructure projects across Africa 'have to be understood in relation to inherited material and discursive scaffoldings that remain from the colonial period' and argue that 'recent mega infrastructures inhere, in their planning, financing and implementation, to a colonial racialism, despite rhetorical claims to the opposite'<sup>141</sup>.

As well as defining the parameters of urban policy in Kenya, Vision 2030 outlines plans for two 'flagship' new cities, to be built from scratch: Konza and Tatu. The stated aims are to build new cities is in response to rapid urbanisation in order to 'relieve the pressure' from existing urban centres and attract foreign investment. However, proliferation of plans for new cities across Africa, has been critiqued as reflecting a form of 'speculative urbanism'<sup>142</sup>, 'linked to the highly remunerative challenge of transforming rural economies into urban real estate'<sup>143</sup>. Often marketed with reference to globally circulating imaginaries of 'smartness'<sup>144</sup>, these cities are in varying states of emergence, and exist primarily as glossy architects renderings on billboards and online, in what Smith refers to as the 'spectacle of official planning'<sup>145</sup>.

Despite the optimism they exude, new cities in many cases perpetuate unequal configurations of power and colonial ideals of modernity<sup>146</sup>, hence Manji has argued that Kenya Vision 2030 'functions predominantly as a political manifesto for the continued polarisation of wealth and power which has scarred the city since the colonial period'<sup>147</sup>. Watson refers to these cities as 'fantasies' or 'nightmares'<sup>148</sup>, and various authors have drawn attention to the ways in which these new cities cater for a relatively wealthy minority in urban contexts in which the majority populations are often facing extreme hardships and lack of basic services. Van Noorloos, and Kloosterboer compare these new cities to gated communities for middle and higher classes and highlight their tendency to implement 'post-democratic private-sector-driven governance', which they argue, means that at best, these cities are 'unsuitable for solving Africa's urban problems, and at worst they will increase expulsions and enclosures of the poor, public funding injustice and socio-spatial segregation and fragmentation'<sup>149</sup>.

The process by which a small but seductive set of visions, policies and templates have duplicated (or aim to replicate) the same spectacular skylines, neoliberal structuring and corporate management systems has been described as a trend of 'urban replication'<sup>150</sup>, or 'business consultancy urbanism'<sup>151</sup>. The concern of these visions with the 'symbolic power' of the city and the achievement of 'world class' status can be understood as a form of 'urban entrepreneurialism' in which cities are framed as actors competing with one another on the global stage to attract investment. A report by Pricewaterhouse Coopers typifies this narrative in claiming that 'competition among cities is intense, and a strong city brand is a potent weapon to maximise the visibility of a city's qualities and allow it to differentiate itself from its competitors'<sup>152</sup>.



Crucially, this focus on achieving ‘world class’ status has been critiqued as implying a primary ‘concern with the importance of a city in relation to other cities rather than the extent to which it functions for its citizens’<sup>153</sup>. Imaginaries of a hyper-modern ‘smart city’ have been critiqued as ‘telescopic’, by Amin who highlights the partial nature of visions in which ‘the prosaic, jobbing, informal, making do, surviving, unkempt, hybrid spaces occupied by the majority population—blurs out of focus, barely acknowledged as linked to the urban growth machine’<sup>154</sup>. In these visions, if informality features at all, it tends to be a problem (e.g. the ‘hawker menace’<sup>155</sup> to be solved through surveillance, containment and removal (often through violent policing)<sup>156</sup>.

### 4.3 Exploring imaginaries of urban future using Q methodology

As discussed in section 4.1, there are a number of standardised steps that together constitute a Q study: 1. Building the concourse (a process which aims to capture the discursive diversity around the focal topic); 2. Q set selection (a process which attempts to reproduce the diversity of the concourse in a smaller, more manageable number of statements, to be sorted by participants); 3. Purposive selection of participants and the Q sort/interview; 4. Factor analysis and interpretation of results.

#### *Building the concourse*

In the present research, we kept the focus broad, on ‘*imaginaries of transformation of cities in Kenya*’ (rather than an alternative, narrower focus on e.g. imaginaries of ‘smartness’). Our rationale was to enable an exploration of the highly visible future-making visions of actors involved in large-scale mega projects such as Konza City (and their linkages with internationally influential imaginaries of the ‘smart city’), but also to pay more symmetrical attention to the possible importance of other configurations of narratives and storylines, and crucially to examine the links between them.

An initial academic literature review identified key academic and policy documents on urban transformation (including e.g. Kenya Vision 2030; Nairobi Metro 2030 Strategy and Nairobi Integrated Urban Development Master Plan and others), and mapped the contours of the debate. This was followed by a broad internet search to identify non-academic material on urban transformation in the Kenyan context, using combinations of search terms: future cities, urban futures, transformation, digital infrastructure, smart city, urban technology, ICT, urban planning, sustainability. Material was read in detail and statements relevant to the focus of the study were extracted. Statements were collected in this way until a level of ‘saturation’ was reached, whereby it was felt that the addition of further statements would not significantly add to the diversity of statements in the concourse. The final concourse consisted of 198 statements from a diverse corpus of sources, including academic texts; policy/ government documents; corporate texts/advertising; civil society/NGO texts; magazine articles; blogs; newspaper articles; youtube videos and online comments on these.

#### *Selection of the Q set*

The aim of this process is, as far as possible, to capture the diversity of the larger concourse in a smaller subset of statements. In the present research, we were guided by our emerging understanding of some of the key tensions, debates and differences that appeared in the literature, and selection aimed to ensure that statements representative of these diverse views were present in the Q set. Statements were all written in English<sup>157</sup>. Statements were input into the free online software [Qsoftware.net](http://Qsoftware.net) in order to carry out the sorting process remotely. A small pilot was carried out with three team members at Sussex and two invited participants in Kenya, in order to check the clarity and comprehensiveness of the statements and the sorting instructions, and to test the Qsoftware. Following the pilot a number of statements were edited for clarity. The final Q set consisted of 36 statements<sup>158</sup>.

#### *Participant selection and Q sorting*

Participants in a Q study are purposively selected on the basis of their immersion in the discourse in question, and with a view to maximising the diversity of views. In the present study, an initial participant list was drawn up from individual authors of some of the statements that had been included in the concourse (for example academics; government officials; civil society members; journalists and others). These were approached by email, and a snowballing approach was adopted whereby participants who took part were asked to identify others whose view might differ from their own. To date [21/01/21] fifteen people have undertaken the Q sort

online, eleven of which interviews have been recorded, and the process of transcribing and analysing the data is underway.

### *Emergent themes*

Although the study is ongoing, the desk based research and interviews carried out to date do hint at the presence of multiple imaginaries of urban futures in the Kenyan context. Although these emergent themes will not be the same as the narratives that emerge from the Q study, Figure 11 (overleaf) provides some tentative indication of the plurality of imaginaries apparent in the Kenyan context, and offers some candidate clusterings of views, and the dimensions along which these might be distinguishable from one another.

**Figure 11. Plural imaginaries of urban transformation in Kenya**

	Imaginary A	Imaginary B	Imaginary C
<i>Dimensions of imaginaries:</i>			
<i>transformation is:</i>	inevitable: digital technologies are transforming /will transform urban space in Kenya; governments and individuals must adapt to new realities or fall behind; happens through top-down Master Planning and visioning (e.g. Kenya 2030)	not happening in any meaningful/structural way: technology is entrenching and repeating the imperial patterns of colonialism	Bottom-up; community lead; slow; incremental (not really transformation?)
<i>cities are:</i>	systems of systems; brains; machines; compete with one another on the global stage	historically situated spaces; constrained by architectures (physical and discursive) of colonialism	culturally vibrant spaces of meaning; informality is key
<i>focus on a population who is:</i>	Aspirational middle class (growing), & want security. Ideal citizen is 'a 'digital entrepreneur' in the knowledge economy	mostly poor; need jobs and housing; work in informal economy; rights to be protected	mostly poor; need jobs and housing; work in informal economy; rights to be protected
<i>concerned with:</i>	attracting external investment; infrastructure as key to development; natural population growth and urbanisation	addressing inequality; questioning / redressing unequal colonial/ capitalist relations	meeting the basic needs of urban poor; making visible the invisible; tools for challenging power; building community
<i>digital technologies:</i>	are crucial to development; ICT (inc. big data, internet of things, robotics etc.) can shape city planning in optimal ways	reproduce colonial relationships through 'techsplotation'; are associated with multiple risks (surveillance; securitisation)	can help develop community involvement in urban planning; could build urban inclusion; allow bottom up mapping (making visible the invisible)
<i>key risks:</i>	falling behind; an insufficiently (digitally) skilled workforce	entrenching poverty; authoritarian governance	entrenching poverty
<i>Africa:</i>	is 'rising'; last frontier; but in need of external inputs/not ready to take advantage of new realities (deficits); devoid of history 'clean slate for innovative business models'; young population an advantage	is plagued by colonial history and capitalist present; corruption and elite capture	is the source of its own solutions - community building/horizontal engagement; rights-based approaches
<i>the cultural nuances of a city</i>	have little to do with urban transformation, it's the transformation that shapes the emergent culture (toward global consumer culture, entertainment, gaming)	have ties to the traditional norms of societies, that results in emergent niches of transformation in urban settings	Should be the basis for any efforts at urban change: cultural identities at the level of neighbourhoods and cities shape ideas about, and trajectories of transformation
<i>representative vocabulary and tropes:</i>	smartness; competition; industrial revolution 4.0; Africa rising; development corridors; 'Silicon Savannah'	colonialism; capitalism; racism; inequality	inclusion; empowerment; rights; community

#### 4.4 Implications of multiple dimensionalities urban transformations in Kenya

While data is still being collected in the Kenyan context, the review of the literature, and some of the emergent themes coming from the Q interviews, speak to the idea that constructs (imaginaries, transformations) defy simple one-to-one correspondences in comparison with other aspects in focus, and that there are a number of subjective ways in which attributes and scales for analysis might be prioritised, and which might then radically effect the subsequent analysis.

For example, with regard to the idea of 'one to one' correspondence of imaginaries and national or jurisdictional setting, this picture is complicated by the fact that various globally circulating terms (which have all been referred to in the language of sociotechnical imaginaries), are evidently shaping discourse to a greater or lesser extent in the Kenyan context, including for example: the discourse of 'ICT for development'<sup>159</sup>; the 'smart city'; the digital or knowledge economy; the idea of the 'world class city'. These constructs are understood, shaped, used, rejected or ignored by different actors in the Kenyan context in more or less strategic ways, and intersect and interact with a separate range of urban planning discourses and ideas that have been observed to be burgeoning across the African continent and beyond, including in particular the re-emergence of a trend toward conceptualising urban development via grand Master Plans and 'visions' and the idea of 'development corridors'. Further complicating the idea of any one-to-one correspondence, it is apparent that contemporary Kenyan discourses around urban development are also significantly shaped through interaction with specifically Chinese interests in the country, and related discourses and ideas about urban planning and infrastructural development more broadly. In the Kenyan context the space for imagination of urban futures continues to be significantly shaped by the continuing impacts of colonialism, which has left material and discursive 'scaffoldings'<sup>160</sup> and continues to inflict immense 'symbolic violence' on the 'collective African imaginary'<sup>161</sup> leading to what has been described as the 'destabilisation of African imaginations of the future'<sup>162</sup>.

Kenyan discourses around urban futures can be further nested within longstanding, polarised, discourse around African cities, in which on the one hand Africa's urban spaces are imagined as 'hopeless', violent, anarchic spaces of poverty and deprivation (and the site of external 'development' concern from post-colonial powers); versus on the other, a more recent, emergent (for some utopian) view of an African Renaissance or 'Africa Rising' narrative, featuring a growing, affluent African middle class inhabiting 'shiny' new cities, a narrative which draws on, and features many of the discourses referred to at the outset around achieving 'smartness' and becoming competitive and 'world class'.

This complex discursive picture might better be conceived of in terms of an ecosystem of imaginaries that emerge and evolve in relation to one another. The potential that culture may influence the outcome of urban transformation: as such '*cultural transformation*' contributing to whether a city develops towards smartness, or prioritises the equity among its citizens. On the other hand, as a city transforms, the potential that the identity – what a city is associated with/known for, would also change, introduces the plurality of dimensions that may emerge in exploring 'sustainable urban development'. These intertwined relationships between culture and urban transformation, has not been fully explored in this brief, although it presents a polythetic view on the urbanism.

## 5 NON-MONOTONICITY IN NUCLEAR TRANSFORMATIONS IN THE UK AND GERMANY

### 5.1 Conventional understandings of energy transformations

This strand of work focuses on the contrasting energy trajectories of Germany and the United Kingdom (UK) and relates to the thematic area of the ‘nuclear age’ as identified in the GoST proposal. Building on insights generated in previous research at SPRU<sup>163</sup> and using a comparative case study approach, this work offers a preliminary discussion of non-monotonic understandings of sociotechnical change as discussed in section 3 above.

German and UK energy transitions have been widely examined in work on ‘sustainability transitions’<sup>164</sup>. Indeed, Germany in particular has become an iconic example of a ‘regime shift’<sup>165</sup> in the language of this field of research. The familiar story here is of particular ‘niche’ innovations such as wind power and solar energy that over time, gained institutional credibility and increasing policy support and come to ‘destabilise’ dominant sociotechnical regimes including nuclear<sup>166</sup>. While more complex policy processes are addressed such as political and cultural factors including ‘anti-nuclear protest’ in the case of Germany, the multidimensional factors influencing dynamics of change in energy are not given similar weight to the primary focus on niche developments.

In keeping with the analysis here of multidimensionality (Section 2), it can be observed that particular dimensions related to the configuration of imaginaries, institutions, infrastructures and practices that are ‘internal’ to the focal regime are prioritised in analysis over other dimensions that are more peripheral to this core analytic construct of ‘the regime’. This tendency on the part of researchers holds implications for the understandings of temporality that emerge from such accounts. With the primary focus being on the emergence and development of ‘niche innovations’, sustainability transitions accounts tend to be dominated by what might be described as an ‘*innovation temporality*’. By contrast with many of the temporalities discussed in section 3, this tends to take a *linear* form – and be characterised as passing through pre-defined stages towards a certain envisaged horizon (such as technological maturity and decline). The temporality in these accounts can also be understood as singular, in the sense that the temporal dynamics of ‘regime’ or ‘incumbent’ technological infrastructures are understood as a consequence of the emergence of a given novel technological configuration. For example, rather than being studied as a focal point of enquiry with its own dynamics that generate momentum and operate on particular time-scales, energy transitions research tends to frame nuclear power in Germany as being ‘destabilised’ as various sequences of niche development (along with ‘landscape shocks’ such as Fukushima) take place<sup>167</sup>.

The case of the UK is also distinctive when it comes to nuclear and renewable trajectories but for different reasons to Germany. Indeed, what is remarkable is the endurance in this settings of intensely persistent imaginaries of ‘nuclear futures’. This is all the more notable, for coinciding with the marked pattern of deterioration in the UK nuclear industry, an industry that has performed particularly poorly when compared internationally (including especially the same industry in Germany)<sup>168</sup>. Yet, attention to this remarkable temporal endurance remains largely unattended to in sustainability transitions and innovation literatures. Indeed, when the issue is confronted, a key explanation is that what is occurring is ‘regime resistance’ against the ascendancy of renewables<sup>169</sup>. Such an approach highlights the singular way in which temporality is considered. The industrial dynamics of UK nuclear are not considered other than as acts of ‘resistance’ to the seemingly inevitable temporality of an innovation trajectory.

There is of course nothing inherently wrong with such interpretations. In one sense, they offer a valid depiction from a particular perspective, capturing important dynamics in terms of innovation trajectories. Processes like niche protection, nurturing, retention and maturity are important ways of understanding how novel technologies develop and can be supported by policy<sup>170</sup>. However, complexity can be missed in terms of the messier processes through which particular technological configurations emerge. For instance, rather than a singular direction of travel towards a certain end point, trajectories might be influenced by ebbs and flows between

contending sociotechnical futures, with expansions and contractions occurring that can easily be obscured by linear and sequential accounts.

In the present empirical section, we analyse the possible contribution to non-monotonic understandings of temporality in sustainability transformations in two stages. These are as follows: First, we give more equal weight to the dynamics over time of both renewables and nuclear in narrative accounts and how these two trajectories undulate over time rather than prioritising one over the other. Thus we focus on multiple rather than singular accounts of temporality. Here, we focus on the relative intensities of structuration towards trajectories favouring renewables and nuclear rather than beginning from the assumptions inherent in *innovation temporalities*. We discuss this in section 5.2.

Second, we consider the implications for research on sociotechnical imaginaries if the vantage point on time is changed from linear understandings to *rhythmic* understandings of temporality which we discuss in section 5.3. Using the UK nuclear case as an initial example, we focus on the material rhythmic patterns that can be analysed as a way of understanding a crucial question provoked by the discussion below in terms of why it is that the UK sociotechnical imaginary of nuclear futures has defied the usual temporal assumptions of innovation and transitions theory while in Germany the nuclear imaginary has been significantly 'unmade'<sup>171</sup>.

## 5.2 Comparative historical patterns in UK and German energy systems

Elsewhere, we have assessed the respective nuclear trajectories of Germany and the UK based on a range of nine criteria constituted by twenty-nine parameters encapsulating factors considered 'internal' to the niche-regime configuration (such as market structure, strength of industry, resource potentials) of sustainability transitions, and those 'external' (including qualities of democracy, military related factors, and public protest and opinion)<sup>172</sup>. What this research illuminated was that based on 'internal' factors, the discontinuation of nuclear would be considered more likely in the UK rather than Germany, given that the UK's nuclear industry is considerably weaker and the renewables resource the best in Europe<sup>173</sup>. This is of course the reverse of what has actually occurred. Yet, this research did not attend to the same degree to changes over time in each country. Thus, the present work focusses on a narrative account that examine the dynamics of change in renewables and nuclear in each country. This work takes off from the previous criteria-based comparison however, in not prioritising an innovation trajectory focussed on the ascendancy of renewables (with its own temporal assumptions) but attending to the temporal dynamics of both renewable and nuclear trajectories and how these develop over time.

We study a range of factors influencing these trajectories including official policy, politics, governance, sociotechnical developments, and particular problems arising that shape the nuclear debate. Looking at these different dimensions and the relative intensities of structuration towards both nuclear and renewables, rather than a linear progression slowly building up towards a point of technological maturity and stabilisation, we can see temporal dynamics that are more undulating in terms of expansions and contractions and how sociotechnical developments in each trajectory influence one another. For the purposes of an overview, the following bullet points highlight key themes that emerge from such an account that relate to understandings of temporality:

- *Rethinking the sequence of innovation trajectories*. What is clear in the account below, is that the assumed sequence that innovation temporalities follow, in terms of the gradual build-up of niches leading to the destabilisation of the regime, misses the key role that efforts to discontinue certain technological trajectories play in earlier stages of sociotechnical change. In the case of Germany, efforts to discontinue nuclear emerged early on and were as much generative of the development of renewable niches as they were a consequence.
- *Multi-temporal dynamics of technological change*. Rather than the singular *innovation temporality* being the primary shaper of the speed and form in which the technological trajectories develop, in both Germany and the UK, the expansions and contractions of these trajectories were shaped as much by: electoral cycles; economic markets; urgent agendas around privatisation and liberalisation; major

accidents; different speeds and approaches to policy making; cultural movements, and in the case of the UK, military agendas.

- *Non-linear change.* Rather than the gradual linear build-up of renewables and the destabilisation of nuclear, we see undulations occurring in each country, where particularly in the first decade of the 21<sup>st</sup> century, a remarkable resurgence of enthusiasm for nuclear takes place in the UK, and to a far lesser extent in Germany. This resurgence, does not follow the sequential pattern of change that would be expected in sustainability transitions accounts.
- *Temporalities of UK nuclear as an anomaly.* Following on from the point above, it is the case that the resilience of intensities for new nuclear in the UK can be understood as defying the temporal assumptions of innovation and sustainability transitions literatures. Given that at the time of writing, the UK remains intensely committed to new nuclear despite the significant ‘destabilisation’ of the nuclear industry both in the UK and globally as well as the rapid rise of cost-effective renewables, it is worth looking in more detail at how the temporalities of the German and UK nuclear industries contrast to understand this anomaly.

The Figures 12 and 13 below offer a consistently-stylised comparative overviews of broad impressionistic patterns in the unfolding of nuclear and renewables trajectories over the past sixty years, (respectively) in Germany and the UK. With the horizontal axis showing calendar time, the terms used in the twin calibrated vertical axes to each chart were developed for another purpose. But these operationalise quite serviceably for present purposes, two different lenses on temporality.

The first (shown on the left hand axis of each chart) addresses the degree of alignment in governance processes towards the sustaining of the trajectory in question (nuclear or renewable) – addressed on a moment-by-moment basis as a derivative of passing time. The second (shown on the right hand axis) portrays the intensity of consequent structuration around each of the two trajectories in focus (nuclear or renewable) – addressed on a cumulative basis as an integral of passing time. What emerges is a stylised illustration of how key dynamics bearing on the reinforcing or eroding of the nuclear trajectory or the building or reversal of the incipient renewable trajectory can be understood to be non-monotonic in their temporalities. We discuss below in more narrative form, key features and associated evidence that might be taken to lead to this broad picture

Fig 12: Temporalities in German energy dynamics

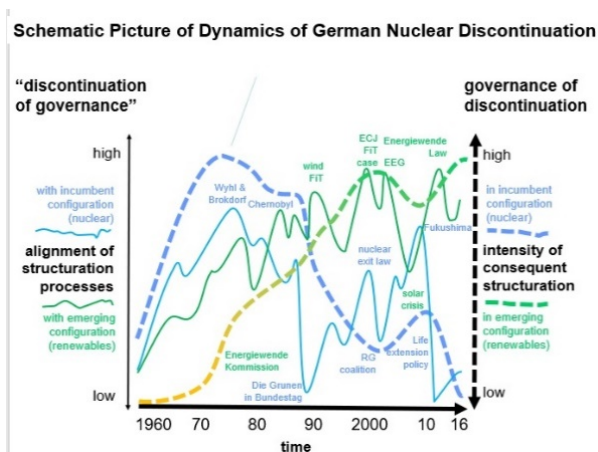
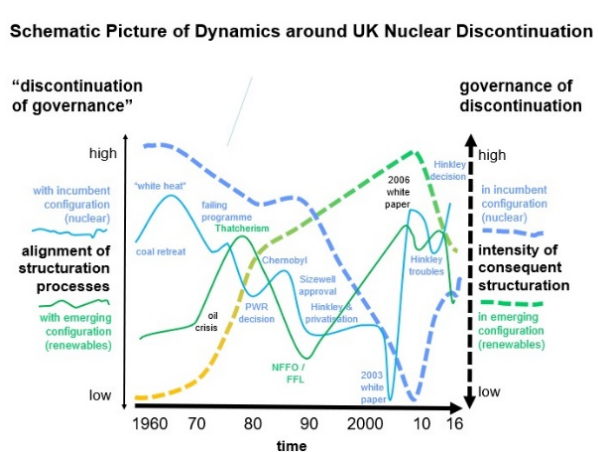


Fig 13: Temporalities in UK energy dynamics



In both national settings between the 1970s and 1980s, there was an *unravelling of the consensus around nuclear*. At the beginning of this period, policy was strongly in favour of the development of nuclear. Imaginaries of nuclear futures dominated policy discussions. However, through a series of issues, including on-land management and marine dumping of waste, civil-military connections, and particularly in the case of Germany, the perceived authoritarian processes through which nuclear plants were being authorised and constructed, scrutinization and protest against nuclear steadily grew. Significant grassroots protest movements

emerged in Germany<sup>174</sup>, and to a lesser extent in the UK at sites including Torness<sup>175</sup>. These collective endeavours to end the use of nuclear power emerged before the presence of 'mature' alternatives to nuclear energy technologies. In other words pressures to end or discontinue nuclear power, might be judged to be more generative, than they were a consequence, of the development of renewable 'niches'.

In the 1980s, the *institutionalisation of the nuclear debate* unfolded in each country in differing ways. In the UK this occurred through the setting of the public inquiry and planning process, while in Germany the more rapid political institutionalisation of the nuclear debate was influenced by what Johnstone and Stirling<sup>176</sup> recognise on the basis of a wide extant literature to be the contrasting 'qualities of democracy' in these two countries. This phrase refers to a number of different dimensions, including centralisation, secrecy, and the finer grain accountability achieved through the proportional representation system in Germany which enabled significant Green Party representation in the German Bundestag, but none at all in Westminster, despite levels of support that were not so massively different<sup>177</sup>. Indeed, it was not until 25 years after the Greens entered the Bundestag in Germany that a single Green Party MP was elected in the British Parliament.

The Chernobyl disaster proved a pivotal moment in 1986, which saw the position of nuclear power being significantly more adversely affected in Germany than in the UK with the Social Democratic Party announcing a gradual phase out. However, in the UK, imaginaries of nuclear futures were also set back. This was not due to political pressure to the same extent, but rather the deteriorating conditions of the industry itself. As part of a sweeping set of economic reforms, 1989 saw Margaret Thatcher bringing in the Electricity Privatisation Act<sup>178</sup>, inadvertently revealing the true cost of nuclear with a consequence that it became evident that new nuclear construction would not be possible in 'liberalised' electricity markets.

For contrasting reasons then, by the 1990s nuclear had to a certain extent *fallen out of favour* in the policy sphere in each country. Yet, the extent to which the gradient shifted towards renewables as a consequence was significantly different. While in Germany, mechanisms including the 1,000 roofs programme and the First Feed-in-Law to support renewables were implemented, in the UK the Non-Fossil Fuel Obligation (NFFO) was implemented which supported all non-fossil fuel emitting technologies including nuclear, rather than technology-specific interventions to support renewables<sup>179</sup>. On top of this, the failures of nuclear to function in liberalised energy markets saw nuclear uniquely shielded from the effects of electricity market reforms and it was not until 1996 that the company British Energy was privatised<sup>180</sup>. With the economic realities of nuclear now so clearly exposed, there were no firm political commitments made towards new nuclear in the 1990s in the UK.

At the start of the 21<sup>st</sup> century, the economic take-off of renewables permitted by the emerging policy instruments, saw the intensity of imaginaries grow around possible renewables-based futures. Further *nuclear decline* was experienced in both countries. However, in the latter part of that first decade processes of *nuclear renewal* began to consolidate in both countries. In terms of the undulating nature of the evident temporality, this is one of the most revealing periods. Roughly simultaneously, imaginaries became more aligned around both nuclear and renewable energy infrastructures, with associated institutions also consolidating at broadly the same time in support of each trajectory.

Again, the ways in which opportunities for renewables arose in the first decade of the 21<sup>st</sup> century in each country were different. In Germany proportional representation helped a 'Red-Green' coalition Government enter power and through negotiation with the nuclear industry, form an agreement on the Nuclear Exit Law in 2002<sup>181</sup>. This followed the landmark Energy Act (EEG) in 2000 which saw long-term support for renewables through Feed-in-Tariffs (FiTs). Yet at the same time, the rising climate change agenda also helped reinforce the prominence of nuclear imaginaries over this same first decade of the 2000s, with a realpolitik that was widely expected to see an unravelling of the phase-out plans.

Exceptional policy developments also occurred during this period in the UK. Against the backdrop of the particularly poor performance of the UK nuclear industry with the collapse of British energy through bankruptcy and its bailout in 2002, an Energy White Paper released in 2003 was the first in the Post-Second World War period not to support the construction of new nuclear power, instead favoring renewables and energy efficiency<sup>182</sup>. This was the consequence of another anomalous occasion in UK energy policy, where for the first time a dedicated and detailed review by a broad range of independent energy expertise, rather than civil



servants and industry, contributed to the formation of energy policy<sup>183</sup>. Again, as in Germany, the support base evidently continued around nuclear power, but the more visible policy movements were in the opposite direction.

Against the grain of this ostensibly linear trajectory in the emergence and diffusion of renewable niches, processes of nuclear renewal were actually also taking place in both countries over this same period, albeit in radically different ways. In Germany, the resurgence of nuclear took the form of industrial pressures and rhetorical support from the Christian Democratic Party (CDU) to extend the lifetime of nuclear power plant operations and Angela Merkel managing to win a majority in the Bundestag, passed a law granting life extensions in 2010<sup>184</sup> which was met with significant protest<sup>185</sup>. The renewal of nuclear in the UK on the other hand, occurred with marked intensity and speed. Only three years after the 2003 Energy White Paper referred to nuclear power as “unattractive”, Prime Minister Tony Blair launched a new energy review, which despite being found “deeply flawed” by the Royal Courts of Justice, led Blair to conclude that nuclear ‘had a role to play’<sup>186</sup>. In 2008, another White Paper specifically for nuclear followed, setting out ambitious plans to construct a fleet of new nuclear power stations, with it later being outlined that several reactors would be built “significantly before 2025”<sup>187</sup>.

What is notable about this resurgence, is that expert nuclear debates register in this period no marked improvements in the economic or technical problems that had formerly plagued UK nuclear power. Nor were there developments in energy systems that would undermine the findings of the conclusions of the 2003 White Paper. Yet intense policy enthusiasm for nuclear-based futures had returned in a very short period of time. With this period in particular exemplifying the non-linear and undulating nature of sociotechnical change, the dynamics underpinning this are worthy of further investigation. While clear signs are evident of intense ‘lobbying’ activity, there has not been sufficient explanation of why that lobbying should have been so relatively strong and successful in the UK given the country’s particularly weak civil nuclear industry<sup>188</sup>. We discuss this query further in the next section, where dimensions of UK nuclear developments are discussed that extend beyond energy policy into military nuclear activities.

From 2011, the respective trajectories in the fortunes of nuclear and renewables were heavily influenced worldwide by the nuclear disaster at Fukushima in Japan. This is now a well-known ‘landscape shock’ in the language of sustainability transitions<sup>189</sup>, yet had profoundly different effects in Germany and the UK. In Germany, the effect was effectively to curtail the growing momentum against the nuclear phase-out noted above, with the decision famously made to phase out nuclear by 2022, a commitment that has remained steadfast in the preceding decade. In the UK, by contrast, intense commitment to new nuclear was redoubled over the ensuing decade and firm commitments and financial agreements reached to construct Hinkley Point C, despite massive clear cost-disadvantages. Indeed, in 2010, the UK established FiTs and support mechanisms for renewables that – with the UK’s superior renewable resource considered – saw rapid construction of renewables and plummeting costs. Counter to official expectations, it has been the dramatic growth of renewables, not the ‘nuclear renaissance’ which contributed to the rapid reduction of coal use in the UK between 2010-2020. However, despite the rapid growth of renewables between 2010-2015 intense prioritisation towards new nuclear rather than renewables occurred in 2015 as a number of policies supporting renewables were scaled back or scrapped while extra support for new nuclear including loan guarantees was provided<sup>190</sup>. The UK nuclear new build programme did not materialise in the timescale that had been articulated in visions set out in the UK ‘nuclear renaissance’. Indeed, almost every official projection concerning the speed and cost of renewables transitions in the UK have been proved false in that renewables have surpassed expectations, while nuclear projections have been proved false for different reasons: nuclear has failed to deliver on the stated aims set out to justify new nuclear power.

Yet, despite the indisputable fortunes regarding each sociotechnical trajectory, where renewables continue to outperform nuclear both internationally and in the UK, at the current juncture UK sociotechnical imaginaries for nuclear futures remain intense with recent commitments to a range of nuclear projects including entirely untested Small Modular Reactors<sup>191</sup>. In the past year, lobbying efforts in favour of nuclear have become particularly intense with a range of groups set up to promote the technology and ‘repentant environmentalists’

emerging to promote nuclear in the media, at exactly the time when it has become increasingly evident that the long-time horizons and huge costs of new nuclear are not suitable given the urgency of climate change<sup>192</sup>.

The narrative above is necessarily brief but serves to outline the kinds of contrasting undulations that have occurred with renewables and nuclear trajectories in Germany and the UK. More work is required to bottom out these dynamics, however approaching long-term change in this way, and focusing on changes in intensity towards respective trajectories over time, seems to capture the more undulating nature of sociotechnical change that has occurred rather than simply re-confirming a singular and linear understandings. This vantage point has important implications for thinking about future change and the assumptions that often underpin projections of technological progress.

Of course, many aspects of the above narrative raise serious questions that are worthy of further investigation – and which we discuss in the next section. It is evident in particular that undulations in dominant sociotechnical imaginaries around nuclear in the UK have transgressed the usual monotonic form of a mainstream ‘innovation temporality’, experiencing major apparent reversals in the late 1990s and early 2000s, only to reintensify. Indeed, it is now apparent in hindsight, that – unlike the pattern in Germany – the UK has proven distinctively immune to the worldwide destabilisation of the nuclear industry occurring through the 21<sup>st</sup> Century. Judging by design and construction activities, the UK’s own civil nuclear industry has been in consistent decline since the 1970s. The economic conditions of liberalised energy markets have made the UK an even more prohibitive environment for nuclear development than the greater sustained democratic and civil society opposition has managed to do in Germany. Yet, despite this and the striking growth in renewables surpassing expectations, elite British imaginaries remain steadfast around an asserted ‘need’ for nuclear. Perhaps most remarkable, the ‘external’ shock of the Fukushima accident counter-intuitively coincided with an upturn in official and media support for civil nuclear power in the UK. In the next section, we explore the dynamics of UK nuclear in terms of ‘rhythms’ – offering an example of the relevance of multiple temporalities in transformations to energy sustainability.

### 5.3 Implications of multiple temporalities for transformations to energy sustainability

In this section, we focus on the case of UK nuclear power to explore the implications of *multiple temporalities* as addressed in section 3 above, explicitly directing attention towards the potential *rhythmicity* of sociotechnical change as a distinct vantage point to imaginations based on conventional innovation temporalities involving neatly sequenced, one-directional understandings. As discussed in section 3 there emerges a crucial possible relationship here between multiple dimensionalities and multiple temporalities. This requires an expansion of attention beyond the usual focus of analysis in sustainability transitions and transformations research on particular ‘systems’ or ‘regimes’ (such as energy or food) that stages the ‘dance’ of sociotechnical change<sup>193</sup>. Possibilities emerge that momentum may also accumulate through processes of resonance between infrastructural rhythms extending well beyond this focus. With regard to UK nuclear, this involves looking at UK nuclear infrastructures across diverse activities in both civil and defence programmes, and asking questions about how elite UK sociotechnical imaginaries have been constituted historically in terms of the material drumbeat of infrastructural development. This has important implications in terms of shifting the emphasis away from the *evolution* of an ostensibly single sociotechnical imaginary towards a specific point of development, towards a focus on the *sustaining* of an assemblage of sociotechnical imaginaries through more undulating patterns of infrastructural change.

As discussed in Section 4 above, various strands in social theory have drawn on notions of *rhythm* to help understand social phenomena, often building on Lefebvre’s rhythm analysis to study how recurring patterns occur in everyday life and are constituted through the action of bodies. Time is not a constant in these accounts, but rather there are multiple-temporalities that are perceived, experienced, and performed through repeated social processes at different scales<sup>194</sup>. In a similar way, particular technologies have been understood from the perspective of rhythm, for example Friedman, in a discussion a variety of theories including life-cycle assessment models and Thomas Hughes’ the evolution of technological systems models, outlines the

particular ‘beats’ that can be understood within the development of Information Technology where *“the rhythm comes from the similarity of structures between the patterns, but not from the identical direction of sequencing within each occurrence of the pattern”*<sup>195</sup>. In a discussion on the ‘rhythms of infrastructure’ J alas et al highlight that energy technologies offer a particularly pertinent example of the need to maintain rhythm in infrastructural development given the risk of ‘interruptions’, and ‘blackouts’ that could occur, and that *“energy infrastructures can be understood and analysed through the rhythmicity that they produce and are embedded in”*<sup>196</sup>.

At face value, nuclear power in the UK seems to offer a particularly pertinent case for further study through a lens of temporal rhythmicity. Indeed, it is in exploring the discourse surrounding enduring intense elite UK policy imaginaries of nuclear futures, that the importance of rhythm seems particularly apparent. To an extent not seen with other technologies, emphasis is repeatedly placed on the importance of sustaining a regular ‘drumbeat’ of nuclear construction projects. Former Prime Minister David Cameron stated the importance of a regular ‘drumbeat’ of nuclear projects so that *“universities can see it’s worthwhile teaching nuclear expertise [and] colleges start doing the training programmes”*<sup>197</sup>; the Department of Business Innovation and Skills, repeatedly emphasised the importance of a regular drumbeat to secure nuclear investment<sup>198</sup>; as does the documentation around the Nuclear Sector Deal in emphasising the importance of a ‘regular operating drumbeat’<sup>199</sup>.

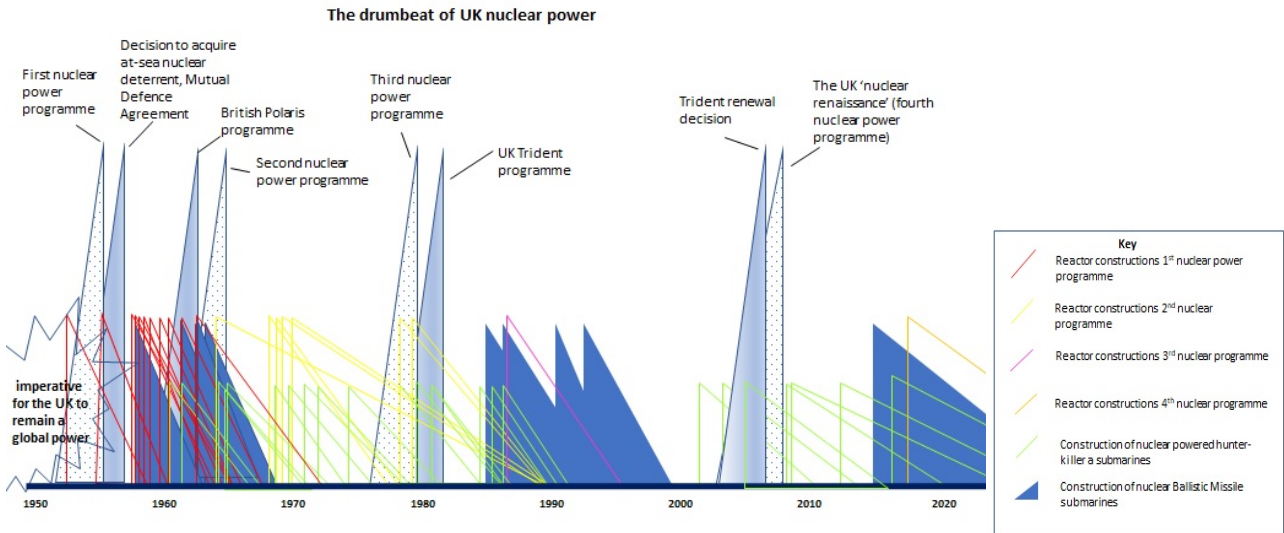
A further specific curiosity emerges with respect to elite emphasis on the ‘drumbeat’ around civil nuclear power, which relates to considerations of multi-dimensionality. For the other infrastructural area where anxieties are arguably most acute around the need to sustain a regular “drumbeat” lie not in energy but around the intractable industrial challenges of constructing nuclear-powered submarines. Here, since the early 2000s<sup>200</sup>, high level reports and official documentation have emphasised that without a regular drumbeat of submarine orders the UK will struggle to retain the industrial capabilities and skills to construct ballistic missile submarines that underpin the UK’s nuclear weapons system<sup>201</sup>. Civil nuclear features in discussions concerning the sustaining of skills and capabilities for nuclear weapons infrastructures, where it is stated by the Keep Our Future Afloat Campaign (KOFAC) that *“the decline of the civil UK civil nuclear programme has forced the military nuclear programme, and in particular the submarine programme, to develop and fund its own expertise and personnel to remain operational. Retention will be seriously threatened by any disruption to the production drumbeat”*<sup>202</sup>.

As discussed in section 5.2, a persistently entrenched elite UK policy imaginary around civil nuclear power has defied the presumptions of technological life cycle models and innovation temporalities in that an industry that has in so many ways become ‘destabilised’, nonetheless remains so manifestly resilient. In terms of multi-dimensionality as we have documented elsewhere, a candidate factor worthy of examination for this resilience is that the UK, unlike most other countries in the world, is a ‘nuclear state’ that must retain domestic British nuclear skills, capabilities, and supply chain activities in order to continue undertaking the massively complex engineering challenges of nuclear submarine construction, on which the British nuclear weapons system depends. As extensively documented, the links between civil and military nuclear activities is something that has been openly acknowledged by policy makers on several occasions since 2017<sup>203</sup>. Secret documentation obtained through Freedom of Information request further acknowledges how historically strongly intertwined the UK nuclear submarine programme and civil programme have been. Grimes et al, state that *“historically the MOD’s nuclear programme had been underwritten by civil nuclear research”*<sup>204</sup>. This suggests that nuclear activities were dependent historically on the civil nuclear programme however these historical linkages have not been studied in detail.

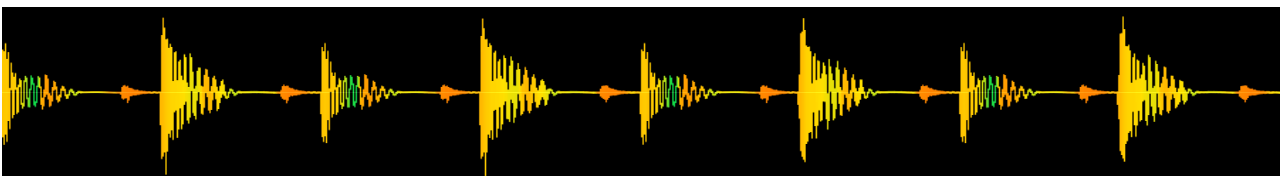
Given the present-day stated links, the concerns in both civil and military nuclear on sustaining a ‘drumbeat’, and the historical associations between civil and military nuclear in terms of one ‘underpinning’ the other, it seems worth taking the drumbeat phrase seriously and studying both civil and defence nuclear drumbeats to offer a preliminary examination of the rhythmic patterns of key announcements and construction projects. The aim here is to visualise the rhythm of UK nuclear infrastructures, inspired by the way in which a ‘drumbeat’ is represented in waveform in music recording software (see figure 15).

Figure 14 below outlines a preliminary analysis of the multiple temporalities implicating both civil and military nuclear infrastructures in the UK. Comprehensively addressing all major civil and defence construction projects and programme announcements, the figure charts each successive submarine and nuclear power station programme at a higher level on the y-axis, because these involve the highest magnitude economic and politics stakes. The right-angled triangular representations of each 'beat' are marked by vertical line at the time of formal public announcement, approached by an angled slope representing the prior associated policy development and consultation period. Correspondingly scaled in stylised ways, individual episodes of nuclear power station and nuclear submarine construction are marked with the vertical lines showing formal project start-dates and the subsequent descending slope representing the construction period.

**Figure 14: A non-monotonic 'drumbeat' in unfolding UK nuclear developments**



**Figure 15: A drumbeat in wave form**



Source: Opensound.org.

With an analogy provided in Figure 15 of a soundwave for a physical 'drumbeat', Figure 14 provides an overall view on UK nuclear temporalities. Accordingly, what can be seen here metaphorically is an evident rhythmic structure in which a regular 'bass' beat paces the unfolding of more irregular, but clearly-episodic, higher-frequency drumbeats involving individual civil nuclear reactors, ballistic missile submarines and nuclear-propelled attack submarines. In this way, national skills capabilities and industrial capacities are carefully coordinated to minimise disruptions and interference between projects. Relatively absent as it is from extant public policy imaginations (yet more prominent in more private planning), it is this evidently more materially-driven pattern in physical infrastructures that may arguably best help understand the observed otherwise less explicable pattern in the undulating fortunes of sociotechnical imaginaries.

#### 5.4 Preliminary Narrative account of the UK nuclear drumbeat

After the Second World War, the UK (and especially the British policy elite) uncomfortably found the ascendancy of the USA and Soviet Union driving a vastly diminished national status on the world stage, Elite anxieties prioritised a need to retain the UK's status as a 'global power', with acquisition of nuclear weapons and associated delivery capabilities featuring as the key technological trajectories around which these broad imaginaries of global power might crystallise<sup>205</sup>. The creation of the United Kingdom Atomic Energy Authority (UKAEA) saw civil nuclear and military nuclear activities under the same umbrella and uniquely protected from parliamentary security reporting directly to the Prime Minister<sup>206</sup>. In the figure above, the 'build up' periods for key policy decisions encapsulate intense activities taking including civil nuclear research and development and military nuclear and weapons testing. The UK had been shut out of American research on nuclear despite the previous collaboration in the Manhattan Project, and Britain had developed its own airborne nuclear weapons system, however many perceived this to be particularly vulnerable from attack<sup>207</sup>. Meanwhile, the UK built up the capacities for nuclear reactor construction for electricity production and this crystallised in the announcement of the UK's first programme of nuclear power in 1955<sup>208</sup>. The military use of these plants, for plutonium production for weapons production is well known<sup>209</sup>. Meanwhile, a turning point related to nuclear weapons occurred as the signing of the Mutual Defence Agreement with the USA in 1958 gave the UK access to the knowledge and technology to construct its first nuclear submarine, *HMS Dreadnought*.

A second wave of activity in UK nuclear infrastructures occurred in the first half of the 1960s. After significant debate concerning the best strategy for a UK nuclear weapons system, the decision was announced in 1962 that the UK would commit to a submarine-based nuclear deterrent named *Polaris*. The construction of four ballistic-missile nuclear submarines was planned. In 1964, the UK's Second Nuclear Power programme was announced, committing to a fleet of British designed Advanced Gas-cooled Reactors (AGRs). Beginning in the mid-1960s, a steady construction of attack submarines began (green lines). After a period of rapid and intense construction in the first nuclear power programme, the rhythm of civil nuclear construction was changing as serious problems with AGR technologies saw extremely long construction times with some power stations beginning construction in the late 60s only beginning commercial operation in the late 1980s as indicated by the yellow lines.

In 1979 a third programme of nuclear power was effectively announced with the declaring of plans for 15GW of new nuclear with 10 new power stations built in the decade<sup>210</sup>. Represented in the build up to this decision, significant consultation and debate was now occurring with regards to new nuclear and internal discussions in the CEBG were centred on whether to continue with British AGR technology or to go with the American Pressurized Water Reactor (PWR). The decision was made to opt for the PWR in the 1979 announcement. In 1980, Margaret Thatcher made the decision to construct four more ballistic missile submarines as part of the Trident programme for UK nuclear weapons. The proceeding two decades were seriously problematic for UK nuclear infrastructures and was the time where the UK nuclear infrastructures lost their rhythm as the drumbeat stalled. Only one new power station was built in the third nuclear programme, Sizewell B. Meanwhile the most serious interruption to the UK nuclear drumbeat occurred in the early 2000s. As can be seen, after the construction of Trident submarines, there was a brief moment where there was no civil nuclear new build occurring and no attack submarines under construction. Thus, construction activities across all UK nuclear infrastructures had stalled.

Countless documents on the military side, point towards this period as being particularly problematic in terms of the UK losing skills and capabilities related to the construction of nuclear submarines<sup>211</sup>. The effects of the declining fortunes of UK nuclear can be seen with regards to the problematic and slowed rhythm of attack submarine construction from the early 2000s onwards, where construction was taking around ten years compared to around five in previous waves. Again, this has been pinpointed by experts as being a consequence of the loss of momentum in nuclear construction in the 1990s and early 2000s where vital skills and capabilities were lost<sup>212</sup>. As discussed in the previous section, the early 2000s were particularly problematic for civil nuclear as this was the first time an energy white paper set out a preference for renewables and energy efficiency rather than new nuclear due to nuclear waste and prohibitive costs<sup>213</sup>.

Yet, a rapid and largely unexplained reversal in this decision occurred between 2003-2006. It was exactly at this time that policy was intensifying around the replacement of the Trident nuclear weapons system and grave concerns were being raised about the loss of capabilities and skills due to the drumbeat of UK nuclear infrastructures effectively grinding to a halt in the late 90s<sup>214</sup>. A vote was held in Parliament in 2006 in favour of replacing the UK's nuclear weapons system<sup>215</sup>. Imaginaries of the need to retain the UK's status as a global power, that emerged so strongly after WW2, had clearly intensified once again around nuclear infrastructures, with Prime Minister Tony Blair later confessing that while the moral and military arguments against Trident were persuasive, letting go of the weapons system would have meant "*a downgrading of the status of the nation*"<sup>216</sup>.

The rapid revival of civil nuclear culminated in an Energy White Paper in 2007 that recognised that nuclear 'had a role to play' and a further White Paper in 2008 setting out what was the fourth wave of UK nuclear power construction<sup>217</sup>. Between 2010-2020 despite intense policy prioritisations around civil nuclear construction, the realities of the superior performance and cost effectiveness of renewables and global shifts in energy production towards renewables has meant it has proved extremely challenging for the UK to secure nuclear investment from the few companies that still construct new nuclear<sup>218</sup>. With the construction start delayed by many years and at triple the original cost, the only new nuclear power station under construction presently is Hinkley C beginning in 2018. Indeed, the intended 'drumbeat' for this wave has not materialised. While the drumbeat of attack submarines has once again resumed, significant technological and economic problems have been experienced in these projects that have received significant criticism<sup>219</sup>.

What has occurred as time has passed, is a continued and growing insistence at the highest levels of policy that the UK needs to construct new nuclear, seemingly regardless of the realities of cost of performance of renewables. The latest policy juncture has seen a White Paper committing to both large new nuclear stations using even more eccentric models to fund reactor construction. As well as intensities growing to construct entirely untested Small Modular Reactors (SMRs), to be built by submarine reactor manufacturer Rolls Royce who have openly highlighted the benefits for such a programme for sustaining and covering some of the costs of the Ministry of Defence's (MOD) defence nuclear enterprise<sup>220</sup>. Construction has started in 2016 on the UK's new ballistic Missile submarine *HMS Dreadnought*, yet the National Audit Office has raised grave concerns about the financial 'black hole' in the MOD's financing of the new nuclear weapons system, and that the costs are escalating to such a degree that there is a risk the programme could destabilise the entire MoD budget<sup>221</sup>. As other reports have highlighted, a key reason for this is the atrophying of capabilities and skills related to the submarine programme caused by the slowing of the nuclear drumbeat<sup>222</sup>. As the language of the importance of the nuclear 'drumbeat' has intensified, a host of policy endeavours have focussed on the retaining of UK nuclear capabilities and skills through the 'Nuclear Sector Deal' that specifically highlights synergies between civil nuclear and defence and the need to enable crossovers between the two<sup>223</sup>. Amplified by Brexit, deeper imaginaries have also intensified around the UK's status as a global power<sup>224</sup>.

To conclude this narrative, there are several broader points to consider. What this work has sought to offer in a brief and preliminary way, is the importance of considering multiple temporalities across diverse activities related to nuclear infrastructures that are not confined to particular 'sectors', 'systems' or 'regimes'. In a superficial way, it can be seen that patterns of key decisions related to civil and defence nuclear have tended to coincide, and that the intensity of the UK nuclear drumbeat has slowed and at one point significantly stalled. Given high-level statements on the serious problems created by this slowing drumbeat, and the loss of capabilities and skills, it seems worthy of further investigation to explore the extent to which continued intensely-asserted sociotechnical imaginaries for new civil nuclear power are given momentum by the rhythm not just of energy policy rationales but the temporalities of military imperatives, in particular, the challenge of how does Britain continue to construct, maintain and operate ballistic missile nuclear submarines. It seems plausible that these could be the main artefact setting the overall rhythm given that it is these that enable the continuation of deeper imaginaries centred on Britain as a global power.

There is much still to be done, however the figure above at least offers a starting point for exploring certain critical junctures further. Comparatively, it may be worth also documenting the drumbeat of German nuclear

power construction and documenting the extent to which the language of ‘drumbeat’ or an equivalent term forms part of the rationale for nuclear construction in the past or not. In the UK, it may be worth exploring in more detail in policy documentation from past critical junctures the extent to which this kind of rhythmic language appears. The implications are significant in terms of understandings of sociotechnical imaginaries. By focussing on multiple temporalities of different aspects of UK nuclear infrastructures and exploring rhythmic patterns the vantage point is changed from a linear progression oriented around a certain defined policy goal and finite time horizon, to an understanding that is focussed on a continual *sustaining* of an imaginary that manifested intensely after WW2. This raises significant questions about the relations between material activities and periods of intensity with respect to policy goals. Rather than the material construction being as a consequence of certain imaginaries, it may be worth paying more attention to the extent to which policy goals may be responding in an almost sub-conscious manner to the rhythmic patterns of infrastructural development.

### 5.5 Implications of multiple temporalities in sustainable energy transformations in the UK and Germany

We now reflect on the implications of the above analysis for considerations of multiple temporalities in sociotechnical imaginaries and energy transformations more broadly. What is clear is that the subjective prioritising of attributes regarding the constituting of energy transformations has significant implications for the empirical patterns of change that can be identified in sociotechnical analysis. In particular, what comes into focus is the *innovation temporality* that is so prolific throughout so much research and policy debate on sociotechnical change. Sometimes referred to as ‘trajectorism’<sup>225</sup>, this assertively-imagined temporality involves a disproportionate focus on a supposedly monotonic progression in whatever is held to be the focal technological configuration. While this can be a valid understanding in some contexts – and certainly a useful one for particular interests – it offers only a crudely simplistic picture. Diverse temporalities can be subsumed in a simple sequence of stages in a supposedly singular ‘innovation trajectory’<sup>226</sup>. Just as Ptolemaic epicycles can explain any conceivable astronomical trajectory<sup>227</sup>, so a linear ordering of such categories can obscure from view, the more multiple and undulating patterns of change that we have highlighted in the recent political dynamics UK and German energy infrastructures.

The link articulated earlier in this paper between temporalities and dimensionalities is also arguably underscored, in that dimensions that are typically excluded as ‘residuals’ from a central focus in conventional sociotechnical research and policy analysis concerning ‘energy transitions’, can be seen to play far more formative roles in these patterns of change than is usually acknowledged. In the case of the contrasting dynamics of nuclear power in Germany and the UK, these conventionally-side-lined dimensions include deep and pervasive historical conditions (of entrenched coloniality and post-Fascist recovery); associated formations in national elite cultures, networks and structures; contrasting electoral institutions, procedures and political cycles; broader related political economic conditions and market circumstances and (especially) some hitherto almost entirely concealed contrasting military dispositions, which evidently shape the temporalities and time horizons of the state itself.

Against this background, a conventional innovation temporality (and its scaled translation in conventional understandings of energy transitions) can be seen to fit less with the ostensibly robust and comprehensive (effectively monothetic) pictures that are typically claimed, and appear more as artefacts of prior subjective framings in analytical perspectives. In keeping with the insights underpinning both co-productionist and polythetic analysis with which this paper began, those framings that are as a result most privileged, tend to be those that best reproduce the most expedient social orders for dominant interests. In particular, it is notable that high-level UK policy making is very clear – in a relatively private way – about a non-monotonic ‘drumbeat’ imperative. Arising from material necessities in the reproducing of entrenched military interests around nuclear weapons infrastructures systems reflecting deep historic currents of coloniality, this non-monotonic temporality evidently serves a crucial internal role in policy making spanning (contrary to sociotechnical ‘regime’ framings) both military and civil sectors. But with this essential function discharged

in that elite setting, it is the contrasting monotonic temporality of the “nuclear renaissance” that better fulfils the conventional role of trajectorism in wider public policy debates – building momentum towards a presumptive singular and inevitable future. It is in these kinds of ways that dimensionalities, imaginaries and temporalities can come together in more complex ways than a monothetic picture might resolve.

This point underscores a further finding in relation to the theoretical analysis with which this paper began. It suggests that rather than notionally discrete ‘regimes’ of activity in sociotechnical transitions each operating within their own distinct timelines (eg: ‘civil’ and ‘military’ nuclear developments), these canonically separated fields may actually be seen as mutually dependent and jointly formative in the constituting of contrasting temporalities that are actually far more pervasive than this, but differentiated in relation to a deeper underlying political functionality – that of sustaining a hegemony as a whole rather than an incumbent sectoral interest. Thinking about this in terms of sociotechnical imaginaries, the crucial role played by temporality, can be seen to contrast markedly in two distinguishable imaginaries that are arguably equally diagnostic of elite UK policy discourse: the ‘nuclear drumbeat’ and the ‘nuclear renaissance’. Neither explicitly refers to the other. Each stands alone, respectively as a nonmonotonic rhythm driven by the material imperatives of a hard-pressed industrial infrastructure and an essential driving storyline for the purposes of imposing discipline and momentum on recalcitrant wider political arenas. In this way, it emerges that the imaginaries in play in this regard around energy futures and their variously-nested alternative pathways, are actually highly diverse in their temporalities (even in an ostensibly circumscribed setting) – with both monotonic and nonmonotonic forms serving vital functions in respect of different dimensions. Beyond this, it is evident that the imaginaries that these temporalities partly constitute, are also more dynamic, mutually-entangled and co-constitutive than may sometimes be acknowledged.

Thus empirically supported (albeit not fully validated), some of the key broad theoretical points made in this working paper hold potentially important practical implications for policy interventions and wider political actions aimed at driving and steering sustainability transformations. What this analysis suggests, is that what ‘sustainable energy’ movements (of diverse kinds) are each seeking to build, are actually far wider and more socially ‘massive’ than is typically envisaged in received notions of ‘an incumbent regime’. Likewise, the formations that need to be ‘discontinued’ or ‘destabilised’ in order to achieve this are also correspondingly more pervasive in many dimensions, not only sectorally, but across privileged configurations in cultures, institutions, infrastructures and practices that may (like those associated with patriarchy, coloniality and modernity) be far more pervasive than individual political jurisdictions. With processes equally of imagining and enacting transformation in any particular feature of politics, thereby ‘holographically’ implicating the totality, processes of transformation become even in the most specific of sectors become identifiable less as relatively technical and collaborative matters for ‘policy’ and more as irreducibly social and unavoidably contestational issues for ‘politics’.

Returning in this light at the end to some more specifics of our own UK nuclear case study, some more practical implications arguably become clear. First, it may prove impossible to achieve a transformation to sustainable energy in a country like the UK, without directly and actively addressing the hidden military links that presently lead uneconomic and sustainable nuclear infrastructures to be treated as if ‘sustainable’. It may of course be initially more difficult to challenge these more pervasive and deeply entrenched formations around military nuclear contributions to continued colonial imaginaries of UK identity on the ‘world stage’. But these are evidently the most formative drivers of the problematic energy commitments. And it is becoming clear more generally that imperatives to actively assist the obsolescence of nuclear power and nuclear weapons are more easily addressed together than either is individually.

A second practical political point that follows from this, concerns the role of democracy in the broadest sense (of ‘*access by the least powerful to capacities for challenging power*’<sup>228</sup>). If imperatives for transformations to sustainability are treated primarily as technical matters for segmented expertise and stratified elite agency in separate policy silos, led by incumbent interests in big business in arenas convened by the State, then the hidden wider complexities, entanglements and countervailing inertia illuminated in the present analysis mean that entrenched interests will continue to find it easier to manipulate and side-line more substantively progressive political energies. If instead challenges of sustainability transformations are recognised



fundamentally as matters for democratic struggle, driven primarily by social moments and steered through values-based collective action in civil society – with big business and branches of the State serving crucial but subordinate facilitating roles – then the prospects for success may be more positive.

## 6 DISCUSSION, CONCLUSIONS AND IMPLICATIONS

### 6.1 Overview

For the purpose of the present document, conclusions can only be provisional at this interim stage of the described research. As outlined in section 1.2, the main aim has been to inform discussions among the wider GOST Project team about possible onward research. And it remains the case on several fronts, that much work remains to be done. But a number of heuristic propositions do emerge in relation to the key general questions substantiated conceptually in Sections 2 and 3. These may be summarised in the same broadly shared sequence as the practical implications indexed from (i) to (vii) in Sections 2.7 and 3.7.

What is generally clear from the foregoing theoretical and empirical accounts, is that these emerging findings seem to apply in principle equally to multiple dimensionalities and multiple temporalities. And they seem to do so similarly, as these relate to both of the central constructs in this analysis: sociotechnical imaginaries and sustainability transformations. It is for this reason, that the present working paper is titled (as a question) '*transforming imaginations?*'. For what is arguably simultaneously in focus as a result is:

- i) the affirmed formative power of imaginations in helping to shape wider transformations;
- ii) sometimes under-addressed complexities in patterns and changes in imaginations themselves;
- iii) the potential to help shape further practice in analysing complexities and dynamics in imaginations.

### 6.2 Do transforming imaginations depend on subjective prioritising of attributes for analysis?

It is clear from the preceding empirical accounts that the observed constituting both of sociotechnical imaginaries and sustainability transformations can depend to a significant extent on the prioritising of attention to different framing attributes and temporalities. What the Q method exercise is showing in Kenya, is that there exist in relevant discourses, a multitude of dimensions of meaning by means of which variously to constitute contrasting imaginaries of urban transformation. A strong role for subjectivities is evident here, equally on the part of the analyst, the research subjects with whom analysts interact and the wider social agents exercising formative effects on the shape of the imaginaries themselves. Were the Q concourse to have been comprised of different specific statement, it might be that a contrasting picture would have emerged. Likewise, rich contrasts between respondents illustrate the affordances for divergent interpretations and reproductions of ostensibly discrete imaginaries. With respect to temporalities, it is clear from this research that routine assumption in transformations research of an 'innovation temporality' obscures from view what are actually observed here to be more complex and intractable kinds of temporality.

### 6.3 Do transforming imaginations display variable degrees in how they might be distinguished?

It is also clear from the preceding empirical accounts that abilities to distinguish between ostensibly discrete instances both of sociotechnical imaginaries and sustainability transformations are varied across different aspects of the settings in question. With respect to urban imaginaries in Kenya, there exists a complex interplay of globally circulating imaginaries and discourses ('smartness'; the 'digital knowledge economy'; 'ICT for development' etc) within a pan-African urban planning trend privileging 'Master Plans' and visions, and the building of new 'world class' cities from scratch; and shaped by specifically Chinese interests in infrastructural development in the country. This interplay takes place in the polarised context of Africa being imagined as either 'the hopeless continent' or as undergoing an African renaissance, or of 'Africa Rising'. The framing of analysis would determine to a large extent the particular imaginary identified.

With respect to temporalities, it does remain the case that the conventional storylines of 'nuclear renaissance' in the UK and 'nuclear phase-out' in Germany do remain relevant to some degree – and each follow (in respect of their own orientations) the conventional linear narrative. But at the same time, it is also clear that other

temporalities of kinds that are not well documented in the literature, do in fact remain important in each setting – including both disorderly and more rhythmic undulating patterns in the evident orientation of change in each setting. In the particular case of the UK, the presence is quite striking of a more regular nonmonotonic pattern named in private policy language as a nuclear ‘drumbeat’. That this ‘drumbeat temporality’ is evidently so prevalent in imaginaries concerning nuclear infrastructure dynamics extant in particular quarters of elite policy cultures in the UK provides an interesting contrast to the conventional ‘innovation temporality’ that is so prominent in the ‘nuclear renaissance’ that these same cultures are otherwise so keen to propound publicly.

#### **6.4 Are transforming imaginations to some degree co-located collectively together in each setting?**

It follows from the observations made in the above subsection (concerning the challenges experienced in attempts to distinguish between dimensionalities and temporalities in each empirical setting), that a number of broadly discernible contrasting instances are evident of both sociotechnical imaginaries and sustainability transformations. Equally in Kenya (concerning urban transformations) and the UK and Germany (concerning energy transformations), it is possible to identify in play, a diversity of recognisably distinct sociotechnical imaginaries and candidate modalities for sustainability transformations. Whilst further work might elucidate which of these are more prominent in which particular sub-settings, what is already clear is that it would be problematic simply to assume a one-to-one correspondence between either of these constructs and the settings in question.

#### **6.5 Are transforming imaginations less independent than dependent in their mutually constituting relations?**

It emerges from the above point concerning the evident co-location in each empirical setting of contrasting instances equally of sociotechnical imaginaries and sustainability transformations, that it becomes unreasonable simply to assume that particular instances are constituted independently. It is clear from the emerging findings here, that at least one strand in onward research is to look for relations that span instances.

In the case of urban transformation in Kenya, for instance, imaginaries such as the ‘globally competitive smart city’ or a contrasting imaginary in which digital technologies feature in the service of ‘bottom-up community self help’ can be understood – following Amin (2013) – as being equally ‘telescopic’ in their focus on limited parts of the city (the former on the CBDs, gated communities, shopping centres, and other lifeways of the urban elites; the latter on the slums). A need to ‘bring the whole city back into view’ necessitates a more relational understanding of the city, and imaginaries of urban futures.

In the case of temporalities, there are in the UK nuclear case, manifestly formative relations operating between transformations and imaginations relating to ostensibly separate ‘civil’ and ‘military’ activities. Indeed, this is so much so, that it becomes difficult to justify interpreting these dynamics in terms of circumscribed ‘*nuclear power* imaginaries’ or ‘*energy* transformations’ alone. What are clearly in play are dynamics at the far more aggregated level of *UK political cultures as a whole* – with elite imaginations in particular driving an unusual mismatch between projected identity and material international standing. In more specific terms of the temporalities conditioning energy transformations in this setting, it must be noted to be likely that that both the contrasting linear and various high and low frequency undulations are to some extent mutually formative in particular ways (rather than constituted in isolation). But unpicking the details of this is not possible on the basis of the present provisional empirical picture.

### 6.6 Do transforming imaginations defy simple one-to-one comparative correspondences?

This question gets to the heart of the epigram from Borges (1952) reproduced on the title page of this working paper: “[i]t is hazardous to think that a coordination of words... can have much resemblance to the universe”<sup>229</sup>. Equally in respect of kinds and instances of sociotechnical imaginaries and sustainability transformations, the stories that may be told about how these are constituted and how they unfold and relate to other constructs (like periods of history, political-economic sectors or national jurisdictions) are typically artificially simplified. In particular, it is evident that great caution must be exercised in expedient assumptions that particular singular kinds of imaginary are in play – or transformations unfolding – in specific identified settings. Tabular representation like that stylised in Figure 2 may thus offer only a relatively poor representation of the kinds of picture that can emerge here, which may to a greater extent resemble the patterns stylised in Figure 7.

This said, it does remain possible that simple one-to-one correspondences of the kinds sometimes effectively assumed in academic literatures concerning sociotechnical imaginaries and sustainability transformations, may nonetheless hold heuristic value for understanding or strategic traction for action. The original Spanish term used by Borges in the quoted sentence (*‘aventurado’*) is sometimes translated as *‘venturesome’*<sup>230</sup> rather than *‘hazardous’*<sup>231</sup>. Indeed, *‘hazard’* itself can hold connotations of the kinds of bold agency associated with adventure<sup>232</sup>. In circumstances where knowledge production or policy interventions are oriented towards programme-building of some kind, then, it may remain the case that this kind of more *‘venturesome’* role for monothetic representations could in particular contexts be more important.

Indeed, it is when insights of co-productionist understandings are taken most seriously (as discussed when this paper began), that it might be asked what other kinds of knowledge production might exist, than those that are in some sense *‘venturesome’*? After all, it is the associated manner in which the contents of knowledge are shaped by encompassing actions – and strongly oriented towards shaping onward expedient actions – that lie at the heart of the dynamics through which knowledge is entangled with more material social orders. It is through telling stories about particular kinds of socio-technical imagination, for instance, that particular kinds of sustainability transformation may be held to be more likely to be enacted.

But the telling of different particular expedient stories can also be a means to help co-produce other kinds of social order – with no necessary relation to sustainability transformations. Examples might include, for instance, the advancing of particular cultural, institutional or disciplinary programmes that are anyhow extant in specific settings – implicating contending interests and cross-cut contrasting kinds of transformation. It is in this regard, that more nuanced considerations may emerge (raising both analytic and normative questions), as to what the particular *‘venture’* in question might be in any emerging body of understanding? Questions thus arise not just over variously perceived and accredited forms of veracity that can be associated with such a body of understanding, but the extent to which the specific embodied *‘venturesome’* interests might be shared or aligned? Depending on this, even knowledge that might privately under any view, be acknowledged as *‘invalid’* in some sense (for instance, through oversimplification), may still be seen as useful.

### 6.7 Do transforming imaginations display *‘ecological’* patterns in relations of dimensions with temporalities?

It follows from the discussion of dependencies between constructs in subsection 6.5 above, it may be held to be likely, that there may exist – at least in specific settings – distinguishable *‘ecological’* patterns in these relations. Schematized in Figure 7, these will be higher order and more relational constructs than the ostensibly more unitary forms of sociotechnical imaginaries or sustainability transformations that are conventionally envisaged. Beyond questionable one-to-one relations between these and particular settings diagnosed with caution in subsection 6.6 above, analytic questions arise as to what these material-discursive *‘ecosystems’* may look like around and between contending *‘imagined transformations’*. Here again, the empirical analysis that has been possible thus far, is sadly inadequate to the task of confidently resolving any discernible pictures.

Yet one general finding that does emerge with quite high confidence is that which was hypothesised in Figure 10 – relating to the likely intimate relations between multiple dimensionalities and multiple temporalities in sustainability transformations. Here, the evident multiplicities and ambiguities in sociotechnical imaginations around urban transformations being documented in Kenya, resonate with the picture of energy transformations in the UK and Germany, where contrasting imaginations are also evidently in play concurrently and contending and associating with each other across different political spaces. Here, the wider picture of similarities in the broad kinds of imaginary across these settings (despite the contrasting detailed patterns and dynamics), suggest that contrasting national jurisdictions and discourses may not so much represent discrete settings for particular kinds of imagination or transformation, as contingently-distinguishable arenas within which more broadly expansive configurations of imagination and possible transformation play out.

In this sense, perhaps particular political and jurisdictional settings are better seen as crucibles within which subtly different alchemies play out between concurrent pluralities of interacting imaginaries and transformations that are in themselves both more widespread across different settings and (as elements in the mix) less definitively distinguishable than these relational ecosystems in which they variously sit?

Perhaps there is a sense in which the wider soils into which these roots extend, might be addressed in a much more generalised sense – in terms of landscapes of globalising modernities around the world? If so, then (variously anticipated as they surely are) these kinds of interpretation might offer alternative bases for further interrogation, that are all the more potentially fruitful for being so relatively neglected by comparison with conventionally more unitary understandings of imaginaries and transformations. By at least opening up scope for apprehension of greater complexity and plurality than is conventionally possible, it may be that attention to multiple dimensionalities and multiple temporalities may tend to aid less restrictive – and therefore in some senses more democratic – discourses around sustainability transformations

Either way, whether or not – and to what extent – such possibilities may hold, must be a matter for greater deliberation and research than has been possible at the present stage in this analysis. But we hope that the ideas and frameworks and findings outlined here, may nonetheless be useful in the crucial task of onward research aimed – equally in the substance and the orientations of resultant understandings – at facilitating more plural and empowering imaginaries that help can to co-produce more emancipatory transformations.

### **6.8 Does study of these issues hold practical implications for the enacting of sustainability transformations?**

It is clear then, that the challenges on which this study has focused are both fundamental and general to the ways social transformations to sustainability are imagined and how they variously unfold. Although themes of ‘multiple dimensionalities’ and ‘multiple temporalities’ may seem arcane, the preceding discussion details concrete practical implications that arise from such study specifically in relation to energy transformations in the UK and Germany and urban transformations in Kenya. Although much work needs to be done – in this strand of research in this project as well as in the wider field – a number of more general implications arise.

First, what counts as a ‘transformation’ or ‘imaginary’ can crucially depend on subjective framings of actions and understandings. By recognising constituting categories (and associated phenomena) as polythetic rather than monothetic in the systematic ways detailed here, research and mobilisation can be more robust and reflexive. So, neither focus can be expected to be stable, but will likely change not only in simple monotonic ways, but also in more complex non-monotonic patterns that inter-relate in different social dimensions.

Second, to be effective, the resolving or enacting of any given ‘transformation’ or ‘imaginary’, must recognise there are no hardwired definitive boundaries to what this does, or does not, entail. As polythetic constructs, these are ambiguous, nested and relational. Overall resulting patterns of change can be dissonant as much as synchronised. No matter how progressively motivated, treating these relations as fixed categories can inadvertently reinforce the very regressive forces that research for sustainability is intended to challenge.

Third, no 'transformation' or associated 'imaginary' need be seen to stand alone in any context, but may well instead be part of a dynamic assemblage of parallel, contending and synergising counterparts. If so, the most progressive understandings or actions will be those focusing more on moving assemblages of relations, than on notionally individualised categories. That both imaginaries and enactments of transformation recognise and engage with polythetic relations and non-monotonic processes may thus be crucial for their success.

Fourth, to focus disproportionately on a notionally singular 'transformation' or 'imaginary' in any setting – whether in critical or instrumental, or constructivist or positive ways – can be highly reductive in its effects. Whether intended or not, resulting 'forced categories' and 'fixed relations' can obscure (and so undermine) more complex and holistic dependencies between what is imagined or transformed. In this way, hierarchical instrumental understandings are co-produced with hierarchical instrumental social orders. So, unless it is more careful, ostensibly critical or deconstructive action or analysis may actually drive opposing effects.

Fifth, there follows a further practical implication for understanding and action across contrasting settings. If any given 'imaginary' or 'transformation' is performed to display a simple one-to-one correspondence in comparison across particular geographical, institutional or cultural settings, then – irrespective of progressive or radical content – the resulting assertion of a 'forced category' or a 'fixed relation' can help reinforce regressive and incumbent interests that thrive on such representations of the world, as if it were structured in reductive monothetic ways. Although inaccurate, these representations can persist because they are so convenient. It would be ironic if constructivist critique were inadvertently to reinforce this hegemonic move.

Sixth, the most important feature of any context for the imagining and enacting of transformation, will typically lie not in notionally individual 'visions', 'actors', 'structures', 'processes' or 'practices' (as is often emphasised), but in more distributed 'ecological' patterns of relations between far more radically disparate agencies, dimensions and temporalities. Being too complex for the aspirationally controlling storylines favoured alike in policy-makers 'decisions', consultants 'recommendations' – or critics contending narratives – these may often be matters for less determinate and unruly kinds of political and cultural murmuration<sup>233</sup>.

It would be premature at the present stage of research to seek to draw firm conclusions from any of this. What has resulted from this theoretically-explicit and systematically-organised enquiry grounded in real-world empirical settings, are just a set of questions and potentialities. Yet these are all the more important for being so presently relatively neglected, equally across much work and associated action on sustainability transformations as well as key research with prescriptive implications around sociotechnical imaginaries.

To sum up the most important repercussions at the present interim stage, we can return to the epigram at the start of this working paper. If Borges can be rendered in English as meaning that "[i]t is **hazardous** to think a coordination of words, can have much resemblance to the universe"<sup>234</sup>, then what has been clearly illuminated is an array of such epistemic and political 'hazards', relating to simple 'co-ordinations of words' around and between current practices concerning 'sustainability transformations' and 'sociotechnical imaginaries'.

If, on the other hand, Borges can be rendered in English as meaning that "[i]t is **venturesome** to think a coordination of words, can have much resemblance to the universe"<sup>235</sup>, then what is also clearly pointed to, is that such simplifying practice can invisibly (knowingly or not) serve the 'ventures' of many different interests. Unduly 'forced categories' or 'fixed relations' may be highly misleading in relation to the phenomena they ostensibly describe, but nonetheless remain effective in promoting particular academic identities, disciplinary profiles, sectoral interests, policy patronage or more generally regressive political justification.

The crucial importance of this arises if sustainability is recognised to be about a repertoire of more subaltern progressive values and interests that have been struggled for over many generations of global collective action. It is these kinds of emancipatory aims, that can easily (if inadvertently) be undermined by more circumscribed forms of instrumental parochialism – whether these be academic or more widely political. And it is in this regard, that we may turn in closing at the end from Jorge Borges, to the nineteenth century French writer Alphonse Karr. In ways variously picked up in subsequent years, Karr famously pointed out in 1849 "*plus ça change, plus c'est la même chose*" – "*the more things change, the more they remain the same*"<sup>236</sup>.

It is a neglected central and necessary feature of whatever can be imagined to be a 'social transformation', that implicit commitments concerning salience of contexts, comparabilities of settings, commensurabilities of dimensions, and congruence of temporalities can all invisibly conspire to take particular crucial issues for granted. The emerging effect can be that some epistemically or normatively focal 'change' is highlighted, but the tacit presumptions involved in this at the same time render effectively invisible, what remains an encompassing matrix of continuity. To the extent that this matrix remains not only untransformed, but entirely unaddressed by critical reflection, the associated normative and epistemic aims can be undermined.

In other words, a key implication of this analysis is to underscore responsibilities equally for rigour and accountability, in ensuring clarity about which dimensions of any transformation are being taken for granted as necessarily continuing, and which are highlighted as reflecting possibilities for supposedly radical change. Otherwise, references to 'transformation' can become reduced to little more than instrumentalised rhetoric.

So it is a crucial practical upshot of the identification of these responsibilities, that it is arguably only through polythetic styles of analysis, that systematic provision can be made to allow the dimensions, categories and relations in play to be engaged with and communicated with a requisite degree of rigour and accountability. And this is also arguably only possible if systematic provision is also made to recognise that what may comfortingly appear as monotonic temporalities in some dimensions, may actually conceal much less familiar or expedient complexities in others. If transformations are to be both robust in their forms and democratic in their processes and directions, then a strong case arises for more thought and work on these challenges.

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## Endnotes

- <sup>1</sup> (Borges, 1952)
- <sup>2</sup> (Beck *et al.*, 2017)
- <sup>3</sup> (Borges, 1952)
- <sup>4</sup> See: <https://council.science/wp-content/uploads/2017/08/transformations-sustainability-programme.pdf> [accessed January 2021]
- <sup>5</sup> See: <https://www.ufz.de/gost/> [accessed January 2021]
- <sup>6</sup> (Jasanoff and Kim, 2009) (Jasanoff and Kim, 2015)
- <sup>7</sup> (Hackett *et al.*, 2008)
- <sup>8</sup> Eg: (Cloke, Mohr and Brown, 2017; Nabavi, 2017; Galafrafi, 2018; Ghosh, 2018; Ockwell *et al.*, 2018; Arora, Sharma and Stirling, 2019; Longhurst and Chilvers, 2019; Pel *et al.*, 2019; Sovacool *et al.*, 2020)
- <sup>9</sup> (Beck *et al.*, 2017)
- <sup>10</sup> (Onyango *et al.*, 2019). A. Stirling (2019). *Imaginations of Transformations: some ideas for the GOST Project*. Presentation for the Governance of Sustainable Transitions inaugural meeting, Umweltforschungszentrum Leipzig (UFZ), Leipzig, 1<sup>st</sup> March.
- <sup>11</sup> Eg: (Onyango *et al.*, 2019)
- <sup>12</sup> (Beck *et al.*, 2017)
- <sup>13</sup> (Cinar and Bender, 2007) (Lehtonen, 2014) (Delina and Janetos, 2017)
- <sup>14</sup> (Barnes and Bloor, 1982) (Latour, 1991) (Bijker and Law, 1992) (Andrew Feenberg, 1999) (Hacking, 1999) (Lynch, 1993) (Collins and Pinch, 2002) (Yearley, 2005) (Felt *et al.*, 2008) (Harding, 2015)
- <sup>15</sup> (Jasanoff, 1996) (Jasanoff, 2004) (Chilvers and Longhurst, 2014) (Miller and Wyborn, 2018)
- <sup>16</sup> (Irwin and Wynne, 1996)
- <sup>17</sup> (A Feenberg, 1999)
- <sup>18</sup> (Stirling, 2019)
- <sup>19</sup> (Jasanoff, 2004)
- <sup>20</sup> This implicates many more deeper and more detailed considerations than can be fully discussed in the present working paper. For some of the wider repercussions for social research on issues of transformation, see (Stirling, 2018). A summary of some further strands of thinking behind this contrast between 'monothetic' or 'polythetic' phenomena (Needham, 1975), might relate it to what is arguable the single most central and distinctive feature of social science identified by Giddens as the 'double hermeneutic' (Stirling, 2011). The contrast that arises here is between, first: a *monothetic* view of a phenomenon as if adequately definable according to a specific stated characteristic (like membership of the category 'regime'); and second: a *polythetic* view in which the focal phenomenon is acknowledged instead to require characterisation encompassing a more complex diversity of cross-cutting dimensions, defying Euclidean category structures (Appadurai, 1990). As illuminated in Wittgenstein's metaphor of 'family resemblances' (Wittgenstein, 1958), the resulting disparate attributes may not relate to each other in the kinds of conveniently orderly ways that allow categories to be confidently partitioned and instances neatly segregated (Brightman, 1995). With resulting relations often then taking a 'fractal' form (Appadurai, 1996) (transcending clearly distinguishable 'levels' or 'scales' (Biggiro, 2001) (Byrne, 1998)), correspondences may be radically more mismatched than is expedient for assertion of analytical frameworks with the requisite "necessary simplification" (Smith, Voß and Grin, 2010). To ignore this more directly phenomenological view (Schutz, 2011) and reduce such polythety to monothety (Pearce, 1994) is to fall foul of Whitehead's 'fallacy of misplaced concreteness' (Whitehead, 1948) and so risk the error of 'reification' (Slobodkin, 2001).  
To some, such errors may seem like somewhat esoteric concerns, but it is difficult to overstate the practical importance – especially for research purporting to address high stakes environment and political challenges like those around socio-material incumbency. To treat a set of neatly-bounded, segregated and ordered frameworks of words and categories as settled upon within a particular discipline, as if these necessarily correspond in directly consistent ways with the implicated phenomena in the outside world, is not only to perpetrate an error, but to become dangerously vulnerable to inevitable to mismatches (Robinson, no date). Where a focal phenomenon "cannot be described simply by a conjunction of properties" (Cohen and Lefebvre, 2005), it is (as Borges has it) "hazardous to think that a coordination of words... can have much resemblance to the universe" (Borges, 1952). Another result is a blindness to particularity – as Bourdieu points out: "in reducing the polythetic to the monothetic, objectivism destroys the specificity" (Bourdieu, 1990). To recognise a phenomenon as polythetic, by contrast, is to acknowledge that "the occurrence of a single feature in every member of a category is not sufficient to justify any claim that this is the essence of the category" (Cohen and Lefebvre, 2005). The resulting complexities are inconvenient to the kinds of 'simplifications' held to be 'necessary' (Smith, Voß and Grin, 2010) for purposes of disciplinary policing and policy justification. But they are crucial if the understanding of socio-material incumbency is to move away from the superficiality of what Ritzer calls a 'monothetic glance' and be open instead to apprehending what he calls the 'polythetic flux' in associated power dynamics (Ritzer, 2000).
- <sup>21</sup> (Hjørland and Gnoli, 2021)
- <sup>22</sup> (Wittgenstein, 1958)
- <sup>23</sup> (Needham, 1975)
- <sup>24</sup> (Evans, 2009) (Rayner, 1979) (Rayner, 1992)
- <sup>25</sup> (Bourdieu, 1990) (Hibbard, 2005) (Mills, Eurepos and Wiebe, 2010) (Schutz, 2011) (Schneider and Wagemann, 2012) (Seising and Sanz, 2012)
- <sup>26</sup> Despite the alignments noted here – and with a few exceptions aside - eg: Weiss-Evans (2009) and Rayner (1979; 1992) – constructivist science and technology studies rarely refers to, let alone uses, polythetic approaches.
- <sup>27</sup> (Joss, Cook and Dayot, 2017) (Martin, Evans and Karvonen, 2018) (Miller and Miller, 2019) (Cugurullo, 2020)
- <sup>28</sup> (Warner, 2007) (Arora, Sharma and Stirling, 2019) (Arora *et al.*, 2020)
- <sup>29</sup> (Levidow and Papaioannou, 2020) (Ballo, 2015) (Smith and Tidwell, 2016) (Gailing and Moss, 2016) (Cloke, Mohr and Brown, 2017) (Becker and Naumann, 2017) (Hajer and Pelzer, 2018) (Simmert, 2018) (Watts, 2018) (Longhurst and Chilvers, 2019) (Levenda *et al.*, 2019) (Delina, 2019) (Sovacool, 2019) (Morrissey *et al.*, 2020) (Levidow, 2020) (Kainiemi, Karhunmaa and Eloneva, 2020)

- <sup>30</sup> (Tacoli, McGranahan and Satterthwaite, 2008; Bouzarovski, Salukvadze and Gentile, 2011; Bulkeley *et al.*, 2011; Sýkora and Bouzarovski, 2012; Barau and Qureshi, 2015; Mendizabal *et al.*, 2018; Noori, Jong and Hoppe, 2020)
- <sup>31</sup> (Fouquet, 2010) (Barry *et al.*, 2015) (Burke and Stephens, 2017) (Brisbois, 2019) (Johnstone *et al.*, 2020) (Pearse, 2020)
- <sup>32</sup> (Redman and Foster, 2008) (Tsakok, 2011) (Davidson, 2015) (Bilali, 2019) (Bilali, 2019) (Shelton and Eakin, 2020)
- <sup>33</sup> (Geels, 2010) (Lawhon and Murphy, 2011) (Markard, Raven and Truffer, 2012) (Redclift and Springett, 2015) (Scoones, Newell and Leach, 2015) (UNRISD, 2016) (Blythe *et al.*, 2018) (Temper *et al.*, 2018) (Schot and Kanger, 2018) (Köhler *et al.*, 2019) (Johnstone *et al.*, 2020)
- <sup>34</sup> (Scoones *et al.*, 2020)
- <sup>35</sup> (Needham, 1975). In other contexts, this ‘polythetic approach’ is variously referred to (Rayner, 1987) as a more specific property of phenomena that are “polysemic” in holding many meanings (Mouzelis, 2008) or “polytypic” in displaying many sub-types (Hull and Ruse, 2007).
- <sup>36</sup> (Ritzer, 2000)
- <sup>37</sup> (Appadurai, 1990)
- <sup>38</sup> (Descola and Palsson, 1996)
- <sup>39</sup> (Goddard, 2008)
- <sup>40</sup> (Clarke, 1978)
- <sup>41</sup> (Appadurai, 1996)
- <sup>42</sup> (Hibbard, 2005)
- <sup>43</sup> (Steele, Jordan and Cochrane, 2010)
- <sup>44</sup> (Scott-Ram, 1990)
- <sup>45</sup> (Schneider and Wagemann, 2012)
- <sup>46</sup> (Evans, 2009)
- <sup>47</sup> (Wittgenstein, 1958)
- <sup>48</sup> (Sokal, 1974)
- <sup>49</sup> (Chłodnicki and Winiarska-Kabacińska, 2018)
- <sup>50</sup> (Gareau, 2015)
- <sup>51</sup> (Manoff, 2000)
- <sup>52</sup> (Scott-cato and Hillier, 2010)
- <sup>53</sup> (Dillet, MacKenzie and Porter, 2013)
- <sup>54</sup> (Beck *et al.*, 2017)
- <sup>55</sup> (Licker, 2003) (Thompson, 2010). Significantly, (Boudon and Bourricaud, 1982) and (Outhwaite, 2006) identify the difficulties in presuming monotonicity in measurements in social (when compared with physical) phenomena, as being a crucial distinguishing feature in this regard.
- <sup>56</sup> (Licker, 2003) (Thompson, 2010). A general dominance of default assumptions about monotonicity in modern thought, is illustrated by debates over the only relatively recent (and sometimes still resisted) development of non-monotonic reasoning in western philosophy (Jacquette, 2002)
- <sup>57</sup> For instance, in discussing general patterns in policy making worldwide, the influential RAND Corporation state that “*Decisionmaking is based on the insight that complex, co-evolving endeavors rarely unfold as predicted; the false assumption of monotonic progress is made, not because anyone really believes it, but rather because facing reality is too complex*”
- <sup>58</sup> (Zand and Sorensen, 1975) (Funnell and Rogers, 2011) (Taplin and Clark, 2012)
- <sup>59</sup> Although occasionally briefly deprecated in particular contexts in innovation literatures (Teubal *et al.*, 1996) (Roberts, Schaffer and Dear, 2007), the entrenchment of an overwhelmingly monotonic imagination of what we are here calling an “innovation temporality” is discussed in the critical literature around “trajectorism” (Appadurai, 2012) (Felt, 2015) and graphically illustrated by the shocked tone of discussions of the prevalence of the phenomenon of “lost knowledge” – sometimes in the most surprising settings of highly-funded advanced technology. Examples include globally-disappeared techniques for evenly-thin hammering of bronze sheets in post-Roman England (Mercer *pers.comm* 1983), medieval Japanese ‘katana’ sword-blade manufacture (Lillard, 2009), production of the ‘Fogbank’ aerogel for US thermonuclear weapons in the 1990s (Lewis, 2018) (Lillard, 2009), and forging for minimum embrittlement in nuclear reactor pressure vessel head penetrations at the world-leading French Le Creusot plant during the 2010s (Large, 2016) (Stoithard, 2016).
- <sup>60</sup> (North, 2000) (Stein and Valters, 2012)
- <sup>61</sup> Kinna notes criticism of revolutionary political thinking in anarchism, on the grounds of inadequate attention to more diverse possible theories of change (Kinna, 2012). Hewlett notes the same criticism made of revolutionary Marxist thinkers like Badiou (Hewlett, 2007).
- <sup>62</sup> (Duncan *et al.*, 2018)
- <sup>63</sup> Transition studies is often criticised for becoming a theory of change monoculture of (Walker and Shove, 2007), privileging innovation studies perspectives on a broad evolutionary theory of change (Boonstra, W., Joosse, 2013). Geels and Schot review multiple relevant theories of change in (Grin *et al.*, 2010)
- <sup>64</sup> Although the two terms are often used interchangeably, an even wider and deeper multiplicity of theories of change tends to be discernible among studies declaring themselves to be concerned with ‘transformation’, than among those nominally focusing on ‘transition’ (Stirling, 2015) (Scoones *et al.*, 2020).
- <sup>65</sup> See: <https://council.science/wp-content/uploads/2017/08/transformations-sustainability-programme.pdf> [accessed January 2021]
- <sup>66</sup> In a key text on political economic transformations, leading protagonists Richard Lipsey, Kenneth Carlow and Clifford Bekar say in contemplating nonmonotonicity, for instance, “*this seemingly counterintuitive result, which goes so much against our usual training. We are used to functional forms where the growth rate is smooth and continuous and usually monotonic so that the average and the total always align*” (Lipsey, Carlow and Bekar, 2005)
- <sup>67</sup> (Stirling, 2011) (Stirling, 2018)

- <sup>68</sup> The relative dominance of varying-monotonic frameworks in organisation, management and innovations studies bearing on transformation, is perhaps illustrated (even in the most nuanced and comprehensive work) by the fact that four of the five contrasting forms of developmental progression influentially distinguished by Van de Ven actually take some kind of monotonic form (Ven, 2007). His 'unitary', 'multiple', 'cumulative' and 'conjunctive' progressions are all in some way monotonic. Only his 'recurrent progression' is – albeit in a highly regular form – non-monotonic. Other kinds of temporality mentioned later in this paper here are all the more notable both in their absence, for the nuanced partitioning of forms of monotonicity.
- <sup>69</sup> (Nakicenovic and Grubler, 1991)
- <sup>70</sup> See a variety of chapters in (Hanusch and Pyka, 2007) for a series of different reasons across contrasting contexts, for simply assuming the salience of a logistic curve description in the mainstream 'Schumpeterian' body of work on transformation process. As other chapters in this work also repeatedly show, this is then simply "fitted" to relevant data. The chapter by Foster acknowledges that a prime reason for this lies in the mere mathematical expediency that *"the advantage of using the logistic curve to capture this parameter variation is that we can obtain a fixed parametric representation of such a nonlinear growth path"*. Foster also clarifies that the principal authority for reproduction of this expediency, lies simply in past practice. As noted by (Galbraith and Merrill, 1996), the results are notoriously prone to manipulation.
- <sup>71</sup> Mainly on grounds of past precedent in innovation studies, an "s-curve model" (Loorbach, 2010) is almost ubiquitous across research on 'transitions', canonically distinguishing between notionally fixed phases of *"predevelopment"*, *"take-off"*, *"acceleration"*, and *"stabilization"* (Rotmans, Kemp and Asselt, 2001).
- <sup>72</sup> (Elzen, Geels and Green, 2004)
- <sup>73</sup> (Werbeloff and Brown, 2016)
- <sup>74</sup> (Tran, 2014)
- <sup>75</sup> (Safarzy, Frenken and Bergh, 2012)
- <sup>76</sup> A common phrase in this regard is often – eg: (Berkes and Berkes, 2009) (Herring and Sorrell, 2009) (Martin, 2017); but reportedly unduly (Gaunand and Matt, 2017) – attributed to Albert Einstein "[n]ot everything that can be counted counts, and not everything that counts can be counted". A detailed critique of the general syndrome can be found in (Muller, 2018).
- <sup>77</sup> (A. Stirling, 1997)
- <sup>78</sup> Eg: (Grin *et al.*, 2010) (Penna and Geels, 2012) (Sovacool and Geels, 2016) (Markard, 2018)
- <sup>79</sup> (Stirling, 2011) (Avelino and Grin, 2016)
- <sup>80</sup> (Nightingale, 2004) (Silver, 2012)
- <sup>81</sup> This general syndrome is well analysed by (Galbraith and Merrill, 1996)
- <sup>82</sup> (Abramowicz, 2007) (Taagepera, 2008)
- <sup>83</sup> (Robert K. Colwell, 1974)
- <sup>84</sup> (Smith, 2006)
- <sup>85</sup> (Mouzelis, 2008)
- <sup>86</sup> (Armstrong, Martin and Place, 1996) (Bell and Colebrook, 2009) (Anderson and Harrison, 2010) (Morfino, 2014)
- <sup>87</sup> (May and Thrift, 2003) (Lefebvre, 2004) (Garud and Gehman, 2012) (Appadurai, 2012)
- <sup>88</sup> (Clark, Freeman and Soete, 1981) (Mandel, 1995) (Therborn, 2000) (Lente, Spitters and Peine, 2013)
- <sup>89</sup> (Modelski, Devezas and Thompson, 2008) (Drechsler, Kattel and Reinert, 2009) (Perez, 2016)
- <sup>90</sup> (Canter, Gaffard and Nesta, 2009)
- <sup>91</sup> (Meadowcroft and Steurer, 2013) (Hodgson, 2007) (Croteau, Hoynes and Ryan, 2005)
- <sup>92</sup> (Freeman and Louca, 2001) (Perez, 2003)
- <sup>93</sup> (Mandel, 1995)
- <sup>94</sup> (Barnett, 1998) (Morone, 2016)
- <sup>95</sup> (Solomou, 1990)
- <sup>96</sup> (Downs, 1972) (Meisner, Sriskandarajah and Depoe, 2015)
- <sup>97</sup> (Schumpeter, 1939) (Freeman and Perez, 1988) (Dubois, 2016)
- <sup>98</sup> (Gartner, 2011) (Alkemade and Suurs, 2012) (Lente, Spitters and Peine, 2013)
- <sup>99</sup> (Niemann, Tichkiewitch and Westkamper, 2009)
- <sup>100</sup> (Fischer and Forester, 1993) (Fischer, Miller and Sidney, 2007)
- <sup>101</sup> (Holling, 2001) (Berkes, Colding and Folke, 2003)
- <sup>102</sup> (Gunderson and Holling, 2002) (O'Brien, 2011) (Olsson, Galaz and Boonstra, 2014)
- <sup>103</sup> (Turchin and Nefedov, 2009)
- <sup>104</sup> (Geels and Penna, 2015) (Penna and Geels, 2015) (Perez, 2016)
- <sup>105</sup> (Kleinknecht, Mandel and Wallerstein, 1992)
- <sup>106</sup> (Spinney, 2012)
- <sup>107</sup> (Herod, Tuathail and Roberts, 1998)
- <sup>108</sup> (Hertin *et al.*, 2009) (Kenter *et al.*, 2019)
- <sup>109</sup> (Collingridge, 1980)
- <sup>110</sup> (Hilgartner, 2004)
- <sup>111</sup> (Mabey and Morrell, 2011)
- <sup>112</sup> (Stirling, 2014) (Stirling, 2019a)
- <sup>113</sup> (Sewell, 2005) (Langley *et al.*, 2013) (Walker, 2014) (Klinke, 2016)
- <sup>114</sup> (Eliade, 1957) (Cormack, 2003)

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- <sup>115</sup> (Moran, 2015) (Tymieniecka, 2007)
- <sup>116</sup> (Rawes, 2008)
- <sup>117</sup> (Reid, 1978) (Butler, 1997) (Livingstone, 1997)
- <sup>118</sup> (Walker, 2014) (Monaghan, 2016)
- <sup>119</sup> (Abbinnett, 2007) (Mishkova, Trencsenyi and Jalava, 2014) (Morfino and Thomas, 2018) (Sewell, 1990) (Manicas, 2006)
- <sup>120</sup> (Mensch, 11988) (Moran, 2005) (Rodemeyer, 2006) (Mondada, 2009) (Candea, 2010) (Flaherty, 2011) (Kuznetsova, Ganeri and Ram-Prasad, 2012) (Scoones and Stirling, 2020)
- <sup>121</sup> (Brubaker *et al.*, 2009) (Brown, 2013) (Solakidi, 2019)
- <sup>122</sup> (Hodge, 2007) (Hoy, 2009) (Barnard, 2011) (Ernst, 2020) (Helin, 2020) (Manchester, 1975) (Martinon, 2007)
- <sup>123</sup> (Stirling, 2019)
- <sup>124</sup> (Bustamante, 2017)
- <sup>125</sup> (Andrew Stirling, 1997) (Yearley, 2001)
- <sup>126</sup> (Stirling, 2002)
- <sup>127</sup> Eden, S., Donaldson, A. and Walker, G. (2005) 'Structuring subjectivities? Using Q methodology in human geography', *Area*. Wiley Online Library, 37(4), pp. 413–422.
- <sup>128</sup> Nost, E., Robertson, M. and Lave, R. (2019) 'Q-method and the performance of subjectivity: Reflections from a survey of US stream restoration practitioners', *Geoforum*. Elsevier, 105(August 2018), pp. 23–31. doi: 10.1016/j.geoforum.2019.06.004. 'Nuclear Sector Deal Two Years On' (2020), (September).
- <sup>129</sup> (Sneegas, 2020, p. 83)
- <sup>130</sup> (Robbins and Krueger, 2010)
- <sup>131</sup> Government of the Republic of Kenya, 2007
- <sup>132</sup> (Nairobi City Council, 2014)
- <sup>133</sup> Including the 'Digital Economy Blueprint', the National ICT Master Plan 2019 the National ICT infrastructure Master Plan (Ministry of Information Communications and Technology, 2019) and the ICT authority's strategic plan (ICT Authority, 2019)
- <sup>134</sup> (Al Dahdah and Quet, 2020)
- <sup>135</sup> (ICT Authority, 2019)
- <sup>136</sup> (Mosley and Watson, 2016)
- <sup>137</sup> (Justin Zhuang, 2014)
- <sup>138</sup> (Hu, 2019)
- <sup>139</sup> (Cain, 2014, p. 563)
- <sup>140</sup> (Hursh, 2019)
- <sup>141</sup> (Kimari and Ernstson, 2020)
- <sup>142</sup> (Watson, 2014)
- <sup>143</sup> (Goldman, 2011)
- <sup>144</sup> (IBM, 2012; Sadowski and Bendor, 2018; Joss *et al.*, 2019; Shuilenburg and Pali, 2021)
- <sup>145</sup> (Smith, 2017)
- <sup>146</sup> (Côté-Roy and Moser, 2019)
- <sup>147</sup> (Manji, 2015, p. 207)
- <sup>148</sup> (Watson, 2014)
- <sup>149</sup> (van Noorloos and Kloosterboer, 2018, p. 1123)
- <sup>150</sup> (Bunnell and Das, 2010)
- <sup>151</sup> (Amin, 2013)
- <sup>152</sup> (Pricewaterhouse Coopers, 2005, p. 2)
- <sup>153</sup> (Watson, 2014)
- <sup>154</sup> (Amin, 2013)
- <sup>155</sup> (Linehan, 2007)
- <sup>156</sup> (Dragsted, 2019)
- <sup>157</sup> Note on language: Kenya is a highly multilingual society with more than 40 languages spoken (Dwivedi, 2014). English and Kiswahili are the dominant languages, being widely spoken across the country, but there are many other lesser known languages which often serve as markers of ethnic identity. Furthermore the linguistic landscape of Kenya is not static, as illustrated by the notable example of Sheng, a hybrid language which emerged in the 1970s and is increasingly adopted as the language of Kenyan urban youth (Garnier, 2020). This linguistic diversity and dynamism draws attention to the partial nature of any exploration of imaginaries solely in English (as in this study) which is therefore blind to alternative ways of imagining as expressed in other languages. However, given that many of the high level, influential government and corporate policies, strategies and visions of urban futures are written in English, and draw on globally circulating English language terminologies (such as the vocabulary of 'smartness'), despite the limitations, this kind of work can at least provide a space from which to question the inevitability, or universality of these narratives, illustrating their cultural and historical specificity, and revealing as particular their implicit understandings of the world, desired futures, natural relations, and appropriate means and ends (cf. Ndlovu-Gatsheni 2014)



<sup>158</sup> We set out below a table of the entire 'Q set' of statements:

Statement:	
	'Informal' development is intrinsic to Kenyan cities.
	The collaboration of organized communities and local authorities is the cornerstone of planning for inclusive and resilient cities in Kenya.
	The booming young population of Kenya is more likely to adopt technology, including smart city technologies, and to produce innovation.
	Kenya's delay in urbanization could be an advantage, as new cities or city districts can be designed with smart city solutions in mind from the start
	In the future there is a risk that digital infrastructure in Kenyan cities will be used for surveillance and to police behaviour of those who are deemed to be deviant.
	Kenya needs to build the next world class smart city in order to be competitive and attract investment
	E-governance in smart cities will radically reform governance of urban Kenya, through removing human intermediation and embedding a culture of monitoring and evidence-based planning and decision making.
	Unlike the historical haphazard growth of Kenyan cities, in a smart city every building, dam, site or road, will be well-thought out and installed with a view to accomplishing sustainability
	The smart Kenyan cities of the future will offer citizens a seamless urban experience: from connected homes, to the use of Wi-Fi-enabled transport, to hyper-connected workplaces
	Culture is a luxury that is secondary to other urban priorities in Kenya, like fresh water, decent jobs, adequate housing and education
	The risks of pandemics like COVID 19 remind us that tackling basic sanitation is the first step in building a healthier city: that means providing appropriate water and sanitation systems and good quality houses for all must be a priority for urban transformation
	Kenya needs the optimism and inspiration of visionary ideas like Konza city
	Smart urban technologies can be most transformative when they act as an enabler for people to feel part of the city: that they have a right to the city and the services the city offers
	Until the rights of whole of the urban population are respected, inequality will prevent a sustainable urban transformation in Kenyan cities
	Without culture there is no future for Kenyan cities: cities need vitality, meaning and identity
	City planners need to cater to the needs of Kenya's rapidly growing middle class and address Nairobi's shortage of urban middle class housing
	Urban problems in Kenya are rooted in corruption, unresponsive governance, and lack of proactive urban planning
	In the future, technology will provide solutions to some of Kenya's cities biggest challenges
	The conditions of the urban poor in Kenyan cities can be improved without a need for their involvement in planning processes.
	Building new cities in Kenya could provide a solution to ease the pressure off the old cities and could, if done right provide a sustainable solution to rapid urbanisation
	Industrialisation is at the core of Kenya's structural transformation, and infrastructure is its catalyst
	ICT is one of the primary enablers or foundations for the socio economic transformation of Kenyan cities.
	It is vital that Kenya develops a vibrant digital economy lest it be swamped by fast moving global brands and companies
	ICT-enhanced urban services in Kenyan cities will ultimately benefit all urban residents
	The current virus pandemic could provide a once-in-a-lifetime opportunity for speeding up the introduction of digital technologies aimed at improving the lives of city dwellers in Kenya
	One of the great advantages for the digital revolution in Kenya, is that there's far less legacy to get in the way than in other regions, creating a clean sheet on which companies can develop their own distinctive business models
	COVID 19 has proven how important it is that policy makers focus on developing digital urban infrastructures in Kenyan cities

	As digital technologies become the cornerstone of daily activities in Kenya, Governments, businesses and individuals must adapt to this new reality
	Contemporary urban crises in Kenya require a 're-humanizing' of the urban environment
	Colonial exclusionary measures in Kenyan cities (which were largely retained at independence) are at the core of widespread urban apathy in Kenya today.
	Kenya is engaged in a race with other countries to establish information supremacy: those who are able attract the high value and knowledge-intensive manufacturing, research, software, IT, and services jobs will be the ones that will prosper
	We need to see urbanisation in Kenya as a tool for development not just an accumulation of problems
	Kenya, and Africa more broadly, is neither 'rising', nor undergoing any meaningful structural transformation
	An important question to ask is whether Kenyan cities should aspire to become 'smart' or to create more equitable, inclusive and sustainable habitats for all.
	To seize opportunities and build sustainable prosperity, Kenyan cities need to become smarter and take a holistic approach to managing the system of systems on which they depend
	The most likely outcome of new master-planned cities such as Konza is a steady worsening of marginalization and inequality

- <sup>159</sup> (Bowman, 2015)
- <sup>160</sup> (Kimari and Ernstson, 2020)
- <sup>161</sup> (Sarr, 2019)
- <sup>162</sup> (Ndlovu-Gatsheni, 2014)
- <sup>163</sup> (Johnstone and Stirling, 2020)
- <sup>164</sup> (Jacobsson and Lauber, 2006; Strunz, 2014; Hermwille, 2016)
- <sup>165</sup> (Strunz, 2014)
- <sup>166</sup> (Geels *et al.*, 2016)
- <sup>167</sup> (Geels *et al.*, 2016)
- <sup>168</sup> (Brown, 2008; Thomas, 2010; Birmingham Policy Commission, 2012; Cox, Johnstone and Stirling, 2016)
- <sup>169</sup> (Geels, 2014)
- <sup>170</sup> (Markard, Raven and Truffer, 2012)
- <sup>171</sup> (Feola, 2020; Johnstone and Stirling, 2020)
- <sup>172</sup> (Johnstone and Stirling, 2020)
- <sup>173</sup> (DECC, 2011b)
- <sup>174</sup> (Glaser, 2012)
- <sup>175</sup> (Purdue, Kemp and O'Riordan, 1984; O'Riordan, 1988; Johnstone, 2014)
- <sup>176</sup> (Johnstone and Stirling, 2020)
- <sup>177</sup> (Morris and Pehnt, 2012)
- <sup>178</sup> (Dewey, 1989)
- <sup>179</sup> (Group *et al.*, 2010)
- <sup>180</sup> (Taylor, 2007)
- <sup>181</sup> (Rogge and Johnstone, 2017)
- <sup>182</sup> (DTI, 2003)
- <sup>183</sup> (PIU and UK\_Cabinet\_Office, 2002)
- <sup>184</sup> (Conolly, 2010)
- <sup>185</sup> (Patterson, 2010)
- <sup>186</sup> (DTI, 2007)
- <sup>187</sup> (DECC, 2011a)
- <sup>188</sup> (Thomas, 2016)
- <sup>189</sup> (Hermwille, 2016)
- <sup>190</sup> (Johnstone, Stirling and Sovacool, 2017)
- <sup>191</sup> (HM Government, 2020)
- <sup>192</sup> (Sovacool *et al.*, no date)
- <sup>193</sup> (Shapira and Smits, 2010)
- <sup>194</sup> (Simonsen, 2005)
- <sup>195</sup> (Friedman, 1999): 377)
- <sup>196</sup> (Jalas, Rinkinen and Silvast, 2016): 17).
- <sup>197</sup> (Cameron, 2020)

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- <sup>198</sup> (BIS, 2013)
- <sup>199</sup> ('Nuclear Sector Deal Two Years On', 2020)
- <sup>200</sup> (Schank, Cook, *et al.*, 2005; Schank, Riposo, *et al.*, 2005)
- <sup>201</sup> (KOFAC, 2006)
- <sup>202</sup> (House of Commons North West Regional Committee, 2010)
- <sup>203</sup> (Stirling and Johnstone, 2020)
- <sup>204</sup> (Grimes, Ion and Sherry, 2014): 59
- <sup>205</sup> (Ritchie, 2012; Jack, 2016)
- <sup>206</sup> (Jones, 2017)
- <sup>207</sup> (Gowing, 1974)
- <sup>208</sup> (HM Government, 1955)
- <sup>209</sup> (Pocock, 1977)
- <sup>210</sup> (Howell, 1979)
- <sup>211</sup> (Schank, Cook, *et al.*, 2005; House of Commons Defence Committee, 2006; House of Commons North West Regional Committee, 2010)
- <sup>212</sup> (Ireland, 2007)
- <sup>213</sup> (DTI, 2003)
- <sup>214</sup> (House of Commons Defence Committee, 2006)
- <sup>215</sup> (Blair, 2006)
- <sup>216</sup> (Norton-Taylor, 2015)
- <sup>217</sup> (DTI, 2007; BERR, 2008)
- <sup>218</sup> (Ooroschakoff, 2019)
- <sup>219</sup> (Hopkins, 2012; NAO, 2019)
- <sup>220</sup> (RR, 2017)
- <sup>221</sup> (Bond and Pfiefer, 2019)
- <sup>222</sup> (Grimes, Ion and Sherry, 2014)
- <sup>223</sup> (BEIS, no date)
- <sup>224</sup> (O'Toole, 2018)
- <sup>225</sup> (Appadurai, 2012) (Felt, 2015)
- <sup>226</sup> (Dosi, 1982)
- <sup>227</sup> (Rosen, 2012)
- <sup>228</sup> (Stirling, 2014) (Stirling, 2019)
- <sup>229</sup> (Borges, 1952)
- <sup>230</sup> (Sfard, 2008)
- <sup>231</sup> (Needham, 1975) (Scholes, 1977)
- <sup>232</sup> (Bernstein, 1996)
- <sup>233</sup> The English word (from Latin) '*murmuration*' offers a notable instance of serendipity in ostensibly contingent contrasting meanings combined in the etymology of a single word, in that contrasting contexts in its evolution have involved meanings relating both to 'exuberant motion' as well as to 'subdued dissent'. In respect of the latter (now more antiquated) usage, for instance, Bloom recently says of the 1968 cultural revolution "*hip communes of every genre imaginable were silently cropping out of the earth by the hundreds. And in time, the faint word-of-mouth rumored murmurations about their whereabouts had swollen into enough of a knowledgeable whisper among alienated young folks to set them off in collective exodus once again*" (Bloom, 2003). Writing of a late sixth century letter to the Byzantine Emperor Maurice from bishops in Aquilea, Sotinel translates an early recorded usage in this broadly similar anti-authoritarian sense ("*de murmuratione totius populi patrium istarum*") as "*the grumbling of all the people of these regions*" (Chazelle and Cubitt, 2007).
- <sup>234</sup> (Needham, 1975) (Scholes, 1977)
- <sup>235</sup> (Sfard, 2008)
- <sup>236</sup> (Stein *et al.*, 2009)

