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Doing business model innovation for sustainability transitions — Bringing in strategic foresight and human centred design

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ABSTRACT

This paper brings together socio-technical transitions theory with strategic foresight and human centred design. The aim is to bring in new methods for analysing the business model element of sustainability transitions. We propose a process for doing business model innovation work. Business models have become a key area of focus, particularly in the energy sector. Recent work shows how the development of new business models co-evolves with elements of the energy system, either driving technological innovation, changing user practices or placing pressure on the institutional or policy regime. At the same time, there is no recognised process for business model research aimed at transition management. It is time therefore to propose a more formalised and theoretically grounded approach to business model innovation work. We use this contribution to synthesise the lessons of a four-year research project centred on energy utility business models with industrial, commercial and government stakeholders. We describe the process adopted, and insights this process generated. We seek to establish this process in the literature, invite others to utilise it, adapt it and critique it.

1. Introduction

The aim of this paper is to establish a process for doing business model research in low carbon transitions. We offer a theoretically grounded process that will allow scholars to replicate business model innovation work. We demonstrate the usefulness of this approach by summarising a four-year research project on electric utility business models in low carbon transitions.

To manage low carbon transitions, we need both swift political action, *and* we need to materially retrofit existing socio-technical systems [1]. In order to do this with minimal unintended consequences [2], we develop analytical and theoretical tools to help us unpack the complexity of these systems. In this paper we review recent analytical work on the business model element of energy and sustainability transitions. We find that in-spite of a recent expansion of business model work in transitions research [3–5] "we", as a community of business model researchers, still lack a formalised process for business model research that is compatible with transition management. Here we propose one such process using tools from strategic foresight and human centred design approaches.

The research programme used as case material is the 'Utility 2050' project, a four-year project aimed at understanding how electricity utility business models might evolve in different low carbon futures [6]. Using a broad Multi Level Perspective, we classify energy utilities as part of the 'Regime' of energy transitions. A more or less stable set of institutions, technologies, user practices and business models [7–9]. The business models of utilities will have to change to accommodate energy transitions. Regimes can be disrupted from within, from below by niches, or from above by landscape factors beyond the system [7]. The utility business model is always under change pressures within liberal democratic capitalism, where the forces of competition are designed into markets for energy and other pipe and cable utilities. Thus, we can

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expect business models to be under constant pressure; both to adapt to societal demands for sustainability transitions, and to survive under the market's own internal dynamics [10,11].

In Section 2 we briefly review literature on the role of business models in societal transitions; we point to a lack of methodological clarity on how to *do* business model research generally, much less in a way that is compatible with the system models and scenario work used in so much energy policy and system planning [12,13]. We then introduce the 'strategic foresight' and 'human centred design' approaches, review their origins and use to date, and argue that these tools complement a socio-technical approach to studying business models. In Section 3 we report on how we used the principles of strategic foresight and human centred design to guide our research on utility business models, reporting briefly on the suite of findings and insights synthesised in the Utility 2050 project. Section 4 identifies the ways in which strategic foresight and human centred design can be productively integrated with wider elements of socio-technical transition study. Section 5 reflects on the limitations of the process, not least its resource and stakeholder intensive nature, and invite others to use this process, refine it, critique it and apply it to other sectors beyond electricity system transitions.

2. A socio-technical approaches to business model research

The socio-technical transitions (STS) field broadly recognises "markets" as a key element in socio-technical regimes [14]. The other elements are industrial networks, techno-scientific knowledge, user practices, technology, infrastructure and cultural or symbolic meaning [ibid]. These system elements were simplified by Foxon (Fig. 1), who argued each element co-evolves with the others, iteratively shaping different transition pathways [15]. This co-evolutionary approach uses an analytical framework with five discrete elements: ecosystems, institutions, technologies, user practices and business strategies [11]. Scholars that use this co-evolutionary framework can isolate discrete elements of the system and study them in depth, without losing a broader systems perspective. For example, those exploring the role of institutions have shown how institutional traditions and systems of finance affect pathways for energy transitions [16,17], how domestic political institutions and historical energy infrastructures can differently influence systems change [18], the co-evolution of progressive energy policy and institutional innovation [19], and the effect of policy mixes on domestic energy retrofit [20]. In the STS field, explorations of institutions have been dominated by sociological or organisational institutionalism [21], investigating the regulatory, normative and cognitive rules, which shape energy systems [22].

To date, those interested in developing the 'business strategies' element of this framework, or pursuing business model research within the wider MLP perspective, have explored how the business models of firms involved in the energy transition change over time, as they co-evolve with new technologies and user practices, Fig. 2.

This co-evolutionary business model lens has been applied to the evolution of district heating [24] the limited success of energy 'as a service' business models [25], the viability of local energy systems [4], the evolution of incumbent utilities towards renewables led systems [26], and the business models that are suited to scaling up energy efficiency retrofit [27]. Not all STS scholarship on business models explicitly uses the co-evolutionary framework, but the co-evolutionary framework is useful because it isolates business models/strategies as explicit elements of the system. A co-evolutionary perspective invites us to consider how the wider system affects business models *and* how business models affect the wider system. This is critical to our analysis.

Much of STS business model scholarship begins with one of several definitions of what a business model is. Many draw on Amit and Zott's definition of a business model as 'a system of interdependent activities that transcends the focal firm and spans its boundaries […] enable[ing] the firm, in concert with its partners, to create value and also to appropriate a share of that value [28]. Often in transitions research the objective is to steer the regime towards more sustainable business models, to design 'a modified or new activity system, […] recombining the existing resources of a firm and its partners [29]'. This recognition of a business model as a 'system of activities' beyond the focal firm, is compatible with a socio-technical perspective that studies material technologies, users and institutions as important factors beyond the firm's boundaries. We find it helpful to distinguish two types of research adopted by STS business model research.

The first type of STS business model research identifies and explores how different business models, extant or otherwise, are *affected by* the wider system. Here, the different institutional settings, technologies and user preferences are external boundaries on the business model's capacity to innovate. This allows researchers to show what types of business model innovation is happening, and where institutions, technology, or user practices/preferences are acting as barriers or enablers of more sustainable business models. This approach often leads to concrete policy or regulatory prescriptions, either to facilitate further innovation or make space for latent business models. Examples include explorations of business model innovation for prosumers in an era of diminishing subsidies [30], the creation of market, consumer and environmental value through digitisation [31], the ways in which regulatory and legislative context shapes Municipal energy company business models [32], and how mini-grids business models in developing settings need close attention to both technical design and institutional operation [33].

The second type of STS business model research explores how the business models can exert pressure outwards on the rest of the system. Bidmon and Knab identify how business models can act in three ways on socio-technical transitions, first by hampering and opposing system transitions that threaten their existing source of value appropriation

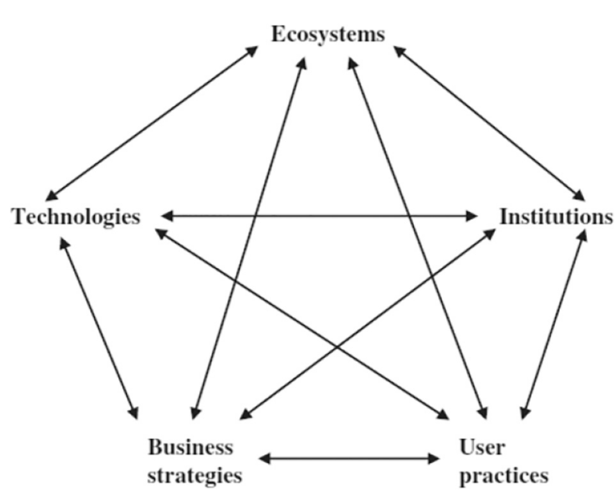

Fig. 1. Foxon's co-evolutionary framework [11].

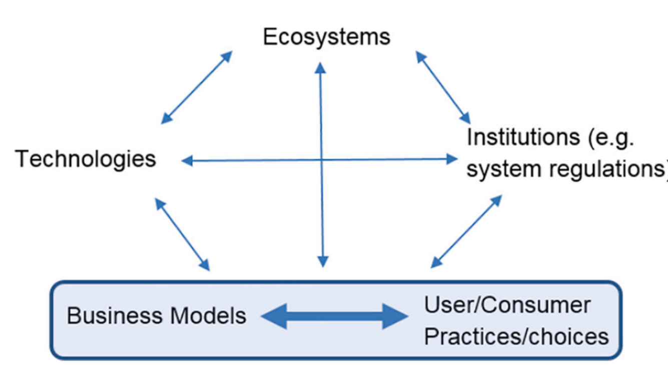

Fig. 2. Centralising the business model for analysis [23].

[34] also see [35]. Second as enablers of transitions, exerting pressure for regulatory or policy change as in distributed solar in Germany and California wider system [36], farm power in Finland [37] or utility business model relations to user practices [38]. Together this burgeoning landscape of business model research for socio-technical transitions paints a rich picture of how business models co-evolve with different parts of different energy transitions. Within this field, there is however a distinct lack of methodological guidance as to how one should undertake such research, and which analytical frames can be used beyond a broad 'MLP' focus.

2.1. Tools and techniques used in STS business model research

There are a broad range of methods and tools adopted by STS business model researchers. This is a rapidly expanding field and it is not within our scope here to provide a systematic review of methods and tools used to date. Instead we are proposing a process and set of tools we found helpful in our research and opening this process up for replication and debate. However, it does serve to indicate three general trends.

The first methodological trend is the attempt to create typologies and archetypes of different business models, see [4,30]. This involves initial reviews of cases, desk-based research and often-primary workshops [3]. The results are sets of archetypes and long lists of different ways in which business models create and capture value in the energy system. Some use business model component diagrams and co-creation [39–41], others use secondary sources or cross case comparison [42], many use or adapt the business model canvas approach to identify the building blocks of different models [43,44]. Each attempt to categorise and represent energy business models expands our understanding of the diversity of possible options and the often relatively uniform business models, which comprise the regime.

The second methodological trend is to undertake qualitative work with elites to explore the regulatory, policy, commercial and technical context of business model change [16]. Here the relation to institutions is most clear, where regulation and policy play a vital role. Deep, qualitative engagement is often used and a characterisation of the regulatory risks and policy barriers to entry are prioritised [44,45]. Many of these studies are already building on the first methodological trend, using typologies to assess which regulatory or policy instrument relates to, constrains or enables a given business model. Often elite semi-structures interviews, focus groups and workshops are used to gain deep insight from those close to the regulatory and policy landscape.

The third methodological trend, though perhaps the least common, is an attempt to explore the impact on consumers of business model innovation and how different business models create and secure different consumer, social and environmental value [38]. This can be done using representative sample surveying of consumer attitudes [46,47], systematic literature reviews [48], choice experiments [49] or through further primary qualitative analysis with users [50].

If we take a wide co-evolutionary lens, we find four important gaps. Firstly, there is very little quantitative attention to the actual markets for the goods and services in question and how they are evolving. This is surprising given the commercial nature of the study object. In many cases market trends or opportunities are qualitatively described but not quantitatively evaluated. Second, there is little engagement from the business model field in with the various scenarios and futures work that underpins so much energy policy design, not least that emerging from the cost-optimisation and scenario modelling community. Third, there is very little attempt to explore the relation of consumers to business model innovation, and almost no future facing work to explore how consumers/user practices might enable of constrain different types of business model innovation. Finally, while the co-evolutionary framework and wider STS community invites us to explore the linkages between Business models and other system elements, there is little to guide researchers on how might systematically undertake this journey. We will return to these gaps when we discuss the utility of the process we propose in Section 4.

We argue that adopting strategic foresight or (futures) work, along with Human Centred Design can solve some of these problems and develop a coherent step by step process for understanding business models in socio-technical systems work. In what follows we introduce Strategic Foresight and Human Centred Design, before summarising how we used these tools to organise our research process in the Utility 2050 project.

2.2. Strategic foresight and futures work in energy research

We know there are multiple possible energy futures, multiple pathways via which energy systems can either reach decarbonisation targets or not, deliver social goals or not. Most business models work does not integrate with energy scenarios work. We argue here that we can use Strategic Foresight to make the link between different possible futures and the co-evolution of business models in the energy system.

'Strategic Foresight' involves creating a series of different visions of the future and using these visions to develop new organisational strategies and decision tools [51,52]. Strategic Foresight is a blend of 'futures' work and firm oriented strategic management approaches [53,54]. The emphasis is on individual organisations, how they can anticipate and react to multiple emergent futures to remain competitive or achieve 'success' broadly defined [55]. Strategic Foresight is an emerging field which, is theoretically compatible with the co-evolutionary framework and wider STS work because it often utilises evolutionary economics as a theoretical base [56], exploring how a firms 'dynamic capabilities' can be enhanced by a structured and facilitated foresight activity [57]. "*Foresight is seen as a process which involves systematic inquiry into longer-term futures, including emerging and novel issues, which in turn enables present decision-making and action*" [58].

Dynamic capabilities are "a firm's behavioural orientation constantly to integrate, reconfigure, renew and recreate its resources and capabilities and, most importantly, upgrade and reconstruct its core capabilities in response to the changing environment to attain and sustain competitive advantage." [59] Strategic foresight is used to explore this changing environment and create strategic responses to maintain this competitive advantage.

Strategic foresight has been productively applied across sectors as diverse as; the airline industry [60], telecommunications [61], and public policy [62]. However very few examples exist from the energy industry (though see Shah et al. [63] who used a strategic foresight lens to find that utilities which secure early competitive advantage from new technologies may lose the ability to continuously innovate as they become the new incumbents). While most foresight work is limited to single firm strategies, some work has moved to explore 'collaborative open foresight' [64] where firms or organisations seek partners in foresight activities to avoid being limited to existing metal models.

This lack of published[1] strategic foresight work is surprising as the energy sector is not short of informative and closely developed futures scenarios which strategic foresight processes could draw on [65–67]. Though not always named as strategic foresight some work is using energy scenario work to explore business model innovation; see [68–70] for contributions which explore servitisation, digitalisation, and wholesale market specialisation. To date however there has been little attempt to link STS business model work explicitly to energy futures.

Futures scholarship in the energy field is largely conceptualised as energy 'scenarios' work [71], this field uses a variety of quantitative models and narratives to describe plausible pathways towards low-carbon energy systems of different types, i.e. market led, community led, state led [72]. Recently, energy scenario work has been driven by

[1] We are aware that energy firms undertake foresight activity, but we are referring to the lack of scholarship on this trend and its lack of integration into the energy or low carbon transitions literature.

the need to achieve an energy transition [73,74]. These scenarios include international modelling effort [75], individual corporate scenarios (i.e. Shell International [76]) pan national modelling [77] and multiple approaches to energy scenario building at the national scale [78].

In the UK, one of the most consistent scenario developers is National Grid, whose 'future energy scenarios' suite develops four socio-technical pathways for energy system transitions in the medium to long term (e.g. 2021 [79]). From within this community there is a recognition that the demand side is often underrepresented and that energy models lack insight on consumer behaviour, and as a result risk favouring more quantifiable mitigation options such as emissions removals [80]. These models are found to have limited scope to accommodate the combined effects of investment and commercial decision making under conditions of uncertainty [81]. In short, the roles of consumers, investors and utilities have been relatively poorly incorporated into energy scenarios and futures work — see Table 1. Not only can STS business model work benefit from a futures and foresight approach, but vice versa.

There have been several recent studies which have sought to develop approaches that combine quantitative, participatory, qualitative and scenario-based processes [86–89]. Such combined approaches have started to explicitly engage with the extent of uncertainty in energy transitions [90]. Barazza and Strachan [17] to develop an Agent Based Model to integrate the diverse decisions of financial and commercial actors into energy scenario work. Barazza and Strachan's work is focussed on the effect of diverse commercial and financial decisions on installed capacity, while this is of critical importance, we view developments in the utility business model itself, along with the evolution of the consumer relation (the demand side) as equally deserving of further investigation.

Table 1
UK energy system modelling decision support tools — features and limitations.

Model name and analytical approach	Features	Limitations
MARKAL — bottom-up: econometric — cost optimisation [82]	• High level of technological detail and sectoral coverage. • Perfect Foresight of Competitive Markets	• Lack macro-economic completeness and fails to capture realistic micro-economic interactions.
MARKAL — MACRO — hybrid: econometric — cost optimisation and partial equilibrium [83]	• Combined the detail of MARKAL with macro-economic trends. • Uses non-linear programming	• Decisions are based on solely economic benefit. • Does not take into account the behaviour of individual actors and customers
TIMES — bottom-up: econometric — cost optimisation [84]	• 4 levels of time granularity. • Decides which energy carriers and technologies can be used to meet the demand. • Data gaps are filled by interpolating or extrapolating data values linearly	• Assumes that decisions are based solely on economic benefit. • Does not take into consideration other socio-technical interactions i.e. customers. • Lack of heterogeneity in demand. • Oversimplification of technologies. • Coarse representation of time steps
ESME — bottom-up: econometric — cost optimisation [85]	• Technology-rich • Limited heterogeneity on demand-side	• Endogenous or exogenous factors which affect prices of technology or fuel are absent. • Assumes decisions are based on economic benefit
STETs — hybrid: techno-economic modelling with socio-technical framework [74]	Covers three domains: • Techno-economic detail • Actor heterogeneity • Transition pathway dynamics	• Trade-off between depth and breadth in the 3 domains • High level of complexity in modelling • No insights on business models and consumers.

Strategic Foresight, like the co-evolutionary framework, originates in evolutionary economics. It is a process of mapping possible futures and reflecting these futures against a firms dynamic capabilities, its ability to innovate technologies or business models to survive and thrive across multiple different futures. Energy futures work specifies what these futures could be. These scenarios are used to evaluate policy mixes, and plan energy systems but we do not use them in business model research. We argue that we should draw on energy scenarios in forward facing business model research. This is because a business model that is viable in one scenario may not be viable in another. How we achieve this is detailed in Section 3 below, but first we want to introduce Human Centred Design as a way to explore and 'stress test' different energy business models.

2.3. Human centred design as an organising construct

Imagine we are now doing business model research in the context of multiple possible futures. We want to explore how different business models might perform in these futures. Will a volume sale utility still be able to exist? Will a consumer led renewables model thrive? How might prosumer business models fare? Is there space for municipal ownership? How do we answer these questions over multiple scenarios with a coherent set of tools? This research team adopted Human Centred Design to meet this challenge.

Deign thinking for sustainability is best regarded as a process for placing humans and their needs at the centre of a process of problem solving as opposed to a specific product or service [91]. While Design thinking has been used to explore 'product specific' user needs in the energy transition [92] it can also be used to inform organisational strategy and business change [93]. Design thinking in an organisational context relates to a culture of experimentation and prototyping [94] It is well aligned with growing a firms dynamic capabilities, those skills and practices that enable and encourage business model innovation [95,96].

One seminal contribution is that of the IDEO.org whose 'Filed Guide to Human Centred Design' [97] has received over 150,000 downloads and is used across a broad range of developmental contexts (op cit) and is included as one of three most influential models of design thinking [93]. This framework retains three core principles, Human Centred Design should create solutions that are: (i) Desirable — to the people who own the problem at hand; (ii) Viable — in that the finances can be made to work; and (iii) Feasible in that the materials and technologies needed are available for implementation. In a systematic review of design thinking, scholars found creativity/innovation, user centeredness and problem solving as key aspects of design thinking, with the link between business model innovation and users frequently addressed (op cit). Design thinking has been used to inform corporate strategy in large organisations such as Samsung [98].

Our research team wanted to explore the co-evolution of business models in a low carbon energy transition. We adopted Strategic Foresight so we could do business model innovation work that accounted for multiple futures. We then selected Human Centred Design as an organising construct because it mapped very closely onto the co-evolutionary framework (Fig. 3).

Here the relation between business strategy and user practise in the co-evolutionary framework is imagined as the 'desirability' element of human centred design, the relation between business strategy and technology as 'feasibility' and the relation between institutions of the market and users as 'viability'. This is the broad premise the research team aimed to test. Our final conceptual challenge was to do this work under multiple possible futures, i.e. use a strategic foresight approach. We drew on the work of Schultz [99] and others [100,101] using pre-developed scenarios to inform business model innovation work and corporate strategy. Our process is summarised in Fig. 4:

The process in Fig. 4 is a generalised approach to Business Model work in Sustainability transitions, derived from strategic foresight and

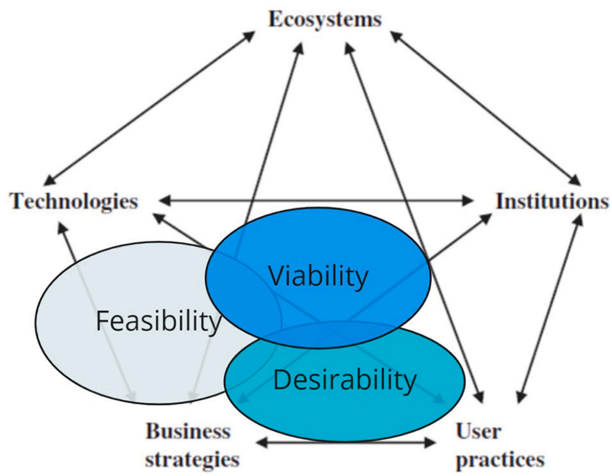

Fig. 3. Human Centred Design elements define the success of business strategies in the co-evolutionary framework.

human centred design. It begins with Horizon Scanning, a key feature of SF work which aims to set the scene and explore medium to long term system challenges [102,103]. It then uses business model rapid prototyping, collaborating with stakeholders to create a long list of business models which could respond to the Horizon scanning exercise. Rapid prototyping is a key feature of the HCD process, be it for individual products or in this cases whole business models. The business models are then reflected against the different possible futures of each energy scenario. Each business model is then tested for consumer desirability and technical feasibility. Once these elements of the process are complete the researcher is in a position to explore how each business model, or the sum of business models generated invite changes to the regime or indicate new evolutionary pressures upon it. In Section 3 we recount how we used this framework in a multi stakeholder energy research project 'Utility −2050', in Section 4 we discuss its usefulness and limitations as a process for adoption into the wider 'business models for sustainability transitions' debate.

3. Adopting the framework in the Utility 2050 Project

Utility 2050 was an energy futures project undertaken by a university and industry based consortium made up of University of Leeds, Imperial College London, University of Newcastle, Anglian Water, The Energy Research Partnership, The Energy Systems Catapult, Innology/ Charles River Associates, The Foreign Commonwealth Office, Turquoise Capital, ATKINS, Shell, Drax, Buglass Advisory, SSE, Hitachi, Poyry and Welsh Government. The project ran from 2016 to 2019 and was used as a proof of concept as to assess insights that might be elicited via a strategic foresight approach which utilized human centred design methodologies. The objective of the project was to understand how electricity utility business models might evolve in different low carbon futures

3.1. Horizon Scanning and rapid prototyping through business model collaboration

On June 15th 2016 the project team initialised the project with a Horizon Scanning exercise with 38 industry, academic and government stakeholders. Stage one of the process used a simple challenge ranking process whereby small groups ranked a set of challenges to the utility business model posed by energy transitions. There was space to create new challenges and have these ranked also. Stage 1 prioritised six threats to the incumbent volume sale utility model, these were: 1. Policy

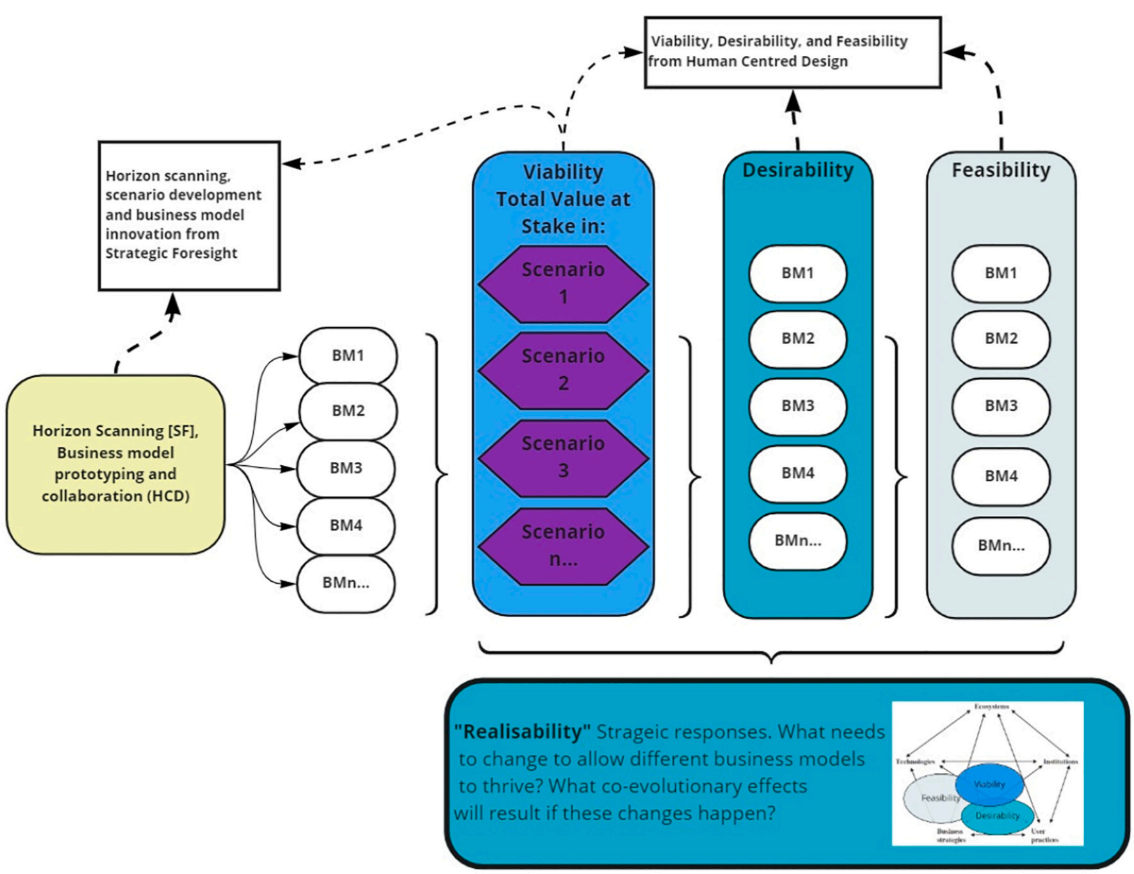

Fig. 4. A process for doing STS business model work under multiple futures.

Uncertainty, 2. Large Penetration of Intermittent Renewables, 3. Demand side management, 4. Diversifying Supply Market, 5. Cost of Capital, and 6. Increasing Micro-decentralised Optimisation.

Following this the same groups were asked to evaluate six hypothetical business models created by the advisory team of the project. These were in component diagram form [104]. This process of rapid prototyping is central to human centred design, and is also reflected in the business model innovation literature [105,106]. Fig. 5 shows the business model descriptions.

This process is covered in more depth in Hall et al. [107] which is a key output of this project. Once we had undertaken a horizon scanning exercise and undertaken rapid prototyping of business models that could meet these challenges, the next task in our process was to again draw on strategic foresight and explore these business model solutions across multiple possible futures. This meant selecting energy scenarios to work with. The project board selected eight scenarios from three different sources that covered the UK energy system These were: The realising transition Pathways research consortium three energy scenarios, namely 'Market rules, Central Co-ordination, and Thousand Flowers' [15]; Two were chosen from the most up to date National Grid Energy Scenarios, namely 'No-Progression and 'Gone Green' [108], three were taken from DECC's 2050 scenarios, 'High Nuclear Less Energy Efficiency', 'More RE less EE', and 'Higher CCS more bioenergy' [109]. These were the different futures we would use to contextualise our business model insights. The next task was to explore the market dynamics of each possible future to inform the 'viability' of different business models.

3.2. Viability assessment, how to explore financial viability across multiple scenarios, a value pool approach

To assess the financial viability of different business models we opted to undertake a market sizing study. Inspired by the work of Accenture Strategy [110], we set out to find the size of different markets under different energy scenarios. The six value pools we chose to calculate were "plant efficiency, large scale low-carbon electricity, flexibility optimisation, carbon capture and storage, energy service provision and local low carbon electricity".

Across the scenarios identified we found that different markets are hugely sensitive to different energy scenarios, therefore a business model such as 'pure low carbon generator' Could face a very large future market of over £8bn a year in scenarios such as 'DECC High Re' whereas in the 'Thousand Flowers' scenario there is far more distributed generation and community ownership and therefore a very small market for large scale low carbon power familiar to the existing utility business model. Fig. 6 shows the range of values in these value pools across all scenarios:

Conversely a utility business model facing energy service provision or electrification will have a much greater total available market in scenarios where the electrification of heat and transport is achieved. In this way we were able to evaluate which business models might be more or less viable in different energy system futures. Wegner et al. [111] is the primary source reporting these findings.

3.3. Feasibility assessment, are these business models technically possible?

To assess the technological feasibility of a business model is critical in energy transitions, as many of the proposals generated relied on some forms of flexibility, optimisation or enhanced consumer metering. During the Horizon Scanning and Business model collaboration workshop in 2016 the team included a section on key enabling technologies for the business models proposed. Taking this long list of technologies the research team undertook an expert panel survey to determine where technology gaps existed. The team asked the expert panel to evaluate the Technology Readiness Level [112] of each of the key enabling technologies.

The research team found that, according to expert opinion, technology in general was no barrier to the business models proposed, and that only wholesale market communication tools, generation optimisation, and virtual power plant operation were in need of further development to allow the proposed business models to thrive. The empirical study undertaken by the team is reported in Mazur et al [113].

3.4. Desirability assessment, are these business models attractive to consumers?

The final element in the Human Centred Design approach is the Desirability of different business models to consumers. The general approach to Human Centred Design is to start with desirability [97]. In reality the research team undertook each of these assessments in parallel due to resource constraints. For our desirability assessment we needed to know what the appetite was from energy consumers for these new types of utility business model. To investigate this we convened a representative sample of UK energy consumers with some responsibility for choosing their households energy supplier. We presented the

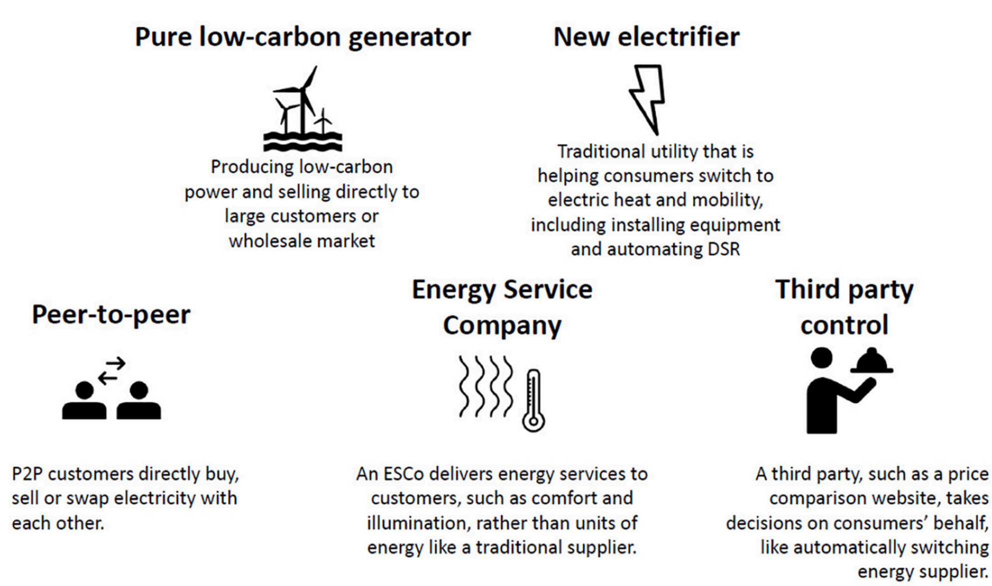

Fig. 5. Business models generated by the Horizon Scanning workshop:

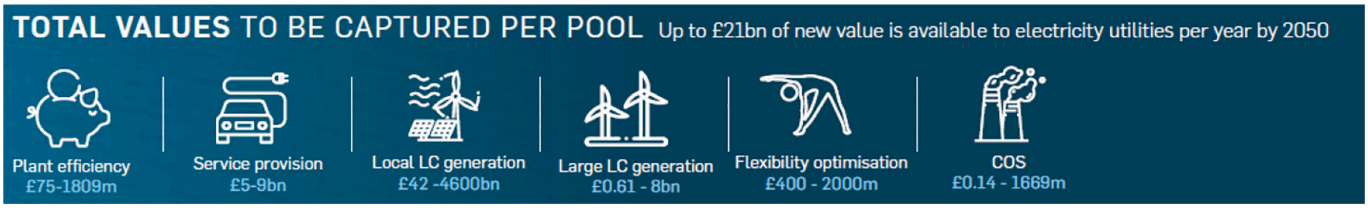

Fig. 6. The total financial values available in different energy futures: source [6].

characteristics of five of the six business models generated by the 2016 workshop[2] and a control 'same but smart' business model to our sample in a hypothetical switching experiment.

We found four broad consumer archetypes with differing appetites for innovative utility business models, with most of the sample returning a fairly low appetite for the most innovative business models. Further, we were able to show that if these business models were to thrive, there is a real risk of regressive outcomes, as homeowners and those with high social capital benefit most from flexibility and energy service provision, while those with lower social capital are likely to avoid new types of energy contracts largely driven by low trust in a broad range of institutions, including but not limited to utilities. The primary empirical work reporting these findings is found in Hall et al. [107].

In summary we were able to use strategic foresight and human centred design to inform a process whereby we explored the challenges for the energy system (horizon scanning) used rapid prototyping to develop business model concepts that could meet these challenges, and used energy scenarios to describe multiple possible futures in which these business models could exist. We then 'stress tested' these business models for viability, feasibility and desirability, allowing us to see where different scenarios financially favour different business models, how technology development is needed but not a substantial block, and which types of consumers prefer which types of business model and the social impacts that might have. Individually these were useful insights. However, we are concerned with how these insights can be synthesised and used with the energy sector and policymakers. As such we undertook a final piece of work which brought all this data together to explore what was needed for these business models to thrive and what the co-evolutionary effects on the rest of the system might be… we called this the 'realisability' section of our process — see Fig. 4.

3.5. Using these insights to drive business model innovation

Prioritising business model innovation. In a recent contribution to this journal [114] the research team reported on a series of 'decision theatres', undertaken with regulators, policymakers, investors, entrepreneurs and utilities. These workshops posed the question "What needs to change in the United Kingdom energy system, to allow low carbon business models to thrive?" The methodological innovation of these workshops was that they were 'decision theatres', closely facilitated sessions which provided the participants with the headline outputs of the project to date (i.e. the insights in Section 3) before exploring the research question via a process of solution prioritisation.

In these decision theatres the objective is to reach consent between all participants on the top priority solutions, in this case for allowing the low carbon business models to thrive. The deeper process is reported in that published article, however a short summary was that five strong themes emerged: (1) the necessity of clear and consistent carbon pricing; (2) regulatory frameworks must change to allow for experimentation; (3) consumer benefits and consumer protection are critical and cannot be abandoned; (4) a heat and transport electrification strategy is needed from UK Government; and (5) an open platform for market services should be created. Readers with an interest in the energy market specific messages are referred to this article.

What interests us here though is that we were only able to go into such an intense series of decision theatres because we had a consistent set of data across realistic scenarios, which had an assessment of financial viability, and assurance on technological feasibility and a narrative on consumer desirability. In these sessions the participants were able to reflect on how these business model changes might affect other parts of the system, i.e. user practices (consumers) market creation and regulation (institutions) and the key enabling technologies that needed support. In short, this process allowed us to explore empirically how business model innovation might co-evolve with other parts of the energy transition.

A summary of the contextual, experimental design and outputs as well as explanations for each component of the Utility 2050 project can be found in the citations in Table 2, below.

4. Discussion — realising business model innovation

In Section 2 we noted three under researched areas in the STS business model debate:

- Little quantitative attention to the actual markets for the goods and services in question and how they are evolving;
- Little engagement from the business model field in with the various scenarios and futures work that underpins energy policy design;
- Few attempts to explore the relation of consumers to business model innovation; and
- Lack of a replicable process to guide researchers on how might systematically undertake this journey.

We test our process by evaluating whether or not its use could fill these gaps.

First, we were able in the 'viability' assessment to undertake a thorough evaluation of the evolution of different value pools in different energy scenarios, we could then discuss and evaluate the business models proposed by industry stakeholders and developed with the project team against these different markets. In some ways then, ensuring a 'viability' assessment, a quantitative exploration of future value pools is undertaken does fill this gap and ensuring this part of the process is not missed in STS business model work will enhance the discipline. At the same time our approach of quantifying future value pools based on published scenarios has several weaknesses. First, it is riven with false precision. Research teams must assume fairly stable price rises or technology cost curves. This is notoriously difficult to do and since at the time of writing we are facing huge rises in wholesale energy costs due to conflict and war, the values we developed in 2017 will need substantial revision. Secondly, this is just one of four resource intensive processes adopted by the research team and will be difficult to replicate in small studies. Therefore, we would recommend, where practicable a quantitative assessment of future markets is attempted; though this may be done using secondary sources. Our argument is that some recognition and comparable assessment of market development is attempted when studying business model innovation.

[2] We did not present 'Purelow carbon generator as it has no retail market presence'.

Table 2
Utility 2050 — human centred design components within the integrated strategic foresight approach designed to stress test business models in the dynamics of broader low carbon transitions.

Human centred design component	Strategic foresight/ energy futures dimension	Methodological process in Utility 2050 and references
Viability: What possible financial value could be available from the next phase of electricity system decarbonisation and what business models could capture this value?	Revenue opportunities in different possible energy futures Financial viability of Business Models based on revenues they could access.	Eight UK Energy Sector Scenarios[a] were parameterised into 'value pools' of possible revenues which crowd generated business models might access [111]. Whilst we focused on electricity, these scenarios included transport and heat for an 80% emissions reduction target — which was the emissions target in 2016.
Feasibility: How feasible are these business models in terms of the necessary technologies and their stage of development and present policy construct?	Technological feasibility of Business Models	Elite stakeholders were surveyed to assess the technology readiness levels of the sub-components of the crowd sourced business models [113].
Desirability: What is the appetite for these different business models among consumers?	Desirability of energy service value propositions being provided by the new Business Models	A UK consumer facing, representatively segmented, stated preference survey was undertaken to assess how attractive the business model value propositions might be to electricity bill payers [107].
Realisability: What policy initiatives need to be implemented to enable new business models and deliver a low carbon future?	Realisability — what changes to the system are needed to capture value and catalyse the next wave of energy innovation	Four Decision Theatres were held with electricity sector incumbents and new entrants, regulators and policy makers and investors in Europe and the US to assess what changes they need to realise possible electricity futures as envisioned by the revenues and business models generated above [114].

[a] The eight scenarios were: (1) National Grid Energy Future Scenarios 2016 — No Progression; (2) National Grid Energy Future Scenarios 2016 — Gone Green; (3) DECC 2050 Higher Renewable Energy and more Energy Efficiency; (4) DECC 2050 Nigh Nuclear and less Energy Efficiency; (5) DECC 2050 — Higher Carbon Capture and Storage and more Bioenergy; (6) Realising Transitions Pathways 2016 — Market Rules; (7) Realising Transitions Pathways 2016 — Central Co-ordination; and (8) Realising Transitions Pathways 2016 — Thousand Flowers.

Second, we hoped to link STS business model work with the energy modelling and scenario development community using tools from strategic foresight. We would argue this has been achieved by stress testing the business models we were researching in different scenarios and futures. We argue there can be a productive two-way dialogue between STS business model work and the wider modelling community. Discrete inputs such as consumer segmentation and business model viability can be used to enhance the credibility of different narrative scenarios and further work is needed to explore how these insights can be soft or hard linked to quantitative energy systems models.

The third contribution of this process is to ensure a desirability' appraisal is incorporated into STS business model work. We used a representative panel survey and undertook consumer segmentation, however, multiple methods can be accommodated into a desirability assessment, quantitative and qualitative. What matters here is that those involved in business model innovation work for low-carbon transitions take explicit account of the users involved in business model innovation and do not assume lower prices, lower carbon electricity, or other service offers are automatically attractive to consumers.

Finally, we reflect on whether this is a replicable process for those researching business models in the broad socio-technical transitions field. We have argued that strategic foresight is theoretically compatible with co-evolutionary approaches and by extension STS approaches to low carbon transitions. This is because of its focus on multiple possible futures and the dynamic capabilities of actors in each system. Human Centred Design is a less theoretically grounded approach but is nevertheless a recognised tool in in corporate innovation work. In our empirical work and synthesis we found no theoretical incompatibility and we also found this stepwise process extremely helpful in justifying a research plan, selecting appropriate methodologies, and leading an interdisciplinary study with a coherent narrative.

There is nothing in this process that limits it to the UK energy system. The process outlined in Fig. 4 could be adopted for most socio-technical systems in most places with little amendment to study the business model dynamics of low carbon transitions.

This is not without limitations, however. This process presupposed there are existing scenarios and narratives for systems change to draw on. If not the first stage would need to be creating these different possible futures, which is a large research task in and of itself. Secondly there needs to be substantial stakeholder involvement, ideally over the lifetime of the research project, who can co-produce some of these insights, particularly at the horizon scanning phase. Finally, there remain instances where STS business model researchers would not find this framework useful, particularly when evaluating ex-post business model transitions, or when focussing on a single firm case.

We argue this process is best suited to exploring the business model element of socio-technical transitions towards uncertain but ideally more sustainable futures. This is because we want to expose how the wider socio-technical system imposes boundaries on business model innovation, but also how business model innovation pushes back and affects these boundaries, informing the challenge of system regulation, creating new technologies, new user practices and disrupting existing markets. Single cases and historical narratives would be best served by other methods.

5. Conclusion

This article set out to propose a process for doing business model research in the broad socio-technical systems field. We found that business model work in the field is thriving and rapidly developing new insights on the role of business models in enabling or constraining transitions. We found a distinct lack of replicable processes for doing business model research, however, and argued that Strategic Foresight and Human Centred Design could bring some procedural clarity to the work of business model scholars.

We then proposed such a process and summarised how we used this within the Utility 2050 project. We showed how a strategic foresight approach can link business model work to energy scenarios work, inviting researchers to consider multiple possible futures. We summarised how horizon scanning and rapid prototyping can establish a research object of hypothetical business models that are more suited to the energy transition that the incumbent regime utility model. We then used viability, feasibility and desirability assessments to see how these business models fared with users, technologies and institutions. Finally, we took these insights to an international set of experts in a decision theatre approach and demonstrated how each insight can be used to synthesise priorities for energy policy.

We recognise this process sits within a broad church of methods and analytical frameworks that serve the socio-technical transitions field. However, we also recognise that it has real potential to enhance the replicability and validity of business model work. We recognise its resource heavy nature, at least in the way we have used it. Nonetheless, we would invite researchers to perhaps select one or two of the elements for empirical work. There is no reason each element of the process needs to have primary data associated with it. More this is a stepwise process. If one already possesses robust scenarios and market data then the focus may lean towards consumer desirability and technological feasibility or vice versa. Our hope is that this process is adopted, tested, refined and critiqued in the hope of enhancing our knowledge on the role of business model innovation in sustainability transitions.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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