The role of business in constructing sustainable technologies: Can the Silicon Valley model be aligned with sustainable development?

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Abstract

Businesses are increasingly focussing their efforts on developing *sustainable* technological innovations. In doing so, they face obstacles in the systemic nature of innovation processes, the uncertain and ambiguous nature of sustainability, and in reconciling their business model and strategy with social and environmental value creation. This is particularly the case for those trying to emulate the so-called 'Silicon Valley model', which prioritises speed to deliver on its ambitious socially significant mission, relies on high-risk venture capital financing, and encourages flexibility and curiosity on the part of employees. This article uses data gathered during an action research case study to explore whether this much vaunted model could be better aligned with sustainable development. While, in this case, we find systemic and cognitive challenges to be currently precluding concerted action on sustainability, we also identify opportunities for greater alignment. Changes in the market and financial environment promise to provide new incentives for sustainability while the use of public deliberations such as citizen assemblies could help to reduce ambiguity. Complementary application of approaches like Constructive Sustainability Assessment within companies would allow business models to be more proactively and demonstrably aligned with employee values and ambitious sustainability missions.

1 Introduction

The development and application of new technological innovations is widely put forward as a key enabler of sustainable development (Cervantes & Hong, 2018; UNCTAD, 2018). In market economies, businesses play central roles in the development and deployment of these technologies (Kline & Rosenberg, 1986). Consequently, the sustainability agenda and the need for *sustainable* technological innovation implies responsibilities for these businesses that go beyond profit maximisation (cf. Friedman, 1970). Recently, there has been a rise in attention to corporate sustainability, where businesses seek to understand, report on and improve their contribution to sustainable development (Linnenluecke & Griffiths, 2013). Over 12,000 businesses have signed up to the United Nations (UN) Global Compact which aims to rally businesses in support of the Sustainable Development Goals (SDGs), bringing together environmental sustainability with social justice and responsibility (UN, 2015). In line with this, some businesses now seek actively to pursue sustainable innovation, where “the renewal or improvement of products, services, technological or organizational processes not only delivers an improved economical performance, but also an enhanced environmental and social performance, both in the short and long term” (Bos-Brouwers, 2010, p. 419).

While there may be growing consensus over the urgent need for action, and thus a moral responsibility for companies to actively integrate sustainability considerations into their technology development processes, many barriers and challenges remain (Álvarez Jaramillo et al., 2019; Engelken et al., 2016; Kiefer et al., 2018). To the extent that sustainable development requires the wholesale transformation of socio-technical systems (Schot & Kanger, 2018), such transitions require the underpinning of collective action. This presents challenges and a somewhat unclear role for individual businesses. Many of the costs and benefits involved in addressing sustainability represent externalities, which raises difficult questions for how businesses can create and capture value through sustainable business models (Geissdoerfer et al., 2018; van den Bergh, 2010). Moreover, the malleable and ambiguous nature of the sustainability concept and inevitable uncertainty concerning the sustainability implications of new technologies collectively pose challenges and dilemmas for individual businesses as to how to operationalise sustainability during technological development (Collingridge, 1980; Kates et al., 2005).

Numerous frameworks have been proposed to help overcome some of these issues such as responsible research and innovation (RRI) (van de Poel et al., 2017) and business transition management (Loorbach et al., 2010). We have previously elaborated a framework for Constructive Sustainability Assessment (CSA) which seeks to grapple with these issues

through the use of both analytical sustainability assessment and deliberative governance within an iterative, open-ended, and participatory approach (Matthews, Stamford, et al., 2019). Such frameworks suggest a slower, more precautionary, and deliberative approach to innovation (Reber, 2018; Steen, 2021). However, the perceived urgency of contemporary sustainability challenges also calls for rapid and disruptive innovation (UNCTAD, 2018).

In this context, it is instructive to examine settings where disruptive innovations to achieve ambitious goals and economic scale are pursued to explore whether and how sustainability and deliberative approaches can be embedded into business strategies and models. We focus here on California's San Francisco Bay Area, which is renowned for nurturing start-ups that excel in rapid technological innovation and scale-up, hosting three out of five of the 'GAFAM' family of big-tech companies.¹ The idea of the 'Silicon Valley model'² has been used to explain the success of the region's companies. It can be characterised by a focus on rapid growth and innovation; a dependence on venture capital financing; an ambitious, socially significant mission (such as sustainable development); and a people-centric approach that encourages flexibility and curiosity on the part of employees (Steiber & Alänge, 2016c). Yet, while this model receives much praise for exemplifying Schumpeterian ideals of creative destruction (Schumpeter, 1934), it has also been associated with heightened inequality and environmental consequences (Walker, 2018). The model's prioritisation of speed and agility appears to be in tension with more precautionary and cautious approaches such as RRI and CSA, which have been put forward as ways to overcome some of the challenges posed by sustainable development for innovators.

This paper sets out to explore these apparent tensions and contradictions, asking whether and how the pursuit of rapid technological innovation and scale-up within a Silicon Valley model could be more aligned with sustainable development. We take as an empirical case a San Francisco Bay Area-based synthetic biology company³ employing the Silicon Valley model. We build on evidence gathered during an action research case study where the CSA framework⁴ was applied collaboratively with the case company. The main aim of this

¹ GAFAM is an acronym of Google (Alphabet), Apple, Facebook, Amazon, and Microsoft. Apple, Facebook, and Google are all based in the San Francisco Bay Area while Amazon and Microsoft are based in Seattle, WA.

² Note that the Silicon Valley model is not synonymous with the geographical location which inspired it, as is further clarified in Section 2.3.

³ Alongside Boston, MA, the San Francisco Bay Area represents an epicentre for synthetic biology development, both in the US and globally (Cumbers, 2019).

⁴ The CSA framework brings together analytical sustainability assessment with deliberative social science governance frameworks to derive a three-step methodological approach through which innovators can integrate sustainability considerations into the design, development, and scale-up of emerging technologies (Matthews, Stamford, et al., 2019).

collaboration was to test the applicability of the CSA framework in a business context and the primary results of this have been reported in a previous publication (see Matthews, Cizauskas, et al., 2019). This previous article demonstrated how the application of the framework was successful in highlighting sustainability trade-offs at an early stage of development and thereby identifying avenues through which the business could pursue more substantive action towards sustainable development. However, cognitive, systemic, and business model challenges seemed set to preclude its broad uptake. Unpacking these challenges here enables us to derive insights for the literature as well as policy-makers and business actors.

We argue that while there are tensions between the rapid growth-focussed Silicon Valley model and sustainable innovation, this much vaunted business approach could be put at the service of sustainable development through changes both internally and externally to individual companies. Importantly, this article does not take up a position as to whether the Silicon Valley model should or should not be emulated. Indeed, we have sympathy with many of the very valid critiques of the model (e.g. Audretsch, 2021; Pahnke & Welter, 2019), as will be further discussed. Rather, given the widespread interest in emulating the model, we believe that it is worth considering whether it can be aligned with the demands of sustainable development.

The next section proceeds with a literature review outlining the key concepts, ideas, and theories that underpin the paper. Section 3 then describes the research approach and methodology before the findings are outlined in Section 4. Section 5 discusses the implications of the findings before some concluding remarks are offered in Section 6.

2 Literature review

2.1 The multiple challenges of sustainable innovation

Businesses face many challenges when attempting to innovate in a manner that is in line with sustainability development. This literature review starts by identifying and describing three key challenges faced. Next, frameworks and approaches which have been put forward to address these challenges are introduced. Finally, the Silicon Valley Model is conceptualised with consideration given to where there might be tensions with the previously described frameworks.

The first challenge relates to the broad and ambiguous nature of sustainability as a concept, which, while a highly influential concept, lacks consensus as to its specific meaning, with

multiple, often contrasting definitions proposed.⁵ Bos et al. (2014) conceptualise such 'big words' as ideographs - loosely defined but generally agreeable normative concepts that can have powerful structuring effects. However, these ambiguous characteristics can pose cognitive dilemmas for business managers (see Hahn et al., 2014). In response, innovators can 'articulate alignment' to these broad societal missions by establishing and reaffirming links to the overarching idea and thus legitimising research and innovation avenues (Fujimura, 1987). A consequence of this articulation process can be that once a link between a particular technology and the ideograph in question has been thoroughly established it then becomes black-boxed⁶ and is no longer perceived as needing further elaboration (Bos et al., 2014), closing down discussion.⁷

As well as ambiguity over the concept, there is also a lack of clarity concerning how to operationalise sustainability. Its broad nature, spanning social and natural domains (Elkington, 1997), makes the concept difficult to develop metrics for, as some dimensions lend themselves to quantification while others do not. While assessment approaches such as life-cycle assessment (LCA) have been put forward as a means to grapple with this complexity (Sala et al., 2015), there is a limit in the degree to which expert, science-based assessment approaches that tend to be relied upon can provide answers to subjective and values-based questions concerning the impact and desirability of certain technological trajectories (Matthews, Stamford, et al., 2019; Nathan & Coles, 2020). Such questions require shared values to be established before the science can inform the route forward (Sarewitz, 2004). Taken together, these features make it difficult for businesses to operationalise lofty sustainability goals down at a level which are appropriate for organisational decision-making. This may help to explain why a lack of resources and expertise, as well as the high cost of implementing assessments, are some of the most frequently cited barriers to SMEs implementing sustainability-focussed initiatives (Álvarez Jaramillo et al., 2019).

The second challenge relates to barriers arising from the systemic character of innovation processes and the systemic contexts within which businesses operate. These include research and development and scaling challenges; technical financial, and market risk; and

⁵ While initiatives such as the SDGs aim to break down the concept and give more specificity, they remain rather all-encompassing which allows them to support many different priorities and competing conceptualisations (Kates et al., 2005; UN, 2015).

⁶ This process is analogous to the black-boxing described by Latour (1987) with respect to the scientific process.

⁷ See Stirling et al. (2008) for a comprehensive discussion of how discussions around science and technology can become closed down.

154 uncertainty over legal and regulatory incentives (Álvarez Jaramillo et al., 2019; De la Tour et
155 al., 2019; Delmas & Burbano, 2012; Gurzawska et al., 2017).

156 The systems of innovation approach emphasises that businesses do not operate and
157 innovate in isolation but rather are embedded within complex multi-actor systems (see
158 Lundvall, 1992). The activities of individual businesses are therefore influenced and
159 constrained by their interaction with and interdependence on other businesses (e.g.
160 suppliers, customers, and competitors) as well as investors (public and private), governing
161 authorities and regulators, consumers, and non-governmental organisations (Edquist, 2009).
162 Another key concept is the importance of institutions - the “sets of common habits, routines,
163 established practices, rules, or laws that regulate the relations and interactions between
164 individuals and groups” (Edquist & Johnson, 1997, p. 46). This perspective helps to avoid
165 the pitfalls of idealised, linear models of how innovation occurs and provides a more realistic
166 and holistic account of innovation characterised by non-linearity, interdependence, and
167 evolutionary behaviours (Edquist, 2009).

168 The systems approach has been taken forward by sustainability transitions researchers
169 seeking to understand the determinants of stability and change which could then be
170 leveraged to inform policy intervention (Jacobsson & Bergek, 2011; Kanger et al., 2020).
171 Within this literature, the multi-level perceptive (MLP) provides a widely-used framework for
172 understanding the dynamic processes that govern transitions (Geels, 2002). Rather than
173 focus on institutions, the idea of socio-technical *regimes* is used to refer to “the semi-
174 coherent set of rules that orient and coordinate the activities of the social groups that
175 reproduce the various elements of socio-technical systems” (Geels, 2011, p. 27). Meanwhile,
176 radical innovations are thought to first emerge through actors such as entrepreneurs
177 occupying *niches* that can provide semi-protected spaces for early development and
178 experimentation (Geels, 2002). However, to bring about transitions, niche innovations have
179 to eventually diffuse and become established. During this process, existing regimes exert
180 selective pressures and are likely to favour those that are more compatible with the logic of
181 incumbent regimes (Schot & Kanger, 2018). Consequently, to enable the emergence of
182 sustainable socio-technical regimes, strategic niche management (SNM) focusses on how to
183 intentionally support experimentation in niches, not simply with new technologies but also
184 with new institutional frameworks, user practices, and networks of actors (Schot & Geels,
185 2008). However, while these systemic understandings might accurately describe the
186 processes and challenges and provide insightful policy implications (e.g. Kanger, Sovacool,
187 & Noorköiv, 2020), they provide limited guidance concerning what individual niche actors
188 such as innovating businesses should do.

The third and final challenge is that of aligning business models with sustainability. The business model is of central importance as it “defines how the enterprise creates and delivers value to customers, and then converts payments received to profit” (Teece, 2010, p. 173). This conceptualisation aligns with the traditional view of businesses as profit-maximisation engines⁸ but is increasingly in tension with the contemporary repositioning of businesses with broader responsibilities to society and the environment. Correspondingly, there has been considerable research on the subject of sustainable business models which create both monetary and non-monetary value for a broader range of stakeholders, often through the exploration of where the sustainability agenda can be used to generate competitive advantage (Carrillo Hermosilla & Del Rio Gonzalez, 2009; Geissdoerfer et al., 2018). However, while a weakly positive relationship between financial and environmental performance⁹ has been reported at the level of firms (Endrikat et al., 2014), the relationship is not well established and remains contested (Boons & Wagner, 2009; Trumpp & Guenther, 2017). This is perhaps not surprising given that many of the costs and benefits involved in sustainability are externalities for individual businesses (van den Bergh, 2010). Consequently, businesses introducing disruptive technologies with new value propositions such as improved sustainability often face the dual challenge of a lack of broad demand for their core value proposition and of their technology being inferior in other respects (such as price) compared to incumbents (Bohnsack & Pinkse, 2017).

Others have more fundamental concerns regarding making the “business case” for sustainability. Dyllick & Hockerts (2020) argue that embedding CSR and corporate sustainability within a business case framing can lead to crowding out of the more fundamental moral and legal rationales. Meanwhile, Henderson (2015) points out that the business case for sustainability is more of a long-term “strategic bet” that in most future scenarios will lead to net benefits for the firm. Thus, while the overall benefits for society of sustainable development and particularly of tackling climate change have been evident for a long time (e.g. Stern, 2007), this does not mean that there will necessarily be an obvious case for individual businesses to take action unilaterally, particularly given issues of externalities and discounting.

⁸ Friedman famously stated that “the social responsibility of business is to increase its profits” (Friedman, 1970).

⁹ Much of the current evidence focusses specifically on the alignment between environmental/ecological performance and economic return, while often excluding the third pillar of social sustainability.

2.2 Strategies to support sustainable innovation

Numerous frameworks and strategies have been suggested to tackle and overcome the challenges outlined above. In the face of uncertainty and ambiguity, RRI frameworks suggest potential avenues to proceed prudently and embed responsible practices at the early stages of technological development in order to proactively create social and environmental benefits (van de Poel et al., 2017).¹⁰ Yet, applying RRI in business settings remains a relatively new development. Recent efforts have sought to build on experience in research settings to develop and apply business-focussed strategies (see van de Poel et al., 2020). But others have argued that without a fundamental reframing of how markets operate, there will need to be a pragmatic re-evaluation of some core tenets of RRI to enable widespread operationalisation in industry, particularly concerning the principles of stakeholder engagement and democratic governance (Brand & Blok, 2019; Lubberink et al., 2017; Noorman et al., 2017). We have previously outlined a framework for CSA, which provides a methodology to support organisations such as businesses to actively take account of sustainability considerations in their innovation processes (see Matthews, Stamford, et al., 2019). This approach draws on RRI as well as other frameworks such as constructive technology assessment (Schot & Rip, 1996), placing analytical assessment approaches such as LCA within a broader iterative and deliberative process which helps to alleviate some, though not all, of the challenges brought by ambiguity and uncertainty in the context of sustainable development (Matthews, Stamford, et al., 2019).

With respect to systemic challenges, it has been proposed that actors such as businesses can reshape the institutional arrangements that maintain incumbent regimes, but doing so involves assembling multiple forms of power - normative, convening, legal, informational, and financial (see Diaz Anadon et al., 2015). While assembling this power may be challenging, actors can take responsibility by engaging in “institutional entrepreneurship” - developing divergent visions and mobilising other actors to support, achieve, and sustain them (Battilana et al., 2009). Frameworks such as business transition management have also sought to articulate how businesses can go about this.¹¹ Reflecting the fact that the control of innovation processes is inherently collective and shared amongst a range of

¹⁰ RRI activities can be defined along four dimensions - exploring and anticipating potential future directions and implications of innovation; pursuing inclusive engagement with a broad range of stakeholders; promoting reflection on individual and organisational values and motivations; and responding accordingly to embed insights from these activities in innovation trajectories (Stilgoe et al., 2013).

¹¹ Business transition management describes how cycles of strategic envisioning, tactical networking, operational innovation, and reflexive monitoring and evaluation can enable them to become frontrunner businesses in promoting sustainability transitions while also gaining competitive advantage (Loorbach et al., 2010; Loorbach & Wijsman, 2013).

actors, a common theme amongst such efforts is the critical role for collaborations and alliances (Kishna et al., 2017; Loorbach et al., 2010; Schaltegger et al., 2018).¹²

To address business model challenges, numerous strategies have been proposed. For example, the lack of a sufficient value proposition from sustainable technologies can be addressed by mitigating inferior characteristics, enhancing superior characteristics, and/or coupling to other products or services (Bohnsack & Pinkse, 2017). Likewise, van Lente & van Til (2008) in the case of nanocoatings describe how improved sustainability of products can be combined with other features such as lower cost or ease of use which serve as “vehicles of sustainability”. However, this strategy is only effective if these vehicles are truly commensurate with sustainable outcomes.

Others have argued for more fundamental changes. Elkington (1997) put forward a triple bottom line framework to account for financial, environmental, and social impacts and outcomes. However, Dyck and Silvestre (2018) refute this approach to SI and propose ‘SI 2.0’ which involves focussing on the active enhancement of socio-ecological wellbeing with financial viability relegated to a secondary, *subservient* necessity. This argument appears to be gaining some traction with the growth of social innovation initiatives such as the B-corps (Stubbs, 2017; van der Have & Rubalcaba, 2016). Similarly, Loorbach and Wijsman (2013) suggest that for commercialisation processes to support more sustainable innovation and contribute towards a transition, sustainability first has to be embedded at the organisational core, entailing the restructuring and reconceptualization of what a company *is* and *does*. These changes require business model innovation to embed a broader and long-term conceptualisation of value in business operations (Geissdoerfer et al., 2018). This can be brought about either through the creation of new companies or through existing companies transforming, diversifying, or acquiring new models (ibid.).

2.3 The Silicon Valley model: Can it address the challenges of sustainable innovation?

The responses described above to the previously described challenges of sustainable innovation are heavily implicated in the internal behaviours, operations, and cultures of companies. Similarly, the organisational behaviours and structures of firms are also important determinants of different kinds of technological innovation (Teece, 1996). The Silicon Valley model, named based on the typical characteristics of many highly successful start-ups from the San Francisco Bay Area, represents one such archetype of organisational

¹² This also aligns with RRI frameworks, early proponents of which emphasised the collective and shared nature of responsibility for the future impacts of innovations (EC, 2013; Stilgoe et al., 2013; von Schomberg, 2013).

behaviour and structure which is associated with driving radical, disruptive technological innovation of the sort which could play an important role in sustainable development (ibid.). Given the level of interest shown in emulating this model around the world, it is pertinent to explore whether it can be applied in a way that is commensurate with the demands of sustainable innovation.

Before discussing this model further, it is important to clarify two assumptions concerning the conceptualisation presented here. Firstly, the “model”, while closely linked to the business practices often seen in the geographical location of Silicon Valley, is not synonymous with it. Thus, companies following the model do not necessarily have to be based in Silicon Valley while companies based in that region do not necessarily all follow the model. Secondly, this article does not profess a normative position as to the overall value of the Silicon Valley model or on whether it should be emulated. Indeed, many different approaches to innovation are found around the world and these are often interdependent on specific local contexts with their particular institutions, priorities, and values (Audretsch, 2021; Pahnke & Welter, 2019). Rather, given the widespread interest in emulating the model (Audretsch, 2021; Casper, 2007a), we believe that it is worth considering whether and how it can be better aligned with sustainable development.

The Silicon Valley model is conceptualised here according to four key features: *speed*, the use of high-risk *venture capital financing*, a *socially significant mission*, and a *people-centric approach*. These features are described below, drawing out potential tensions with sustainable development which are then further explored and elaborated upon in this article.

The first feature, *speed*, is possibly the most ubiquitous and the ‘Lean Startup’ methodology is widely employed to try and operationalise this (Ries, 2011). It involves shortening product development cycles through the rapid deployment of Minimum Viable Products (MVPs) which are intended to ‘fail fast’, allowing the company to learn and pivot towards new and better opportunities (ibid.). This approach is widely sought-after and emulated, but this attention to speed can also be criticised as symptomatic of the “tyranny of urgency” (Joly et al., 2010, p. 26) in modern societies which risks undermining more cautious and responsible innovation practices (Steen, 2021). Linked to this, companies following this model often prioritise innovation and fast growth over cost and profitability, particularly at the early stages, which means access to plentiful high-risk *venture capital financing* is a key enabler (Casper, 2007b; Teece, 1996). These kinds of investors are willing to tolerate high levels of financial risk in return for the promise of significant returns on investment if the company is successful in scaling up and diffusing its technology. A consequence of this is a pressure to

identify and appropriate private benefit in order to generate this return on investment which risks crowding out attention to broader value creation (Hegeman & Sørheim, 2021).

Third, seeking to address a bold, *socially significant mission* is thought to be a key feature driving the rapid innovation they pursue and helping to underpin a strong company culture (Steiber & Alänge, 2016c). Increasingly, Silicon Valley entrepreneurs and investors promise and target new technologies to address sustainability concerns (Sanderson, 2021).

Importantly, having a mission that addresses a socially significant issue does not necessarily mean they will achieve it, as is demonstrated by recent controversies involving firms seemingly employing the Silicon Valley model¹³ while the approach has also been implicated in the uneven distribution of economic growth and prosperity in the USA (Audretsch, 2021).

Finally, a *people-centric approach* is generally employed which seeks to avoid traditional hierarchical and rigid approaches to coordinating company operations through rules and standardisation, instead emphasising flexibility, freedom, and experimentation on the part of employees accompanied by a relatively flat organisational structure (Steiber & Alänge, 2016c). Steiber & Alänge (ibid.) label companies that follow this model as “startups in large suits” (p. 146) because they seek to maintain the agility of a start-up even when they become very large. Recently, tensions have emerged in this apparent prioritisation of human capital with employees in several large Silicon Valley technology firms protesting at perceived unethical behaviour and demanding more say in what technology the companies develop and how it is deployed (Laviertes, 2018; Tiku, 2018).

More fundamental tensions may well also be at play here. The often much sought-after, though not uncontroversial, financial and business strategies described above are more typically found in the context of varieties of capitalism which align more with liberal market economies (LMEs), associated with low regulation, such as the US (Casper, 2007b; Soskice & Hall, 2001). However, frameworks such as RRI and business transition management which aim to tackle the challenges of sustainable innovation are typically aligned with and were often developed in the context of varieties of capitalism which align more with the coordinated market economy (CME) classification (Soskice & Hall, 2001). Such economies, typical of Western Europe, tend to have institutional frameworks that favour more consultative and collaborative business practices (ibid.). Accordingly, attempts to emulate Silicon Valley-style conditions in CMEs have often run into difficulties, in part due to tensions with the wider institutional frameworks (see Casper, 2007a). On the other hand, businesses that prioritise flexibility, dynamism, and fast growth may be impatient to devote time and resource to run sustainability assessments, engage in broad coalitions, or conduct

¹³ For example, see: <https://hbr.org/2019/01/the-era-of-move-fast-and-break-things-is-over>

deliberation with wider stakeholders, as is called for by many of the frameworks described in Section 2.2 (Matthews, Stamford, et al., 2019; Steen, 2021). This implies that efforts towards promoting more sustainable innovation through more cautious and precautionary models might be in tension with business approaches often thought to support rapid and radical technological innovation.

This potential trade-off would have serious implications for those that position technological innovation as a critical enabler of sustainable development (e.g. UNCTAD, 2018). However, for others, this would be consistent with a view that present preoccupations with technological innovation and novelty are fundamentally incompatible with sustainability needs and that we instead need a focus on bringing about “degrowth” or “responsible stagnation” (Nierling et al., 2018; Saille & Medvecky, 2016). These somewhat fundamental contradictions between different pathways reflect the often underexplored politics of sustainable development (Scoones, 2016).

In summary, multiple factors influence and obstruct the capacity of businesses to truly construct sustainable technologies. These have been delineated here in three broad challenges: i) the ambiguity and uncertainty brought by the sustainability agenda, ii) the systemic nature of innovation processes, and iii) the tensions brought by trying to reconcile sustainability with existing business models. While, as this literature review has outlined, these challenges and obstacles are relatively well characterised and understood, there is a need for greater practical knowledge and strategies for how they might be overcome. We have identified a potential tension between existing frameworks for supporting more sustainable and responsible innovation, which tend to emphasise more precautionary approaches, and the Silicon Valley model. Given the level of interest seen in transferring this model to other contexts (Casper, 2007a; Steiber & Alänge, 2016a), it is particularly pertinent to unpack these tensions and explore whether and how such business practices could be mobilised to construct sustainable technologies. Therefore, this study asks the action-oriented research question of how the pursuit of rapid technological innovation and scale-up within the Silicon Valley model could be more aligned with sustainable development.

3 Research approach

To address the research question, this paper analysed data derived from an action research case study involving a single business. While the case study approach is widely used in social science research for descriptive analysis, theory testing, and theory building (Eisenhardt, 1989; George & Bennett, 2004; Stake, 1995; Yin, 2018), single cases have sometimes been criticised for their lack of generalisability and face the accusation of anecdotalism. However, such research has a robust defence as a means of providing the

rich descriptions and insights which are necessary for theory development (Flyvbjerg, 2006; Ragin, 1992). Accordingly, rather than seeking statistical generalisation, we pursue what can be described as analytic generalisation, seeking to relate the findings back to the theory presented in the literature review (Yin, 2018). Meanwhile, taking an action research approach allows the translation of theory into practice, working in collaboration with practitioners and stakeholders (Coghlan, 2017). This yields highly contextualised data which allows the development of rich understandings and practical knowledge that cannot be gained by other “at a distance” research methods.

The case study was carried out in collaboration with a globally leading synthetic biology¹⁴ company. Based in California, USA, the company was (and continues to be) actively engaged in developing and commercialising technological innovations in the field of biotechnology. It had received substantial venture capital investment and was growing rapidly throughout the research period from a size of several hundred employees towards a size nearing one thousand by the end of the collaboration. The company broadly emulated the Silicon Valley model of doing business described in the literature review with an emphasis on speed, flexibility, freedom, and experimentation; coordination through an ambitious socially significant mission; and a dependence on venture capital financing (Steiber & Alänge, 2016c). Its primary business model was originally focussed on engineering existing industrial biotechnology organisms to optimise efficiency but subsequently pivoted towards developing novel bio-based products. In both cases its business model was business-to-business, providing its technology platform as a service to other businesses or working through partnerships.

The case study took place between July 2018 and May 2019 during which time a potential product - bio-based¹⁵ nylon - was subjected to a sustainability assessment using the CSA framework (Matthews, Stamford, et al., 2019). This represented the intervention of the action research. CSA provided a framework to operationalise responsible innovation practices, enabling the sustainability implications of emerging technologies to be explored and anticipated, provoking reflection by innovation actors and allowing them to identify avenues for action. This case thereby allowed the applicability of such frameworks to be tested while

¹⁴ Bringing together advances in molecular biology, data science, and automation, the field of synthetic biology promises to enable a more rational, engineering-inspired and application focussed approach to innovation through biology (RAE, 2009). The field is also accompanied by many promises of improving sustainability, such as by providing sustainable alternatives to the use of petroleum, improving the efficiency and reducing the footprint of agriculture, or enabling bioremediation (Chui et al., 2020).

¹⁵ “Bio-based” is a commonly used phrase to describe a product that is derived from biomass typically after conversion or processing.

identifying both barriers for change and opportunities for further development. The precise process, results, and outcomes of the CSA process have been described previously (Matthews, Cizauskas, et al., 2019). The intervention also provoked exploration and reflection on the part of company employees concerning how they could (or could not) take responsibility for the sustainability of their innovations. It is on these reflections and discussions that this paper focusses on.

Company employees were engaged extensively throughout the course of the research through workshops, interviews, and surveys which generated a large amount of primarily qualitative data (Table 1).¹⁶ Protocols for the workshops and interviews as well as survey outlines are provided in Appendices A and B. This data was supplemented with documentary evidence which was collected primarily in April and May 2019 and included news reports, publicly available interviews with senior leadership, and information published by the company such as white papers and their website. Together, this data formed a rich picture of how the company engaged with sustainability in its practices.

Quantitative data collected through the two surveys was processed and summarised using Excel and the R statistical programming language (R Core Team, 2021). Quantitative summaries of the survey results are outlined in Tables S2-3. Qualitative data took the form of documentation, notes, and reflections of the first author¹⁷ from interviews and workshops as well as free-form responses provided in the two surveys. This data was collated in Nvivo 12 (QSR International, 2018) and analysed thematically according to best practices in social science research (Mason, 2017; Nowell et al., 2017).

Data analysis for this study sought to understand the sustainability commitment of the company and its employees and how this translated into the roles and responsibilities they took on. This involved exploring the opportunities and barriers perceived by the study participants in terms of operationalising sustainable practices in their business model and strategy. At first, broad descriptive codes were used to organise the data. These initial codes, namely “barriers”, “roles and responsibilities” and “sustainability commitment”, allowed the data to be organised and enabled researcher familiarity with the data to be established. During this process, mind-mapping was used to develop more specific thematic codes which then guided subsequent rounds of coding. Several iterations between the literature, data analysis, and summarising were then undertaken which led to the thematic

¹⁶ The data collected from these workshops and surveys was also used as part of the results presented in a previous publication (Matthews, Cizauskas, et al., 2019).

¹⁷ All data collection was undertaken by the thesis author.

442 organisation presented subsequently in the findings. A summary of themes and their
 443 accompanying data sources is provided in Table S3.

Date	Activity	Participant/role	Participants	Duration	Data collected
Aug-18	Survey	Company employees	153	NA	Survey Results
Aug-18	Workshop	Development team	4	1 hour	Notes
Aug-18	Workshop	Legal team	4	1 hour	Notes
Aug-18	Workshop	Business Development team	8	1 hour	Notes
Aug-18	Workshop	Manufacturing team	4	1 hour	Notes
Mar-19	Interview	Head of Modelling	1	30 minutes	Notes
Mar-19	Interview	Projects team lead	1	30 minutes	Notes
Mar-19	Interview	Member of the senior leadership team	1	30 minutes	Notes
Mar-19	Interview	Materials development	1	30 minutes	Notes
Mar-19	Interview	Manager of projects	1	30 minutes	Notes
Mar-19	Interview	Business Development	1	30 minutes	Notes
Mar-19	Interview	Materials and Chemical Development	1	30 minutes	Notes
Mar-19	Survey	Company employees	54	NA	Survey Results
Mar-19	Workshop	Development team	5	1 hour	Notes
Mar-19	Workshop	Legal team	6	1 hour	Notes
Mar-19	Workshop	Business Development team	5	1 hour	Notes
Mar-19	Workshop	Modelling team	6	1 hour	Notes
Mar-19	Workshop	Products team	5	1 hour	Notes
Mar-19	Workshop	Manufacturing team	5	1 hour	Notes

Table 1: A summary of data collection activities to inform this study (excluding documentary evidence).

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4 Findings

This section outlines the primary findings of this study and is structured around three key streams of analysis that emerged from the data. These are each described in turn here, starting with the vision, strategy, and business model employed by the company, followed by an account of the cognitive roadblocks faced in operationalising sustainability. Finally, the systemic context of the company, from the perspective of its employees, is explored. These findings form the basis of the subsequent discussion in Section 5.

4.1 The vision, strategy, and business model

In line with the Silicon Valley model (Steiber & Alänge, 2016c), the case company put forward an ambitious *socially significant vision* of how their business could contribute to sustainability challenges. This was evident in both internal and external communications and from both the company leadership and more widely in the views of company employees.

According to the company's leadership and mission statement, they wanted to go beyond simply avoiding harm and wanted their technology platform to be used to actively create broader societal and environmental value. The capacity of new biological processes to replace those which at present derive from petrochemicals was seen as a major benefit of new synthetic biology developments and thought to yield substantial benefits, particularly in terms of the renewable use of resources.

This ambitious vision was shared by many of the company's employees. For example, one employee summed up their personal viewpoint of what biotechnology should be about:

"The biotechnology sector should be the sector that spearheads our ability to heal the earth." (Survey response, development scientist)

Such idealistic visions concerning what the biotechnology sector should deliver were not universal. Others commented on their more pragmatic drivers behind their work – such as to do interesting science and create a profitable company. Yet, a survey of employees asking their view on the relative importance of different outcomes from shifting to bio-based chemicals and materials production returned combating climate change and preserving global resources, ecosystems, and biodiversity as the most important (Figure 1). Employees also reiterated how the company's attention to sustainability was an important motivator for their work and careers, and therefore wanted to see it actively evaluated and considered in company decision-making, as expressed in this survey response:

"I would really like to see [The company] have a meaningful impact on sustainability, and I believe many of our employees buy into this notion and

live that ethic. Once I see us making major strategic decisions aligned with that, I'll be fully bought in.” (Survey response, desk-based scientist)

However, when a slightly different question was asked – how important sustainability was for decision-making at the company (Table S2, Question 6, n=52) – the most common response was “an important consideration among others” (67%, n=35) followed by “background relevance” (27%, n=14). While sustainability might have been perceived by some surveyed employees as an underlying mission of the company, it was also subsidiary to profitability when it came to their commercial strategy and business model:

“I think sustainability is an important part of the story that we tell about ourselves, but it's also secondary to business and strategic concerns in [the company's] decision-making.” (Survey response, desk-based scientist)

Figure 1: The relative prioritisation of different outcomes for bio-based production to deliver according to company employees. The graph summarises the responses given by company employees when asked “In your opinion, to what extent is it important that the bio-based production of chemicals or materials results in the following?” (Source: Survey of company employees, March 2019, see Table S2, Question 4, n=53).

The underlying value proposition and business model of the company were more overtly evident in more client-focussed statements and publications. Here, the ability of the technology platform to improve the efficiency of existing compounds was a key value proposition and links to the original business model focussed on organism engineering services. Another, mentioned particularly frequently throughout the engagement with the case company and the third most important factor in Figure 1, was novelty – the idea that by harnessing the diversity present in nature, materials and compounds with novel characteristics and capabilities can be made available.

This need to develop novel products was underpinned by the fact that, particularly being reliant on *venture capital financing*, there was an urgent need to demonstrate a workable business model that could generate returns for investors. Yet, there was a clear perception,

as is elaborated further in Section 4.3, that sustainability does not pay and that bio-based technologies cannot compete on a like-for-like basis with incumbent petrochemical-based production processes. Thus, just appealing to the *ideograph* of sustainability was not sufficient to legitimise and make the business case for their technology. By appealing to the idea of novelty, which can be seen as another competing ideograph, it established a value proposition that appealed to its customers and thus underpinned a viable business model.

In this case, we saw an attempt to use efficiency and particularly novelty in a way comparable to what van Lente & van Til (2008) have described as “vehicles for sustainability”. This allowed the company and its employees to maintain the underpinning mission of sustainable development, which was especially important for employee motivation as well as for some clients and investors, while also achieving a viable business model.

In addition to this, there was also some acknowledgement in discussions with company employees concerning the potential trade-offs between the profitability of the business model and the underlying vision of sustainability. Several employees tried to rationalise how to manage this trade-off, for example:

“Delivers a profit in my opinion is the key behind bio-based production methods catching on and becoming more widespread. Few companies would consider it if it was at great cost. The key is to balance the profitability of these methods with the benefits it provides so that they can simultaneously occur, without the focus shifting towards only profitability.” (Survey response, desk-based scientist)

Others explained how, in the short term, they needed to focus on profitability to develop their technology platform and establish a financially viable company before turning their attention to other priorities. Thus, a focus on novel products would allow them to grow rapidly (at speed) from their niche and potentially displace incumbent industries, at which point they would be in a position to more directly address matters of sustainability. The challenge is how to avoid “shifting towards only profitability”.

The above-described strategy reflected not just a pragmatic compromise made necessary by a lack of explicit demand for sustainable products, but also a particular viewpoint concerning the role that technological innovation should and will play in enabling a more sustainable society – a commitment to a technology-led transition (Scoones, 2016). This assumption is not without logical support as such innovations could create new markets and disrupt and displace incumbents – both critical mechanisms for enabling socio-technical transitions (Geels, 2004; Mazzucato, 2018). However, technology-led transitions are just one of many

transition pathways.¹⁸ The technology-led pathway has also received much criticism, as highlighted in the literature review, from those that see a continued focus on technological innovation as likely to drive further unsustainable growth through rebound effects and continued mass consumption (e.g. Nierling et al., 2018). Furthermore, it is worth noting the pursuit of novelty in this case rather than the direct replacement of existing production processes. Does this run the risk of simply augmenting rather than displacing incumbents, driving increased consumption and thereby increased environmental impact?¹⁹

These questions and issues will be further explored and unpacked in Section 5. Meanwhile, the following subsections will explore what inhibited sustainability in itself being a critical value proposition, focussing on cognitive challenges and the systemic context of the company.

4.2 Cognitive roadblocks

As previously discussed, sustainability is an ambiguous and high-level concept with broad and diverse interpretations. Its generally agreeable nature also gives it the power to legitimise innovation trajectories such that it can be beneficial for innovators to establish links between their technologies and sustainability (Bos et al., 2014). In this case, it was possible to see this articulation process in action. The key link involved replacing non-renewable petrochemical-derived products with renewable biomass-derived alternatives. Sometimes, this link was specified further in terms of reduced global warming, and the ability to use milder processes with less toxic waste. Meanwhile, employees also commented on aspects that their technology could not address. In particular, the goals of promoting equality, peace, and justice (encapsulated in SDGs 4, 5, 10, and 16) were typically seen as too big and high-level for the company itself to influence through its technological innovation activities (Table B.13).²⁰

In the literature review, we also described how, during this articulation process, the link between a technology and sustainability can become black-boxed, closing down critical consideration (Bos et al., 2014; Stirling, 2008). Indeed, during engagements with employees at the case company, it was sometimes assumed that bio-based production processes are intrinsically more sustainable than their petroleum-based incumbents. However, it is also

¹⁸ Scoones (2016) describes four pathways for transformation - “technology-led, market-led, state-led, and citizen-led” (p. 295) - which can be employed in varying combinations.

¹⁹ Note that while bio-based production processes may have a reduced impact compared to incumbents (although not always), the total uncoupling of production from ecological and social burdens is unlikely (Escobar & Laibach, 2021).

²⁰ This result was previously reported in a separate publication (Matthews, Cizauskas, et al., 2019).

well-established that the implications and impacts of new technologies are determined through their interactions with and embeddedness within society rather than purely technical characteristics (Collingridge, 1980). Therefore, technologies cannot be considered inherently sustainable or unsustainable, particularly at the early stage of development when many of these determining interactions have not occurred. Furthermore, specifically for bio-based and synthetic biology-enabled innovations, the potential for trade-offs and undesired impacts has been widely described (Escobar & Laibach, 2021; French, 2019; Matthews, Cizauskas, et al., 2019; Ögmundarson et al., 2020). Critical assessment is essential to validate sustainability claims and minimise unforeseen consequences and burden shifting.

On the other hand, the CSA process which was undertaken collaboratively with the case company through this article demonstrated an appetite within the company to engage with this ambiguous concept and critically evaluate the sustainability of their products . For example, during the formulation stage of CSA, there was a chance to explore different conceptions of sustainability. While there were not the resources available or appetite to undertake a broad stakeholder engagement, it was possible to mobilise the diverse viewpoints of company employees who demonstrated a rich and deeply considered view of these issues.²¹ This drew upon the *people-centric approach* followed by the company. During workshops, while there was an evident focus on environmental issues, particularly greenhouse gas (GHG) emissions, when discussing what would make a biotechnology product sustainable, much broader notions, including potential social impacts, were also frequently highlighted. The complex and integrated nature of the challenge was also discussed and participants showed broad awareness of potential trade-offs and acknowledgement of the significance of different worldviews.

The subsequent stages of the CSA process involve carrying out evaluations and then interpreting the results to inform future actions and decisions. Here, the broad definition of the concept again brought challenges. Firstly, there was a diversity of viewpoints regarding what sources of data were valid for understanding sustainability implications (Table S1, Question 7). For example, when asked how different sources of information might influence their perceptions of the sustainability of a product, impacted stakeholders were seen as quite influential to some, while others saw them as biased by their own experiences and therefore not influential. Expert viewpoints, alongside real-world and (to an extent) modelling data, were more universally approved of as influential factors.

²¹ Here, we do not suggest that engaging with company employees was a direct substitute for the inclusion of a broad range of stakeholders, a core tenet of RRI (Stilgoe et al., 2013). Yet directly engaging company employees in this process brought its own benefits, as is further discussed in Section 5.

596 Additionally, the evaluation stage led to qualitative results across numerous economic,
597 social, and environmental impact categories. Discussion of these results in further
598 workshops as per the CSA framework led to some success in opening up perspectives and
599 identifying avenues for further action (Table S2, Question 10). Yet, the variety and
600 uncertainty of outputs and the evident trade-offs between different aspects, while potentially
601 accurately representing the nature of the issue at hand, made it somewhat intractable for
602 company employees who found it difficult to translate the findings into clear implications or
603 actions. Meanwhile, when attempts were made towards further aggregation to provide
604 clearer outputs, for example using end-point rather than mid-point LCA characterisation²²,
605 this was not perceived as a valid approach as it involved too many subjective interpretations.
606 This demonstrates a tension between the perceived validity and salience of sustainability
607 data.

608 Fundamentally, this case illuminated some of the problems faced when an individual
609 company tries to embed sustainability considerations in its operations. There was a desire
610 expressed in workshops for specific, quantitative answers to sustainability questions. Yet,
611 the holistic characteristics of the concept require the integration of different sources of
612 knowledge and expertise from a variety of domains and inevitable subjective trade-offs that
613 cannot simply be resolved through more advanced analytical approaches. They require
614 values-based discussions and deliberations. Taken together, these issues might partially
615 explain why, despite sustainability being an important priority for the company and its
616 employees, this did not necessarily translate into directly informing actions or decisions. In
617 some cases, critical evaluation of claims can seem unnecessary due to a black-boxed link
618 between particular technologies and sustainability. When an evaluation is required, it
619 necessitates grappling with thorny values-based issues that individual companies often do
620 not have the resources, time, or legitimate authority to resolve.

621 In this case, grappling with these issues was further exacerbated by the company's Silicon
622 Valley-style model of doing business (Steiber & Alänge, 2016c). This approach prioritised
623 experimentation and flexibility to promote innovation and rapid growth. The *speed* at which
624 the company was growing and initiating new projects did not allow sufficient time for the
625 widespread application of more cautious, reflexive, and deliberative processes such as CSA
626 which could enable organisations to grapple with subjective and value-laden sustainability
627 questions.

²² Mid-point LCA indicator scores relate to more technical measures such as “kg CO₂ equivalent”, while end-points attempt to quantitatively relate them to the final impacts that are trying to be avoided, such as the impact on human health measured in quality-adjusted life-years (QALYs).

4.3 The systemic context

The other thematic area which was prominent in the case study was discussions concerning the innovation system within which the company found itself. It was clear that company employees felt that the actions of the company were considerably constrained by this systemic context. From these engagements, it was possible to deduce a map of how they viewed the system around them, which will be elaborated upon in this section (see Figure 2).

The case company operated “B2B”, primarily using their technology platform to provide services to clients who would then produce products for consumers (Figure 2, Point 1). This is not uncommon for developers of emerging technologies, particularly in the case of the platform technologies typical of synthetic biology. However, this dependence on clients constrained what the company felt able to do in terms of integrating wider considerations in their decision-making as most key clients were not primarily concerned with addressing sustainability, a view articulated in the following survey response:

“The primary barrier to making it [sustainability] the most relevant [factor in decision-making] is that our primary revenue sources - large companies - are not primarily concerned about sustainability, they are concerned about the bottom line.” (Survey response, member of the business development team)

There were a minority of cases where sustainability was a key driver for a client. However, because of the black-boxing phenomena described in the previous sub-section, simply labelling a product as “bio-based” could often be sufficient to achieve the legitimization and marketing benefit conveyed by the sustainability link. This meant that there was little perceived need to specify or critically evaluate the claims unless a client actively asked for it, perhaps to avoid accusations of greenwashing.

This lack of incentive from clients to actively consider and evaluate sustainability implications aligned with a view that wider societal incentives were also lacking (Figure 2, Point 2). There was a widely held perception that consumers were generally not willing or able to pay extra for a more sustainable product (there was no “green-premium”). In addition, the company’s technology typically involved genetically modified organisms (GMOs), leading to a concern that even if there were potential environmental and social benefits from the technology, consumer demand might be lacking due to a lack of trust in GMOs. Of course, company employees are also members of society and consumers in their own right (Figure 2, Point 3),

and as demonstrated in Section 4.2, they showed a considerable desire for more sustainable products.²³ The possible implications of this are discussed in Section 5.

On the other side of the perceived lack of incentive from clients and society was the perception that the system was stacked against them (Figure 2, Point 4). Industrial-scale production of high-volume commodity products, currently derived predominantly from fossil fuels, involve highly optimised processes often with fully depreciated machinery. More broadly within society, technologies, infrastructures, and institutions were all ‘locked-in’ to fossil fuel-based resource use. In combination, these factors were seen to make it difficult for the company to compete on the key metric valued by clients: price. As a result, while long-term returns may be possible, the level of investment needed to get there made it difficult to persuade *venture capital investors*, who also prioritised financial return (Figure 2, Point 5), that bio-based production was intrinsically a worthwhile investment. The high-risk nature of any such investments further reinforces the demand for profit and the single-bottom-line as high-risk investments typically demand a high rate of return. Thus, in the short-term at least, bio-based products needed an additional benefit in order to compete.

A common factor perceived to underpin the lack of demand for more sustainable products and the difficulty in competing with incumbents was the fact that the main benefits of bio-based processes related to externalities in terms of reduced GHG emissions, which are not currently represented in prices. Therefore, they saw themselves as operating on an uneven playing field, which if levelled would broaden the avenues that the company could pursue in terms of developing sustainable technologies. This point was summed up in the following survey response by a company employee:

“We’re a business and we don’t necessarily get paid for producing sustainable products. If there were carbon trading schemes or other methods of capturing the costs of sustainability then it would become a more relevant consideration in decision making.” (Survey response, desk-based scientist)

²³ For example, when asked “How much more would you be willing to pay for an everyday product if it was considered more sustainable?”, the vast majority of employees (92.70%, n=127) stated that they would pay at least some amount more (Table S2).

Figure 2: A map of the systemic context reflecting the perspective of the company employees. The numbers circled in red provide tags which are referred to in Section 4. (Source: Authors elaboration based on engagement with company employees).

**Note that in some contexts clients may also be from incumbent industries.*

The way in which this “levelling” could occur typically involved some form of a carbon tax (Figure 2, Point 6).²⁴ Regulation was also cited as an option, with regulatory compliance an important driver of company and client operation, but lacking for sustainability:

“...everything is regulated in this world except sustainability” (Interview response, Member of the Senior Leadership Team)

In combination, the systemic context that the company employees perceived did not appear to provide the necessary incentives or leave space for consideration and integration of the wider *socially significant mission* of sustainable development. This was confounded by the fact that the case company was reliant on *venture capital finance*, driving an increasingly urgent need to demonstrate that the technology platform could generate returns for investors in the future. From the perspective of many of the company employees engaged in this study, this meant that applying the company’s technology platform with the prime aim of addressing sustainability concerns, which would presumably be the most beneficial option for society as a whole, did not provide a financially viable business model in the short-term for the company itself.²⁵ Instead, the company pursued an alternative value proposition – novelty, as was discussed in Section 4.1.

5 Discussion

This action research study of a synthetic biology company has sought to build up a rich picture, triangulated from multiple data sources, of how they related and aligned their practices with sustainable development. Despite not being a digital or IT company *per se*, the company in question was in many ways archetypal of the Silicon Valley approach, being venture capital-funded and employing many of the key organisational characteristics (Steiber & Alänge, 2016b). This approach has been successful in enabling the company’s rapid growth and the generation of bio-based technological innovations with novel properties providing a value proposition that can potentially compete with and disrupt incumbent petroleum-based industries. The critical question, which this section will consider, is whether this approach is aligned with sustainable development, and what modifications might be necessary to better embed sustainability.

²⁴ It should be noted that a carbon tax focusses on just one of many sustainability dimensions and risks detrimental impacts for the world’s poor if not combined with active redistribution policies (Vogt-Schilb et al., 2019).

²⁵ A more proactive approach towards sustainability may also make long-term strategic sense for the company (see Henderson, 2015) but such an approach would require extremely patient investors.

At face value, the strategy for achieving sustainability through the “vehicles” (van Lente & van Til, 2008) of novelty and improved material performance could be judged as a pragmatic solution to the challenges of sustainable innovation, allowing the company to disrupt incumbents and replace petroleum-based production processes with seemingly renewable bio-based alternatives. However, as explained in the findings, this strategy is potentially problematic from the perspective of sustainable development based on the assumptions it involves about the inherent sustainability of specific (bio-based) technologies and its implicit prioritisation of a technology-led transition. The risks described previously in viewing technological innovation as intrinsically beneficial are well established and many frameworks and practices for more proactively and cautiously managing the emergence of new technologies in line with societal needs have been proposed and applied (BSI, 2020; Collingridge, 1980; Frantzeskaki et al., 2012). Given the apparent tensions between these frameworks and the Silicon Valley, “startup in a large suit” approach to innovation, as discussed in Section 2.3 and in the findings, we could argue that such business models are simply incompatible with sustainable development and that business practices need to be fundamentally transformed instead, putting sustainability at the core and making financial return subsidiary to social and environmental value creation (Dyck & Silvestre, 2018; Loorbach & Wijsman, 2013). However, we will elaborate here a middle-ground position that we believe could leverage ongoing trends in the market and financial landscape to put the Silicon Valley model at the service of sustainable development. The remainder of this discussion will consider how this (re)alignment can be achieved with reference to the four features described in Section 2.3: *speed*, *venture capital financing*, *a socially significant mission*, and *a people-centric approach* (Table 2).

Starting with *speed*, this seems to be in the clearest tension with approaches such as CSA because of the time involved in undertaking deliberative and analytical approaches. It can also limit opportunities for engagement with wider stakeholders and the formation of alliances and coalitions which can help to address systemic challenges (Kishna et al., 2017; Loorbach et al., 2010; Schaltegger et al., 2018). However, there is also a potential synergy between the agile lean start-up approach used to enable this speed (Ries, 2011) and the requirement of responsiveness – a central tenet of RRI (Stilgoe et al., 2013). The issue at present is that the former is responsive in a financial sense while the latter requires being responsive to the broader needs of society and the environment. On the other hand, policy interventions such as emissions trading schemes and public procurement incentives are increasingly being used to “tilt the landscape” in favour of more sustainable socio-technical systems and could help to bring the two forms of responsiveness into alignment (Kanger et al., 2020; Mazzucato, 2016). This increasing regulation could be seen to undermine the

Silicon Valley model, which is thought to thrive within lightly regulated LMEs as discussed in the literature review (Casper, 2007b; Soskice & Hall, 2001). However, these developments mainly involve strengthening existing price-based mechanisms²⁶ and therefore would not significantly increase the regulatory burden. Still, there is likely to be a limit to which regulation and price-based mechanisms can achieve in the face of uncertainty and contested priorities (Rosenbloom et al., 2020). Therefore, we suggest that complementary use of approaches like CSA will still be necessary to align the Silicon Valley model with sustainable development, therefore necessitating a slightly slower approach. This also brings potential benefits for other key features of the model, as will be discussed.

Feature	Tensions	Opportunities
<i>Speed</i>	<ul style="list-style-type: none"> • Allows limited time for deliberation and assessment. • Limits capacity for broader engagement. 	<ul style="list-style-type: none"> • Ongoing efforts to tilt the landscape in favour of sustainable technologies. • Streamlining of the CSA approach.
<i>Venture capital financing</i>	<ul style="list-style-type: none"> • Drives an emphasis on generating financial value. 	<ul style="list-style-type: none"> • The ESG trend in investing emphasises a broader definition of value. • Investors are increasingly likely to demand evidence of sustainability claims.
<i>Socially significant mission</i>	<ul style="list-style-type: none"> • Scepticism over the authenticity of such missions given recent controversies. 	<ul style="list-style-type: none"> • Implementing CSA provides a mechanism to demonstrate alignment. • Citizen assembly-type activities can provide guidance on the mission.
<i>People-centric approach</i>	<ul style="list-style-type: none"> • Emerging employee frustration regarding who and what the technologies are being developed for. 	<ul style="list-style-type: none"> • CSA empowers employees and helps to demonstrate alignment of company decision-making with their values. • Employees provide an (albeit limited) source of broader perspectives.

Table 2: A summary of the tensions and opportunities for alignment between the Silicon Valley model and sustainable development. The four features are those identified in the literature review (see Section 2.3) and mobilised throughout the article.

Another feature that seemingly inhibited the company's ability to focus more holistically on sustainable innovation was its reliance on *venture capital financing*. However, partly in response to current and anticipated government interventions such as those described above, as well as the need to maintain legitimacy in the face of existential risks, investing in sustainable companies is increasingly seen as a prudent, if not essential, long-term strategy

²⁶ For example, long-standing emissions trading schemes exist in many areas including the EU, UK, and California

in preparation for anticipated sustainability transitions (Hegeman & Sørheim, 2021). Consequently, there is a growing trend within the finance and investment community of demanding evidence of broader value creation from investments, often under the auspices of Environmental, Social, and Corporate Governance (ESG) metrics. This brings with it a considerable opportunity for this critical feature of the Silicon Valley model to also become a powerful driver for sustainable innovation as investors seek out companies that can evidence their contribution to sustainable development.

The potential and ongoing changes in the market and financial incentives described above could provide considerable rewards to companies following ambitious, *socially significant missions* in support of sustainable development. However, as discussed in the literature review, controversies involving prominent Silicon Valley companies have raised questions concerning the authenticity of these missions. Therefore, such companies may well find themselves under pressure to demonstrate how they are embedding these missions within day-to-day decision-making. Approaches like CSA provide an opportunity to clearly set out such a mission, evaluate progress towards it, and iteratively incorporate insights to improve alignment (Matthews, Cizauskas, et al., 2019; Matthews, Stamford, et al., 2019).

A further incentive to embed such activities within company structures and operations derives from the fourth and final feature of the Silicon Valley model considered here: the *people-centric approach*. Committed employees driven by a strong company culture are thought to play a crucial role in the perceived success of the model (Steiber & Alänge, 2016c). However, recent controversies have also revealed simmering tensions between such companies and their employees, frustrated by a lack of alignment with their values and priorities (Lavietes, 2018; Tiku, 2018). Company employees, who were the main focus of the engagements and data collection efforts for this study, demonstrated a deep and considered understanding of sustainability, including its tensions and complexities. For many, sustainable development was also a key motivator for their lives and careers. Therefore, engaging company employees in approaches like CSA and embedding them within company decision-making offers an opportunity to better align company practices with the priorities and values of employees, as well as sustainability, while in the process improving employee motivation and satisfaction (Aguinis & Glavas, 2019; Gurzawska et al., 2017; Spanjol et al., 2015). Still, such a move is not without trade-offs as it implies implementing a more democratic governance approach within such companies, something which may well bring new tensions (Lubberink et al., 2017).

The changes in emphasis of the Silicon Valley model discussed above and outlined in Table 2 might go a long way to tackling the business model and systemic challenges faced by

companies trying to innovate sustainably within the Silicon Valley model. These developments could provide incentives for the application of the CSA framework in a business context. Meanwhile, CSA can support companies to actively demonstrate the alignment of their decision-making with sustainability missions as well as their employees' values. Furthermore, the deliberative workshops at the core of the CSA approach can mobilise internal stakeholders (i.e. company employees) and the increased diversity of viewpoints they bring to help tackle cognitive challenges. This might represent a pragmatic way to open up the innovation process to broader priorities, albeit in a relatively limited manner, while having comparatively low resource and expertise requirements.

However, there is a limit to which internal deliberation can resolve cognitive challenges driven by ambiguity in the sustainability concept, as was discussed in Section 4.2. This caused the company great difficulty in rationalising, measuring, and taking action on the grounds of sustainability.²⁷ If, however, greater specificity could be provided through deliberation and citizen consultations at the national, regional, or sectoral level (e.g. Climate Assembly UK, 2020), this might give innovating companies specific targets to align their missions with by indicating more specifically the relative societal desirability of different innovation trajectories. The corresponding reduction in ambiguity and clearer signals provided would likely enable the streamlining of CSA-type activities by reducing the amount of time needing to be spent deliberating on priorities, trade-offs, and actions. That said, there are likely to be considerable limitations on the degree to which localised consensus regarding sustainability can be realised (Scoones et al., 2020) and to which approaches like CSA can be responsibly streamlined (Stirling, 2010).

Finally, a common theme of many frameworks for responsible and sustainable innovation is a focus on engaging with citizens and collaborating and forming coalitions with other organisations (Kishna et al., 2017; Loorbach et al., 2010; Schaltegger et al., 2018). However, as such an approach is challenging when working at speed and poses considerable tensions for businesses, as discussed in the literature review (Brand & Blok, 2019; Noorman et al., 2017), this discussion has focussed on how alignment can be achieved assuming that such broader engagement is largely not present, as was the situation in the case study. If, perhaps facilitated by a slightly slower approach to innovation, companies were able to invite wider stakeholders to engage in internal deliberations or were able to engage with other

²⁷ This corroborates previous findings that a lack of resources and expertise are major barriers for businesses operationalising RRI and sustainable innovation (see Álvarez Jaramillo et al., 2019; Auer & Jarmai, 2018) and supports the proposition by Hahn et al. (2014) that the ambiguity of the concept poses cognitive challenges for business managers and precludes radical action.

organisations to formulate collective missions and/or convene citizen dialogues, this would of course be likely to further strengthen the alignment with sustainable development.

6 Conclusion

In this article, we have described how cognitive, systemic, and business model challenges can obstruct the explicit construction of sustainable technologies by a company, even when this is a core part of their underlying mission. Consequently, we saw in this case how the company employed the additional characteristic of novelty as the key value proposition in its business model, acting as a potential vehicle for sustainability. The success of this approach in enabling sustainability transitions depends on one's assumptions regarding the necessity of technology for sustainability transitions and the intrinsic sustainability of bio-based processes, both of which are potentially problematic.

The Silicon Valley model employed by the company was heavily implicated in driving these outcomes. In the discussion, we returned to the research question posed in Section 2.3 to explore whether and how this model could be more rigorously aligned with sustainable development. We discussed modifications and developments which might enable this alignment. Firstly, changes in the market and financial environment, many of which are already underway, offer to partially resolve some of the systemic challenges faced by providing incentives for companies to embed sustainability considerations more actively in their operations. Secondly, public deliberations could provide greater specificity concerning the 'wants' and 'needs' of society with respect to sustainability, helping to alleviate cognitive challenges. Thirdly, these developments might provide an opening for the complementary application of CSA-type approaches at the company level which would allow businesses to align their decision-making more proactively and demonstrably with employee values and the overarching company mission.

Admittedly, these changes do suggest a slightly slower and more deliberative approach to innovation in a more regulated economic context, something more in line with what is prescribed by frameworks like RRI and CSA (Steen, 2021). This could be argued to fundamentally undermine the core features of the Silicon Valley model. However, if a streamlined form of CSA were applied, the *speed* penalty may not be all that great. Furthermore, such an approach might help to resolve some of the internal tensions faced by many Silicon Valley companies by helping to better align decision-making with employees' values and the overarching mission while also creating a model which is robust to an evolving finance and market landscape that increasingly expects demonstrable sustainability credentials. Therefore, we believe that such an approach might enhance rather than undermine the Silicon Valley model.

Finally, we acknowledge that, deriving from a single case study, there is an inevitable trade-off between the depth and richness of the case and the possibility of broad generalisation. However, by positioning our findings within the burgeoning literature on this subject we have been able to elaborate some tentative implications and recommendations. We do not put forward this approach as a rebuttal to other, more planned and structured frameworks for embedding sustainability such as business transition management (Loorbach & Wijsman, 2013). But given the traction that the Silicon Valley model has around the world, we believe that there is value in the discussion presented here concerning how it can be better aligned with sustainable development. We welcome rebuttal or further elaboration by fellow researchers, practitioners, or policy-makers on this matter.

7 Acknowledgements

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Appendix A: Copy of the workshop protocols

Note: These workshop protocols were previously reported in the methods section of in Matthews, Cizauskas, et al., (2019).

The formulation workshops explored the following topics:

- What does it mean for a product to be sustainable? What aspects matter?
- In terms of sustainability, what sources and types of information are useful and influential?
- What kinds of data and presentation formats are preferred?

The interpretation workshop explored the results of the sustainability assessment and how they could be integrated into decision-making and inform future work. After a short presentation of the results of the sustainability assessment, the following topics were discussed:

- Discussion of results: What do you think of the results? Are they as expected? Were there any unexpected results?
- Making decisions: How could the results be used? Do they change how you might make decisions?
- Future work: Where do we need more information and clarity? What are the priorities for further analysis and data collection?

Appendix B: Copy of the interview protocol

This interview schedule gives an overview of the questions that will be covered during the interview as outlined in the participation information sheet. The questions aim to explore how your view sustainability in the context of synthetic biology and your views on the constructive sustainability assessment framework. Some follow-up questions may be asked during the interview.

If you have any inquiries or concerns, do not hesitate to contact the researcher. The researcher will be happy to clarify any questions during the interview.

Sustainability and synthetic biology

- What do you think about the role of synthetic biology/biotechnology in sustainable development?
- What are the possible sustainability benefits of synthetic biology?
- What are the possible risks or detrimental sustainability impacts of synthetic biology?

Constructive sustainability assessment

- Can you tell me what, if anything, you know about the framework for constructive sustainability assessment that I have been working on in collaboration with [The Company]?

Depending on the answer to the above question the researcher will give more details on the constructive sustainability assessment process and ask some appropriate follow-up questions such as:

- What do you think of the process? What impact has the process had?
- Can you tell me anything that has changed, or you think will change as a result of the process?
- More generally, what role does/could sustainability assessment play at [The Company]?
- Could a process like constructive sustainability assessment have an impact on decision-making in the future?
- Can you see this type of process being applied more widely and permanently?
- What are any barriers to doing so?

Competing considerations

- How do sustainability considerations fit with other aspects in choosing and promoting synthetic biology applications?

- 1219 • How does this fit with scientific and technical considerations?
- 1220 • How does this fit with considerations of profitability and business competitiveness?
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