Redefining SME Productivity Measurement and Assessment for a Low Carbon Economy

PIN - Productivity Projects Fund

Pioneer Project Report

Redefining SME Productivity Measurement and Assessment for a Low Carbon Economy

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Table of Contents

List of Tables

List of Figures

Executive Summary

The UK faces the joint economic policy challenges of raising productivity and tackling climate change. This report challenges prevailing narrow market-based views of productivity, by examining the £4bn UK early stage Cleantech innovation finance market. We find that Cleantech innovation is frequently capital intensive and long horizon (5-10+ years), measured by shorter-term technology readiness level (TRL) and intellectual property (IP) progression. Longer-term sustainable productivity impacts remain little understood and, where applied, narrowly relate to customer adoption. This leads to Cleantech environmental impact investor logics that primarily relate to end user financial value (customer sales). There is little consideration for non-market values from, for example, circular economy (CE) and wider environmental spillover impacts (e.g. supply chains). Whilst few Cleantechs currently successfully commercialise, a small proportion exhibit high employment and sales growth and global environmental impact. Improved understanding of the broader environmental impacts of Cleantechs, through the adoption of environmental impact metrics (EIMs) can (i) add to a more holistic notion of productivity and (ii) improve the efficiency of the finance escalator, enabling more Cleantechs to contribute significantly to establishing the UK as a globally leading low carbon economy.

The report reveals that a narrow understanding of productivity is contributing to current market inefficiencies in the Cleantech finance sector through information asymmetries (IA) within a Stakeholder Triple Nexus (STN) at the intersection of Cleantech, investors and policymakers, due to:

- **Cleantechs** do not know how to present their environmental value alongside their economic value proposition to investors
- **Environmental Impact Investors** primarily seek financial return but cannot assess Cleantech value proposition without suitable financial and environmental impact metrics
- **Policymakers** seek environmental energy efficiency by supporting renewable energy adoption, but fail to regulate and support cleantechs through promoting circular economy (CE) and longer term environmentally sustainable metric solutions.

The report provides simple framework guidance for STN actors through the improved use of environmental impact metrics (EIMs) to reduce IA and raise the volume and quality of investment.

Methodological Approach

The report addressed a key research question relating to the financing of early stage Cleantech SME innovation: **What are the appropriate metrics and policy responses for environmentally sustainable productivity development?**

This required a multi-disciplinary, mixed methods approach to examine and understand the roles and actions of different STN actors in the context of the UK Cleantech finance ecosystem, involving:

- Review of relevant contemporary academic, practitioner and policy literature
- Review of the UK Cleantech small and medium-sized enterprise (SME) finance market using national public and private data sources
- Primary qualitative key informant interviews (42) with key actors in the UK STN
- A pilot online survey with experienced UK environmental impact investors
- Four workshops to test findings and recommendations with a full range of UK key actors

Key Research Findings

- All actors in the Cleantech early stage financing stakeholder triple nexus (STN) recognise a need for improved understanding and consistent standardised use of environmental impact metrics (EIMs). The different actors' perspectives and dominant logics currently prevent this, but can converge through their combined need to understand the Cleantech environmental value proposition for sustainable productivity.

- Early stage innovation Cleantechs and investors view productivity in terms of TRL and IP progression towards commercialisation with considerations of productivity impacts often restricted to potential customer efficiency improvements.
- Cleantech innovation is typically capital intensive (requiring multiple, often £1m+ rounds) and long horizon, with few exits. Around 5% are dormant 'zombie' companies at each stage of investment, suggesting that finance gaps exist across their innovation finance escalator development.
- A small proportion of UK Cleantech SMEs exhibit rapid employment and sales growth and major global environmental impacts, but more could succeed with timely, adequate finance.
- Impact investors' Cleantech venture portfolio selection is driven by financial return, rather than environmental trade-offs. However, when EIMs combine with financial metrics they enhance understanding of the Cleantech value proposition, increasing the likelihood of their investment and raising the quality of impact investor selection.
- Good practice impact investors are adopting EIMs in their portfolio selection and evaluation (e.g. using assessment scorecards), driven to some extent by their institutional investors' reporting requirements for environmental impact evidence.
- There is broad STN actor convergence towards using CO2 reduction, renewable energy use and energy efficiency, and reduction of waste indicators. However, more consideration could be given to all 6 Greenhouse Gas (GHG) emissions.
- There is little consideration or understanding of Circular Economy (CE) (e.g. carbon and rare earth mineral process inputs and product outcomes such as longevity, repair and repurposing) and wider environmental spillover impacts (e.g. into supply chains). Government could do more to regulate to support Cleantechs and create a stabler investor market for them.
- Cleantechs struggle to present their environmental value proposition credentials to investors and require guidance from investors and support providers. This is exacerbated by a lack of UK national environmental benchmarking data for SMEs and the wide range of Cleantech sector activities, involving different business models and material use.
- Private market support solutions involving EIMs are currently being developed, ranging from carbon footprint (Carbon Trust) to more complex materiality benchmarking to enable case by case assessment across various sectoral nuances (e.g. Future Fit, Cranetool, SASB).
- Good practice suggests adopting Sustainability Development Goals (SDGs) as strategic guidance, followed by a combination of core energy/efficiency metrics in combination with specific sector materiality and composite measures of CE and supply-chain impacts. Using a scorecard approach, this can provide investors and policymakers clearer indication of value proposition and potential impact for low carbon and sustainable productivity. The report details this approach and a 'how to' guide for investors and policymakers has been produced.

Key Policy Recommendations

- Develop **Standard UK EIMs** through **integrated cross-departmental use for business finance policies**, adopting consistent greenhouse gas (GHG) metrics alongside CE measures for carbon and rare earth mineral inputs and outputs and consideration for greening supply chains.
- Ensure that public-private **co-financing and tax incentive policies for business investment, use environmental metrics** to encourage environmentally sustainable development.
- Collect **national environmental audit data annually to assist SMEs** to undertake environmental benchmarking to enable progression to a greener economy. These data can assist impact investors, offering baselines to assess cleantech environmental impact.
- Offer **environmental sustainability support programmes alongside SME support and finance** programmes, integrating these with leading private market support providers.

Introduction

The UK faces the twin challenges of low productivity growth and the threat of climate change (Government, 2017, 2019). Public policy is searching for interventions to address these, with considerable emphasis on improving access to finance for innovative small and medium-sized enterprises (SMEs). This report addresses the research brief for round 3 of the ESRC Productivity Insights Network (PIN) which required new, alternative and disruptive innovative approaches to measuring productivity in UK small and medium-sized enterprises (SMEs).

Productivity is frequently narrowly defined as labour productivity (e.g. Gross Domestic Product per employee) – relating to the output of service or product units or revenue generated per employee in a given time period (Owen et al, 2019). However, a more rounded approach accounts for total factor productivity (TFP) where the mix of labour (including entrepreneurial management skills), capital investment and land resources are taken into account in order to seek increasingly efficient combinations to deliver economic growth, typically represented by increased wages and living standards (Romer, 2015). As such, many studies are preoccupied with developing management and labour skills and infrastructure objectives (HM Government, 2019 Business Productivity Review; Henley & Song, 2018), whilst taking less heed of the environment and longer-term sustainability benefits of cleantech innovation (Polzin, 2017).

Sustainability comprises broader concepts of value than current prevailing, narrow marginalist economic views of productivity (Drupp et al., 2020). The UN (2015) Sustainability Development Goals (SDGs) establish a socio-environmental framework for economic growth, clean energy and climate actions (among a range of 17 socio-economic indicators) that offer critical multi-stakeholder normative assessment of productivity, including at the micro business level (Muff et al, 2017). This approach enables re-assessment of productivity which extends beyond customer use value to include hedonic qualitative of innovative products and services value and their impacts on the wider economy and environment. Such an ecological approach requires normative environmental as well as economic metrics to assess progression to a low carbon net zero economy.

This study addresses the PIN call by advocating a broader sustainable productivity perspective that incorporates both environmental and commercial sustainability. Critically, it examines how capital investment in cleantech SMEs accounts for both longer term financial and environmental impacts to the firm and the wider economy and society through circular economy (CE) (e.g. carbon and rare earth mineral process inputs and their product longevity, repair and repurposing outcomes) and spillover supply-chain and customer linkages. It also acknowledges that this investment process might involve opportunity costs for revenue production in the shorter term, notably where research and development (R&D) employment increases without revenue generation, rendering standard labour revenue productivity measures ineffective (Owen et al, 2019). Hence, the study identifies ways for improving the measurement of productivity by taking a broader, long horizon approach in order to address climate change by facilitating the transition to a low carbon economy and meeting net zero carbon and other greenhouse gas (GHG) emission objectives by 2050, or sooner.

The report does so by focusing on SME productivity and looking at how sustainable environmental impact metrics (EIMs) can be applied by environmental impact investors and policymakers to assist in the selection and evaluation of early stage innovative cleantech SMEs. This aims to improve both private and public assisted (e.g. through public-private co-investment) impact investment practices by more clearly ascertaining cleantech environmental and financial impacts, creating a more efficient cleantech innovation funding escalator to deliver more rapid sustainable low carbon impacts and establishment of more efficient sustainable low carbon economic productivity.

We note that providing a full set of sustainability metrics suitable for SMEs is a major challenge that is beyond the scope of this study. Various organisations, such as Future-Fit Business (F-FB), the Impact Management Project (IMP), Cranetool and the Sustainable Accountants Standards Board (SASB) are already undertaking this work. Our objective is more narrowly focused on establishing the role and application of environmental impact metrics (EIMs).

The focus is therefore on the early stage Cleantech SMEs. These are typically smaller, often micro enterprises (<10 employee) that are pre-trading, or in early trading. Their innovations have goals to lower carbon use or greenhouse gas (GHG) emissions to contribute to achieving net zero. Whilst a great deal of Cleantech research focuses on renewable energy, we recognise that Cleantech innovations impact across a range of sectors, including engineering and manufacturing, infrastructure (e.g. transport and construction), primary production (e.g. farming and food), recycling, bio-science and associated digital technology (e.g. digitech developing online platforms, Apps, Smart meters etc.). As such we adopt the MIT (2016) cleantech definition 4 categories:

(i) clean energy use (adoption into industry);
(ii) energy efficiency (energy use reduction);
(iii) clean renewable energy generation and associated production and services activities;
(iv) recycling and waste management (as a leading business activity).

From an economic perspective these early stage innovation Cleantech SMEs face the challenges of a '*stakeholder triple nexus*' (STN) of information asymmetries (IA) at the intersection between cleantech, impact investors and policymakers. This occurs where financiers (public and private) find it difficult to assess the environmental and economic value proposition of cleantech. Failure to fund viable cleantech SMEs slows down their R&D progression and the potential impacts of their innovations on the economy and environment. From a productivity perspective this indicates that measuring sustainable productivity is unclear and accounts for different aspects, depending on who is asked to describe it.

The stakeholder triple nexus (STN) spans three main types of stakeholders – Cleantech SMEs, environmental 'Impact' investors and Policymakers and associated delivery support organisations. All three are necessary to address climate change, however their collaborative efforts and impacts are severely limited due to an inconsistency in expectations and approaches:

(i) **SME Cleantech** relate here to for-profit independent ventures. Their early stage innovation is often long horizon, requiring lengthy (upwards of 5-10+ years) periods of R&D and substantial levels of capital investment. Inevitably these companies will spend a great deal of time in pre-revenue and early revenue stages, a period often described as the 'valley of death' (Mazzucato & Semieniuk, 2018). As such, they present a high-risk proposition to investors and little shorter-term evidence of productivity in the traditional sense of delivering increased economic outputs per employee (e.g. sales and revenue/turnover).

(ii) **Impact investors**, defined by the Global Impact Investment Network (GIIN, 2020), are investors seeking 'positive, measurable environmental impact, alongside financial return'. In the UK these are typically equity investors providing financial capital for a share of the business; for example business accelerators, business angels and seed venture capitalists (VCs). They are concerned with climate change and consider investing in SME Cleantech early stage innovation but face difficult risk-reward calculations that are exacerbated by high due-diligence costs (Owen, Lehner, Lyon, & Brennan, 2019a). Furthermore, investors may not be fully or sufficiently remunerated (in the short or long-term) for the environmental sustainability benefits that their investments deliver, because of unclear reporting and measurement practices (Bocken, 2015).

(iii) **Policymakers** find it difficult to calculate the value of long horizon SME Cleantech innovation investment. Part of this problem may be that policies are shorter-term, driven by UK government five-year term objectives and not aligned with the longer-term objectives of cleantech innovation. This embodies the problem of the Rowlands (2009) patient capital finance gap where a longer horizon, often 10 years plus period of R&D Technology Readiness Level (TRL) progression to established commercialization, yields little or no conventional productivity increase (e.g. revenue outputs per employee). Furthermore, climate change creates another complex dimension, which requires urgent attention and improved understanding, as it should be a key driver of UK government long-term economic policy (Frontier Economics, 2019).

Recognizing these differences, this study therefore addresses the broad research question: **What are the appropriate metrics and policy responses for environmentally sustainable productivity development?**

In this way we address how the adoption and use of appropriate, useable, environmental impact metrics (EIMs) can overcome the information asymmetries which currently create barriers in the stakeholder triple nexus (STN). We explore this intersection between early stage innovation Cleantech SMEs, their potential impact investors and the policymakers and assess the role of EIMs as tools to help all stakeholder actors to address market failure and more effectively support and finance this market and deliver low carbon environmentally sustainable productivity.

The report progresses by outlining the methodological approach, presenting findings from secondary and primary data, identifying case examples of good practice and recommendations for future policy and practice. The report comes at a critical time for the UK economy, in the wake of the Covid-19 pandemic, and has considerable relevance to policymakers in developing a more balanced approach to 'building back better' a globally leading environmentally sustainable UK economy.

Methodology

There is urgent need for a study which redefines productivity measurement, to explore this within the context of the emerging low carbon economy and inform policy which focuses on SMEs generating a sustainable green economy.

Key to energy transition is the switch from fossil fuels to renewables. This requires businesses to rethink their strategies and business models. Cleantechs emerged as a promising business model with the goal to develop innovative products that align with the clean energy agenda. Gaddy et al (2017: p.4) position "*cleantech companies as those which are commercializing clean energy technologies or business models, including those developing, integrating, deploying, or financing new materials, hardware, or software focused on energy generation, storage, distribution, and efficiency.*" Yet, the rollout of this concept is hindered by two factors.

First, cleantechs are typically young companies that face significant obstacles in obtaining finance, mainly due to the accrued and thus lagged capture of R&D cost and value, resulting in many never progressing beyond initial R&D phases (Cai & Li, 2018; Rennings, 2000). Second, crucially, the accurate measurement of their potential sustainability impacts is problematized by lack of data and unreliable forecasting. Policy has focused on the sub-aspect eco-efficiency (Rodriguez et al., 2020), where environmental and economic performance are evaluated concomitantly, but cleantechs (notably younger ventures) not only face the difficulty of measuring the correct environmental impact, but also the dilemma of how to integrate (long-term) externalities that are connotated to eco-innovation, into short-term investor paradigms.

We adopt a multi-disciplinary, mixed methods (Creswell, 2003) approach to study the UK early stage cleantech innovation entrepreneurial finance ecosystem. This highlights an under researched, underfunded policy area in the UK (and globally) which faces a STN of information asymmetries (IA) contributing to market failure business investment finance gaps and where environmental impact metrics can play a key role to overcome these. By combining multidisciplinary approaches, we aim to improve understanding of the early stage cleantech innovation market and the role of environmental metrics in assessing their value proposition in environmental and financial terms. Policy theory and evaluation, productivity and low carbon innovation progression, sustainable accounting and finance econometrics, and entrepreneurial and behavioural finance are drawn together to provide a framework for the research which includes quantitative and qualitative approaches designed to capture sufficient data and insights to provide robust findings and recommendations for a more efficient investment market.

Our methodology consisted of three phases:

Phase 1: literature and secondary data review

We start with a structured review of academic and grey policy and practitioner literature to establish what are the key environmental impact metrics currently in use or under consideration and the extent to which these have been or can relate to SMEs. We also examine how these metrics relate to concepts and approaches to measuring sustainable productivity. Whilst academic literature was drawn mainly from Scopus searches (the largest global dataset for academic papers), the grey literature focused on UK policy and practitioners and was drawn from internet searches and an initial sweep of key informant interviews across a wide range of policymakers and practitioners in the cleantech innovation entrepreneurial support and finance ecosystem.

The study also explored secondary data sources which combined cleantech businesses with environmental impact metrics and external financing for R&D and commercial scale-up, seeking global best practice data and UK specific data, as well as any application to earlier stage cleantech SME innovators. A key tool here was the development of a proprietary data set of 82 mainly UK early stage innovation cleantech SMEs' written '*Pitchdeck*' presentations used for external finance equity fundraising purposes.

Phase 2: Key informant interviews, impact investor survey and cleantech case studies
The literature and data review work informed the second phase data collection approaches and survey instruments. Our priority was to undertake at least 40 key informant interviews across a broadly representative range of actors in the UK early stage cleantech innovation entrepreneurial finance market. These included policymakers from government departments (e.g. Department for Environment, Food and Rural Affairs and Department for Business, Energy and Industrial Strategy), non-departmental bodies (e.g. Innovate UK, British Business Bank), a range of private (accelerators, angels, VCs, impact investment banks) and public supported (e.g. VCs, Low Carbon Innovation Fund) impact investors and support providers (e.g. Future-Fit, Impact Management Project, innovation centres, accountants). Interviews were undertaken by telephone or online (via Teams, Zoom and Skype) using semi structured topic guides (see Annex E). These explored the informant's background and experience, their organisation's role, knowledge and use of sustainable productivity and impact investment metrics – notably relating to investment selection and evaluation - and suggestions for their future development.

Nine in-depth cleantech innovation UK SME case studies were also undertaken. These aimed to explore the relationship between cleantech founders and their impact investors and demonstrate the extent to which funding gaps exist and impact metrics have been adopted as part of the business promotion to impact investors and its progression towards environmentally sustainable outcomes. Where possible CEOs' views are triangulated by interviewing their impact investors.

A short on-line Qualtrics survey of early stage cleantech impact investors was promoted through the Green Angel Syndicate and with other angels and seed VCs encountered. This pilot survey was used to test different types of impact investors on their investment selection and ongoing portfolio business progress evaluation criteria from an environmental sustainability perspective.

Phase 3: Initial dissemination of findings and refinement of recommendations
The final phase involved a series of 4 workshop presentations and discussions with UK policymakers, support providers, impact investors and academics. These aimed to present the initial review and fieldwork findings to a range of different actors in the STN and to stimulate discussions around developing academic thinking and practical support tools and policy recommendations. We aimed for clear pathways to deliver practical impacts with the key actors.

Key project outcomes relate to this final dissemination report alongside summary toolkits to assist cleantechs and impact investors to come together through the adoption of key environmental sustainability impact metrics and recommendations for policymakers to facilitate early stage impact investing for cleantechs.

Literature Review

Key Literature Review findings:

- Productivity remains narrowly defined by market exchange value, rather than calculations of non market values which are crucial to understand environmental impact and support progress to a low carbon economy.
- Environmental metrics are highly contested with no consistently agreed approach to determine their selection and use. This is due to the complexity of cleantech activities and different perspectives of academics and stakeholders. Our evidence suggests there is scope for convergence through simplified, case specific approaches.
- Policy is preoccupied with efficiency measures and typically fails to account for wider environmental context and requirements for composite CE metrics.
- Most studies relate to corporate ESG reporting data, overlooking the challenge facing smaller cleantechs to present their value proposition to impact investors, notably given a lack of benchmarking environmental reporting data for smaller companies.

The project aims to redefine productivity measurement along the lines of sustainability. But what do either of these terms mean and how can sustainability measures contribute to a more nuanced understanding of productivity that addresses the issues of climate change? The following sections draw from a systematic literature review (detailed in Annex C) to provide definitions of both sustainability, especially environmental sustainability measures and productivity measures.

Productivity Measurement

The basic premise of productivity is that it is measuring the effective transformation of resources into something valuable. Consequently, the output measure used in a given productivity study is a reflection of an (often implicit) judgement about what is valuable.

The majority of productivity measures use market metrics as the output variable. We see this in government documents. For example, the UK Industrial Strategy only refers to productivity in terms of GDP (BEIS, 2018). It is often narrowly defined as GDP per employee. Narrow definitions also extend to academic studies. *The Oxford Handbook of Productivity Analysis* overwhelmingly focuses on market metrics (Griffell-Tatje et al., 2018). An instructive example is Firfiray et al.'s. (2018) analysis of the labour productivity of family firms. This starts with a discussion of the fact that many family-owned firms have multiple objectives beyond production of market value: reinforcing of social ties, emotional attachment, and family bonds. But these non-market values are ignored when it comes to choosing a productivity output measure. Rather, Firfiray et al., examine how attempting to produce non-market value will impact productivity measured in terms of market values. In this way, non-market is made subservient to the production of market value, with the latter remaining the object of productivity analysis.

The use of market measures as output in productivity analysis can be understood when put into the context of the development of economic theory. Productivity as we understand it today evolved from attempts to understand how 'value' was created in capitalist economies (Foster, 2016). Productivity discourse in policy, academia and the media is largely defined in terms of mainstream economics which is descended from the marginalist tradition of economics (Abbott, 2018). Although value itself is imprecisely defined within mainstream economics today, one of the defining features of the marginalist tradition was the adoption of a very particular theory of value which saw market value as a pure function of use value (Mandel, 1986).

Prior to the marginalist school, economists tended to distinguish market value ('exchange' value) from use values. Market value is the value of an object in terms of what it can be exchanged for on the market. It is determined primarily by the costs of production. Use value is the value of an object in terms of its actual function. This distinction is most famously laid out by Marx

(1873/2001), using linen and coats. The two commodities have different uses and therefore different use values. But their exchange values can be the same. If, for example, 1 coat sells for £100 and 10 yards of linen also sells for £100, then the two commodities have different use values but the same exchange value. A central task of the classical economists was to attempt to synthesise and explain the relation between these two value forms.

On the other hand, the marginalists argued that exchange value is derived almost purely from use value (Mandel, 1986; Martins, 2015). In this way of thinking exchange value depends only on how useful a given commodity is to a given consumer. The amount of money I am willing to exchange for a coat, say, is dependent on how useful that coat is to me. The cost of that coat's production might impact whether a firm is willing to produce it, but it does not impact the value of the coat. Such a subjective theory of value lends itself to making markets the central object of study. The marginalist theory of value assumes that our willingness to spend money on a commodity is a good guide to the usefulness of that product. Consequently, markets are not merely a particular social form of distribution. Rather they become the site within the economy where people's individual judgements of value become manifest (Martins 2015).

This has been strongly criticised by economists in non-marginalist traditions. Ecological economists emphasise incommensurability of different value types, arguing that it is impossible for all forms of value to be manifested in markets (Martinez-Alier et al., 1998). Likewise, for example, feminist economists have argued that markets are best understood as socially and institutionally conditioned. They argue that markets and market values rest on non-market production by nature and in the home, yet *by definition* markets exclude these areas from being considered producers of value (Dengler & Strunk, 2018; Federici, 2014). From a policy perspective environmental value is considered in environmental impact assessment (EIA) and cost benefit analysis (CBA), but is seldom considered in relation to developing sustainable productivity measures (Barbier et al., 1990).

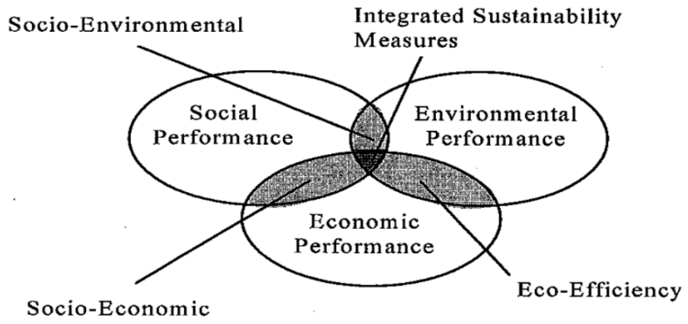
Sustainability Measurement

Literature on Sustainability Measurement is as multi-facetted as the construct sustainability itself. As a result, a plethora of definitions, dimensions, indicators and approaches discussing sustainability and related measurements exists. Hence, prior to discussing the potential difficulties in assessing sustainability performance, and various dimensions of it, it is crucial to clarify what we actually want to measure.

Essentially, the construct sustainability in its original definition from the World Commission on Environment and Development (WCED, 1987: 41) means "*development that meets the need of the present without compromising the ability of future generations to meet their own needs*." Additionally, more recently introduced Sustainable Development Goals (SDGs) by the United Nations (2015) provide normative goals to guide action. 17 goals are grouped into three broad categories; social, environmental, and socio environmental. Sustainability thus covers a broad variety of aspects. Measuring each aspect and progress made towards the 17 goals is therefore an enormous task which no one has yet administered fully.

Ranganathan (1998) uses a three-fold sustainability measurement schematic, calling for full "integrated sustainability measures".

Figure 1: Sustainability Measurement according to Ranganathan (1998, p. 2)



Integrated reporting and impact measurement thereof capture all three dimensions of sustainability (social, environmental and economic as of the Triple Bottom Line; (Elkington, 1998)), suggesting that the desired economic or financial value is dependent on social and environmental factors likewise. In this study we focus on the nexus between economic and environmental sustainability measurement, hence we focus on literature which examines eco-efficiency. What becomes clear is that measuring sustainability and/or its sub-dimensions is as multi-facetted as the concept sustainability itself. The following sections provide a brief overview over how measuring eco-efficiency is currently approached.

Semenova and Hassel (2015) define eco-efficiency based on Sinkin, Wright, and Burnett (2008: 13) as "*maximizing the effectiveness of business processes while minimizing their impact on the environment.*" In this realm the term eco-innovation (Scarpellini et al., 2018) evolved as an instrument seeking to optimise the use of natural resources in industrial production.

To date, measuring eco-innovation is difficult, as it has various drivers and aims to account for external factors that are hard to measure in a simple input-output function (Sonnenschein, 2016), notwithstanding a monetary value (Burritt, Hahn, & Schaltegger, 2002). Furthermore, eco-innovation measurement often deals with the implementation of an Environmental Management System (EMS), in which strategic goals (e.g. SDGs) are presented and connected to the relevant indicators. Unfortunately, companies often focus on the implementation of such an EMS only, because this raises awareness of ecological sustainability and transfers legitimacy (Adams & Frost, 2008; Cai & Li, 2018; Dias- Sardinha & Reijnders, 2001; Johnston & Smith, 2001). Similarly, indicators that aim to capture eco-efficiency stem either from an accounting perspective that aims to assess short-term and long-term effects in monetary (e.g. activity based costing) or physical (material and energy flow) information (Schaltegger & Burritt, 2000), or follow economic valuation approaches that include hedonic pricing, benefit transfer (Wang, Shao, Nathwani, & Zhou, 2019), or life-cycle assessment (Motta, Issberner, & Prado, 2018).

Adding to the complexity of the measurement of eco-efficiency, literature defines Corporate Environmental Performance (CEP) as appropriate to capture impact in the context of an organisation (Trumpp et al., 2015). According to Escrig- Olmedo et al. (2017: 143) "*CEP is a construct, that is, a 'theoretical creation that can be defined in conceptual terms but cannot be observed and therefore anchored to observable reality by means of indicators."* Their findings suggest that companies are influenced by an economic rationale that prioritises shareholders and perhaps stakeholders. Integration of environmental performance measurement mostly fails through lack of clarity for what environmental impact means and the lack of coherent approaches. Similar to the notion on eco-innovation, alongside the implementation of a performance measurement system, organisations usually only focus on the strategic (or even governance) dimension of CEP. This typically builds strong strategic commitment to sustainability, but poor operationalisation of goals and an even blurrier measurement of these (Dragomir, 2018). As a result, the sustainability efforts of an organization are often falsely dismissed as unnecessary and avoidable cost (DesJardine at al., 2020). Noting these difficulties in combining qualitative and quantitative criteria and making a multidimensional concept such as CEP measurable, Escrig- Olmedo et al. (2017) include linguistic variables in measurement systems (Muñoz et al, 2008). These aim to capture externalities and potential spillover effects that may only be stated in written report texts (Ness et al., 2007). Such methods address the points of Banerjee (2002), Haigh (2013) and Windolph (2011) who note environmental sustainability particularly inherits various meanings that inevitably lead to different outcomes. Such approaches thus aim to provide a basis for a broader understanding of what value means.

What do we know about indicators and their selection?

As outlined above measuring sustainability is inherently difficult, even if we focus on eco-efficiency alone. Multiple concepts aim to measure the same thing (i.e. the economic-ecological nexus). Hence, choosing the right concept alone is incredibly difficult. However, as various indicators are attached to these concepts, the actual measurement of the intended outcomes and impact is even more critical (Nicholls, 2010; Rosenzweig & Roth, 2007). Many literature streams examine sustainability indicators for different industries. We require focus and simplification and highlight key studies to corroborate the most relevant environmental impact indicators. We then list the metrics which form the basis for our practical inquiry and data triangulation in table 1.

Aiming to clarify eco-innovation, García-Granero, Piedra-Muñoz, and Galdeano-Gómez (2018) review the literature on eco-innovation performance indicators. They identify the 30 most cited firm performance indicators, classifying them into four green innovation types: (i) product - cleaner material, recycled material, optimize use of raw material, reduce product components, longer life cycle products; (ii) process - reduce use of energy, recycle waste and water or materials, R&D, renewable energy, acquisition of patents and licenses; (iii) organizational - green human resources, environmental audit, cooperation with stakeholders, new systems for remanufacturing, invest in research; (iv) marketing - returnable/reusable packaging, green design packaging, quality certifications.

Remaining in the context of CEP, Haffar and Searcy (2018) analyse the extent to which environmental indicators disclosed in corporate sustainability reports address the broader sustainability context. Such context-based indicators are important for the environmental impact assessment as they address broader socio-ecological company systems and account for potential spillovers. The opposite of such context-based indicators are self-referential indicators. The authors identify 463 environmental indicators, with none being context based. Rather, companies use 57% absolute (A), 37% relative (R), 5% equivalent (E) and <2% benchmark (B) indicators.

The above studies highlight the need for indicators to address various bases of innovation. The most difficult one certainly being the process innovation part, where multiple stakeholder interests and externalities are to be combined in a single number. The difficulty in doing so becomes even more apparent in the last paragraph, which highlights that only a minority of indicators actually includes external benchmarking references or relative goals. Hence, the efforts of providing more holistic indicators are not (yet) reflected in the above-mentioned, most commonly applied concepts and approaches.

To tackle this issue, the Circular Economy (CE) has recently evolved as an increasingly accepted business model for greening and redesigning the supply chain (Kravchenko, Pigosso, & McAloone, 2019; Saidani et al., 2019). With this, the efforts of developing appropriate holistic indicators has become more pertinent – especially for young businesses, which adopt the business model logic most commonly. Given the traction and the importance of the CE, multiple scholars have started to develop and analyse appropriate indicators and approaches to measure the circularity of industries, companies and products (Saidani et al., 2019). For example Garza-Reyes et al.(2019) identify twelve requirements that should be measured: (i) reducing environmental damage; (ii) increasing internal awareness; (iii) reducing input of materials; (iv) reducing critical materials; (v) reducing non-renewable resources; (vi) increasing durability of products; (vii) increasing external awareness; (viii) increase value-chain support; (ix) increase green market; (x) increase longevity of products; (xi) increase technologies (xii) increase legislation development. The first six appear more directly relevant to internal company operations, whilst the latter are more difficult as they capture externalities. Similarly, Rossi, et al. (2020) propose nine environmental indicators that should support CE. Corona et al (2019) critically assess CE metrics, offering perhaps the most advanced and useful product level (micro) indicators. Giannakis et al. (2020) also propose a helpful sustainability performance measurement framework for supplier evaluation and selection.

Finally, it is notable that the literature is primarily drawn from corporate studies where ESGs have been adopted for legal reporting reasons (e.g. the UK requires all businesses with 500 employees to provide annual environmental audits). This is highlighted by CO2 emissions including both Scope 1 and Scope 2 emissions in order to assess the directly related emissions to a company and products. In addition, Scope 3 emissions are included by referring to waste production and transportation outside the organisations. A crucial consideration for our study of early stage cleantech SMEs is the extent to which such data is suitable for SME adoption.

These studies highlight that a majority of indicators focus on economic aspects, where actual progress of the individual companies and products towards sustainability goals remains uncaptured or is diluted by the missing benchmark. While measuring the right outcome or impact is one aspect that remains difficult, picking the correct type of indicators is another. The type of indicator mostly determines which kind of input is to be used to measure or assess outcomes and impact. Put simply, qualitative analyses and indicators are based on different datasets than quantitative ones.

Academic authors suggest three indicator types according to the nature of their input; single quantitative, analytical tools and composite indicators. While practice seems to adopt fewer indicators in general, it does not adopt composite indicators at all, which, as the above authors note, might suggest that simple indicators are preferred. The gap between academia and practice is omnipresent throughout industries. For example, Lou, Jayantha, Shen, Liu, and Shu (2019) recently analysed the application of low-carbon city (LCC) indicators, notably finding that the indicator “total carbon emission” is extensively applied in practice but not recommended by academia. Furthermore, the most popular dimension in academia is energy use, while in practice it is urban mobility.

Review of the above studies highlight that sustainability measurement is difficult. Even when focusing on the ecological impact dimensions in combination with economic impact, there is no clear approach. Rather, the opposite is the case. Research and practitioners have developed a variety of approaches and related indicators to assess potential impact and economic productivity. The next section summarises the most commonly used environmental impact indicators. We then address behavioural questions to explain why and how measures are adopted by various actors.

Most commonly used environmental impact indicators

Based on the literature review and a weighted average count method in Excel, Table 1 presents the most commonly adopted environmental indicator measures and their metrics, relevant to cleantechs. Notably, the table covers five dimensions where there is some convergence: environmental impact, which is populated by CO2 rather than broader greenhouse gas indicators; energy consumption, which contains CE measures of waste; material use, which accounts for sectoral nuance and CE measures of recycling, reuse and longevity; strategy in terms of mission, goals and certification; commerciality in terms of revenue, return on investment and reflecting the policy aim of efficiency and cost saving, which aligns with productivity and competitiveness measures.

Table 1: Summary of Key Environmental Indicators from Literature

Dimension	Indicator	Metric
Environmental Impact	CO_2 emissions (or carbon footprint)	t
	CO_2 intensity of energy supply	%
	CO_2 intensity of the economy	%
	Nitrogen emissions (NOx)	t
Energy Consumption	life cycle energy use of product	kwH per time unit
	energy use during operation	kwH
	energy efficiency	%
	Energy use (total and per unit of product)	kwH
	Fresh water consumption	Liters
	Waste water	Liters
	Percent energy from renewables	%
	Solid waste	kg
	Hazardous waste	kg
	energy consumption	kwH
	level of clean technologies	%
	amount energy consumption during the recycling	kwH
	Energy cost savings	monetary unit
Material Use	Materials used (total and per unit of product)	kg
	level of recycled material in product (circularity degree)	%
	recycling time	hs/days
	reuse potential indicator	%
	longetivity indicator	time unit
	global resource indicator	kg/functional unit
Strategy	ISO 14001 certification	y/n
	EMS	y/n
	RD&D spending	monetary unit
	number of new products and processes	monetary unit
	availability of eco-labeling	y/n
Commercial	Profits	monetary unit
	Return on investment	%
	Energy cost savings	monetary unit
	Turnover/employee (productivity)	%
	operational cost	monetary unit
	product quality	(technical) characteristics relevant
	eco-efficient value ratio	environmental burden to economic value

Table Note: Indicators based on Ahi and Searcy (2015); Amrina and Yusof (2011); Corona, Shen, Reike, Carreón, and Worrell (2019); Dragomir (2018); Fiksel, McDaniel, and Spitzley (1998); Gong, Simpson, Koh, and Tan (2018); Kafa, Hani, and El Mhamedi (2013); Kravchenko et al. (2019); Sonnenschein (2016); Veleva and Ellenbecker (2001) as well as the OECD and the EMAS frameworks.

The problem with environmental impact indicators

As presented, environmental sustainability measurement is inherently difficult, mainly because of a definitional blur and a plethora of attached indicators. This is reflected in the Pope et al. (2017) framework of sustainability assessment, which distinguishes between two dimensions: (i) the sustainability concept (i.e. what sustainability represents); and (ii) the decision-making context (how is sustainability reflected in indicators). This is also reflected in the overview of indicators above. We lack a clear understanding of what should be measured in order to track both progress and impact accordingly. Rodriguez, Pansera, and Lorenzo (2020) highlight this in their evaluation of commonly applied indicators. They examine how different framing potentially impedes the usefulness and correct application of energy and carbon intensity indicators. They find that efficiency and intensity, both often framed in terms of productivity, are used equivalently. Because of that energy and carbon intensity indicators are attractive for policy makers as they allow the design of political targets (such as the Paris agreement) without questioning the right kind of economic growth of powerful emerging economies like BRICS. Hence, the incorrect (or even missing) consideration of carbon efficiency indicators can be misleading.

The lack of harmonisation and standardisation within the various academic disciplines and similar difficulties in practice leaves a puzzle of (i) which indicators and metrics to use for what and (ii) when these might be apt (Fernandez, 2014; Ramos & Caeiro, 2010; Searcy, 2016; Sonnenschein, 2016). We aim to address these questions by first identifying the most relevant indicators proposed by literature and second, triangulating their usability in practice. Ferran, Heijungs, and Vogtländer (2018); Howard, Hopkinson, and Miemczyk (2019); Niemeijer and de Groot (2008) encapsulate the relating issues that organisations struggle with in measuring environmental sustainability neatly as the following:

- The lack of agreement on how to select indicators that represent both, ecological and environmental impact.
- An unclear approach to integration and normalisation, which leads to multiple different measurement scales.
- Confusion about how indicators should be aggregated, either via simple weighting or complicated formulas – yet this might be difficult as environmental impacts can differ significantly given the sector companies operate in.

How can productivity and (environmental) sustainability then be connected?

Sustainability concepts and indicators challenge the marginalist conception of value and provide a basis for using broader conceptions of value in a productivity measure. The interdependency of factors is also what proves difficult in assessing productivity. Productivity as we understand it today evolved from attempts to understand how 'value' was created in capitalist economies (Foster, 2016). Productivity discourse in policy, academia and the media is largely defined in terms of mainstream economics which is descended from the marginalist tradition of economics (Abbott, 2018). Although value itself is imprecisely defined within mainstream economics today, one of the defining features of the marginalist tradition was the adoption of a very particular theory of value which saw market value as a pure function of use value (Mandel, 1968).

Use value describes the value of the actual function of a product and overrides the exchange value of a product (i.e. the value that is based on the production cost) (Mandel, 1968; Martins, 2015). The amount of money I am willing to exchange for a coat, say, is dependent on how useful that coat is to me. The cost of that coat's production might impact whether a firm is willing to produce it, but it does not impact the value of the coat. Irrespectively of what kind of value subsides the other, the focus of such approaches is on the market where individuals judge the use value of a product. Thus, the single focus on market excludes non-market areas such as nature – which however have a strong impact on how values are perceived or can be understood in the first place (Dengler & Strunk, 2017; Federici, 2014).This suggests a need to draw on environmental impact evaluation (EIA) and extended cost benefit analysis (CBA) techniques to assess the wider environmental impact of cleantech activity (Barbier et al, 1990).

Ultimately, sustainability concepts challenge the marginalist conception of value and provide a basis for using broader conceptions of value in a productivity measure. With it, the measurement of (economic) productivity and other sustainability dimensions becomes a difficult undertaking.

Reflecting on this, the indicators that are used to assess a company's impact represent a crucial tool in assessing what environmental sustainability means. With respect to the huge variety of indicators and approaches in use, this study thus undertook the effort to assess what indicators (related to both productivity and environmental impact) mean to different actors (qualitatively and quantitatively). We examine the cleantech use value proposition (in financial and environmental terms) and seek appropriate indicators that can bridge the information asymmetries within the STN for SME cleantech financing.

Summary Review of Contemporary Practitioner and UK Policy Literature

The literature review also examined contemporary: (i) practitioner (investors and accountants) on approaches and metrics used to assess potential impacts of low carbon investments; UK government policy interventions designed to deliver low carbon and wider sustainability policy objectives (evaluation evidence and procurement documentation); and (iii) productivity literature, including that by the Productivity Insights Network (PIN) to examine where environmental metrics are considered. The key findings are summarised below:

Practitioner literature

Impact investors take no single approach to measuring impact, using various tools, frameworks and standards. A crowded, fragmented landscape reveals some more widely used approaches (GIIN, 2017) namely: IRIS metrics; 17 United Nations Sustainable Development Goals (SDGs); B Analytics and/or Global Impact Investing Rating System (GIIRS); and the Principles for Responsible Investment. Other relevant frameworks include: EU Taxonomy; Future-Fit Business (FFB) Benchmark; Global Reporting Initiative's (GRI) Sustainability Reporting Standards; Good Finance's Outcome Matrix; the International Integrated Reporting Council's (IIRC) International Integrated Reporting Framework; the Natural Capital Protocol (NCP); and Sustainability Accounting Standards Board standards.

In addition to publicly available tools, standards and frameworks, some impact investors have developed their own impact frameworks. Notable examples include ETF Partners' 'impact scorecard' (which includes some custom, business-specific metrics) and Earth Capital's 'Earth Dividend'. Annex B includes a list of metrics more commonly cited in practitioner literature.
Two organisations – the Accounting for Sustainability (A4S) network and the Impact Management Project (IMP) – have taken a slightly different approach to promoting best practice in impact measurement and reporting by focusing on fostering collaboration and knowledge sharing (instead of developing a framework or a set of tools).

Notably, low carbon is part of the sustainability umbrella, with little focus on productivity:
Practitioner literature typically combines low carbon metrics with wider sustainability measures (e.g. biodiversity; waste; water and soil pollution) under the umbrella of 'sustainability' or 'environmental sustainability'. Indeed, the Social Impact Investing Taskforce (2018) identified lack of a common "language" and use of inconsistent terms as a major hurdle for impact reporting. Terms like 'impact', 'social return, 'value', 'results', 'effects' and 'outcomes' are used interchangeably, with confusion about different types of investing (e.g. sustainable, ethical, responsible, impact).

There is little focus on productivity in practitioner sustainability literature. Where it is mentioned, this is typically done in passing (e.g. citing ‘local productivity growth’ or ‘wage productivity’ as an impact) and with no guidance as to how this should be measured.

Government

There is little guidance on approaches to assess low carbon impacts in programme application or evaluation documentation, even where interventions have explicit low carbon focus (Frontier Economics, 2018). This is particularly the case for R&D/innovation-related interventions to encourage the development and commercialisation of new low carbon technologies, compared to Government interventions related to e.g. the adoption of low carbon technologies where impacts on emissions are already known or those related to measuring carbon impacts at a business level[1].

Many evaluations state that it is too early to assess low carbon impacts at the time of the evaluation. Some evaluations report on progress in achieving environmental objectives, but this is predominantly self-reported/non-quantified evidence from beneficiary surveys. For innovation-related interventions, the emphasis tends to be on leading indicators, intermediate outcomes and proxies, such as development of new products and services designed to reduce carbon emissions, rather than assessing their actual emissions reduction.

Fundamentally, metrics and indicators cited related to high-level objectives and intended impacts expected, with very little explanation of how these will be measured nor intended routes to impact from the intervention. The tendency is to provide commentary on “top down” sector level trends (e.g. specific sector emissions) alongside “bottom up” evidence (e.g. self-reported evidence on intermediate outcomes for innovation), with little attempt to join the two perspectives and assess the plausible contribution of the programme to “top down” trends. This is often due to timings/lag to impact, the scale of individual interventions compared to the scale of the challenge, and the difficulties in disentangling the relative impact of an intervention compared to many other external factors influencing carbon emissions (even within one sector).

The evaluation evidence also demonstrates how some of the metrics are also very context / sub-sector specific, and therefore difficult to aggregate or identify a set of common indicators applicable across projects. A full list of metrics is included in Annex B.

Reference to Productivity and PIN Research

HM Treasury’s Productivity Plan (2015) requires consideration of low carbon and programme evaluations may reference productivity objectives and impacts, including evaluations of programmes with a predominantly low carbon/environmental focus (e.g. Innovate UK’s Low Carbon Buildings Innovation Platform and Energy Catalyst. However, approaches to measurement are limited (Frontier Economics, 2018) – either self-reported impacts in beneficiary surveys (e.g. x% of beneficiaries reported an impact on productivity as a result of the programme) or productivity is derived by dividing turnover by employment.

Only one of the evaluations reviewed makes an explicit link between low carbon and productivity objectives: the EC Innovation Fund, where programme guidance briefly highlights low carbon technologies can improve productivity.

None of the evidence papers produced by the PIN consortium make reference to low carbon issues (or environmental challenges more broadly) in the context of the productivity debate.

[1] Where approaches e.g. BEIS’ “greenhouse gas conversion factors for company reporting” is relevant and accessible

Secondary SME Data Sources

Key Secondary Data Findings:

- Current national public and private SME data sets do not offer environmental metrics
- Private data suggests that the £4bn UK cleantech SME investment market requires long horizon investing. Few cleantechs have exited their investments (only 12% of those invested in prior to 2011).
- Around 5% are 'zombie' ventures (dormant for a year or more) at each investment stage, suggesting potential funding gaps throughout the innovation funding escalator.
- Pitchdeck presentations provide uneven evidence of environmental metrics, suggesting their potential role in presenting value proposition, but uncertainties over their selection and presentation.

This section reviews current and recent UK secondary data relating to SME innovation, external finance and environmental impact metrics. We find a paucity of national data with regard to younger established (<5 years) and smaller businesses (<10 employees) and no robust or useful data relating to SME environmental impact metrics. The section concludes by examining a proprietary project data set of Pitchdeck environmental metrics. This demonstrates that early stage Cleantechs are at least to some extent aware of the need to demonstrate their green, low carbon credentials to investors, but struggle to consistently articulate them.

UK Longitudinal Small Business Survey (LSBS)

The largest UK annual SME survey data source is the Longitudinal Small Business Survey (LSBS), established in 2015 with a baseline of 15,502 SMEs. Whilst the survey reveals difficulties in predicting growth and productivity improvements in terms of sales or employment, there is some evidence that innovation and staff and management training and support might be influential (BEIS, 2019), particularly alongside external financing (Owen et al, 2019).

In the context of this study this key survey reveals major shortcomings and inconsistencies which prevent it being useful to this study:

- There is no Cleantech definition in the survey and only partial and limited data on the environmental mission of SMEs (16.7% stated this was of high importance in 2017 in the only year this was collected, as part of a wider definition of social mission enterprises). This makes Cleantech performance assessment impossible, other than via a limited key sector SIC search, which would be far from inclusive of Cleantech activities.
- The survey suffers from underrepresentation of younger SMEs. Just 12% are under 5 years established; a proportion which declines in the panel survey over time (Owen et al, 2019).
- The survey provides traditional SME growth indicators over time, such as turnover and employment. The limited environmental indicators do not provide appropriate impact metrics. Section E covers SME energy efficiency measures in terms of energy audit, renewables use, efficiency practices and plans, but these are simply generic SME actions. Notably, UK SMEs are unfamiliar with environmental impact indicators, as these are not required under any current regulations.
- Innovation is recorded only in terms of product, service and process and investment in R&D, or utilizing tax credits, whilst intellectual property acquisition and protection was only recorded in 2015 as a reason for sourcing external finance.

The limitations with LSBS data are underlined by the finding that the total data for SMEs in 2017 that stated environment as their main priority, which had invested in R&D in the past three years and which were under 5 years established was 2 businesses! Widening this search to environment as a medium or high priority and under 10 years established only revealed 17 businesses.

We conclude that LSBS is currently an inadequate resource for early stage Cleantech performance and unable to provide any environmental impact metrics.

UK Innovation Survey (UKIS)

The UK Innovation Survey is biennial and part of the EU-wide Community Innovation Survey. The most recent 2019 survey (BEIS, 2020) is the largest UK-wide innovation survey, representing 14,040 UK business respondents (45% of those random stratified sampled by UK region and broad sector). It excludes micro and self-employed businesses (<10 employee) and contains larger businesses (250+ employee). Thus, it is not representative of the young, typically micro enterprises of this study's focus. Whilst UKIS data raises concerns, suggesting a possible correlation between the perceived lack of suitable and acceptable cost external finance and the levels of innovation activity undertaken by UK SMEs in recent years, it does not currently provide vital data required for our study, as follows:

- Young, micro business early stage innovators are not properly represented
- The only environmental data collected by UKIS is whether the business innovation will have an environmental impact, with no specific measure of the type and level of impact.
- Only limited external finance data is collected, which is focused on types of public provider and whether direct (grant, loan, equity) or indirect (Tax Credit, Patent Box) financing.

Beauhurst Equity Data

Private data for equity investments from Beauhurst and Pitchbook offer further insights. Beauhurst, established in 2011, is the leading specialist in providing early stage SME equity financing data in the UK and produces the British Business Bank's annual UK Small Business Equity Tracker reports (Beauhurst, 2019). We use Beauhurst data to provide a UK cleantech SME investment market overview but note that no UK data sources collect environmental metrics or data on informal (unannounced) investment via business angels.

> The market potential of cleantech ventures is yet to be proven, with many companies being classified as "zombies".

Market Overview

Table 2 profiles the 731 UK independent Cleantech SMEs (<250 employees at the time of their first recorded equity fundraise) that have successfully received some form of equity finance (typically business angel or VC) during the period 2011 to the present. The first recorded fund raise year has mainly been within the last decade – 86.4% from 2011. Unsurprisingly, half of Cleantechs are located in London, South East and East of England regions where UK high tech innovation has been traditionally located – notably within the London-Oxbridge triangle (Baldock & Mason, 2015).

The vast majority of recorded first funding rounds were for seed and venture stage companies (89%) – the two stages that this study is most concerned with. Seed funding is typically associated with pre revenue companies that are moving from initial proof of concept into early stage prototyping and initial testing of concept, whereas venture stage businesses are at 'Series A' preparing for, or into early commercialization. Growth stage refers to companies progressing from early commercialization and gaining market traction, whilst established businesses are those that have already achieved market traction, but may be seeking further expansion or re-financing.

As noted, Cleantechs pose problems for data collection, as they are an emerging, evolving, category which comprise established sectors alongside new high tech activities. Here, we define Cleantechs into 4 broad categories which reflect the MIT energy initiative (Gaddy et al., 2017) in relating to: (i) clean energy use, notably in relation to adoption of clean energy practices in sectors (e.g. manufacturing and construction); (ii) energy efficiency, relating to reduced energy costs through processes and practices, including smart software technologies; (iii) renewable energy production and associated activities around renewable energy adoption; (iv) waste management and recycling as a key company function.

Examining the current status of the Cleantech companies in the data set, one fifth have ceased trading and are defined as 'dead', whilst a further 4.4% are designated as 'zombie' (dormant) and not having any signs of business activity for over a year. This may be explained, in terms of what BEIS (2017) journeys of innovative businesses to finance found, as companies which have been frozen or 'shelved' whose main innovation business activities remain dormant whilst they seek finance for progression. Of course, some businesses are able to bootstrap innovation, particularly where they are less capital intensive (e.g. software based) and able to self-invest or earn consultancy income from associated activities, but this form of investment invariably slows down innovation progress and potentially harms market position and potential prime/first mover advantages (BEIS, 2017).

The remaining SMEs show clear signs of progression with the seed stage representing just over one third (or 45% of those that are not dead or zombie) and higher proportions in the later stages. Notably, 6.3% have successfully exited their investments. Exits occur typically through trade sale, but may also take place through IPO, licensing revenue or through private equity buy-in (the type of the exit is unknown).

Table 2: Profile of Beauhurst Cleantech for UK SMEs

Cleantech Co. Profile	**% n=731**			
First investment year			**Current status**	(% not Dead/zombie)
2001 to 2008	2.7		Seed	34 (45%)
2009 to 2010	10.8		Venture	23.3 (31%)
2011 to 2015	47.9		Growth	7.3 (10%)
2016 to 2020	38.5		Established	4.1 (5%)
Region			Exited	6.3 (9%)
London, South East, East	51.4		Zombie	4.4
Midlands & South West	18.4		Dead	20.5
North	15.8		**Employment at first fundraise (n=180)***	
Devolved nations	14.4		Average	17.6
Stage at first recorded round			Median	6
Seed	69		Range	1 to 173
Venture	20		**Employment in 2019-20 (n=370)***	
Growth	7.1		Average	22.7
Established	3.8		Median	8
Broad sector			Range	1 to 338
Clean energy use	18.1		**Turnover status at first fundraise (n=100)***	
Energy efficiency	39		Average	£5.8m
Renewable generation	32.1		Median	£228.647k
Waste, recycling	10.7		Range	£0 to £17.5m

			Turnover status 2019-20 (n=100)*	
			Average	£20m
			Median	£2.25m
			Range	£0 to £80.23m

*Note: Data on turnover and employment excludes dead companies

Further evidence of company progression is demonstrated (Table 2) by the increase in the median and average size of employees and turnover between first fund raise and current 2019-20 company data for registered companies. A caveat is that the data presented (excluding dead companies) is particularly limited for turnover. Where data was provided turnover was registered as zero by 25% of companies at first fundraise, which fell to 20% for 2019-20, suggesting some progression to commercialisation.

Fundraising activity

Overall, there is an average of 3 funding rounds per Cleantech, with 2,085 funding rounds recorded for 731 Cleantechs. The majority (57%) have two funding rounds, but around one in eight have more than five rounds.

Table 3 demonstrates the scale of funding required for Cleantech external equity investment, with approaching **£4bn invested** in these companies and a median size funding round of £1.9m. The median and average amounts of funding raised increase with progression from seed (median £197k), through venture (£750k) to the growth (£2.3m) stage. This progression is as expected, with investment requirements increasing as companies first prototype and test and then scale-up their commercialization. The majority of the funds raised were for venture and growth stages (81.2%), with seed representing 15.2% - again indicative of the substantial external funding required to undertake later stage prototyping, testing and progress through early commercialization to full market scale-up, which is often international.

Table 3: Amount of external finance raised in all recorded rounds

Stage / £000	Median	Mean	Min	Max	Total
Seed (n=875)	197	607	5	47800	591825
Venture (n=810)	750	2030	7	76000	1644300
Growth (n=221)	2300	6800	5	134000	1502800
Established (n=34)	1500	4300	12	49980	146200
Overall (n=2085)	423	1900	5	134000	3885125

Table 4 demonstrates the scale of external funding required for Cleantech investment, for the first recorded investment round. Overall, the 708 Cleantechs (where data was provided) raised over £909m in their first recorded round (about one quarter of the total external funding raised by these companies), with median funding round value of £222k. The seed and venture stages represent two thirds of the funding raised – reflective of the greater emphasis on earlier stage funding and also emphasizing the importance of sizeable external equity funding from an early stage of the Cleantech innovation cycle.

Table 4: Amount of external finance raised in first fundraising round recorded

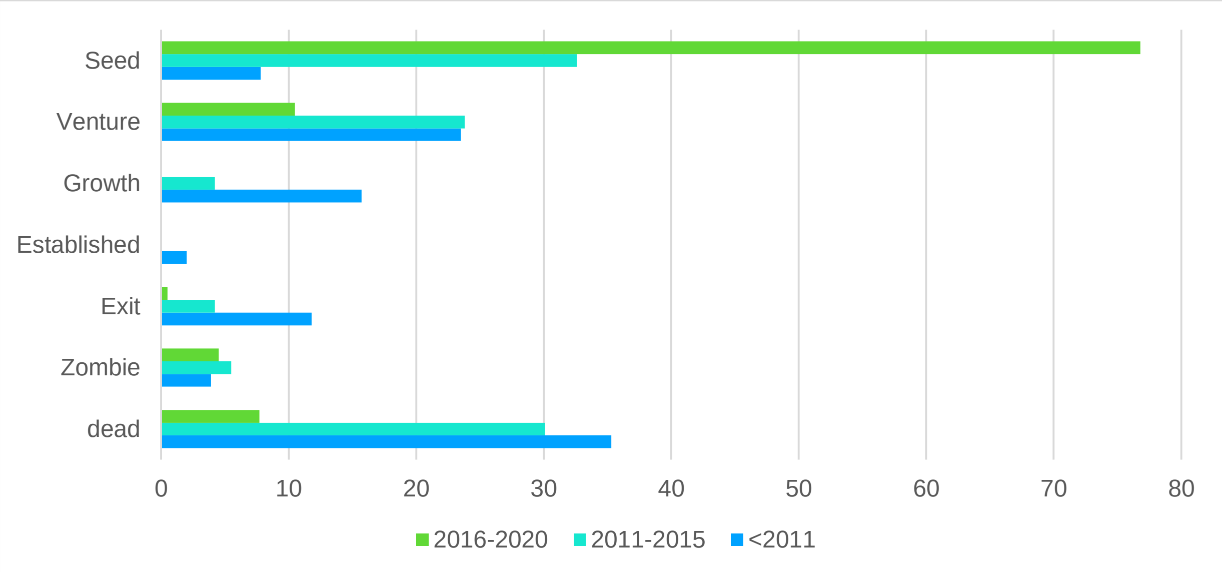
Stage / £000	Median	Mean	Min	Max	Total
Seed (n=496)	159	659	5	47950	326,864
Venture (n=144)	594	2242	10	76290	322,848
Growth (n=47)	1999	3359	16	14680	157,873
Established (n=21)	772	4844	13	50000	101,724
Overall (n=708)	222	1284	5	76290	909,309

Progression Analysis

The Beauhurst data is diverse, covering a considerable time period (companies established from 2001) and stage development (seed through to established trading and investment exits) of the Cleantech innovation cycle. Whilst Cleantech innovation is typically long horizon, data is limited and patchy on the older established companies and also unlikely to be rewarding (in terms of longitudinal tracking) for the more recently established. We therefore focus on seed funding and particularly the group of 236 seed stage ventures from the period 2011-2015 and track their investment and performance to gain an impression of their impact on the UK economy.

During their first seed funding round these companies received a total of £172m in external investment with average investment of £731k (median £150k). Where data on the different types of investors is recorded it suggests that there is typically one investor; four fifths of cases - although the trend is for more early stage syndication in the succeeding 2016-2020 period (one quarter of 220 seed investments had syndication between 2 or more investor types). The most likely private source of investment is a business angel, or group of angels (as suggested in Mason and Harrison (2015)). There is also a notably high proportion of public funded investors, particularly via regional funds (Mason and Pierrakis (2013) note the reliance on public funded VC investment, particularly in regions further away from London) such as Low Carbon Innovation Fund, Regional funds in North West and North East of England, and University seed funds (e.g. Cambridge, Oxford, Swansea), as well as accelerators (e.g. Bethnal Green Ventures), equity crowdfunders (e.g. Crowdcube, Seedrs, SyndicateRoom) and corporate VC such as UK Steel, Shell, Scottish and Southern Electricity.

Figure 2: Cleantech Progress by 2020 by First Funding Seed Round Year Cohort (n=507)



Examining the progression of this subset group of UK Cleantechs (equity funded from seed round) Figure 4 demonstrates the high proportion of seed stage companies (76%) within the most recent 2016-2020 year cohort, whilst the growth stage is only exhibited in the earlier cohorts and the established stage is only exhibited in the pre-2011 cohort. This provides clear evidence of the long periods of time that it typically takes for Cleantechs to progress through the innovation cycle. Furthermore, the proportional rate of company failure increases with cohort age to 35% for the oldest group. Intriguingly, the zombie group is most consistent, perhaps indicating that at all stages there are currently external funding gaps affecting around 5% of Cleantechs (that have received at least one round of equity funding).[2]

Focusing on progression within the 2011-2015 cohort we find that almost two thirds (64%) have survived and are currently active, whilst 10 companies (4%) have exited their investments. There are also signs of stage progression with 23% progressing to venture stage and 4% progressing to growth stage. 30% had closed and a further 6% were designated as zombie (dormant, with no business activity for at least 12 months).

Further analysis by UK region (across all seed investment cohorts n=507) revealed some variations, with London and the South East and Eastern Region appearing to perform better than the other regions, with better progression and slightly lower proportions of dead and zombie companies (24% in London, South East and East of England combined region were dead or zombie, compared with 28.4% elsewhere, but no significant differences were recorded). Significant broad sectoral differences (at <.1 level) suggest that investment in renewable energy development and recycling is riskier; almost one third (32.5%) of renewable energy development and 29% of waste management and recycling companies had closed or were in zombie status and just two of 211 companies in these sectors had exited. Conversely, energy efficiency and clean energy adoption companies were more likely to have exited (5%) and less likely to have dead and zombie status companies (22.6% of energy efficiency and 19.6% of cleantech adopters). These findings underline concerns about market differentiation in early stage Cleantech innovation investing raised by Gaddy et al. (2017). Investing in capital intensive sectors such as engineering for renewable energy and recycling is likely to be expensive and longer horizon whilst lower overhead ICT software solutions for energy efficiency and renewable energy adoption may be less expensive and more rapid to reaching exit. The implication is that expensive long horizon investment will require greater public sector support to address private sector under investment and market failures (BEIS, 2017). This is further supported by the median first seed round requirements for energy efficiency sector companies being lowest (£150k, compared with 167k or more in the other sectors).

Measurable economic impacts

Beauhurst data offers limited performance information, the main metrics being turnover, employment and pre and post funding round valuation. Table 5 summarises key progression data, based upon the limited data for 507 Cleantechs that were first recorded at their seed funding stage (between 2001-2020).

Table 5: Progression of Employment, Sales and Valuation for Seed Stage Cleantechs

Employment	**Pre Seed (n=69)**	**Current (n=279)**
Mean	4	21
Median	3	7
Maximum	19	339
Estimated Total	2028	6921*
Turnover	(n=19)	(n=64)
Mean	£20k	£23.37m
Median	£0	£1.475m
Maximum	£157k	£823m
Total	£380k	£1.5bn
Valuation (n=419)	£850k median	£Post seed 1.09m median

Note: * estimation based on average employment growth for 65% active survival (less dead and zombie cases)

The most robust data (n=419) is for the post funding valuation change which demonstrates that the seed funding round raised the median value of the company from £850k to £1.09m.

[2] Workshop with GAS discussed whether Zombies may be older lifestyle entrepreneurs. Founder data is unavailable, but this seems unlikely as these are external equity funded and at all stages of the innovation cycle.

Employment data is limited to just 69 companies at the pre seed funding stage. This demonstrates that these were small and mainly micro businesses, with a median of just 3 employees. Current, most recent company filed, data (n=279) demonstrates that these largely remain as micro businesses, with their median employment size rising to just 7. However, this group contains some rapid growing outliers, with the largest company employing 339 staff. Extrapolating from this evidence and taking out 35% of companies which are either closed or zombie (which might close) but including exits (where employment may be retained), this group exhibits average employment growth which has generated nearly 5,000 net new jobs, not accounting for employment spillovers which are likely to have taken place through subcontracting (Owen at al, 2019).

Turnover data evidence is very limited, mainly because the vast majority of these companies will have been pre trading at the time of their first seed round and many will still not be trading. Again, despite sparse data, there is evidence of a small number of rapid growing outliers, with the largest company currently recording turnover of £823m. Extrapolating from this, the recorded value of Cleantech turnover has risen from pre seed total of £380k to almost £1.5bn.

Summary

In summary, Beauhurst data is limited, most notably to recording formally announced and publicly available information on equity funding. We cannot determine what proportion of pre seed funding Cleantechs actually get funded, although various UK studies of fund managers (Baldock & Mason, 2015)(BIS, 2010 & 2012) indicate that the funding funnel typically results in less than 5% of applicants being funded. Beauhurst data does appear to be highly representative of UK equity funded Cleantechs (post 2011) and provides some key insights into the nature of the UK Cleantech early stage innovation investment market, as follows:

- The UK Cleantech market is sizeable – 731 SME innovation Cleantechs have received nearly £4bn in investment[3], with seed investment amounting to almost £600m and venture investment amounting to more than £1.6bn (mostly in the period from 2011 onwards).
- Among the selected group death rates are surprisingly low (35%) - perhaps reflective of a relatively stable economic period post GFC and pre Covid-19. This may also result from positive sample selection through good investor selection and the added value of equity investor input to business sustainability and development (Gompers, Kovner, Lerner, & Scharfstein, 2010).
- The persistent zombie group of around 5% suggests that there are potential funding gaps at all innovation funding stages. Cleantechs require substantial external investment (rising from median level initial seed rounds of £159k to around £2m for growth rounds, although they can be considerably high). Investment sums required per business increase at later stages, but more businesses are likely to be affected at earlier stages (due to the natural pyramid progression of sustainable surviving businesses).
- The proportion of exits (6%) is small, indicating that Cleantech innovation progress is slow and lengthy. Moreover, sector nuances suggest that renewable energy generation and waste/recycling are higher risk and more capital intensive than energy efficiency software. This supports the notion that Cleantechs are typically long horizon. Even where exits might be expected more quickly from software companies, often the most successful high performers still take a long time to exit. Substantial, often global, market traction and value realisation may take between 5-10 years (BEIS, 2017).
- Whilst there is no significant evidence of regional funding disparity, over half of all funded Cleantechs are in the London, South East and East of England region.

[3] In context British Business Bank Small Business Equity Tracker (2017) reported that the annual size of the UK equity investment market was £3.4bn, with an annual seed investment market of £542m and venture market of £894m.

- Cleantech require significant high amounts of investment through several rounds – they may remain pre trading and relatively difficult to assess from a traditional productivity perspective; lacking turnover and with small numbers of direct employment (although there might be subcontracting – Owen and Mason (2017)). Progression via Technology Readiness Levels (TRLs) and IP patents can help, but these types of data are not captured by Beauhurst.
- Beauhurst reveals some very significant impact data in terms of employment and to a smaller extent turnover – but this is related to a few stellar outliers – following the pareto principals of innovation investing (Markowitz, 1952).
- Beauhurst contains no environmental impact assessment data, but we can examine progression and some traditional impact by sector metrics and map this data onto potential outcomes from other sources such as Pitchdeck, where potential environmental impact outcomes are presented by some Cleantechs.

Pitchdeck Information

> CO2 emissions and CO2 efficiency are the most commonly used indicators in pitch decks. Ventures present these alongside capital efficiency measures, or offer creative measures such as tokens. Strategic anchors such as SDGs are rarely mentioned.

While large secondary datasets provide a good overview of the start-up ecosystem in general and the Cleantech sector specifically, hand-collected information from pitchdeck presentations provides more fine-grained insights into single companies. Pitchdecks offer short overviews of a venture's business plan that are presented to potential investors. Mostly, these are created with a third-party advisor or accelerator (e.g. Green Angel Syndicate or Greenbackers), who is supporting the venture to secure external funding. The funding sought is therefore typically from angel or seed VC investors in the advisor's network. Additionally, we collected 11 pitchdecks online from Crowdcube and ClimateKic, which also feature a structured presentation of ventures that were subject to a due-diligence process, presenting venture offers to a broader crowdfunding audience that does not necessarily invest strategically. Pitchdecks typically seek private equity risk funding for early stage activities (e.g. R&D, prototyping, market testing and piloting) through to scale-ups.

In our study we hand-collected 82 pitchdeck presentations of cleantech companies in order to assess how these companies present and measure their environmental impact. Environmental impact is a key issue for companies whose ultimate goal is to provide clean technology solutions that reduce for example carbon emissions. Given this mission, ventures would be expected to report at least some metrics that allow both themselves and investors to assess and track their environmental impact progress. We analysed the pitchdecks according to company profile characteristics (e.g. sector, stage), financial information, future outlook, and the environmental impact indicators that are used and presented.
The 82 relevant cleantech companies have been supported by Greenbackers, Green Angel Syndicate, Crowdcube and ClimateKic between 2017 and 2020. The majority of companies had pitched for funding at the time of analysis (June, 2020), 35% having pitched in 2020 and 28% in 2019. One in ten are current pitchdecks that are yet to be presented to investors, whilst one quarter did not have a pitch date.

Sector Analysis

The majority of pitches are in broad sector activities relating to *clean energy use* (35%) through transitioning to renewable energies and *energy efficiency* (44%) in relation to reducing the energy input per unit of activity. The vast majority (82%) of companies require early seed financing to develop or progress patents, prototyping or early market testing. Nine companies (11%) are further developed and seek *Series A* funding. Most of the later stage Series A requirements are for *renewable generation and associated activities* such as developing or installing wind turbines, heat pumps, wave energy or solar PV. There were also a couple of examples of bridging rounds and combining equity and asset finance, whilst for 5 companies (6%) we were unable to determine their funding stage. Many companies had already received funding rounds; 37% had undergone earlier seed financing rounds, 23% had received grant funding (e.g. from Innovate UK, BEIS or European funds) including 11% that had received matching equity.

A similar structure is reflected in the revenue stage of the companies. Most are pre-revenue (55%) or early revenue (37%). The remaining companies did not provide data, although two were recognized as early revenue and one as in revenue. In total £14.17m revenue is reported for 30 companies, representing an average of £470k revenue.

Funding characteristics

Cleantech funding requirements are substantial (Table 6). On average companies had sought £1.86m in their past funding rounds (although our data does not indicate when and over what timespan this funding was secured). For the most recent funding, for which the pitchdecks were created, a total of £133.32m was sought, representing an average funding requirement of £2.08m (with little difference between early revenue at £1.37m and pre revenue at £1.6m, but rising to £5m for a more established scale-up).

Substantial amounts of funding were required across all broad sectors; £44.46m for *clean energy use* (average £1.71m), £42.91m for *energy efficiency* (average £1.95m), £29.5m (average £2.46m) for *renewable generation and associated activities and* £16.45m for *waste management and recycling* (average £4.11m). Substantial Series A rounds contributed to the relatively high average in *renewable generation,* whilst the relatively high capital investment cost for pilot plant development (not attributable to a precise investment stage) contributed to the very high average in waste management and recycling.

Table 6: Funding sought by sector and revenue stage

Sectors and funding type / revenue stage (in million £)	Early revenue (37%)	Early trading (2%)	Pre revenue (54%)	Revenue (1%)	unknown (6%)	Total
clean energy use (35%)	**£ 17.50**		**£ 21.96**	**£ 5.00**		**£ 44.46**
equity and asset finance	£ 0.80					**£ 0.80**
equity seed	£ 15.00		£ 17.96			**£ 32.96**
equity seed and grant	£ 1.70					**£ 1.70**
equity Series A			£ 4.00	£ 5.00		**£ 9.00**
energy efficiency (44%)	**£ 4.35**	**£ 13.56**	**£ 22.10**		**£ 2.90**	**£ 42.91**
equity seed	£ 4.35	£ 13.56	£ 20.60		£ 2.90	**£ 41.41**
equity Series A			£ 1.50			**£ 1.50**
renewable generation and associated activities (16%)	**£ 4.50**		**£ 25.00**			**£ 29.50**
equity bridge	£ 0.50					**£ 0.50**
equity seed			£ 7.50			**£ 7.50**

equity Series A	£ 4.00		£ 17.50			**£ 21.50**
waste management and recycling (12%)	**£ 4.20**		**£ 0.25**		**£ 12.00**	**£ 16.45**
equity seed	£ 4.20				£ 12.00	**£16.20**
equity seed and grant			£ 0.25			**£ 0.25**
Total	**£ 30.55**	**£ 13.56**	**£ 69.31**	**£ 5.00**	**£ 14.90**	**£ 133.32**

In addition, 29 companies indicated an exit option in their pitchdeck, of which two-thirds (19) are looking to exit via trade sale, one fifth (6) via an IPO, and one in seven (4) will seek an exit via buyout. A concern here is that two-thirds do not indicate their exit plans and expected investment timescales. This is concentrated amongst the *energy efficiency* sector and may be indicative of companies that expect to be bought out in a trade sale (but do not state this).

Indicator Analysis

Perhaps the most striking observation is that these are all cleantech environmental low carbon mission ventures and yet 13% provide no environmental impact metric and less than half (48%) present more than one key environmental impact metric. The frequency of environmental indicators recorded is broadly in-line with our broad category Cleantech classification. 45% of all indicators are associated with energy efficiency, 36% to clean energy use, 17% to renewable generation and 2% to waste management. This shows that companies across all sectors are using indicators to demonstrate their intended environmental impacts.

Table 7: Selected Indicators used per Broader Sector (total indicator count = 44)

Indicator use per broad sector	clean energy use (35%)	energy efficiency (44%)	renewable generation and associated activities (16%)	waste management and recycling (12%)	Total use
Air quality	1	1			**2**
biodiversity (%)	2				**2**
capital efficiency (%)	**3**	**1**	**1**		**5**
carbon footprint	**2**	**3**			**5**
chemicals (kg, t)	1	1		1	**3**
CO_2 emissions (t and Δ)	**10**	**7**	**1**		**18**
cost (£)	**3**	**3**			**6**
Cost efficiency (%)		1	1		**2**
cost per unit of energy (£)		1	1		**2**
degree of circularity (%)	**2**	**3**			**5**
energy consumption	1				**1**
energy efficiency (%)	**3**	**6**	**4**		**13**
energy produced (kWh)		1			**1**
longevity (years)	1				**1**
material efficiency (%)		1	1		**2**
material usage (t)	1		2		**3**
Nox emissions (t)		**1**	**1**		**2**
number of renewables			1		**1**

product quality (%)			1		**1**
SDGs	1	2			**3**
waste (kg and ∆)		**5**		**1**	**6**
Water quality (%)	1	2	1		**4**
Total use	**39**	**48**	**18**	**2**	

Table 7 presents a selective overview of the relevant indicators by broad sector. We highlight the most notable by colour theme. Blue cells relate to classic productivity measures such as capital efficiency and cost reduction. Yellow cells relate to greenhouse gas (GHG) emissions, green cells relate to circular economy (CE) indicators and grey cells highlight additionally interesting clusters.

The most frequent indicators used throughout the pitchdecks are *CO2 emissions* (t) (18 counts; 22%), *energy efficiency* (13 counts; 16%), *costs* (£) and *amount of waste produced* (kg) (both 6; 7%), *carbon foot*print and *degree of circularity* (both 5; 6%), *capital efficiency* (4; 5%) and *material usage* (t), *miles per drive* (effective battery reach) and *allocation to SDGs* (all with 3; 4%). The distribution of indicators is related to the sector characteristics. However, a notable focus on CO2 emissions might indicate a profound oversight of the wider GHG reduction potential that is however required for a net zero transition. CO2 is one of six GHG emissions, yet only two companies reported NOx emissions (t) in relation to CO2 emissions (t), with one mentioning methane.

While multiple indicators are used (in total 44 indicators were extracted), only a few seem to be relevant throughout multiple sectors. No indicator was used in all sectors. This might suggest that indicators are indeed highly sector, industry and perhaps even company specific and provide grounds for the need for in-depth studies of industry and company specific indicator sets. This is currently advocated by research where a plethora of studies develop indicators and metrics for specific industries. Interestingly, indicators related to the circular economy (highlighted in green) such as *waste* (kg) and *degree of circularity* (%) are mostly used by companies operating in energy efficiency (a finding supported by key informant interviews). For example, a company addressing this develops robotics and AI to make manufacturing smarter and ultimately more efficient in material use and output. This suggests that indicates circular economy (CE) thinking has progressed beyond its traditional *waste recycling* boarders. Lastly, the use of the indicator waste (kg) was observed in a waste management sector company where the focus is not circularity but instead on the emission of harmful chemicals (this indicator was also observed).

Notably most *energy efficiency* companies mention that to achieve the transition towards a net zero economy, the purpose of their product has to be reconsidered and a change in demand would be required – hence a focus on CE with the degree of circularity being essential to them. However, implementation of CE indicators is shown to be difficult – both in practice and in literature. Often CE indicators (e.g. degree of circularity) only capture the effects of the circularity, but not the actual degree of it (Corona et al., 2019). So, for example, is an increase in recycled plastic a good indicator of a rising degree of circularity, when contextually it would be crucial to evaluate the overall recyclability of the product compared to other materials? The overall environmental impact of plastic might still be worse than for other materials, yet often, due to the missing context indicators, this is not captured in the reporting. Sustainability-related indicators were disclosed in three sectors (not in waste management, where there were few cases), but only included *CO2 emissions* (t) and energy efficiency (%). Companies that use these indicators appear as strong proponents of the UK's net zero goal. A focus on CO2 emissions and the efficiency of current approaches (e.g. for cooling or power distribution) is presented as the best approach to tackle this problem, and where the two indicators mentioned are best suited to capture their intention.

The relatively high frequency of the use of the indicator *CO2 emissions* (t) in the sector clean energy use (10 out of 18 recorded) relates to the high incidence of transport sector activity. By proposing alternative forms of transportation (e.g. use of e-bikes, electronic vehicles for food delivery, more charging options for electronic vehicles) these companies aim to contribute to the UK net zero goal. Similarly, this applies for the indicator *energy efficiency* (%). Most companies are allocated to the sector energy efficiency and are aiming to develop solutions that support the net zero goal. The point highlighted by Rodriguez et al. (2020) – that efficiency and intensity indicators are used equivalently and potentially incorrectly – might be supported by the above observation. While governments urge companies to report CO2 emissions (t), because it allows them to set clear political targets that aim to reduce emissions, the applicability of these can be questioned with regards to whether they denote an overall impact driven reduction. Similarly, the companies in our dataset use the indicator *energy efficiency* as a measure that captures energy savings. Again, savings are potentially easily determinable a-priori, but in order to capture the actual impact a more fine-grained approach would be needed – beyond simply accounting for the peculiarities of different industries[4]. Furthermore, the study of Haffar and Searcy (2018) indicates that the broader context is often not incorporated in contemporary indicators – despite their importance for capturing spillover effects. The indicators we observe throughout the pitchdecks are primarly self-referential and thus potentially exacerbate the issue of context specificity and other external factors.

Another indicator that is used in three of four sectors is *capital efficiency*. Although only 4% of the companies refer to this, it is noteworthy in that it adds to the productivity paradigm prevailing in the seed financing sector. As outlined above, most companies already refrain or are held back from measuring actual relative impact, due to a lack of considered externalities and spillover effects. The frequency of capital related indicators further supports the focus on standard productivity measures – a trend that is potentially fostered by the investors. The greater relevance of costs as a regular productivity measurement in the sectors *clean energy use* and *energy efficiency* potentially points at the increased interest in ability to demonstrate both energy and economic efficiency. According to literature (Du & Li, 2019) the simultaneous consideration of these two is also what drives a low carbon economy. However, as noted above, this might come with "strings attached", which hamper the measurement of the actual impact.

Only three companies make reference the UN Sustainable Development Goals (SDGs). Two were in the energy efficiency sector and focus on technology solutions for either energy project investments or smart manufacturing, the other company operates in the food industry relating to clean energy use. Despite the environmental focus of all companies, the SDGs as a strategic connection tool, that can act as what Future Fit Business describes as something like a Pursuit goal seems to be absent. Both practice and literature show a great disparity between the strategic implementation and the operational measurement of environmental impact (Adams & Frost, 2008; Cai & Li, 2018; De Mendonca & Zhou, 2019; Dias-Sardinha & Reijnders, 2001; Johnston & Smith, 2001). One factor could be that often companies do not fully disclose their strategic goals when it comes to sustainability aspirations and hence reject indicators that are aimed to capture the impact of these aspirations as an add on to the classic productivity focused indicators.

To corroborate the above, environmental indicator selection and use is problematic for SMEs – in particular cleantechs. Indicators are used to support the value proposition of a company and thus are especially crucial. While many companies highlight their overall goal of contributing to

[4] Points addressed later by Future-Fit Business and Cranetool

the net zero target of the UK, they appear to struggle to put this into numbers. Given our analysis, this might be due to the following:

- Lack of strategic sustainability goals (i.e. even SDGs and subgoals are rarely mentioned), hence investors might struggle to truly relate and subsequently assess the progress towards these goals.
- GHG emissions are mostly approached from a reductionist CO_2 perspective and only a few companies take NO_x emissions or other GHGs into account.
- Indicators mostly capture intensity (both CO_2 emission and costs)
- Relative indicators do not use the appropriate baseline. Energy efficiency for example is used to express a relative number compared to the prior version of the product or the customer who uses the product. Similarly, CE indicators such as the degree of circularity often only express an amount of circularity but not the relative change that has been induced by that.
- The limited and relatively simple use of environmental metrics may well stem from a lack of demand and understanding of the value of appropriate metrics from early stage impact investors and a lack of knowledge by SMEs and investors as to where to go for contextual industry benchmarking data (explored in next section).

Primary Data Sources

Key Primary Data Findings:

- Early stage innovative cleantechs and their impact investors are primarily focused on progression of TRLs and IP, rather than productivity. They primarily view productivity as occurring through potential future environmental efficiency impacts on customers.
- Financial return is the prime motivation of investors and there is little evidence of consideration for environmental trade-offs
- Establishing the cleantech value proposition is crucial to the investment decision. Environmental metrics can help establish market position and support financial forecasting, therefore reducing the information asymmetries (IAs)
- UK cleantech financing policy is unevenly adopting environmental impact measures across departments and funding agencies. It is preoccupied with CO_2 reduction and energy efficiency, with little consideration of CE and supply chain impacts
- More sophisticated impact investor approaches (e.g. scorecards) are being developed by later stage private investors and public-private co-financed schemes, influenced by corporate and institutional investors reporting requirements.

Key Informant Interviews

Introduction

A total of 42 key informants were interviewed (by telephone or online video link) to provide a breadth of contemporary knowledge about the early stage Cleantech SME innovation finance market in the UK. Interviews typically took one hour and used a standard topic guide template to discuss key research themes (lines of questioning) in a consistent manner, whilst enabling deeper exploration into the aspects of the market that informants could offer most experiential insights. All interviews were transcribed and then content analysed by at least two researchers in order to avoid individual researcher interpretive bias. Key themes related to: (i) respondent's background and relevant experience in the Cleantech market; (ii) understanding of the problems in measuring early stage Cleantech innovation progression in terms of productivity; (iii) understanding of how early stage Cleantech innovation SMEs are selected for investment and the value of environmental impact metrics in this process; (iv) consideration of how the progression of early stage cleantech innovation SMEs in investor portfolios can be evaluated in terms of environmental impact. Additionally, the key informants were invited to provide snowballing links and introductions to relevant reports, investment and evaluation frameworks and other key informants in the UK market.

Table 8: Key Informant Interviews

Informant type	No.	Description (examples)
Cleantech Market Support	9	Business support re innovation (St Johns Innovation Centre, Oxford Innovation), Cleantech (Cambridge Cleantech, Low Carbon Trust, Future Fit Business, Local enterprise Partnership (North East), Impact Management Programme), accountancy companies (KPMG) and finance finders (Greenbackers), academic knowledge transfer (Lancaster University)
Private Impact Investors	16	Business angels and angel/equity networks (Green Angel Syndicate, Mylor Ventures), VC (British Venture Capital Association, EFT Capital, Midven, Hermes, Zero Carbon Fund Venture Capital Trust), Accelerators (Bethnal Green Ventures), impact banking and institutional investing (Clearly So), Abundance equity Crowdfunding
Public Impact Investors & Policymakers	9	Policy makers (UK Department for Business Energy & Industrial Strategy, Department for the Environment Food and Rural Affairs, Innovate UK), public supported specialist funds (Clean Growth, Low Carbon Investment Fund, Investment Accelerator Pilot, Cambridge Enterprise Seed Fund)
Market Analysts	8	Private data (Beauhurst, Pitchbook), private (Angel News) and academic market experts (Professors Mason, Glasgow University, Unerman and Davies, Lancaster Management School; Centre for Eco-Innovation Lancaster University)
Total	42	

The objective was to provide deep collective insight into the most useful approaches and metrics to support early innovation stage environmental impact investing in the UK context. Such insight could help to overcome the stakeholder triple nexus (STN) of information asymmetry which currently undermines market operations and the effectiveness of public policy interventions to address private market funding gaps.

The key informants are broadly categorized in Table 8 as:

Cleantech market support providers. These include business support agencies for innovation (e.g. St John's Innovation Centre technology innovation incubator in Cambridge and Oxford Innovation) and specialist cleantech SME support (e.g. Cambridge Cleantech's membership networking organization linking universities, private R&D cleantech SMEs and investors globally). These organisations develop the UK Cleantech market by improving linkages between innovators and impact investors, including some development of environmental impact metrics. They include accountancy companies (e.g. KPMG) and specialist finance finder consultants (e.g. Greenbackers, consultancy for early stage and scale-up Cleantech SME investment readiness pitches and pitchdeck presentations to equity financiers). Universities also offer research and knowledge transfer related to cleantech (e.g. Lancaster University's ERDF Regional Entrepreneurship Accelerator Programme developing low carbon finance).

Private impact investors. We focus on the early stage SME innovation environmental impact investing market. Progressing along the cleantech innovation investment escalator, this includes: (i) accelerators (e.g. Bethnal Green Ventures, which since 2012 has provided initial seed investment - typically £50k for 10% ownership - to 20 environmental, health and social purpose enterprises annually; (ii) business angels and their network groups (e.g. London's Green Angel Syndicate (GAS) and Cornwall's Mylor Ventures which bring together cleantech angel syndicated investments); (iii) seed to Series A venture capital (e.g. EFT Partners (London), ET Capital (Cambridge), Midven Ltd (Birmingham) and Zero Capital Partners Enterprise Investment Scheme backed Venture Capital Trust (VCT)[5] which operate specialist cleantech funds); (iv) crowdfunding has since 2011 become an established early stage equity investment source (e.g. Crowdcube, Seedrs and SyndicateRoom platforms) and we included Abundance (a specialist impact investing platform); later stage VC and institutional impact investors (e.g. Hermes and Clearly So impact investment bank) also provide perspective, as they influence their underlying (seed VC) investment funds.

Public investors and policymakers. We interviewed key strategic UK government departments and agencies, including: Department for Energy and Industrial Strategy's oversight of Cleantech finance programmes (e.g. Energy Entrepreneurs Fund grants and Clean Growth Fund public-private co-finance Series A VC fund); Department for Environment and Rural Affairs (DEFRA) circular economy team; Innovate UK (IUK) grant funding for cleantech innovation (notably Investment Accelerator Pilot (IAP), established in 2017 offering £150k seed proof of concept and early pilot matching grant and seed VC); specialist public supported regional and university funds for early stage Cleantech innovation financing (e.g. ERDF funded East of England Low Carbon Innovation Fund (LCIF) at University of East Anglia and Cambridge Enterprise Seed Fund for Cambridge University spin-out companies). British Business Bank programmes, which are sector agnostic (with the exception of the fully invested UK Innovation Investment Fund) were not included.

Market analysts and experts. These include the two main data providers for the UK early stage Cleantech investment market, Beauhurst and Pitchbook, private sector expertise (Angel News seed investing market intelligence) and academic insight (Professors: Mason re angel seed market; Unerman and Davies re sustainable accounting; Lancaster University Centre for Gobal Eco-Innovation).

Productivity and Early Stage Cleantech SME Innovation

> "[classic] productivity is such a small part of their mission, they have so many other things to worry about."

Early stage Cleantech investing market actors agree that productivity is not a major priority or consideration. Measuring company progress is far more important, as described by one VC described; "*Productivity is such a small part of their mission, they have so many other things to worry about*." It was further explained that Cleantechs that they invest in might consider how their innovations will make other businesses (their clients) more productive and efficient, but they will not be thinking about their own productivity as such. Another VC stated they were "…*not a fan of productivity, it is not clear how it should be measured for pre and early revenue companies."* Furthermore, the earliest stage investors (e.g. accelerators and business angels) have little consideration for standard productivity measures such as employment and turnover ratios (supporting views expressed in Owen et al. (2019a).

The primary problem for productivity measurement is that for early stage innovators revenue from established market traction could be many years away. The director of an accelerator

[5] VCTs operate under the UK government backed Enterprise Investment Scheme (EIS) as umbrella funds for private investors benefiting from Capital Gains Tax benefits.

specialising in first-in seed investment for environmental, health and social sector sustainable digital technology start-ups suggested it could take over 10 years for their investee companies to establish themselves in the market. This could be the case for the highly competitive business to consumer (B2C) market, a view supported by an angel investor who had invested in a sustainable product selling B2C internet-based platform. The long horizon nature of Cleantech investment was also noted by business angel networks and syndicates and VCs that fund at later innovation stages after accelerators. They frequently mentioned periods of 5-7 years for their investments to reach exit, despite exits often occurring after Series A early commercialisation funding, and prior to full commercialisation.

There were mixed views on the impact of the Covid-19 pandemic. Some investors and analysts stated it was causing delays to planned 2020 funding rounds. Uncertainties about the length and nature of the post Covid-19 cleantech investment market recovery led to concerns this could create lengthening timescales to investment exits and commercialisation – perhaps resulting in the circa 2-year investment exit extensions experienced after the Global Financial Crisis (Owen, Mac an Bhaird, & North, 2019b). However, one VC fund manager mentioned that "*the last 18 months have seen increasing interest in Cleantech investing, due perhaps to our resilience in surviving the GFC cleantech crisis, but also to increasing awareness of the rapid need for action and this is highlighted by large corporate companies providing leadership examples - like Robert Bosch declaring net zero goals."* Also, other cleantech investors mentioned that Covid-19 had further raised attention to the need for investment in the environment and health.

All of the impact investors noted that the types of viable potential high growth early stage Cleantech that they would invest in had to demonstrate uniqueness and additionality to their proposed markets. This was best expressed by a typically later stage VC investment fund manager:

"Companies must have a unique emerging market, clearly demonstrate their customer needs and the problems that they are solving. The most successful entrepreneurs plan to minimize risk. Early stage companies need to understand the problems they are solving. Too often we see unrealistic go to market strategies. They need to show they understand the customer."
Progression metrics were preferred to *productivity metrics* for the early stage impact investors. For business angels, the selection of investee companies with founding teams that they can work with and enhance their management – what is commonly referred to as '*skin in the game'* – is crucial to investment decision. For seed VC fund managers there is also a keen desire to influence management practices through board participation and ability to recruit key non-executive directors (NEDs) to assist business management practices (e.g. financial and market expertise) and progression. For all of these impact investors the ability to work with and influence management decisions and development is allied to the need for management teams to be '*milestone oriented'*. Given the often fragmented and multi-staged financing requirements of Cleantech innovators, it is crucial to demonstrate meeting progression goals (e.g. intellectual property (IP) security status, technology readiness levels) to generate what several VC fund managers described as "…*sufficient data to give confidence for further investment*."

Technology Readiness Levels (TRLs) were established by NASA in the 1970s to assess the state of readiness of technology platforms for deployment (NDA, 2014). Subsequently, government programmes adopted TRLs to assess innovative SME development. Innovate UK use TRLs to assess the progress of its grant and co-financed portfolio businesses. TRLs provide an ordinal 9-point scale progression where 1-3 relate to development of proof of concept, 4-6 relate to development through lab to scaling up of pilots and prototypes, 7-9 represent deployment ranging from initial market preparation and testing through to full commercial operation.

Running in parallel to TRL progression is IP protection, which is viewed by impact investors as an important factor in the decision to invest. Mylor Ventures angel investment network in the South West of England provides investment readiness support and a toolkit (Mylor Ventures, 2020) highlighting the importance of the business value proposition and its market protection. Their key informant suggested it is crucial to demonstrate to investors that the business commands a niche market role with potential customers and it is also important that IP protection is in place - in the form of patents and copyrights - or being progressed in order to protect the company's market position.

Mylor Ventures and several VC respondents also point to the significant barriers that regulations present in slowing down progression to the market and successful investment exit. Thus, IP protection is critical alongside requirement for favourable market sentiment and a supportive regulatory environment. "*Even when the innovation's TRL data stack up, investors have to consider the regulatory barriers which founders often underestimate*." This was supported by the seed VCs impressing that the chances for company success in the highly technical and regulatory sectors inhabited by Cleantechs remain low, perhaps '*only 10-15%*' even at the Series A early commercialization stage.

An example was given of an innovative domestic hot water savings device (Showersave, 2020) that will halve home heating energy use and costs and offers the same application at 80% less cost than comparable roof solar panels. However, the take up of the product is very slow. This is because there is no incentive for housebuilders to use the system and for merchants and traders to sell and install this. They are concerned with maximising their profits, rather than selling and installing the most beneficial green products. It was also noted that there has been no 'eco brand' housebuilder yet. As much as anything this situation in the UK is perceived to be due to the lack of support from UK building regulations and the way that they set their standards and calculations for energy efficiency.

In conclusion, the only productivity measures considered are likely to be the potential productivity improvement that cleantech innovations might make on their future client businesses or domestic consumers, such as energy efficiency savings and costs savings that might increase revenues and margins, or reduce labour costs. A typical recurring example is the use of aerial drones and remote cameras for inspection and AI analysis in industries and farming (highlighted by Energy UK (2019)). This reduces labour input and increases efficiencies in maintenance to reduce waste, polluting emissions and increase production, such as farming yields. This is clearly important to policymakers who are interested in the spillover/multiplier economic efficiency impacts of investments, but also to investors who are interested in establishing the value proposition of potential investments. However, from the perspective of the impact investors and their portfolio companies a far more important measure often appears to be the speed of the innovation and company progression, allied to IP protection and market primacy.

Selection of Cleantech Investments

> "Is the positive [environmental] impact intrinsic to the business? We want to invest in the value of the company – businesses that can demonstrate this."

Private investor approaches

Fundamentally, all of the private impact investors interviewed stated that they invest in the cleantech market to make a difference, but that their primary investment selection goal is to maximise returns for themselves and their investors (in the case of VCs). Thus, their "…*approaches to selection are the same as for any other early stage innovation investments*."

Key selection criteria are therefore typical of other early stage investor studies (Mason & Stark, 2004). They relate to the value proposition of the company, what problem it is solving, understanding the customers and market, innovation niche, intellectual property (IP) protection, market potential and venture scalability, qualities of the management team, technical and regulatory issues, capital intensity and exit timetable for the investment. Generally, lower capital intensity and more rapid market scalability and exit are preferred, but with the knowledge that cleantech is often a longer horizon investment. So, whilst cleantech is a desirable sector preference for these investors who want to address climate change, it is typically only an initial broad selection criterion, with traditional investment selection criteria carrying most weight in the selection process.

There is widespread agreement amongst all key informants that"We need new solutions. If we want to see [climate] change, we therefore need to measure it, promote it and ultimately to invest in it – to encourage further innovation." Patrick Sheehan (EFT Partners fund manager).

For all private impact investor key informants, at all stages of innovation investment, the first consideration is whether the potential investment will make a difference and have social and environmental impact. With regard to climate change for some, notably earlier stage investors, this requires a notional signal that the proposal has low carbon (GHG) reduction aims. Few early stage investors considered the circular economy (CE). Notable exceptions include 2 women respondents, an impact accelerator manager and an angel investor. The latter stated; "*My overriding investment aim is to invest in changing consumer behaviours and attitudes. I am most interested in sustainable change and circular economy impact*."

For the Green Angel Syndicate (GAS) of impact investing business angels, who typically invest early – following on from accelerator and initial founding investor rounds, there are numerous difficulties in measuring impact across different investment sectors of cleantech. A cleantech VC elaborated, "*it is difficult to understand technologies and to compare their likely performance*." However, GAS point to one overriding measurement "…*the aggregate tonnes of greenhouse gas emissions that have been avoided thanks to the activity of all portfolio companies taken together – and, at the end of 2019, we estimate that this was approximately 5,200 tonnes of CO2e*." This is broadly in line with the widely-acknowledged 'carbon footprint' approach of the (Carbon Trust, 2018). GAS also mention that some of their environmental investment sectors in conservation and biodiversity do not readily offer low carbon data or wider GHG metrics[6], so a more nuanced approach is required. However, the initial decision to select the pitches that their syndicate will invest in comes down to whether the venture proposition will make a difference to the low carbon economy.

For London-based Bethnal Green Ventures, Europe's largest impact investing accelerator with over 100 investments over the past 8 years, the key selection question comes down to: *"Is the positive [environmental] impact intrinsic to the business? We want to invest in the value of the company – businesses that can demonstrate this."*

For other private investors such as specialist impact VC, which tend to fund later innovation stages (e.g. from Series A) a more sophisticated approach to the selection of investments may be required in order to satisfy their investors, such as institutions and Family Offices. One VC

[6] Carbon Trust (2018) recognizes 6 GHGs: CO2, N2O, CH4, PFCs, SF6, HFCs.

referred to the influence of foreign and institutional investors in their latest low carbon fund: "*China is fixated on compliance and greening their economy, so there is huge funding and rapidly increasing interest in cleantech there and also from international PE investors like Blackstone [$36bn in funds] and Capital Dynamics which invests local government pension funds."*

A leading VC example is ETF Partners 5 step scorecard. ETF are a Series A and later stage VC specialising in European Cleantech investment since 2006. They successfully invested in this emerging market through the GFC. Initially, they focused on CO2 reduction, estimating the potentially enormous CO2(t) saving of their portfolio. "*We produced truly heroic figures which were frankly ridiculous, since not all of the companies would reach full global impact."* They now start with UN Sustainable Development Goals (SDGs), following the approach of corporate governance, whilst acknowledging that such approaches (developing on environmental and social governance) are about large corporate business compliance. SDGs act as an initial '*sense check'* from which ETF Partners have developed a customized scorecard approach to guide both the initial selection and ongoing evaluation of their portfolio of small and innovative cleantech companies. The further parts of the scorecard enable flexible and relevant key performance indicator (KPI) adoption for different sectoral innovations and the benchmarking of environmental impact progress over time (mirroring Lee Iacocca's famous adoption of regular management performance indicators at Ford over 50 years ago). This appears to be a very practical early investing approach, broadly representing a simplification of the Impact Investment Project (Impact Frontiers, 2020, p.29) scorecard impact ratings and financial risk-return metrics.

Case Example: ETF Partners VC 5 Step Environmental Scorecard

- Step 1: does the company align with UN SDGs and ETF's focus on cleantech to assist smart cities, smart industry or smart energy
- Step 2: Environmental impact potential of prospective investments must be significant for ETF to invest. Whether measuring KW of energy savings, or tons of materials recycled, the numbers must be meaningful. Different businesses have different impact potential and achieving it will depend upon a number of factors, including management's ability to execute on the business plan.
- Step 3: Target companies that are solving environmental issues in unique, new innovative ways.
- Step 4: Use impact KPIs which are tangible and business-specific. E.g. m3 of water savings for water savings product innovations. Look at recent growth of the selected impact KPI. ETF encourage portfolio company boards to review KPI impact performance regularly alongside other business performance indicators
- Step 5: Financial maturity. Typical investment businesses are in revenue and this is tracked.

A VC investor has recently adopted using the new US Cranetool7 to promote catalytic capital into early stage innovative businesses. It targets globally scalable new technologies and currently contains circa 200 templates to enable businesses to assess the potential low carbon impacts of their technologies; covering buildings, manufacturing, agriculture, transportation, electricity and carbon dioxide removal technologies. The investor stated it requires a lot of assumptions, but is rigourous and the only tool that allows them to compare low carbon investment propositions. For example, a cleantech's batteries charging speed can be checked and calculated for potential impacts on adoption and emissions.

[7] Cranetool (https://cranetool.org/) recently developed in the US by Prime Coalition, Clean Energy Trust etc.

Public sector approaches

Public sector backed investors present a different picture. Their emphasis is the policy logic model of the intervention; who or what is targeted, the suitability of the delivery mechanism and how best to measure outputs and outcomes. There is clearly growing interest and adoption of environmental impact measurement for climate change related programmes (i.e. BEIS, IUK), but less so for the '*sector agnostic'* innovation and potential high growth SME funding programmes operated by the British Business Bank (e.g. Enterprise Capital Funds, Angel Co-Funds[8]) and Covid-19 Future Funds.

Government climate change funds extend this approach to the selection of suitable early stage VCs to co-finance. For example, the IUK Investment Accelerator Pilot (IAP) which initially offered small-scale early seed financing rounds of matched grant and VC funding (up to £150k) and £20m BEIS private co-financed Clean Growth Fund, assessed applicant VCs based on their cleantech and early stage investing experience. Notably, whilst these programmes expect the private VCs to make money, there is concern that they can demonstrate their commitment to stay on mission, undertake due diligence, offer competitive market priced services and provide hands on assistance to support the management of the portfolio ventures. It is evident that government is concerned with developing the expertise of the early cleantech investing market - seed VCs and potentially regional angel networks through for example the development of the IUK Investment Accelerator Pilot - as well as the companies that can create jobs and revenue to the economy and low carbon environmental impacts.

The Low Carbon Investment Fund (LCIF), based at the University of East Anglia was established in 2010 with ERDF investment (£20.5m) as a £70m public-private co-financed early stage cleantech innovation fund for the East of England region. Notably, when the fund first started, it was not required to capture environmental impact metrics. However, the fund managers recognised the need for this.

"We wanted to establish baseline green metrics to help select business investments. This was finally refined in 2016 - although it is an ongoing process with each case. It is also now a requirement for the further [£22m] ERDF funding round received in 2019. For businesses that come to us with a product or service innovation the question is whether they will make a change to the current baseline of low carbon? We look at each case individually and try to assess what the greenhouse gas emissions currently are and then how much of a change the new product or service will make. Once we establish the degree of change, we can then assess the change in terms of reduction per unit and come to an indicator of absolute change according to forecast business performance. So, for example, if company A produces a widget that reduces the GHGs by 50% per unit, they can multiply the number of widgets per year and get an annual amount of savings change. The principle is simple, but the reality is more complex because each business is different and is assessed case by case."

For BEIS and ERDF the fundamental cleantech impact metric for selection and ongoing evaluation is *tCO2e* (tonnes of CO2 emissions reduction) abatement, based on the benchmark of current operating norms in the market. This can apply to energy efficiencies and also to transitions to increased renewable energy use. Changes can be monetized through carbon pricing (according to a nominal value for *tCO2* for a given time period. This principle can be extended to all GHGs, although CO2 is most often referenced. Extending a policy evaluation approach to public sector impact investing, there are also concerns over the funding attribution and leveraging of additional private funding into projects.

The new Clean Growth Fund will also consider wider production and CE metrics, whilst for LCIF shortening of supply chains is a consideration – "*An increasingly valid factor in a post-Covid,*

[8] Note: ERDF funding requirements for Regional Investment Funds recently adopted some environmental metrics

post Brexit- build back better UK economy." The Clean Growth Fund is taking into consideration; reduction in the costs of energy, processes, GHGs as well as energy efficiency, conversion efficiency and other factors such as production site environmental impacts and circular economy impacts over at least a five-year period. Key production metrics relate to unit cost and price by volume over time (5 years). This reflects policy concerns about innovations potentially having efficiency cost savings that can make clean growth possible. However, this is recognized as insufficient without consideration for GHG reductions per unit and embedded CO2 reduction in the product and process in order to obtain *tCO2e* in relation to expected volumes and timescales for the innovation. Investment selection will also consider circular economy factors (although the nature of product recycling, modularity and potential repurposing are not detailed). Furthermore, whilst regulatory factors are considered, there is no mention specifically about supply chains and wider spillover factors for the UK green economy[9].

Evaluation of Cleantech Investments

> *Who* are beneficiaries, *where* is the impact made,
> *why* is it achieved, and *how* is it achieved?

To a large extent the evaluation procedures presented are a longitudinal continuation of the selection techniques and their degree of sophistication and design are related to the institutional logics of the type of organisation (as noted above). Additionally, there is the role of support agencies concerned with improving SME environmental approaches and investor understanding of environmental impact metrics.

Seven notable evaluation approaches were reported. Three from public investors and policymakers (BEIS Clean Growth Fund, Innovate UK, ERDF Low Carbon Investment Fund), one from a market support agency (Future-Fit) and three from private impact investors (ETF Partners, Zero Carbon Capital, ClearlySo). Each approach is different, suggesting that a coherent market standard to continuously assess the green impact of cleantechs is needed.

The most comprehensive approach to assess environmental impact is laid out by Future-Fit Business (2020). This organisation addresses the disconnect between Cleantechs, impact investors and support agencies, developing frameworks and free web-based assistance tools. They introduce clear strategic goals to tackle particular problems, connect them to relevant SDGs and present various progress and context indicators in order to measure the progress and impact. They, like the SASB Materiality Map, recognise sectoral nuances and are currently developing customised impact metrics suitable for SMEs.

As presented, ETF Partners (a later stage private VC investor) follows a five-step approach, where besides the relevant SDGs and environmental impact potential (including some core indicators) the financial performance is also taken into consideration. Similarly, the approaches from Public Investors include the important financial aspect. Public investors appear more concerned with Balanced Scorecard methodologies, to provide clear timeframes for investments (often 5 years[10]) and some selected key indicators that each project should be assessed for (e.g. BEIS Clean Growth Fund), or the layout and structure of a risk assessment approach, where the impact score is calculated by multiplying a magnitude and likelihood score. Such qualitative approaches are intended to complement the lack of quantitative data for relevant

[9] It should be noted that these were selection and evaluation metrics at a formative stage for this new fund

[10] Five years, whilst not representing the average time to market for Cleantech possibly represents the maximum practical term that policymakers can present, given the current fixed term period of UK Government.

impact indicators such as carbon emissions and energy expenditure. They provide a clearly elaborated set of nine indicators that companies should be reporting on. Besides financial information these include TRL, reduced unit cost of energy, increase in energy efficiency/reduction in energy demand, reduction in energy expenditure, reduction in carbon emissions.

Apart from the complexity of ecological impact metrics, little consensus exists about impact potential. Investors may seek to evaluate for example overall emissions reduction potential and progress of a company. ClearlySo, a major impact market supporter and investor based in London, mention this as the major issue in most companies and support them in communicating their impact potential and also brief investors to look at impact potential. They follow the four questions introduced by Big Society Capital: *Who* are beneficiaries, w*here* is the impact made, *why* is it achieved, and *how* is it achieved. These questions act as initial guideline and evaluation tool and potentially indicate where more information or action is required.

Recently the Prime Coalition, the Clean Energy Trust and other research groups developed the Crane Tool in the US. The aim is to promote capital into early stage innovative businesses, by allowing these businesses to assess the potential (low) carbon impacts of technologies. Zero Capital investors use this tool already and believe it holds great future potential. The interviewee also highlights the strong separation between impact and productivity metrics. In her view, an interesting and meaningful way to combine the two perspectives would be via a Balanced Scorecard Type tool.

Summary

In summary, Table 9 presents the key indicators provided by the key informants. Although a wide range of metrics are presented, they are mainly derived from public sector considerations for demonstrating innovation progression and wider economic impacts in relation to efficiencies and competitiveness (e.g. in reducing costs) and private sector investors' concerns with a wide range of sector specific investments. There is a focus across all key informant types on CO2 emissions rather than other GHGs and relatively little consideration for measuring net change impacts which account for timelines, circular economy and wider environmental spillovers, such as more efficient and shorter supply chains.

Table 9: Key Evaluation Indicators Observed from Key Informants

Indicator and Informant Type	Scale	No. responses
Private - Business Angels		
CO2 emissions (reduction)	t	2
Carbon intensity	%	1
Reduction of (heating) cost	£	1
Recycling	Energy per kg	1
Capital efficiency	%	1
Private - Venture Capitalists		
CO2 equivalent saved	%	1
Energy savings	Mw, %	2
Raw carbon material impact	%	1
Food waste	t	1
Low carbon actions (shared trips, recycled units, drone flights, smart metres installed)	No.	1
Water savings	M3	1
Private - Institutional		
Carbon emissions (scope 1, 2 and 3)	t	1
Working conditions		1
Public Investors and Policy		
CO2 emissions degree of change	% / qualitatively	4
GHG emissions degree of change	%	2

Carbon footprint	tCO2e	1
Energy efficiency (increase)		3
Cost of process reduction	£	1
Conversion efficiency	%	1
TRL (position and progression)	Scale point	1
Reduction of cost of energy	Per unit	1
Reduction of energy expenditure	Mt CO2	1
Market Support Agencies		
CO2 reduction	%	1
TRL	Scale point	1
SASB/IAS		1

Key issues relating to cleantech investment selection:

Regulations do not facilitate demand change and thus do not encourage producers to adapt for the environment's sake. Short term focus on product price holds back market adoption and potential stellar performers that could encourage more impact investment into the market.
Pre trading early stage businesses carry greater uncertainty. Potential market impact is problematic, often unrealistically inflated, undermining its value to investors and policymakers.
Unclear investment time horizon and funding progression requirements (VCs refer as *lack of data*) inevitably creates funding gaps along the finance escalator, leading to commonly referenced Series A investment shortfall, zombie cases, delayed commercialisation and premature trade sales – often to foreign companies with a resultant shortfall in returns to the UK economy (see Owen & Mason, 2019).
Cleantech definitional issues, due to the range of sectors covered in this umbrella term and many sector nuances and appropriate metrics – some not conform to orthodox GHG metrics.

Key issues relating to environmental indicators and ongoing impact evaluation:

Crucially, the environmental impact of the venture has to make a demonstrable difference. This has to be presented using the most appropriate metrics, working from a standard baseline (e.g. national average) and taking into account the market size and scale over time.

- More holistic calculations are required to account for the net impact of the business in terms of carbon inputs (into products and services) and their CE impacts over time.
- GHG is often reduced to carbon emissions only and hence misses the potential of five other emissions (Carbon Trust, 2018).
- There are intensity and efficiency measures which are easily conflated and do not determine the net overall efficiency (Rodriguez et al., 2020).
- Benchmarking is crucial. Progress indicators are used for initial selection and ongoing impact evaluation. These need to be appropriately contexted, but such indicators are far less often cited (Corona et al., 2019; Future Fit Foundation, 2020b). This considerably dilutes impact assessment.
- SDGs are rarely used as a strategic element. They would enable investors to connect to issues and indicate more than just energy efficiency or clean energy use (Future Fit Foundation, 2020b).
- Public investors comply with national standards which can lead to very narrow reporting and demotivation to include green indicators (e.g. BBB studies note green indicators do not apply).

Online Impact Investor Survey

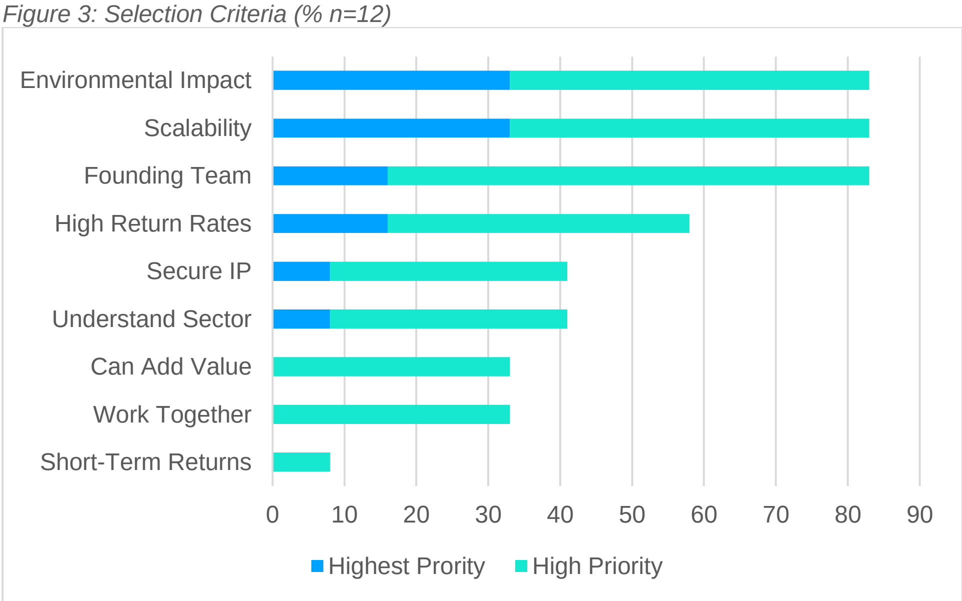
An online private impact investor survey was undertaken with key informants and their Gatekeeper organisations in May-June 2020. The survey was targeted at existing Cleantech impact investors to test their selection and evaluation considerations for portfolio companies. A caveat is that only 12 valid responses were recorded. Respondents are characterized as male (one woman respondent), middle aged (92% aged between 30-67), located in London, South

East or East of England (67%) and experienced Cleantech investors; 92% have invested for more than 3 years and 58% have invested over £100k in the last five years into Cleantech.

Almost all respondents were business angels (92%), with one VC fund manager also responding. All are involved in early stage investing, with angels often as first or second (e.g. after an accelerator) post founder investor. It is notable that angels invest in various ways (5 invested individually, 3 invested through crowdfunding platforms and 10 invest through an angel network and syndicate. The energy sector was predominant amongst their investments in the last 5 years (92%), followed by recycling (67%), digital cleantech and advanced manufacturing/engineering (both 58%), transport (42%) and construction (25%). Expected exit timetables were typically long, 58% forecast between 6-9 years.

Investment selection criteria (Figure 3) are strongly led by environmental impact and the scalability of the investment venture. Perhaps surprisingly, these rank above human capital (about the same as founding team quality, but well above working together with the management team). From our key informant interviews this reflects the key investor concerns with investing in companies that will make a difference to low carbon, as well as provide decent returns on investment. This is underscored by the importance of the founding team's ability to deliver high investment returns (albeit over a long investment horizon). The finding that environmental impact is the highest priority whilst short term returns are least prioritized demonstrates the investors commitment to impactful Cleantech solutions.

Figure 3: Selection Criteria (% n=12)

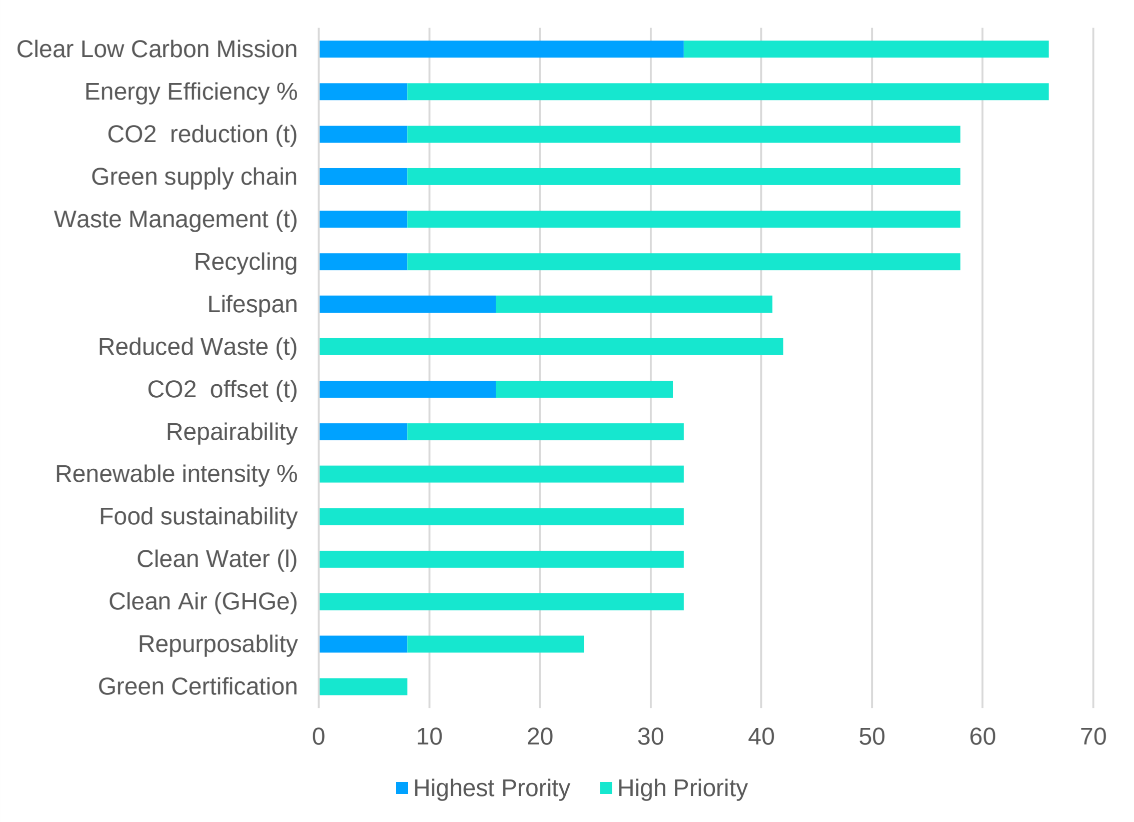


Investors had very little concept of productivity in relation to measuring the performance of their portfolio companies. Text responses suggested that this was "*Not really relevant at early stage*." Four respondents (33%) provided a productivity concept/measure which broadly related to commercial progression: "*Performance according to plan*", "*Efficiency of scalability*" and "*Early evidence of revenue*." Only one respondent provided an environmental metric: "*CO2 impact per person, per time, per money.*" This was an experienced GAS investor who appeared highly committed to impact investing.

It is clear from key informant interviews with early stage impact investors that overriding concerns for portfolio investments typically relate to their progression rather than specific productivity measures, although scalability and revenue are critical. Progression towards environmental impacts was also highly desired, but investors and early stage ventures struggled to suggest how this should be evaluated.

When presented with the main environmental impact metrics offered by current literature, respondents indicated (Figure 4) having a clear low carbon mission was most important (33% stating highest priority, plus 33% stating a high priority). Regarding specific measures, energy efficiency (% change), CO2 reduction (tons) and waste management process reduction (tons) were more frequently mentioned. Notably, CE measures relating to recycling (%), increased product/service lifespan, and reduced waste (tons) were mentioned as at least high priorities for more than two fifths of respondents. There was little recognition for formal green certification.

Figure 4: Priority of Evaluation Metric (% n=12)



There were mixed feelings about the impacts of Covid-19 on the respondents' impact investing over the next year. Half indicated that it would most likely reduce their investment, with one quarter suggesting this was a strong possibility. They pointed to the increased risks of the market, which would impact on company progression and reduced investment capability "*My available capital for all investment has been reduced by the fall in global markets. I expect a slow recovery and will not be investing until I'm satisfied the economic recovery is robust." However, for others (perhaps with more secure personal funding) there is awareness that Cleantech is a long-run investment and also optimism that: "There may be companies which are doing better because of CV19 (more demand, more people aware of their product, etc.) …. regardless of CV19 I will support those which are making a real environmental difference."*

In summary, whilst few impact investors consider productivity they are concerned with environmental impact, both at the selection process and also in the ongoing evaluation of their portfolio companies. There is definitely a desire for environmental impact metrics amongst early stage angel investors and some strong indications with regard to CO2, energy efficiency and waste management. Encouragingly, there is also a desire for broader environmental impact CE and supply chain metrics (a caveat is that the low response rate does not offer sectoral nuance to these findings).

Case Studies

Overview

Nine case studies of UK early stage innovation Cleantechs were undertaken. These were purposively selected to offer a range of equity investment seeking ventures in different sectors across different early innovation investment stages. The aim was to provide insights into external financing issues, the role of environmental impact metrics in this process and to develop working case examples to assist development of toolkit support for practitioners and policymakers. The case studies involved online semi-structured interviews with CEOs following a standard topic guide profiling the business, the cleantech innovation, external finance experience and issues and the role and use of environmental impact metrics in external finance pitching and evaluation of business performance. Interviews typically took 1 hour and were triangulated with current investor interviews and company website information to test the provenance of responses (Creswell, 2003).

Table 10: Summary of Case Study Cleantechs

Case	Descriptor	Estab-lished	Category	Stage	Main funding Sources	Revenue Stage	TRL	Main funding issues
A	Transport App	2016	energy efficiency	pre Series A	Grant and private equity	Pre revenue	7/8	data insufficiencies and missing investor confidence
B	Online Retail	2016	waste management and recycling	Seed	private equity	Early revenue	7/8	data insufficiencies and varying investor requirements
C	P2P energy trading	2013	renewable generation	Series A	Grant and private equity	Early revenue	7/8	fund availability due to COVID
D	Green laundry	2017	clean energy use	Seed	private equity	Early revenue	7/8	duality of impact vs market innovation
E	Plastics recycling	2012	waste management and recycling	Series A	Grant and private equity	Pre revenue	7	different spatial investor foci
F	Alternative refrigerant	2003	clean energy use	Series A	Public/private co finance equity	Revenue	8	sector agnostic investors and communication problems
G	Battery storage for Evs	2017	energy efficiency	Seed	private equity	Pre revenue	6	duality of impact (specifically funding horizon) vs market innovation
H	Energy awareness via smart meters	2006	energy efficiency	Series A	Public/private co-finance equity	Revenue	9+	duality of impact (specifically funding horizon) vs market innovation
I	air purification system	2019	Energy efficiency	Seed	Seeking grant & private equity	Early revenue	8-9	lack of experience and communication problems, fund availability due to COVID

Tables 10 and 11 demonstrate that the case studies broadly represent the 4 MIT cleantech sector classifications and UK market data. The companies are mainly young, micro businesses established since 2016 and at early seed to Series A investment stages, with companies either in pre or early revenue. Two exceptions are longer horizon R&D SMEs in refrigeration and smart meter development which have established markets, but also have further opportunities to introduce new products and services. None of the businesses has undergone an exit, which is indicative for the long-term investment horizon of cleantechs.

Table 11: Cleantech Market Structure (Beauhurst market data)

Category	Sectors and Business Activities (examples)	Percentage
Clean energy use	• Marine and Farming practices • Smart City Logistics and EV infrastructure • Alternative cooling/heating systems	18%
Energy efficiency	• AI solutions for crop planting or construction; • IoT Home automation; • IoT Transportation Integration; • Online platforms for smarter product use • Electricity grid efficiency solutions	39%
Renewable generation	• Windfarms onshore and offshore, wave energy • Energy storage • PV panels and coating and support services	32%
Waste, recycling	• Cleaning products for commercial and private use • Water management • Plastic recycling	11%

The case studies have required considerable volumes of external investment, ranging from; £180k in grant and seed VC funding for early proofing of a transport efficiency app (to integrate public and private transport route planning), to £15m for large-scale commercialization of smart meters (including public co-funding from the LCIF). What is striking is the reliance on early and sometimes large-scale grant funding (BEIS, 2017; North, Baldock, & Ullah, 2013), with substantial grants of almost £2m received by a peer to peer energy trader (IUK grant) and plastic recycling company (BEIS Energy Entrepreneurs Fund). There is also a variety of private equity, including seed VC, accelerator, business angel and in some more developed cases corporate VC – which is frequently raised in syndication and over multiple rounds.

The cases reveal long and complex processes of funding (BEIS, 2017), often involving lengthy

> *"we probably wouldn't have done them [the environmental impact calculations] without assistance."*

fundraising search periods, with long-horizon timelines to investor exit (none has exited), and with several companies requiring further substantial Series A commercialisaton rounds – the most extreme case being £25m required by case E. Whilst some companies have hit the ground running, due in part to recruiting advisory board members with experienced serial entrepreneurs who are used to grant and equity applications, others have struggled. For example, the battery storage company took one year to raise grant and matched business angel equity of £200k for their initial seed round. Half of the CEOs mentioned that their current fundraising, notably for substantial Series A rounds, has been slowed down by Covid 19, although none suggested that this was a major concern.

Critically, the majority of CEOs indicate that appealing to cleantech investors is "*strange and challenging*", particularly at early stages of innovation. As case D's CEO explained; "*Impact investors are not experienced in the sector and there are issues explaining how service sector disruption works. We are not a simple software app, we also have a physical investment need. Ultimately, investors primarily look for risk return factors and ask similar questions, the greenness comes second to return*." Furthermore (for case G); "*Pitching deep tech to investors with a 7-year exit strategy resulted in a lot of rejections.*" Case H, which was eventually funded by the public-private co-financed LCIF stated that they were; "*very frustrated by [private] financial funds.*" Two cases (A, C) really struggled to get equity investment and both pivoted their business models, with case C's CEO explaining; "*Potential equity investors found our initial B2C approach unworkable. Pivoting to a B2B model made the difference*."

Whilst the CEOs did not mention any requirements from prospective early stage private investors for environmental metrics, they recognize that this is required by later stage private funders (e.g. Bill Gates Foundation) and public/private co-financing equity funders. The CEO of case G mentioned that work with the LCIF on CO2 calculations had proved helpful in obtaining further funding. Furthermore, the only woman CEO interviewed (case B) requested that; "*It would be good to have a more centralized and established approach to business data and presentation – if only there was just one form to fill once*." Whilst this was a statement of frustration about the variety of grant application and pitchdeck formats, it also referred to a need for greater understanding of common environmental metric requirements. Similarly, the CEO of case H said "*we probably wouldn't have done the calculations without assistance*."

In summary, all of the CEOs recognized the advantages of providing commonly understood and meaningful environmental impact metrics to investors. These could substantially enhance the financial arguments to support investment and help the businesses to develop stronger business models. Core metrics were formed around carbon and CO2e savings, typically *tCO2* in relation to product or service delivery and benchmarked where possible against industry norms or current best practice to contextualise their impact. Only the CEO of case B mentioned CE metrics in relation to product lifespan, modularity and repurposing. The CEO of case F considered material inputs to their batteries focusing on the reduction in use of rare earth minerals and their input costs, whilst the CEO of case E recognized the implications of spillover impacts in emerging markets where they might displace traditional local labour with fewer, better quality, paid jobs. Case H offers a notable *good practice* case example where the company has established an accredited monitoring system to track the performance of their smart meters in changing consumer behaviour: "*We track our overall impact on the market via a management structure that builds on accreditations such as Eco Vadis and ISO14000*." This has the dual benefit of demonstrating customer cost savings alongside positive environmental impacts. He further explained "… *you have to clearly differentiate between the impact of our products and the impact of the company. The real impact is delivered by our products when they initiate a change in the consumption behaviour of our clients.*" With regard to the company's own operational environmental impact he mentioned the importance of understanding their own energy consumption via either directly measuring the energy consumption, or proxies such as carbon miles (for the miles flown by e.g. executives).

Further information on each case study is summarised in Annex A.

Summary of Who Uses Key Environmental Impact Indicators

Key Summary Findings:

- Most convergence by actors is for environmental impact measures relating to CO2 emissions and intensity and energy consumption relating to efficiency and renewable energy use
- Material input use is highly nuanced by sector activity, with strong convergence for the proportion of recycling undertaken
- CE metrics exhibit far less convergence, mainly being promoted by academics and, thus far, are overlooked by policymakers
- Good practice case examples should exhibit a structured logic model demonstrating environmental and financial strategy with the adoption of a few core and composite (CE) indicators
- Key specialist support agencies (e.g. Future-Fit Business, Cranetool, SASB, Carbon Trust) can assist with case specific sector material nuances and benchmarking data guidance.

Drawing from prior sections, Table 12 presents a summary of environmental impact indicators and metrics from the perspectives of academics, various practitioner key informants, pitchdeck data and policymakers. The green fields indicate major convergence between different actors, where broad consensus exists on the indicator to be used. Blue fields highlight indicators that only used/recommended by government bodies, and grey fields indicate recommendations from academia. Orange fields show those indicators that are used in practice but are not commonly employed by academia or government bodies.

Table 12: Indicator by Stakeholder Group

	Metric	Academia	Practice		Govt
			Investors	Businesses	
Environmental impact					
CO2 emissions (vol/red)	t	x	x	x	x
CO2 intensity	%	x	x	x	x
GHGs (6)	t	x	x	x	x
Environmental impact cost	£		x		x
Biodiversity species	no.		x	x	x
Environment saved/restored	m2		x		x
Environmental quality					x
carbon footprint		x		x	x
Energy Consumption					
Life cycle energy per unit	KwH per time	x			
Energy efficiency	%	x		x	x
Energy use per unit/saved	KwH	x	x	x	x
Energy security					x
Water quality	%			x	
Fresh water consumption	Litres	x	x		
Renewable energy	%	x	x		x
Solid waste	Kg	x	x	x	x
Hazardous waste	Kg	x			
Level of clean technology	%	x	x	x	x
Energy consumption in recycling	KwH	x			
Carbon credits	£		x		

Material Use					
Total per unit	Kg	x	x		
Level of recycled material	%	x	x	x	x
Recycle time	Hrs/days	x			
Recycling saving	energy/kg		x		
degree of circularity	%			x	
Reuse potential	%	x			
Longevity of material	time	x		x	
Area farmed sustainably	ha		x		
Eco labels and accreditations	y/n	x	x	x	

Greatest convergence is observed in the Environmental Impact category. This might be because measurement of carbon emissions is a simpler approach, without necessity for complex externalities calculations. Alternatively, this is the section that appears most advocated by governmental bodies and where more comprehensive databases are available (i.e. Carbon Disclosure Project, Carbon Tracker, etc.).

Notably, for efforts on circularity, no standardised approach or database is available. Companies, especially early-stage ventures, that lack operational histories to refer to, thus struggle to (i) identify the areas of interest, (ii) obtain the necessary industry data and (iii) select/derive the most suitable indicators. This is a classic SME resource-based knowledge failure (Owen et al 2019) compounded when the business model follows a multi-product line, and where identifying all relevant factors along the supply chain is a very difficult undertaking. This is a shortfall that case B in particular struggles with and requiring guidance.

This is perhaps also reflected in the low degree of convergence in the Material Use category. So far, the level of recycled material is the only indicator deemed useful by all interest groups. There is general agreement that the longevity potential of the products should be measured and reported. However, while academia offers many sophisticated measures (we only list the more common), practice is swamped by an abundance of options but still lacks the foundations of how to approach measurement. Government bodies have so far avoided this and do not yet provide the necessary guidance that is so desperately needed for convergence. Conversely, Energy Consumption category indicator convergence is fairly high, perhaps again reflecting the simpler metrics required and advocated by government sources.

Notably, the indicators proposed by government appear very broad in their overall scope which could be a reason why they are not adopted by practitioners or recommended by academia. In addition, academia offers highly sophisticated methods and approaches that are not operable in practice. This follows what we found in our literature review, as well as extracted from our interviews.

Good practice case examples and sector recommendations

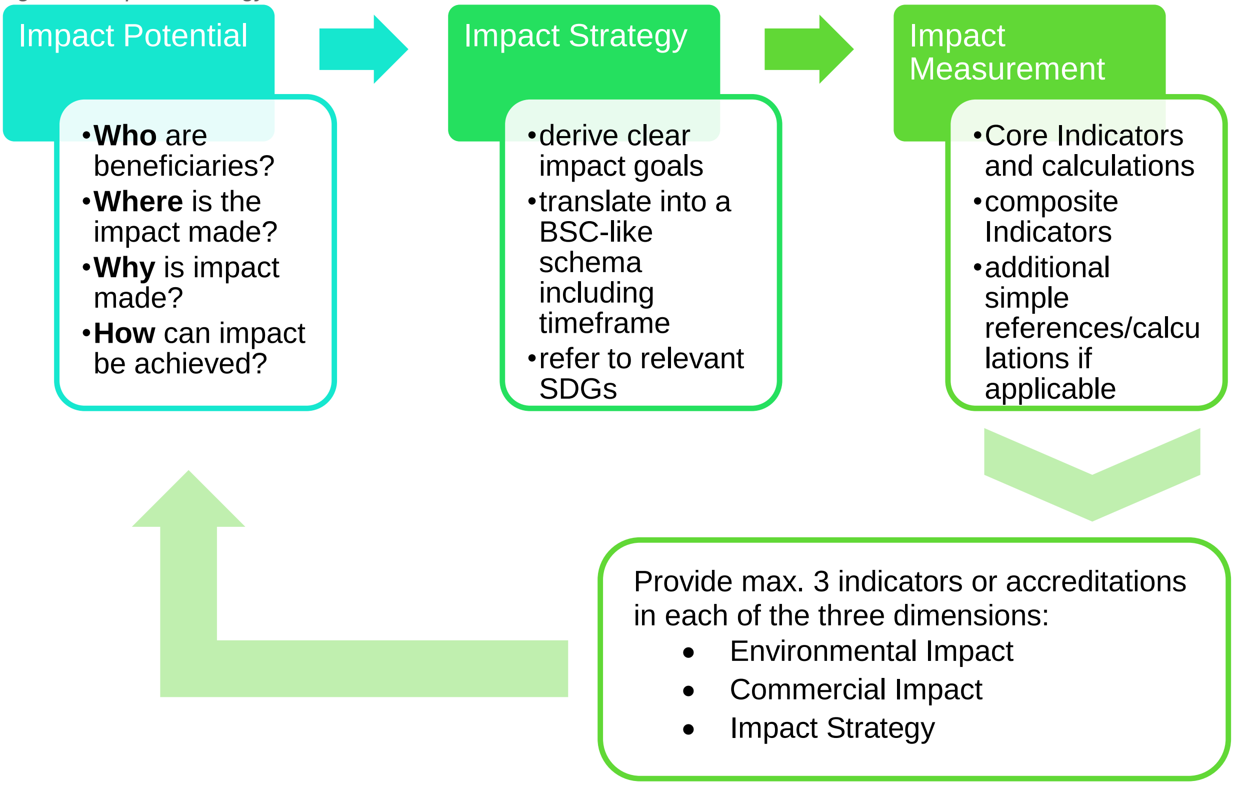
Here we draw on our knowledge of the case studies to provide 4 composite case examples of good practice from each of the MIT broad sector classifications. This was requested by the early stage impact investor workshop participants who expressed considerable interest in how a more consistent toolkit, guided and structured, approach to developing standard environmental metrics might be applied – for example in pitchdeck formats to aid investment selection, or to assist ongoing portfolio evaluation.

This research reveals that most businesses are looking for a specific set of indicators that guide them through their inquiry. Given the plethora of studies proposing relevant indicators and various approaches to embed them in an impact evaluation approach, this is legitimate. However, our inquiry suggests that, rather than a one-size fits all approach, more flexibility is required to assist cleantech SMEs in their funding journey. Not least because the STN exacerbates the need for adaptability and flexibility in order to clearly demonstrate profound viable productivity results.

Thus, based on this demonstrable requirement for companies to establish a meaningful and material impact strategy, we propose core and composite Indicators. Drawing on a selected case study for each broad MIT cleantech sector we suggest how environmental indicators/metrics can be embedded in a case-specific impact communication, which in turn benefits funding endeavours by meeting public and private investor requirements.

According to the Future-Fit Methodology (Future Fit Foundation, 2020a), every company can derive strategic goals by which progress can be measured. We also see the need for a clear impact strategy, from which both businesses and investors in their selection processes benefit. Thus, building on our findings and drawing on conceptualisations from Big Society Capital and Muff, Kapalka, and Dyllick (2017), we outline (Figure 7) an ideal impact strategy process (logic model framework) below.

Figure 5: Impact Strategy Process



Based on our key informant interviews regarding selection and evaluation criteria for cleantech investments, and the insights case study businesses provided, we develop the above graph. The process is iterative and should be used to realign goals, strategy and actions regularly. The three dimensions, in which indicators are presented aim to mitigate a focus on either strategy or operational issues. More crucially, the sections environmental and commercial impact together can provide a nuanced understanding of productivity in the respective cleantech sectors.

In addition, and as discussed in the literature review, it is crucial to use both core and composite indicators for cleantech sectors; where the composite indicators mention a benchmark reference and thus add to a better positioning of the venture. The indicators displayed in bold are regarded as core indicators. In combination with the other proposed composite indicators, they aim to provide a revised, yet environmentally sustainable productivity assessment example for each sector. What is more, the indicators presented aim to cover impact on both external stakeholders such as customers, and impact on internal processes and stakeholders such as employees. Presented below are four broad sector case study operational examples:

Clean energy use

The selected case F is a small-size company that has been founded in 2003. They are developing alternative cooling systems for commercial transport.

Table 13: Clean energy use indicators example

	Goal	Indicator	Metric	Context
Environmental Impact				
	Offer long-lasting and energy friendly cooling systems	**Carbon efficiency**	%	Overall carbon emissions
		CO2 reduction	t/%	Total CO2 levels and required reduction
		Renewable energy use	%	Total renewable energy use
Commercial Impact				
	Reduce cost and danger	Savings per product over lifetime		Total cost of energy conversion motors over lifetime
		TRL		
		Product fitness		Consumer demand and experience
Impact Strategy				
				
		Accreditations (eg. ISO or other technology relevant standards)		

Energy efficiency

Case H is focusing on home automatization and its potential to change consumer behaviour. This is achieved by allowing customers to track their energy consumption via a smart meter.

Table 14: energy efficiency indicators example

	Goal	Indicator	Metric	Context
Environmental Impact				
	Change consumer demand and energy use behaviour	**Energy consumed**	kwH	Total energy consumed
		CO2 reduction	Kg/t/%	Total CO2 levels and required reduction
		Carbon footprint		
Commercial Impact				
	Reduce energy use and cost	Reduction of cost (eg heating)	£, %	Total heating required and total cost
		TRL		
		Product fitness		Consumer tests & quality checks
Impact Strategy				
				
		Accreditations (e.g. ISO)		

Additionally, a carbon impact calculation - as shown below - might add additional value and comparability to the venture. Case H has developed this in collaboration with the LCIF, which has played a significant role in their development of the environmental impact measurement.

Table 15: carbon impact calculation

		Energy Consumption		Metric
		Gas	**Electricity**	
Typical household		20,000	3,500	kWhrs per annum
Carbon factor		215	100	g CO2/kWhr
Carbon generated		4,300	350	kg per annum per house
Reduction	*3.0%**	129	11	kg per annum per house
Duration		15	15	Years
Carbon Impact		1,935	158	kg CO2 per house
devices		4,000,000		units sold to date
carbon saved		8,370,000,000		kg
		8,370,000		tonnes

Note: * represents a national average calculation for smart meter impact on consumer behaviour

Renewable generation

The case company C provides B2B software services in the electrical energy supply market. They offer P2P electricity energy trading for small flexible energy providers via online auctions.

Table 16: renewable generation indicators example

	Goal	Indicator	Metric	Context
Environmental Impact				
	Develop open energy grid system, improve energy storage and efficiency	**CO2 savings per grid**	%, t	Overall CO2 consumption
		GHG reduction per grid	%, t	GHG emissions in industry
		Carbon footprint		
Commercial Impact				
	High transaction numbers	Number of transactions	No	Total market transactions
		TRL		
		Product fitness		Consumer experience and trust
Impact Strategy				
				
		Accreditations (e.g. ISO)		

Waste management and recycling

The selected case is an online store that aims to "*fight the planned obsolence*" of products. They specifically aim to promote circular economy thinking and consumption.

Table 17: waste management and recycling indicators example

	Goal	Indicator	Metric	Context
Environmental Impact				
	Offer sustainable, low-impact products	**Product longevity**	Years	Overall average longevity of such products
		CO2 savings	t	Overall CO2 consumption of product
		Waste reduction	%, t	Overall amount of waste
Commercial Impact				
	Offer a fair price that reflects value of use	Price per use	Cost over lifetime	Overall spending of customers on product
		TRL		
		Product longevity	years	
Impact Strategy				
				
		Accreditations (e.g. ISO, life-cycle labels)		

Conclusions and Recommendations

This study has examined the urgent requirement for reassessing productivity in terms of providing constructive measures for the development of a low carbon UK economy. Now, more than ever before, there is a requirement and an opportunity to 'build back better' the UK economy after the Covid-19 pandemic and Brexit. This can be achieved through economic reconstruction work that puts climate change and the drive towards a low carbon economy at the heart of UK policy. To achieve this, we believe that alongside the larger scale green infrastructure work that UK Government policy will focus on (Green Finance Strategy, 2019), there is also a need to support and create a flourishing leading-edge green, cleantech innovation economy. This will more effectively meet the joint aims of the Industrial Strategy (2017) and Green Finance Strategy (2019), transitioning a wide range of sectors through cleantech (MIT, 2016) to create a globally leading low carbon economy with high quality, sustainable job growth.

To achieve this vision, two points are crucial. First productivity as a simple input-output measure based on market considerations is insufficient (Firfiray, Larraza-Kintana, & Gómez-Mejía, 2018). Cleantech venture innovations not only create market-value once developed, but crucially also create use-value and by that support wellbeing and environmental prosperity (Flower, 2015). A focus on resources might be a first start to advocate a shift in thinking (Elkomy, Mair, & Jackson, 2020; Gollop & Swinand, 1998; Schandl et al., 2018). Even more so, as our findings suggest, an understanding of productivity as a function of resources and thus the consideration of the progression from these resources to the actual outcome as a critical measure.

Second, it requires overcoming the stakeholder triple nexus (STN) of information asymmetries which currently hinder the operation of the private impact investment market for early stage innovation cleantechs and effectiveness of the required intervention policies. Our study demonstrates that the visible UK cleantech SME impact investment market is sizeable (£4bn since 2000), but likely to be inefficient and constrained by lack of data and a disconnect between STN actors; early stage innovation cleantechs, impact investors, and policymakers and their support providers.

Central to the problem is the need for investors (public sector and private) to understand two fundamental issues, what is the cleantech innovation's likely financial return and what will be the environmental impact? As we demonstrate, these questions are particularly difficult to answer for longer horizon early stage innovators where disruptive technologies and business models are difficult to understand and environmental and financial impact outcomes are uncertain. Whilst we cannot guarantee picking winners, we also note that Markowitz (1952) pareto principles apply to the cleantech market with extreme stellar performing outliers (Nesta, 2009 '6%-ers'). The challenge, as Lerner (2010); North et al., (2013); Owen and Mason (2019) recognize, is to create an efficient entrepreneurial finance ecosystem where public and private actors deliver a fluent innovation finance escalator to facilitate sufficient businesses to pass through the valley of death spanning pre- to early revenue early stage innovation stages (Mazzucato & Semieniuk, 2018).

By examining environmental impact metrics we are able to offer solutions to a key piece of this puzzle. Taking a disruptive view of productivity within an early stage cleantech innovation context, our research question is: **What are the appropriate metrics and policy responses for environmentally sustainable productivity development**?

Our summary findings are outlined below:

1. All actors in the STN demonstrate a need for improved environmental impact metrics. There is **lack of clarity** as to what metrics to use and how they should be applied/presented, but there is widespread consensus that they could work alongside established financial impact

metrics to demonstrate more clearly the potential value of the cleantech innovation to the low carbon economy – and likelihood of investor return.

2. Different actors impose **different logics into how they select and adopt environmental impact metrics**, leading to proliferation of metrics and skewed, ineffective use (Rodriguez et al., 2020). There is a need for universally agreed key metrics which establish context and demonstrate real change impacts. This requires a concerted policy response to bring together the diverse actors in the STN to establish the core metrics and also to understand where specific sector materiality (e.g. rare earth minerals conservation) and activities (e.g. water conservation, biodiversity measures) require additional contextual metrics. This failing also extends to economic spillovers relating for example to greening supply chains and subcontracting.
3. All actors appear to **underplay the importance of the circular economy (CE)**. There is evidence of growing CE awareness, particularly by UK government departments (e.g. DEFRA) and through business support organisations (e.g. Climate-Kic; Future-Fit), but as yet limited application by public sector or private investors. CE should certainly be considered but metrics need to be simplified where possible to achieve balance between usefulness and actor buy-in.
4. Cleantechs struggle to present appropriate metrics and would do well to start by considering sustainable development goals (SDGs) in order to **provide environmental mission statements** to derive their specific core environmental impact metrics. Cleantechs also currently focus on the direct environmental impacts of their products or services, which impact on other businesses or the domestic market. They typically fail to demonstrate their own operational carbon footprint (which can be derived from Carbon Trust), their CE or spillover impacts.
5. Impact investors, notably at the earlier stages of innovation, often **fail to set out clearly what they expect to see from venture investment pitches**, and yet they are seeking evidence of environmental impact contributing to net zero to support the likelihood for financial return. They also pay little attention to CE and spillover impacts, since these are more altruistic and less likely to be associated with financial return. This suggests a key role for policymakers to change perceptions and behaviours via financial reward mechanisms (e.g. co-financing requirements).
6. The role of **market supporters**, such as FFB and ClearlySo is crucial, as they have the potential to guide both businesses and investors to achieve a matching understanding of both core and composite indicators. The bundled knowledge of supporters can also help in stewardship type activities, through which sector specificities can be acknowledged.
7. UK **policymakers do not present a cohesive, integrated approach** to supporting environmental impact investing. Whilst key departments like BEIS and DEFRA and non-departmental bodies like IUK are separately working towards co-financing and associated financial support mechanisms (e.g. funding business support Cleantech Hubs, incubators, providing grants and subsidies), the government's main SME finance agency, the British Business Bank remains sector agnostic, typically with no environmental impact requirements (apart from joint ERDF programmes). Furthermore, fledgling attempts to impose green credentials on co-financing impact investors, as well as their cleantech venture investments, fail to demonstrate singularity of purpose and measures, often neglecting CE and spillovers. A more integrated adoption of policy logic models and their associated evaluation scorecard approaches and measures would help.
8. The **lack of UK SME environmental impact data** is a major problem. There are no government or privately accessible data sets, or SME environmental reporting or widespread environmental labelling requirements, to provide consistent evidence of suitable metrics across different cleantech activities and performance benchmarks. Without these, it will remain difficult for cleantech innovators to provide credible environmental impact metrics for impact investor assessment, or for policymakers to assess where interventions can make a real difference to the low carbon economy.

9. There is widespread evidence that **core indicators** relating to carbon reduction and CO2 emissions (e.g. *tCO2e*) are recognized and adopted (albeit inconsistently) by actors in the STN. However, the wider range of the six greenhouse gases (GHGs) are frequently overlooked. Apart from the additional neglect of CE and spillover metrics, including company carbon footprint, there is also a need to reflect the materiality and sectoral nuances of cleantechs. These are many and varied and beyond the remit of this study. However, drawing on the work of the Sustainable Accountancy Standards Board (SASB) and SME support organisatons like FFB, the various actors in the STN can work together to develop more effective case by case measures (as exemplified by the LCIF and case study H).
10. Productivity remains an anathema to early stage cleantechs and their investors. They collectively view **innovation progression through TRLs and IP protection** as the most effective measures, with typically pre-revenue cleantech R&D companies more inclined to view productivity from the perspective of their impact on clients (B2B or B2C). Whilst government recognizes this (e.g. IUK progress trace assisted cleantechs using TRLs), there is a preoccupation with cleantech leading to economic efficiency (e.g. ERDF programmes supporting SME energy efficiency) rather than environmental efficiency. We demonstrate (e.g. in the housing market) that regulations and lack of consideration for environmental efficiency can lead to counterproductive economically inefficient longer-term outcomes.
11. This study was not about Covid-19, but inevitably economic cycles caused by global events impact on investment markets. Our limited evidence suggests that, whilst the cleantech investment market is holding up well (e.g. cleantech crowdfunding on Crowdcube), there will be delays in cleantech commercialization and investor exits as a consequence of less liquidity upstream at Series A and earlier investors in the pipeline getting their assets locked into existing investments (Mason et al, 2010). This suggests an important role for strategic policy intervention, such as through co-financing programmes to address shorter term structural deficiencies in the entrepreneurial finance markets and to prioritise (e.g. through the pandemic Future Fund) support for cleantech innovation and low carbon economy outcomes.

Key Policy Recommendations

- Develop **Standard UK EIMs** through **integrated cross-departmental use for business finance policies**, adopting consistent greenhouse gas (GHG) metrics alongside CE measures for carbon and rare earth mineral inputs and outputs and consideration for greening supply chains.
- Ensure that public-private **co-financing and tax incentive policies for business investment, use environmental metrics** to encourage environmentally sustainable development.
- Collect **national environmental audit data annually to assist SMEs** to undertake environmental benchmarking to enable progression to a greener economy. These data can assist impact investors, offering baselines to assess cleantech environmental impact.
- Offer **environmental sustainability support programmes alongside SME support and finance** programmes, integrating these with leading private market support providers.

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Annex A: Case Study Summaries

Case Study A: Integrated Transport App, Oxford (TRL 5/6), Pre Revenue, Micro Business

Profile
Established 2016 as a transport consultancy. Initial university scoping study led to an integrated demand responsive transport (DRT) system concept. Company developed software app enabling journeyers to plan and use the most efficient combinations of public and private transport. Software was tested and currently requires public trials at the pre Series A late seed funding round stage.

Funding
In 2018 the company received IUK grant and seed VC totalling £150k to develop software and pre public virtual data trial. Subsequently, in 2020 a Transport Technology Research Innovation Grant of £30k was received from Department for Transport to market the app to 3 potential pilot trial UK local authorities. A further £150k is required in 2020 for a single area trial, with £500k Series A funding required in 2021 to complete a further 2 years of area trials across 5 areas. At that stage, with sufficient data evidence, trade sale exit to a private transport operator is planned by 2024.

External finance issues
External funding has been required to develop software and develop market contacts to generate public and private transport data. Initial seed VC funding has not led to follow-on equity, due to insufficient data and investor confidence, leaving the company reliant on grant funds. TRL progression has been slow and potential beneficiaries from efficiency savings like rural public transport, NHS and social services have insufficient funding to invest.

Environmental impact metrics
The app is founded on the concept of integrated transport efficiency which will reduce the numbers of single occupant private vehicles on the road, leading to greater use of car share journeys and public transport. Measures are therefore efficiency driven, such as the generalised notion that public transport is 8x less polluting than private car journeys. On this basis tCO2e calculations can be projected per journey and distance where the app is used. Furthermore, considerable cost savings have been estimated for better integrated public services.

Case Study B: Online CE Products Store, London (TRL 7/8), Early Revenue, Micro Business

Profile

Established in 2016, the company is an early trading "online store fighting planned obsolescence." Products promoted are researched and display circular economy, holistically addressing CO_2 material input, product longevity, repurposing, modularity, repairability and recyclability. They also account for supply chains and socio-economic factors such as labour market conditions.

Funding

Initially founder and relations invested, using family investor experience in 2019 seed funding raised £600k (£500k crowdfunding and £100k angel syndicate). They plan follow-up top-up funding round from angels in Autumn 2020. The COVID-19 crisis has delayed a full Series A raise for commercialising the business until 2021. Top-up funds will develop more marketing evidence to support the full £2m raise from angels and VC. Investment exit is forecast for 2024 via a trade sale to an on-line shopping or niche media outlet, with the CEO aiming to stay "to maintain the vision."

Funding issues

Funding has not been an issue thus far and they are fortunate to have a family member who is a private equity funding expert. However, COVID has slowed down the investment process. The business cannot grow without substantial investment into global marketing. They have a small and growing presence in the US. One key point was that having consistent pitchdeck formats for different investors would save time: "*It would be good to have a more centralized and established approach to business data and presentation – if only there was just one form to fill once*."

Environmental impact metrics

Presenting appropriate environmental metrics has been tricky. Whilst early stage private investors have not required this, they are aware that public and institutional foundation investors do. Different products have different CO_2 inputs and longevity. They ideally need baselines from which they can demonstrate the difference they are making. The example was given of the average lifespan of clothing items (e.g. a fashion industry benchmark is 2.1 years). Another measure they found useful with investors was price per use – for example buying durable cookware that lasts a lifetime, versus multiple purchases in terms of cost (£) and material (tCO_2). Efficiency metrics could be translated into tCO_2 savings. They are also looking for "life cycle labelling of products."

Case Study C: Energy Grid Efficiency, London (TRL 7/8) Early Revenue Micro Business

Profile

Established 2013, software service company operating B2B in UK power grid electrical energy supply market. Disruptive approach enabling flexible energy supply to UK grid, working alongside major power providers. Offer P2P electricity energy trading for small flexible energy providers via online auctions with enabling software for providers to enter details and see whether they qualify to deliver.

Funding

Multiple funding rounds received, highlighted by: 2014 £500k grant from DECC alongside Climate KIC and Nominet Trust to trial P2P energy trading, rolled out to Netherlands and Italy in 2016; 2017 BEIS funding for Flex Marketplace raised £1.9m leading to June 2018 launch of Piclo Flex UK, offering buyer and seller flexibility with 6 area trials and 175 providers leading to 2019 major UK power provider contract. In 2019 £500k was raised from a business angel network, VC and their original accelerator investor to fund initial commercialisation through online Flex auctions.

External finance issues

Potential equity investors found their initial B2C approach unworkable. Pivoting to B2B model in the decentralized market operating through intermediaries was more workable. Subsequent funding has been strong through grant and equity. The current Series A full commercialisation fundraising is for £3m. This will improve functionality of the auction platform and deliver scale-up operation across the UK. They are also seeking US and European market expansion. Covid-19 has slowed fundraising from angel, VC and corporate energy company investors. Funding should be in 3 months. The exit horizon is a 5-year timeline from first angel investments to trade sale energy company exit by 2023.

Environmental impact metrics

"Key metrics are tricky, we are a disruptive system change, so all about efficiencies of energy in the grid. We have a net zero vision!" We improve the use and efficiency of energy storage and renewables into the grid. Currently 1GW of battery tech is used and the grid needs to increase this to 15GW, so there is plenty to do. Number of transactions is the best measure of their efficiencies. More transaction equals more efficiencies. The total market is £30bn in transactions and they aim at £5-10m. "We will create CO2 energy savings by increasing renewable grid efficiencies."

MtCO2 reduction is the common government funding agency measure. This is unhelpful as they do not change the average grid number. As an enabling tech for more renewables, they reduce cost and increase reliability of delivery. They are about reliability, making renewables mor efficient to deliver.

Case Study D: Green Laundry, Oxford (TRL 7/8) Early Revenue, Small Business

Profile

Established 2017 as a university green laundry service, the company aims to provide a net zero complete laundry service, seeking expansion into UK cities. Key elements are low heat wash (20C) using solar array for water heating. They reduce aggressive chemical use with 60% recycling of waste waters. A current IUK grant is funding micro plastic filtration development.

Funding

Transition through investment has been smooth. After initial free university accelerator assistance they received £300k seed investment from an angel and 2 VCs after 5 months search. This funded a pilot early revenue service and software development. They are now ready to scale-up into other cities for roll-out to other cities and secured £1.2m of seed investment from angels and VCs and also £200k equity investment from a London corporate sponsored accelerator with health focus. This will help with building their technology stack roll-out to 3-4 key cities. They then require a further full Series A £8-10m round to scale-up to 10-12 cities in the UK and Europe. They are also looking to license out their operation under franchise elsewhere and develop their software license operations. Eventually in 3-5 years they will consider investment exit via IPO or trade sale.

External financing issues

Appealing to cleantech impact investors is strange. The impact investors are not experienced in the sector and there are issues explaining how service sector disruption works. "*We are not a simple software app, we also have a physical investment need. Ultimately, investors primarily look for risk return factors and ask similar questions, the greenness comes second to return*." The business sells itself on software logistics and laundry process flow, which is unique and can be software copyright protected and scalable.

Covid-19 has impacted the business. It has slowed down the start of the new city office and led to a key pivot. Demand for NHS cleaning services now means that they are seeking NHS accreditation and changing their services slightly to accommodate this. Ultimately, this would be a very big potential market for them.

Environmental impact metrics

Seeking net zero circular economy solutions**.** It is their big selling point for the wider economic impact to the green economy. IUK grant to filter micro plastics out of the waste system. They recycling 60% of waste water and deliver using logistics software and electric bikes. Impacts are quantified in terms of CO_2 savings: key metric 174k CO_2 reduction per ton of washing.

Case study E: Plastic Recycling, Swindon (TRL 7), Pre Revenue, Medium-size

Profile
Established 2012 spin-out of a university plastic waste project. The company has designed and engineered a plastics recycling modular unit which can be used anywhere globally and recycles 95% of all plastics into a trademarked valuable hydrocarbon product.

Funding
First investors were family, friends and founders, followed by business angels. Subsequently, they received angel syndicate and crowdfunding rounds mixed with some IUK and 2 rounds of BEIS Energy Entrepreneur's Fund grants worth £1.8m out of £11m raised. Private equity funding has included multiple crowdfunding and business angel rounds from angel groups, SyndicateRoom and more from Crowdcube. There are 1700 shareholders with investments ranging from £11 to £50k. They are now closing a £12m Series A round with large multi-$bn VCs, including a French cleantech VC (Mirova) and Finland's largest diesel refinery company (Neste) – investors with green recycling strategies seeking international markets, including Indonesia, where they are developing demonstration plants. They will require a further £13m to complete commercialisation in the next year and forecast an IPO exit in 2023-24.

External finance issues
"Earlier stage investors, like business angels, wanted to invest in the man with the plan, whilst larger later stage investors are seeking global scalability – looking for green impact and wider social impacts, such as in Indonesia."

Environmental impact metrics
The ambition is to build 200 machines annually and save around 1.4m tonnes through plastic recycling and generate around 1m tonnes of recycled oil per annum. Net change is key and a holistic CE metric is important. "*A report by Riccardo indicated for every 2.2 tonnes of plastic production our recycling saves 1.8 tonnes. We use carbon in manufacturing, supplying, running, maintaining of machines, but net gains are considerable and increase over time*. *It is important to take a broad view. In Indonesia we will reduce plastic waste in the environment, reducing health hazards. We also consider human well-being, recognising that 50 people may make a living off landfill mining in any given area. We will create local jobs and offer fair pay for plastic collection. We also perform due diligence on suppliers and buyers, following IFCC principles."*

Summary key metric: tCO2 savings on residual plastic waste (RPW) compared with current energy from waste processing.

Case Study F: Renewable Energy, Cambridge (TRL 8), Revenue, Small-size

Profile

Company established 2003 undertaking refrigeration engineering for dairy sector transport and storage. The late 2000s GFC required a change of direction the company invested in new cleantech innovations, focusing on more efficient industry use of renewables. "*Make no bones about it we need to kill the carbon industry!*" Company pioneered global leading DC (rather than AC conversion) motor power for industry direct from their renewable sources such as heat pumps and PV. This is at least 10% more efficient than current conversion techniques and encourages renewable energy use. They are also developing battery storage with bi-directional battery technology for the fast charge EV market.

Funding

Mostly self-funded through re-investing, they successfully applied for UEA Low Carbon Investment Fund investment in 2009. At that time, the company took a mix of friendly angel and LCIF investment for a 50% share of the business for Cleantech adoption in their business. Whilst this supported business development, it did not support the rapid R&D development they would have liked.

External finance issues

They have experienced problems in raising further finance from LCIF which would have helped more rapid R&D and commercialisation. "*The current approach of LCIF and traditional VC investors destroys value. Our business case is nuanced, LCIF appointed Investment Bank people from the city who have no idea about engineering and then appoint people to your board who have no idea what is going on and talk in a different language which is not constructive*."

Environmental impact metrics

"The key indicator metric is carbon efficiency and this means looking at the source of the energy and ensuring that this is not carbon. We have zero carbon responsibility! Calculating the extent to which machines are using carbon is possible through the Internet of Things. Carbon efficiency is the starting point. Investment decisions should be based on this. Se we need metrics which calculate energy cleanness – lower carbon inputs."

A key metric is therefore the % of overall renewable energy use in the activity and overall proportional reduction of CO2.

Case study G: Battery Storage, Cambridge (TRL 6), Pre-revenue, Micro Business

Profile

Established 2017 as a university spin out company with patented technology in developing battery storage solutions for the rapid charge electric vehicle (EV) market. They have developed B2B industry linkages, notably with battery manufacturers and are delivering ethically sourced reduced CO2 and rare earth material solutions resulting in up to 4x less material input. They have successfully progressed patenting and delivered test pilot demonstration of charging that is 3 times faster than their competitors.

Funding

Initially funded by a university seed VC investor, to date thy have received £2.5m equity and £1.3m in grants. The original seed round contained a mix of local angels which matched a £100k propulsion centre grant in 2018 for proof of concept work. This was followed by a £1.5m seed round in 2019 consisting of IUK grants (£1.2m) with angels and seed VCs. In 2020 they received a further £900k equity from the previous seed round investors as a follow-on to progress from prototype proofing to global commercialization in 2022. The overall investment horizon is forecast for 5-7 years.

External finance issues

The initial seed funding round took a year to complete. "*Pitching deep tech to investors with a 7 year exit strategy resulted in a lot of rejections.*" Further funding was supported by a specialist local enterprise agency to find and assist with pitching to potential investors. IUK grants require matched funding and are milestone related, offering partial payments retrospectively over a period of 3 years. EIS tax breaks have encouraged angel and VCT investors with a green investment brief. They have also managed to get a strategic corporate investor which has encouraged the company's B2B business model.

Environmental impact metrics

Investors were interested in cleantech, but their overriding aim was financial return and global scalability of the venture. Only recently, when contacting Bill Gates Foundation, were specific green targets and footprints required. However, green VCTs and university seed funds wanted to demonstrate their green investment credentials to investors and oversight committees. A crucial commercial metric is cost reduction, as batteries represent 50% of EV products. Although the local university and innovation brand encouraged investor interest getting a good third party due diligence report flagging up market opportunity, solution, transparent timelines and sensible low cost, easier market entry business model, really helped. Whilst their main commercial metric is cost efficiency savings, reduced CO2 and rare earth mineral inputs are also noteworthy.

"The industry is becoming more savvy in ethical sourcing of minerals and raw materials. As we are only a small company we cannot at this stage make major differences in the industry, but they are working towards this and the industry is becoming much more aware."

Case study H: Smart home tech, Energy efficiency, Cambridge (TRL 9+), Established trading, Medium-size

Profile

The Company was established in 2006 to provide green energy options to decarbonize homes. Following a consumer research programme, they launched smart home energy systems to help consumers transform their behaviour towards being more environmentally friendly and reduce carbon emissions. They have delivered over 4 million systems and currently have the capacity to deliver 100,000 products a month. They are the leading provider of in-home displays to the UK Smart Metering Programme. In 2017 they won the Queen's Award for Enterprise Innovation. They were listed in the Sunday Times Tech Track 100 in 2016, 2017, and 2018. Annual turnover is circa £25m, with 100 employees. Their main market is the UK, but also includes Nordic countries and the Netherlands.

Funding

In total the company has raised £15m equity funding. When they started consumer research the East of England Development Agency provided £40k proof of concept funding and R&D grant. After initial product testing Carbon Emissions Reduction Target (CERT) innovation funding helped them to build a comprehensive system. They are now privately funded, where their shareholders are cleantech funds, including the East of England European Regional Development Fund (ERDF) assisted Low Carbon Innovation Fund and individual investors. LCIF provided about £3.5 million in two funding rounds in 2009 and 2013. In 2019 they secured 30k funding from BEIS to further develop their product Trio. Most funders have not exited yet, as it is difficult to provide stock liquidity.

External finance issues

"Throughout the financial crisis the funding sector swung back to being very conservative again – they drew in their horns." They welcome the newly set up schemes in the UK, such as through BEIS and IUK to support SMEs. The company was "very frustrated by [private] financial funds" as getting funded turned out to be a leap of faith. The rather short investment horizon of private VCs was the main issue, as it does not reflect the notion of a steady business. The early investment of LCIF and its involvement as board member initiated the set-up of carbon related calculations and the development of impact metrics. This ultimately helped in raising money from private investors who's focus lies on climate issues and by that longer investment horizons.

Environmental impact metrics

Whilst pitching for funding in the early years they did not mention any green metrics at all, rather they focussed on the growth sectors and the necessity of home automation alongside the stable business of energy retailers. Having developed their impact strategy with LCIF they use both hard and soft measures. Their main hard measure of the impact of their products is change in CO2 (t) stemming for example from an implementation of a solar panel or an improved insulation. This is also in line with government recommendations. The soft measure is a qualitative assessment of behaviour change based on the reduction of CO2 above (The Smart Metering Programme follows a Cost Benefit Analysis for the impact assessment). Essentially by providing a baseline of use and then clear costings for domestic uses (e.g. energy use/cost for a cup of tea) they can monitor whether raised awareness changes consumer behaviour. They also track their own overall impact on the market via a management structure that builds on accreditations such as Eco Vadis and ISO14000.

Case Study I: Air purification system, Birmingham (TRL 8-9), Early Revenue, Micro Business

Profile

Established (2019) to pilot and market a US patented UV air purification product in the UK. The product passed EPA and head to head University of Arizona clinical trials, demonstrating market leading air purification capability: *"Simply put – no air purifier on the market eradicates disease-causing organisms as effectively as ClearWave Air. With our patented ultraviolet (UV) sterilization system, ClearWave Air destroys airborne microbial allergens, viruses, mould spores, microorganisms and germs."*

Funding

The company has received no external funding in the UK. However, after over a year of initial investor and market exploration, the CEO has joined a West Midlands incubator offering flexible office space, mentoring guidance and networking opportunities for £100 per month. This has led to the establishment of a company advisory board which includes the CEO of the incubator, and IUK grant funding specialist and a serial entrepreneur engineering with plenty of fundraising experience. Within a few months this board has given the company direction in terms of focus on key B2B markets, which have been highlighted by the COVID-19 pandemic, such as medical facilities (hospitals, surgeries, dentists), hospitality (hotels and restaurants) and office spaces. They will most likely seek IUK grant funding, possibly with equity to develop these markets through initial pilots.

External finance issues

Seeking external finance in the UK has been a long and complex task. The UK CEO has no prior experience of fundraising. Coming from a commercial finance and sales background, and it has been a steep learning curve. They have had difficulties with market focus and finding equity investor networks and potential impact investors – public or private. Finding suitable suitable advisory board members with grant writing and equity finance raising skills has taken time, but they are now in a position to move forward.

Environmental impact metrics

The main environmental metrics relate to Intertek and MIT tests which demonstrate the % of reduction of mould, virus and bacteria in the purification system's atmosphere (controlled room environment) and have been tested against rival manufacturer's units. The Clearwave unit has almost 100% reduction (killing al known viruses), whilst other units appear to have less effectiveness – for example the best comparator unit currently on the market offered only 77% reduction of mould spores. CE measures have not yet been considered, and the product is manufactured in Europe with parts sourced globally – so there is scope to reduce supply chains. A key advantage of their system is that it is environmentally safe and releases no GHGs – as opposed to other rival products currently on the market.

Annex B: Summary of UK Practitioner Literature

Introduction

This section summarises initial findings from SQW's review of practitioner literature (investors and accountants) on approaches and metrics used to assess potential impacts of low carbon investments.

Approaches to measuring impact

Impact investors use a broad range of tools and metrics to measure impact

In 2017, the Global Impact Investing Network (GIIN)[11] published findings from its first comprehensive survey of the state of impact measurement and management. Key findings included:

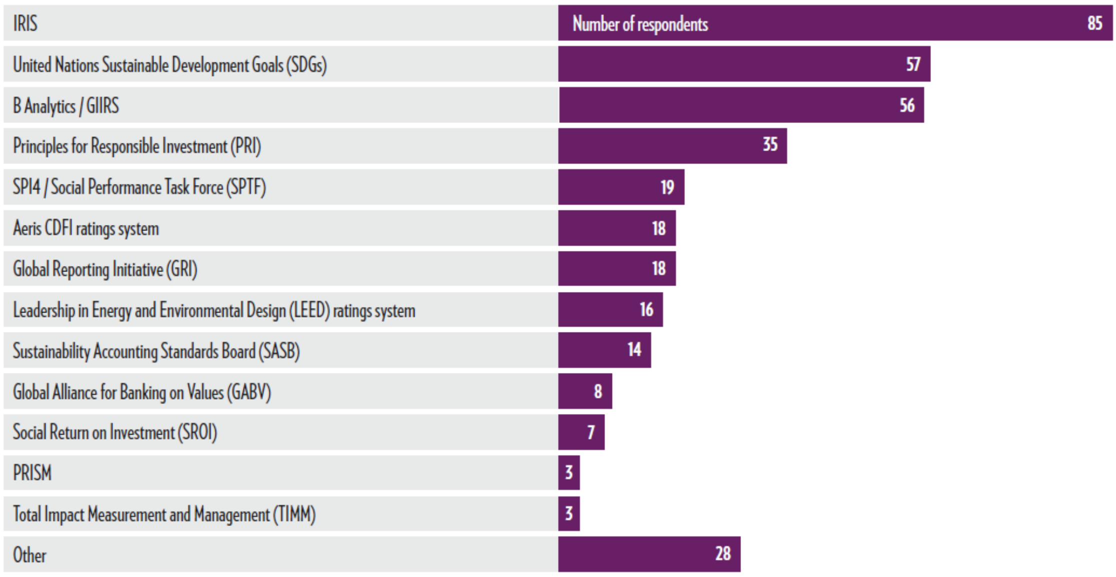
- The vast majority of investors (91%) measure the social and/or environmental *outputs* associated with their investments; over 75% measure the social and/or environmental *outcomes.*
- Over a third also measure the 'depth' of their impact (i.e. significance of the impact for the people or ecosystems affected) or benchmark it to that of their peers.
- Only 38% of participants measure whether they created impact that is additional, and about two-thirds only track the positive impact associated with their investments.
- The most common approach to impact measurement (37%) is a combination of certain standard, portfolio-wide metrics with other metrics customised by investment.
- Although just over half of respondents use a rating system, index, analytics tool or other system to select impact *metrics*, only 20% use these tools to develop impact *targets.*

Impact investors take no single approach to measuring impact, using various tools, frameworks and standards. Although the landscape is crowded, some approaches are being used more widely than others. According to the GIIN survey, the most commonly used tool/framework is IRIS (62%), followed by the 17 United Nations Sustainable Development Goals (SDGs; 40%), B Analytics and/or Global Impact Investing Rating System (GIIRS) (40%), and the Principles for Responsible Investment (PRI; 26%). See **Error! Reference source not found.** for full breakdown and **Error! Reference source not found.** for a brief description of what each of these cover.

[11] GIIN (2017) The state of impact measurement and management practice

Table B 18: Usage of various tools, indicator sets and standards in practice

n = 137 (optional question); respondents could select multiple options.



Note: 'Other' includes Sustainalytics, the Pinchot Impact Index, CSRHub, MSCI ESG Ratings, the Global Real Estate Sustainability Benchmark (GRESB), and the Green Star rating system.
Source: GIIN

Table B 19: Most popular frameworks for measuring impact

Approach/framework/tool	Responsibility	Description
IRIS+	Developed by the Rockefeller Foundation, Acumen and B Lab Stewarded by the Global Impact Investing Network (GIIN)	A set of over 500 generally accepted metrics for measuring social, environmental, and financial performance Aligned to many widely used standards in an effort to address fragmentation in impact measurement, e.g. the Global Impact Investment Rating System (GIIRS), the Global Reporting Initiative (GRI), the United Nations Principles for Responsible Investment (UNPRI), and the SP14 Social Performance Task Force standards for microfinance
Sustainable Development Goals (SDGs)	United Nations	Seventeen SDGs, which build upon the Millennium Development Goals and encompass objectives ranging from ending poverty to achieving gender equality or conserving marine resources Each SDG is accompanied by a set of specific targets and indicators for measuring progress
B Impact Assessment ("B Impact")	B Lab	B Impact is an industry standard for measuring impact for small and medium sized enterprises. It includes a set of standards, benchmarks and tools and has a three-step process: assess, compare and improve. All companies are given a B Impact Score.
B Analytics		B Analytics is a platform that aggregates and analyses data on companies' positive impact practices and performance, thus enabling comparison and benchmarking. B Analytics data are sourced from B Impact. B Analytics data are also used to inform the GIIRS ratings.

Approach/framework/tool	Responsibility	Description
Principles for Responsible Investment (PRI) PRI Principles for Responsible Investment	United Nations	A framework to guide institutional investors to consider matters of environmental, social, and corporate governance (ESG). The Principles are intended to be relevant for large investors with traditional fiduciary duties and include commitments like adding ESG issues into investment analysis and seeking appropriate disclosure on ESG practices from investees.

In addition to the publicly available tools, standards and frameworks, some impact investors have **developed their own impact frameworks**. Most notable examples include ETF Partners' 'impact scorecard' and Earth Capital's 'Earth Dividend'. The former incorporates the SDGs and includes custom, business-specific metrics, to address the challenges outlined below.

"*The metrics that investors typically use to evaluate (and help improve) environmental impact often don't make much sense to us. It is not that they are wrong. It is that they are relevant for established large companies, trying to reduce their existing environmental footprints. We invest in exciting young growth companies whose products and services have the potential to make a huge difference. We evaluate potential, and then help make it happen*." (ETF)

Other relevant frameworks worth highlighting include:

- **The Carbon Disclosure Project's (CDP) framework**, which includes a suite of climate change indicators as part of an Investor Dashboard and allows for benchmarking.
- The **Climate Disclosure Standards Board's (CDSB) Climate Change Reporting Framework** is intended to help companies to report environmental and climate change information in corporate reporting, e.g. in annual reports. Its focus is therefore on larger companies, not SMEs.
- **EU taxonomy**, which provides screening criteria relating to climate change mitigation and adaptation (linked to % of turnover and capex), and links "enabling activities" (such as cleantech) to economic measures.
- The **Future-Fit Business Benchmark** is a free business tool designed to help businesses understand the SDGs and articulate their contribution to these goals.
- The **Global Reporting Initiative's (GRI) Sustainability Reporting Standards** set out the global best practice for reporting on a range of economic, environmental and social impacts. This comprises 'universal standards' and optional 'topic-specific standards' (environmental, economic and social).
- **Good Finance's Outcome Matrix** includes outcomes and measures for nine outcome areas and 15 beneficiary groups, which businesses can use to create a matrix tailored to their activities. One of the nine areas is 'conservation of the natural environment', which includes several outcomes at both the individual and community levels.
- The **International Integrated Reporting Council's (IIRC) International Integrated Reporting Framework** aims to bring greater cohesion and efficiency to the reporting process, adopting 'integrated thinking' as a way of breaking down internal silos and reducing duplication. The focus seems to be on the structure and content of an 'integrated' report, rather than on the specific metrics and indicators that should be included.
- **MSCI IndexMetrics** provides quantitative measures along four dimensions (key metrics, performance, exposure and investability), which includes climate footprint (carbon emissions and intensity), low carbon transition risks, exposure to clean technology solutions (e.g. clean technology solutions revenue, and green/brown net revenue exposure). Some of the most relevant cleantech metrics are summarised in Annex Table B4.
- The **Natural Capital Protocol (NCP)** is a firm-level decision making framework that enables organisations to identify, measure and value their direct and indirect impacts and

dependencies on natural capital. NCP brings together and builds on a number of existing tools, guides, methods and techniques to identify, measure and value natural capital.
- **Social Value UK's Guide to Social Return on Investment** provides a framework for measuring, managing and accounting for social value or social impact. The framework covers social, environmental and economic costs and benefits.
- The **Sustainability Accounting Standards Board** has developed a set of 77 industry standards, which enable businesses around the world to identify, manage and communicate sustainability information to their investors. These standards are explained graphically through the **Materiality Map**, an interactive tool that identifies and compares disclosure topics across different industries and sectors.
- **Sustainalytics:** Data covers 220 indicators and 450 fields, including measures for cleantech businesses. KPIs not publicly available but relate to Sustainable Development Goals such as Affordable and Clean Energy (SDG7), Decent Work and Economic Growth (SDG 8), Industry, Innovation and Infrastructure (SDG 9), Responsible Consumption and Production (SDG 12) and Climate Action (SDG 13).
- The **Task Force on Climate-related Financial Disclosures (TCFD)** has prepared a set of recommendations, which intend to help identify the information needed by investors, lenders and insurance underwriters to appropriately assess and price climate-related risks and opportunities. The recommendations cover four areas: governance; strategy; risk management; and metrics and targets.
- The **United National Global Compact (UNGC)** is a network seeking help businesses implement universal sustainability principles and to take steps to support UN goals. UNGC requires all participating companies to produce an annual **Communication on Progress (COP)** report, which details their work to embed the Ten Principles into their strategies and operations.

There are two other notable organisations that have taken a slightly different approach to promoting best practice in impact measurement and reporting: instead of developing a framework or a set of tools, they focus on fostering collaboration and knowledge sharing:

- **Accounting for Sustainability (A4S)** intends to inspire finance leaders to adopt sustainable and resilient business models, and transform financial decision making to enable an integrated approach reflective of environmental and social issues. Working in collaboration with finance communities around the world, A4S seeks to promote knowledge sharing and embed best practice.
- **The Impact Management Project (IMP)** is a forum for organisations to build consensus on how to measure, compare and report impacts on environmental and social issues. The practitioner community includes over 2,000 organisations. IMP also facilitates the IMP Structured Network, a collaboration between organisations that are coordinating efforts to provide complete standards for impact measurement, management and reporting.

The Business Leadership in Society Database may also be useful[12]. It profiles leading 200+ initiatives working to set standards for responsible business and address ESG issues. It includes a summary assessment of key elements based on a nine-point assessment framework, which includes:
  - Driving Corporate Disclosure, Reporting or Labelling: The initiative is using its platform to encourage improved corporate reporting, e.g. standardized reporting, **best metrics**, or the initiative includes a label component.
  - Target Setting: The initiative has clear commitments and **targets**.
  - Impact Assessment: The initiative assesses its **impacts**.

[12] https://www.highmeadowsinstitute.org/projects/business-leadership-in-society-database/

The database also provides details for 25 countries, 12 GICS sectors, and 26 different ESG themes (one of these is GHG emissions).

Low carbon typically fits under the ‘sustainability’ umbrella

In many cases, practitioner literature combines low carbon metrics with wider sustainability measures (e.g. biodiversity; waste; water and soil pollution) under the umbrella of ‘sustainability’ or ‘environmental sustainability’.

Indeed, the Social Impact Investing Taskforce[13] identified the lack of a common “language” and the use of inconsistent terms and labels as a major hurdle for impact measurement and reporting. For example, terms such as ‘impact’, ‘social return, ‘value’, ‘results’, ‘effects’ and ‘outcomes’ tend to be used interchangeably, and there is some confusion about different types of investing (e.g. sustainable, ethical, responsible, impact):

“Impact reporting’ is often used interchangeably with other reporting approaches associated with effects on society and the environment, such as sustainability, or ESG reporting. The inherently contextual nature of impact makes it impossible to construct a holistic measure that is meaningful across contexts. For this reason, there is no universal definition of impact that can apply to all organisations and institutions, in all circumstances. As a result, stakeholders have developed a wide range of different definitions and approaches to measure and report on impact in a way that makes sense to them.” (Social Impacting Taskforce, 2018)

Moreover, GIIN[14] found that investment in the clean energy sector is driven primarily by social impact instead of environmental objectives: the majority of the investors interviewed invest in clean energy to improve quality of life through access to energy for poor or underserved populations.

Less focus on productivity

Error! Reference source not found. outlines the types of metrics cited in practitioner literature.

[13] Social Impact Investing Taskforce (2018) Growing a culture of social impact investing in the UK: Better reporting

[14] GIIN (2016) Impact Measurement in the Clean Energy Sector. Note that this is based on research with 13 investors.

Table B 20: Indicators cited in practitioner literature

Dimension	Indicator	Metric
Environmental Impact	Volume of CO_2 emissions	t
	Reduction in CO_2 emissions	t
	CO_2 emissions avoided / mitigated / sequestered	t / %
	CO_2-equivalent emissions stored	t
	Types of greenhouse gases emitted through operations (CO_2, CH_4, N_2O, SF_6, HFCs, PFCs)	Type
	Non-GHG air pollutants (PM2.5, PM10, VOCs, NOx, SO_2, CO)	Type
	Social cost of carbon	£
	Volume of renewable energy generated	MWh
	Sale of Certified Emissions Reductions (CERs)	£
	Retirement of Certified Emissions Reductions (CERs)	£
	Reduced personal impact on the environment	?
	Publications relating to R&D in renewable energy innovations	n
	Number and impact of renewable energy innovations developed	n / ?
Energy Consumption	Volume of energy used that is from renewable sources	kW
	Proportion of energy used that is from renewable sources	%
	Spending on renewable energy infrastructure/technology for own use	£
	Energy savings	kW
	Value of carbon credits purchased	£
Material Use	Certified products purchased from sustainable sources	%
	Materials recycled	t
	Recycled content of materials	%
	Increased local sourcing	?
	Area of land farmed sustainably	ha
Strategy	Comparison against targets (e.g. corporate carbon reduction target)	?
	Policies and initiatives introduced to improve energy efficiency	y/n
Commercial	Employment	n
	Clean technologies solutions (> 20% revenue)	%
Wider sustainability	Pollution incidents	n
	Volume of waste produced	t
	Waste diverted from landfills	t
	Volume of water consumed	l
	Water savings	m^3
	Area of natural environment created / restored / protected	m^2
	Peatland maintained or restored	ha
	Value of ecosystem services	£
	Improved support of protected species	?

Opportunities and challenges

GIIN [15] explored impact measurement in the clean energy sector, identifying a set of opportunities and challenges. These are outlined in **Error! Reference source not found.**.

Table B 21: Opportunities and challenges for impact measurement in the clean energy sector

Opportunities
1. Making impact data collection more purposeful (e.g. by integrating data collection into business processes)
2. Reducing the burden of impact measurement on investee companies (e.g. by adopting metrics that make business sense, or those that are already tracked by the investee company)
3. Increasing collaboration among impact investors
Challenges
1. Many metrics used by clean energy investors are based on assumptions about the product or customer, which challenge the overall reliability of data.
2. It is difficult to contextualize the significance of outcomes and impacts if local circumstances are not taken into account.
3. Metrics are often tracked and reported by investees; investors have no way to verify the accuracy and reliability of impact data.
4. Current impact measurement practice in the clean energy sector is largely based on observable but unverifiable data.

Source: GIIN (2016) Impact Measurement in the Clean Energy Sector

References Annex B

A4S CFO Leadership Network (2019) Essential guide to natural and social capital accounting.
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Table B 22: MSCI Index Metrics – low carbon/cleantech

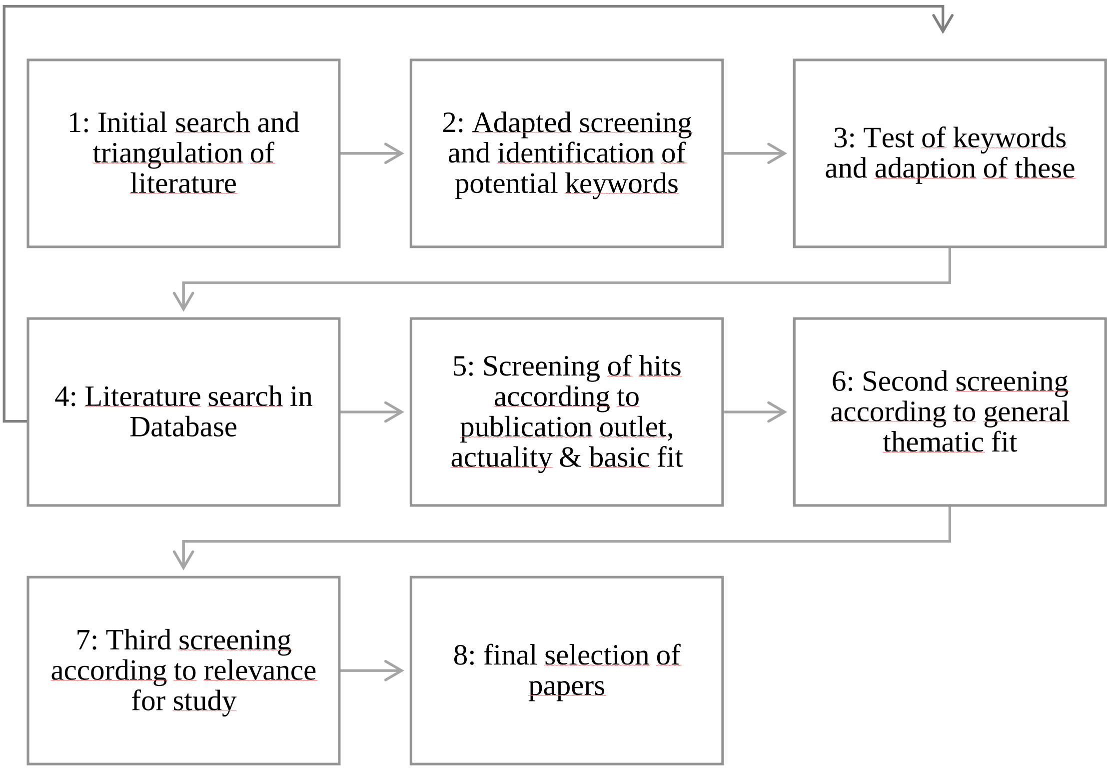
Metrics	Definitions
Carbon emissions (t CO2e/$M invested)	
Carbon intensity (t CO2e/$M sales)	
Clean technologies solutions (> 20% revenue)	Exposure to companies that derive 20% or more revenue from any of the five cleantech themes: Alternative energy, energy efficiency, green building, pollution prevention or sustainable water
Clean technologies solutions revenue (wtd avg %)	Weighted average % revenue derived from any of the five cleantech themes, including alternative energy, energy efficiency, green building, pollution prevention or sustainable water
Green/brown net revenue exposure	The ratio of the weighted average clean technologies solutions revenue (%) or "green revenue" to the weighted average fossil fuel revenue (%) or "brown revenue," which is defined as the weighted average % revenue derived from any of the fossil-fuel-related activities including thermal coal mining, oil and gas extraction, thermal coal-based power generation and oil and gas-based power generation

Source: MSCI IndexMetrics®An Analytical Framework for Factor, ESG and Thematic Investing

Annex C: Systematic Literature Review

A systematic literature review was conducted, screening literature from 2000-2020. This time span was selected, after an initial literature search and scoping, mainly because theoretical constructs such as Sustainability Assessment (SA) only recently emerged whereas earlier streams – such as Environmental and Sustainable Impact Assessment have existed longer (EIA and SIA; Waas et al. (2014)). The keywords and papers were selected following a similar process to Nightingale (2009). After an initial search in Google Scholar, streams in literature were triangulated to get an overview of potential keywords (Figure 1).

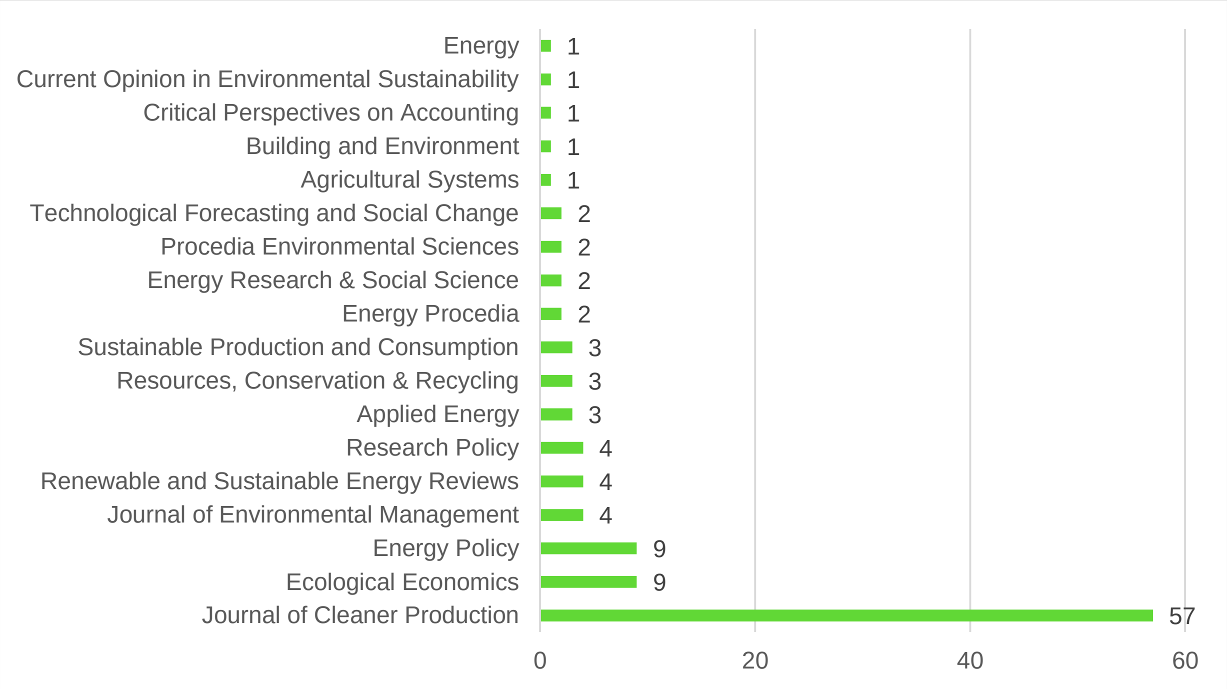
Figure C 6: Process of Literature Review



First, as our study focusses on cleantech SMEs, we set the search term cleantech “OR” clean-tech. The goal of such companies is to facilitate a transition towards a greener economy; hence we adopted the keywords low carbon “AND” (economy “OR” metrics) as the aim is to analyse their impact measurement. Second, according to works of Ahi and Searcy (2015); Veleva and Ellenbecker (2001), terms such as ‘performance measure’, ‘performance evaluation’, ‘performance assessment’ and ‘performance indicator’ are used interchangeably. Hence, we used the search terms performance “AND” (measure “OR” evaluation “OR” assessment “OR” indicator). After a test of these keywords in Scopus (the largest global database of academic literature) we adapted our initial keyword selection (see Figure 1), and ultimately included environmental *performance indicator and *performance evaluation. The terms indicator and metric are also often used interchangeably as we noticed throughout the analysis of our literature, hence we included the search-terms environmental impact *metric, *indicator. Third, as outlined below, the term eco-innovation is often associated with green innovation (Scarpellini, Marín-Vinuesa, Portillo-Tarragona, & Moneva, 2018), hence we further included the terms eco innovation, *indicator.

In the search we only included journal articles and book reviews, and our search was limited to headings, abstracts and keywords of the respective articles. The initial search produced 30,428 hits in total. We screened and selected these hits in three steps. First, a general screening was conducted on the fit of journals, and a general thematic fit concerning industry and journal applicability, which led in total to 2,499 articles included. Second, the articles were screened once again for their thematic fit. Those articles describing and developing industry specific metrics, for example for construction or chemical industries, were excluded from our study. In addition, we excluded technical articles describing a transition to a low-carbon economy. This resulted in 333 papers after the second step. In the final screening step we only selected articles that are highly relevant to our study, and explicitly mention environmental indicators used and practical as well as policy implications. This led us to a final number of 122 papers (Figure 2).

Figure C 7: Number of selected articles in 18 most relevant journals



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Annex D: List of key informants

Table D 23: Key informants

Company	Type	Contact
Cambridge Cleantech	Cleantech Market Support	Martin Garratt
St John's Innovation Centre	Cleantech Market Support	David Gill
KPMG	Cleantech Market Support	Salvatore Di Maggio
Greenbackers	Cleantech Market Support	Robert Holkin
North East LEP	Cleantech Market Support	Robert Lynch
Centre for Eco-Innovation, Lancaster & Liverpool Universities & Inventya Ltd	Cleantech Market Support	Zoe Detko, Hannah Wright, Dion Williams, Ruth Alcock
Oxford innovation	Cleantech Market Support	Jens Tholsrup
Impact Management Project	Cleantech Market Support	Clara Barby, Jo Fackler
Future-Fit Business	Cleantech Market Support	Kevin Horgan
Angel News	Market Analysts	Modwenna Rees-Mogg
Beauhurst	Market Analysts	Henry Whorwood
Pitchbook	Market Analysts	Kerry Ho
Bethnal Green Ventures	Private Impact Investors	Melanie Hayes
Green Angel Syndicate	Private Impact Investors	Antoine Pradayrol, Nick Lythe, Rachel Owen,
Mylor Ventures	Private Impact Investors	Rob Misselbrook
ET Capital	Private Impact Investors	James Griffiths
ETF Partners	Private Impact Investors	Patrick Sheehan
British Venture Capital Association	Private Impact Investors	Chris Elphic
Zero Carbon Capital	Private Impact Investors	Pippa Gawley
Hermes Investment	Private Impact Investors	Michael Viehs, Louise Dudley
Abundance (crowdfunding)	Private Impact Investors	Charlotte Eddington
Low Carbon Innovation Fund	Public Impact Investors & Policymakers	Saffron Myhill-Hunt, Robert Smith
BEIS Energy Innovation	Public Impact Investors & Policymakers	Rob Rutherfoord
Innovate UK (IAP)	Public Impact Investors & Policymakers	Bruce Colley
Seed Fund	Public Impact Investors & Policymakers	Tania Villares Balsa
Clean Growth Fund	Public Impact Investors & Policymakers	Beverley Gower-Jones
ClearlySo	Private Impact Investors	Chris Parsons
DEFRA	Public Impact Investors	Maya De Souza, James Butterworth, Charlotte Lockwood
Glasgow University	Academic Expert	Prof. Colin Mason
Lancaster University Management School	Academic Expert	Prof. Jeffrey Unerman, Prof. Jess Davies

Four workshops were held respectively with St. Jon's Innovation Centre, Green Angel Syndicate, Department for Food and Rural Affairs (DEFRA) and Academics with Centre for Understanding Sustainable Prosperity (CUSP) to test early findings.

Table D 24: Workshop Details

	Participants	**Company**
St John's Innovation Centre (held on 20/07/2020)		
	Tom Graver	St John's Innovation Centre
	David Gill	St John's Innovation Centre
	Martin Garrat	Cambridge Cleantech
	Saffron Myhill-Hunt	Low Carbon Innovation Fund
	Robert Smith	Low Carbon Innovation Fund
	Frank Knowles	Cleantech Angel
	Martin Clark	Allia Cleantech Support
GAS (held on 21/07/2020)		
	Antoine Pradayrol	GAS
	Nick Lyth	GAS
	Rachel Owen	GAS
	Chris Joly	GAS
DEFRA (held on 14/07/2020)		
	Maya De Souza	DEFRA
	James Butterworth	DEFRA
	Charlotte Lockwood	DEFRA
CEEDR/CUSP Seminar (08/09/2020) – academic audience		
	Raffaella Calabrese	Edinburgh University
	John Allison-Walsh	Hull University
	Tang Ka Yee	Santander
	Sean O'Reilly	Technology University Dublin
	Joanna Kitchen	Middlesex University
	Max Middleton	Vala Capital
	Hye-jin Cho	Reims
	Patrick Elf	CEEDR/CUSP
	Fergus Lyon	CEEDR/CUSP
	Sara Hourani	Middlesex University
	Leandro Sepulveda	CEEDR
	Meri Juntti	Middlesex University
	Ciaran Mac an Bhaird	Dublin City University
	Javed Hussain	Birmingham City University
	Jonathan Scott	Waicato University
	Othmar Lehner	Hanken School of Business

Annex E: Key Informant Topic Guide

Redefining SME Productivity Measurement and Assessment for a Low Carbon Economy

Intro: The UK faces dual policy requirements for improved business productivity and progression to a low carbon economy to achieve Net Zero by 2050 or earlier.
Key Research Question: What are appropriate metrics and policy responses for environmentally sustainable productivity development?
Our focus is restricted to green/cleantech SMEs and low carbon investment, since these can demonstrate what actions and measures are required to stimulate low carbon impact investing and create more dynamic change towards a low carbon environment.
We are also interested in how productivity measures can be adjusted to take into consideration the wider sustainability requirements necessary to achieve a low carbon environment.
Our target key informants will be key policymakers, cleantech market experts and support providers, impact investors and investment groups, metrics and evaluation experts and key business case and investor examples.
We seek input and engagement from key actors from the outset and aim to create clear pathways to delivering insights and practical screening and evaluation tools to assist policymakers, business support providers/services and impact investors.
The research process will include key informant interviews, practitioner and policy workshops (*co-virus permitting*), case study example businesses and dissemination via reporting, conferencing and practical toolkits for investors and evaluators.
Note to interviewer: Use topic guide questions where appropriate for interviewee

Interview date/time details:

Background of Respondent:
Name:
Position:
Organisation:

What is the Relevant experience of you and your organization in working with:
Cleantechs/green SMEs, Impact (environmental) Investors, Relevant Government Programmes (e.g. funding mechanisms/instruments/programmes- and associated public and private support)
Re -Organisation –
Re -Individual –

Understanding of Productivity policy and measurements
How do corporate businesses and SMEs currently measure productivity (probe for differences between corporates and SMEs, and what may be relevant to earlier stage, smaller, innovative green/cleantech SMEs)? *Note – we are interested in what is applicable to SMEs*
What types of measures do government support policies and programmes use (to select co-finance organisations (eg VCs) and recipient business beneficiaries and evaluate policy/programme impacts)?
What accounting/assessment measures are typically used that can assist? *(probe on what works well/less well and why*?)

Understanding of Impact investment measurements (ie *Green rather than productivity aims*)
What do government and private investors use to screen for selection and assess their impact investments?
- Probe on how government selects green investment co-funding partners
- Probe on approaches and metrics used – formal versus informal

Probe on what is specifically used for environmental and low carbon investment metrics (as well as wider sustainability development goals)?

Assessment of the value of current approaches/metrics?
How effectively do current approaches and metrics for productivity and sustainability (*focusing on environmental/low carbon*) work?
- Probe for examples of best practice
- Probe on where we can learn more from (source references, organisations – international approaches?)

How could these approaches (eg SDGs/CSR/CBA/EIA/SRI) and metrics (KPIs) be improved?
- Probe for relevance to early stage, smaller SMEs
- Probe for combination (weighting) of productivity and sustainability
- Probe for environmental/ low carbon metrics

To what extent is circular economy (CE) and the wider impact of investment being screened for selection and evaluation purposes?
- Probe on what aspects of wider environment spillovers (supply chains, buyers, innovation clusters etc) that should be measured and how
- Probe on timelines required for sustainable impacts and recycling

What other aspects should be considered?

Summary of future recommendations
To summarise from existing evidence:
What are the most effective and useful screening selection approaches and metrics that combine environmental sustainability with productivity that should be adopted by public and private investors?
What are the key evaluation approaches and measures that should be adopted by public support programmes to account for both environmental sustainability – low carbon and productivity impacts?
Do you have any other associated key recommendations for UK policymakers? (*please detail how these should be operationalized*)

Follow-up: key contacts/organisations/experts, key data and sources of reporting/information

Please provide suitable contacts we should follow-up and introductions where possible – these can include:
Policymakers – strategists (Government departments, and non departmental bodies)
Policy Think-tanks, lobbyists, advisors
Environmental Impact Investor Groups
Business support providers (e.g. specialist innovation and cleantech support hubs)
Private business support providers such as accountants
Market specialist key informants and academics
Suggested key case study cleantech businesses and their impact investors.

Please provide information of key literature, reports, evaluation, and data sources that may be useful?

Further support and engagement with the research:
Willingness to be re-interviewed, attend workshops, or hold workshops – Note we intend to gather information and test our findings and recommendations through workshops