Public procurement for net-zero digital research infrastructure:

A mission-oriented approach for UK Research and Innovation

Mariana Mazzucato
Director and Professor in the Economics of Innovation and Public Value
| UCL Institute for Innovation and Public Purpose

Institute for Innovation and Public Purpose

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About the Institute for Innovation and Public Purpose

UCL Institute for Innovation and Public Purpose (UCL IIPP) aims to develop a new framework for creating, nurturing and evaluating public value in order to achieve economic growth that is more innovation-led, inclusive and sustainable. We intend this framework to inform the debate about the direction of economic growth, and the use of mission-oriented policies to confront social and technological problems. Our work will feed into innovation and industrial policy, financial reform, institutional change and sustainable development. A key pillar of IIPP's research is its understanding of markets as outcomes of the interactions between different actors. In this context, public policy should not be seen as simply fixing market failures, but also as actively shaping and co-creating markets. Re-focusing and designing public organisations around mission-led, public purpose aims will help tackle the grand challenges facing the 21st century. IIPP is housed in The Bartlett, a leading global Faculty of the Built Environment at University College London (UCL), with its radical thinking about space, design and sustainability.

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1. Introduction: Net-zero objectives and digital infrastructure

The achievement of net-zero objectives, and the broader goal of decarbonising our planet, are among the hardest challenges humanity has faced. In line with UN-led global initiatives, such as the latest COP27, many countries have now set their net-zero agendas, defining goals to reduce emissions and to convert their economies away from high-carbon-intensity activities.

The UK has defined clear objectives in the Sixth Carbon Budget Report (CCC 2020) and outlined its preferred strategy to achieve them — what is presented as a *balanced pathway* to net zero will have to combine strong efforts to reduce emissions with equally strong efforts to avoid economic disruptions. The report emphasises that this mission requires active involvement by all economic sectors; significant commitments to changing consumption and production behaviours; and ambitious investments in green innovation and low-carbon solutions. Specifically, four areas are identified as key for action: 1) increasing the take-up of low-carbon solutions; 2) expanding the supply of low-carbon energy; 3) reducing demand for carbon-intensive activities; and 4) transforming land use with stronger support for low-carbon farming activities.

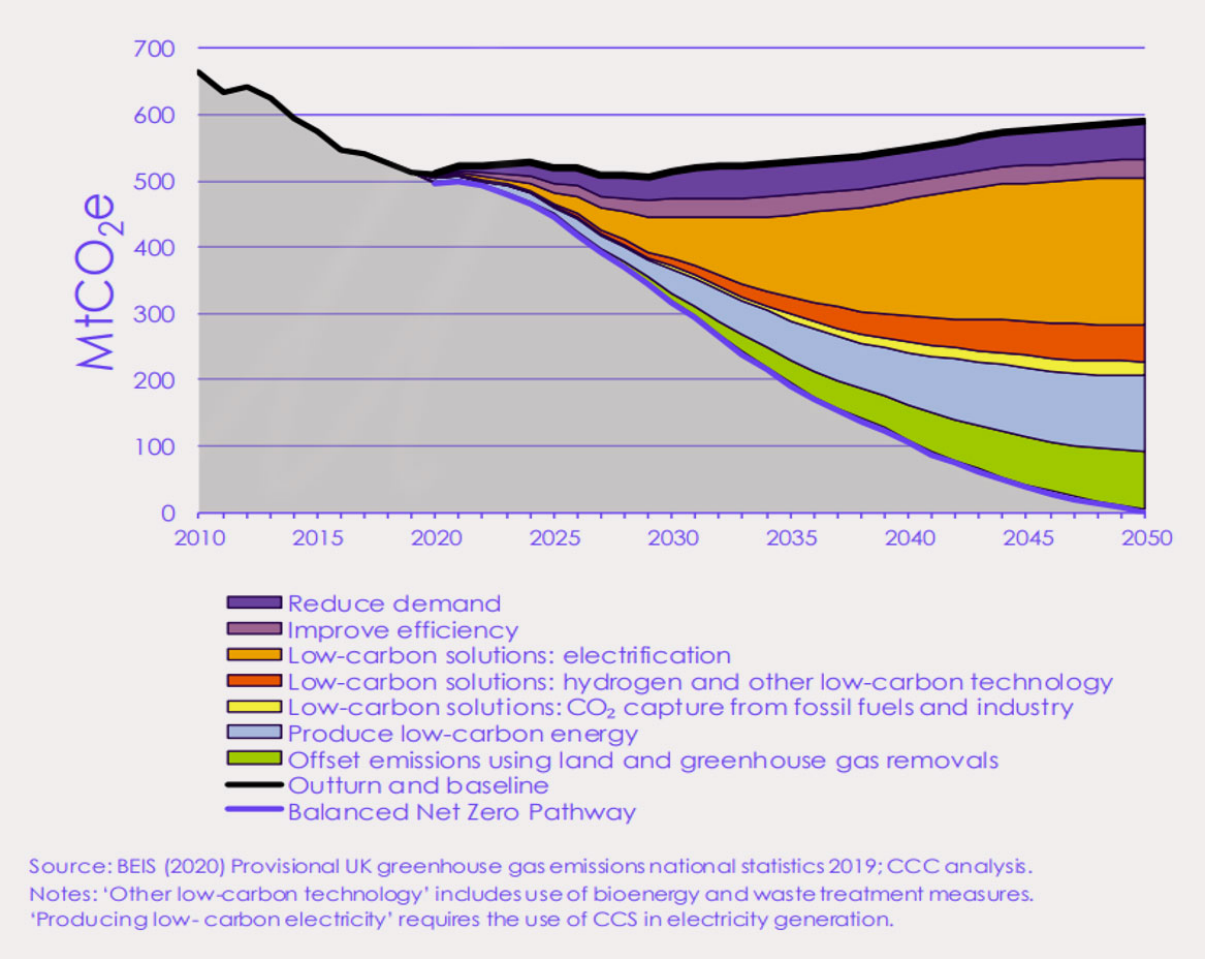
An effective innovation and industrial strategy oriented around these and other climate goals will be critical to the UK's ability to achieve them. Directing innovation and industrial strategy to address big challenges can catalyse collaboration across sectors, and across government ministries and agencies, to foster new solutions, and in so doing can bring the UK closer to solving big challenges like the climate crisis as well as galvanizing economic growth. A mission-oriented approach should cut across the UK's innovation system, from research to commercialisation, and should apply to both supply- and demand-side policies. UK Research and Innovation (UKRI) has a critical role to play in a mission-oriented innovation and industrial strategy, both in its role funding cutting-edge research and as a public sector agency that can redesign its internal policies to align with climate goals, notably around procurement. This paper explores UKRI's role in advancing net-zero missions within the broader UK innovation system, with a particular focus on digital research infrastructure (DRI), which is one area of influence for UKRI.

As a contributor to both greenhouse gas emissions and innovation-led growth, DRI is an important component of a comprehensive approach to achieving net-zero targets. Put simply, while DRI has revolutionised the ways in which we communicate, collaborate and access information, it also accounts for a considerable environmental footprint. As digitalisation progresses and the demand for processing power rises, so does energy consumption, and the demand for data centres and server farms. The electricity needed for powering and cooling these facilities often comes from carbon-intensive sources. Understanding the environmental complexity of DRI is essential for developing strategies that minimise carbon emissions while harnessing its potential.

UKRI supports the development and utilisation of digital resources to empower researchers, foster collaboration and drive innovation. Considering net-zero missions in this context can serve as a valuable case study that may inspire other research institutions, funding bodies and policymakers to prioritize net-zero missions and embed sustainability into their operations. Indeed, the systemic nature of this challenge requires the coordination of multiple actors and interventions at different levels, to develop integrated solutions that reflect the complexity of sustainable digitalisation.

In considering the net-zero implications of UKRI's DRI we first highlight the need for a systemic view of innovation and how a mission-oriented approach can help develop integrated solutions to grand challenges like climate change (Mazzucato 2021). We then consider UKRI's role in this system, particularly in relation to DRI, with a focus on one specific policy tool — public procurement. In particular, we highlight how specific forms of procurement, such as public procurement for innovation and green public procurement, could help mobilise resources to achieve a green transformation in the use of DRI. In this regard, we consider how public procurement could support greener infrastructure adoption, manage resources in a circular way, and stimulate broader behavioural changes in the use and consumption of DRI and big data.

Figure 1. Types of abatement in the balanced net-zero pathway



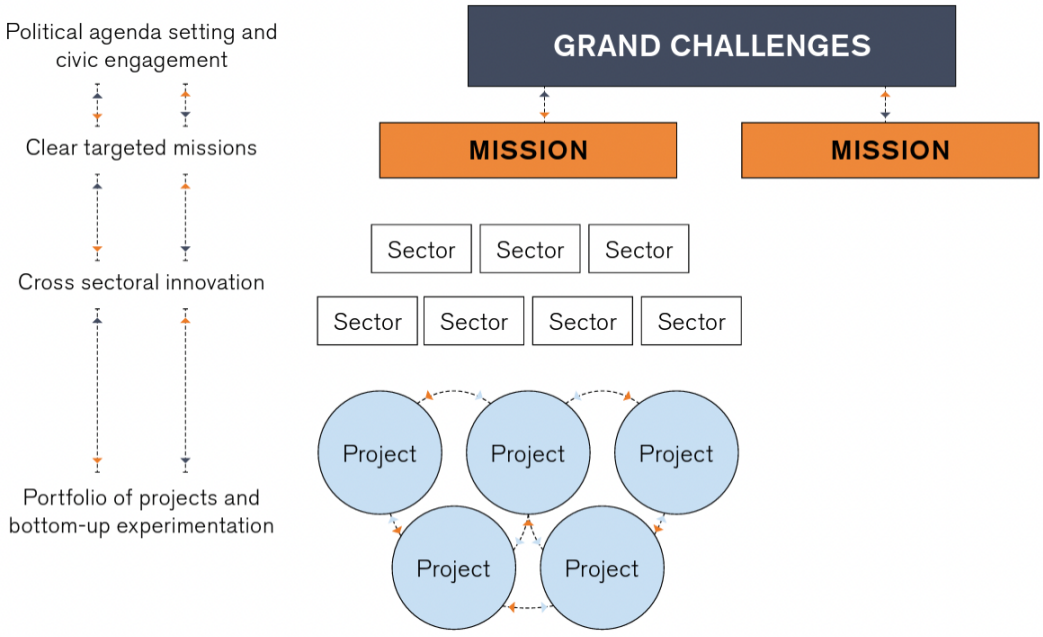
Source: CCC, 2020

2. Directing innovation: A mission-oriented approach

While the ability of innovation to spur economic growth has long been recognised, the fact that innovation has not only a rate but a direction has been less recognised. By acknowledging the directionality of innovation, we can harness the power of research and innovation to achieve wider social objectives, as well as economic goals. This shift enables governments to direct innovation-led growth that is also sustainable and equitable (Mazzucato 2018a).

Missions are an ideal tool to steer innovation, investment and economic growth towards the resolution of wider societal challenges. A mission-oriented approach means putting the problems that need solving at the centre of how economic systems are designed. It starts with a broad challenge that is turned into concrete, targeted missions, which require multiple sectors and actors to develop solutions (Mazzucato 2018b). In other words, missions set clear goals that catalyse cross-sectoral collaboration, investment and bottom-up experimentation (Mazzucato 2021).

Figure 2. From challenges to missions and projects



Source: Mazzucato and Dibb, 2019

In general, missions should:

- Be bold and inspirational, with wide societal relevance;
- Set a clear direction, with goals that are targeted, measurable and time-bound;
- Be ambitious but realistic;
- Encourage cross-disciplinary, cross-sectoral and cross-actor innovation; and
- Involve multiple, bottom-up solutions (Mazzucato and Dibb 2019).

These kinds of grand challenges require a different framing of economic policy — one that is less about fixing market failures and more about co-creating and shaping markets. Indeed, the market is an outcome of interactions between citizens, business and the state (Mazzucato 2013, 2016). Importantly, tilting the playing field — rather than levelling it — is not about picking winners, but about picking the willing by aligning all available instruments to produce collective value (Mazzucato 2018c). In this context, industrial and innovation strategies become key to achieving transformational societal change, by identifying and articulating missions that instrumentalise production, distribution and consumption patterns across various sectors to align with socially desirable directions (Mazzucato 2018b, 2018c).

The debate about directionality should involve a wide array of stakeholders, each contributing to the definition of the challenges, the policy support required to achieve them, the evaluation criteria and the environment for experimentation that could yield successful pilots to be emulated across sectors.

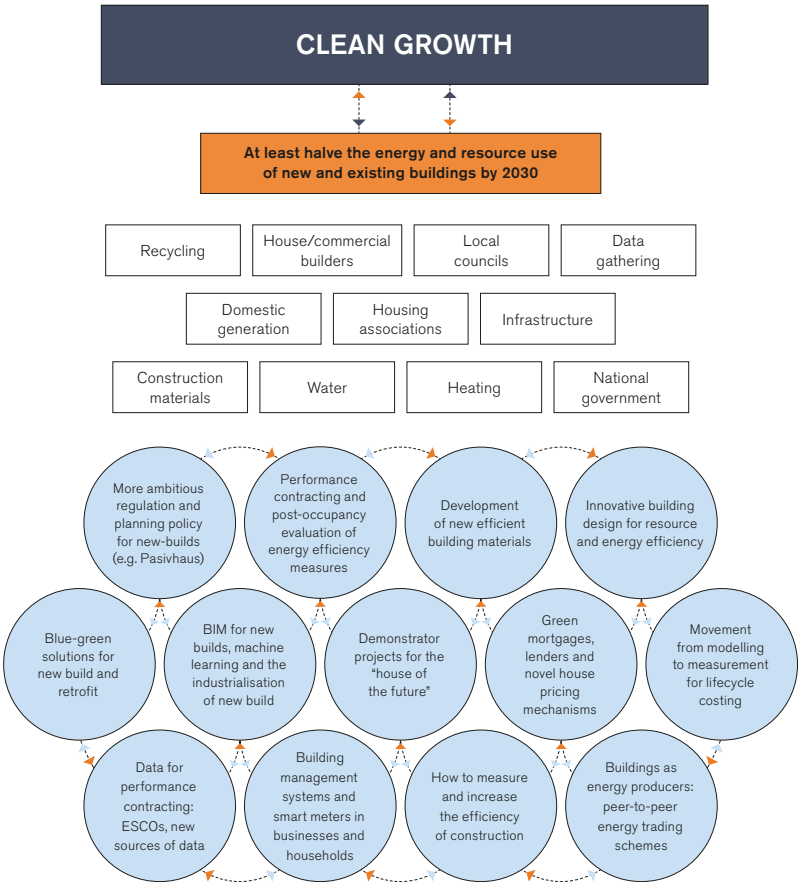
The Horizon Europe programme provides a good example. The programme identified five missions around which research and innovation investments are being oriented, supported by new forms of governance, policy design, collaboration and citizen engagement. These missions were informed by an extensive consultation process. One of them — to deliver 100 climate-neutral and smart cities by 2030 — was informed by the 'mission map' in Figure 4 (Mazzucato 2018). This promising programme could be further extended through missions set more broadly at the level of innovation and industrial strategy, extending beyond one programme to better coordinate multiple programmes and investments.

In March 2018, the UCL Commission for Mission-Oriented Innovation and Industrial Strategy (MOIIS) was formed to advise the UK Government on how to implement an industrial strategy that aligns innovation and investment with solving grand challenges. MOIIS considered four grand challenges articulated by the UK Government at the time — clean growth, AI and the data economy, the future of mobility and an ageing society — to identify relevant cross-sectoral actors, bottom-up projects and paths to delivery.

Importantly, MOIIS pointed out that AI is a general-purpose technology, rather than a societal challenge, and is relevant across missions (UCL Commission for Mission-Oriented Innovation and Industrial Strategy 2019). Changes to DRI design and usage can be thought of in similar terms — as contributing to solutions across a variety of challenges, including the reduction of carbon emissions, rather than as the mission themselves. Importantly, digital and data infrastructure are not neutral. Governance structures are needed to ensure that how they are designed serves the public interest — and this must extend beyond net-zero goals to encompass ethical and human rights considerations (Mazzucato et al. 2022; Ramos and Mazzucato 2022).

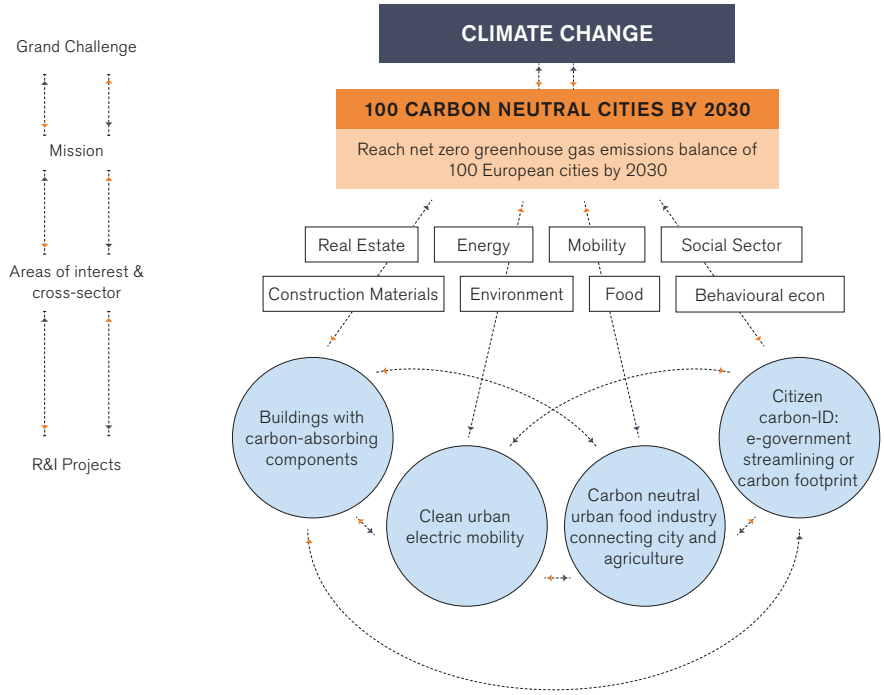
MOIIS' final report continues to provide a strong jump-off point for reinvigorating a discussion about how to shape a UK mission-oriented innovation and industrial strategy, which could engage a wide array of actors, including UKRI.

Figure 3. Example of a mission: clean growth mission roadmap



Source: UCL Commission for Mission-Oriented Innovation and Industrial Strategy (MOIIS), 2019

Figure 4. Example of a mission: 100 carbon-neutral cities by 2030



Source: Mazzucato, 2018

3. Missions in the context of innovation systems

A national innovation system refers to the set of institutions and actors (market and non-market; producers and consumers), policies and regulations that connect economic sectors and technological systems to produce and diffuse new technologies, products, services or processes. Key innovation institutions and actors range from universities and research institutes to those focused on the application of technologies for commercial purposes. Additionally, organisations and funding streams facilitate connections and interactions between the more basic and applied ends of the research spectrum, such as public state banks, R&D funding, public procurement and private investment.

Successful missions depend crucially on strong innovation systems since they can only steer innovation-led economic growth when supported by sectoral and technological capabilities. States must make strategic decisions on the kind of general-purpose technologies that will create opportunities across sectors (for example, energy storage), the type of finance that is needed (Mazzucato and Semieniuk 2017; Semieniuk and Mazzucato 2019), the type of firms that will need extra support, and the type of regulations and taxes that reward desirable behaviour.

Missions do not replace the need to build and enhance the general strength of the UK's innovation system, but rather depend on strong horizontal polices — including with respect to technological capabilities — being in place. In other words, investing in technological development independent of specific missions is crucial for building technological capabilities. Without strong AI competence, for example, the AI sector may not effectively contribute to missions. However, when allowed to engage with ambitious missions, AI advances and expands into new areas, driving innovation. Importantly, general-purpose technologies require particularly careful consideration as their transformative potential is significant. In early stages, when their ultimate application can be unclear, an immediate integration into a mission-oriented framework can hinder the development of their potential (MOIIS 2019). Their transformational potential requires them to be supported independently of any mission. It is therefore crucial that a discussion about a mission-oriented approach to UKRI DRI is embedded in a discussion about how it fits within the broader UK innovation system — including its critical role in promoting general technological capacity.

Section 3 explores possible policy tools UKRI could leverage to achieve net-zero objectives, including through commissioned research and internal policies governing the use of digital infrastructure, with a focus in Section 4 on procurement policy. However, these tools must be considered within the broader context of the UK's innovation system.

4. How a net-zero mission applies to UKRI DRI

It should be noted that while UKRI is an important part of the UK innovation system, it is only one part and it is likely that its carbon footprint is relatively small, as is the carbon footprint of its DRI in relation to wider digital infrastructure in the UK (however, this will be confirmed by future UKRI data analysis). UKRI is also not the only provider of DRI and policy choices within UKRI may cause DRI users to shift to relying on private DRI. Moreover, the carbon impact of DRI relies to a great extent on the carbon intensity of electricity supply in the UK. Net-zero targets for UKRI DRI therefore cannot be looked at in isolation from the rest of the UK innovation system, from digital infrastructure more widely or from the carbon emissions associated with electricity supply. UKRI should ideally be a key actor in wider net-zero or climate missions, set at the national level. Short of this ideal, however, UKRI can play an important role in applying principles of mission orientation to its own policies.

Notably, through commissioning research, UKRI is a key actor in the UK innovation system. UKRI can shape mission-oriented funding for research that contributes to the investigation and development of sustainable technological solutions, and that helps to foster new, cross-sectoral and cross-disciplinary collaboration.

It is also well-positioned to initiate pilot projects and demonstrations to showcase how net-zero targets can be integrated into public policies, including in the area of DRI. In other words, UKRI can consider opportunities to serve as a case study to be emulated by organisations that carry out energy-intensive research requiring extensive data storage facilities and high-performance computers.

Such demonstration projects could, for instance, involve defining the most appropriate tools to reduce emissions, or setting standards around the implementation of energy-efficient computing systems and sustainable data management practices. Through a mission-oriented lens, UKRI can provide tangible examples of how DRI can align with net-zero objectives.

Notably, UKRI could establish clear rules, guidelines, support or incentives around sustainable research behaviours for employed staff and affiliated researchers. This could include restricting computation to times of day when more of the energy supply comes from renewable sources or during off-peak hours, or other energy-efficient data management strategies. It could also include increasing awareness of the emissions associated with consumption patterns and work behaviours, through carbon accounting systems or a 'carbon costing' requirement for grant applications. By incorporating net-zero goals in the research objectives of newly funded projects, UKRI could actively promote sustainable practices, encourage researchers to consider environmental impact throughout their work and decarbonise research activities.

Additionally, UKRI could collaborate with stakeholders to develop guidelines and standards for governing the sustainable use and installation of DRI, including standards for measuring and reporting on energy consumption and the carbon emissions associated with DRI, for example on an hour-by-hour basis (as opposed on a daily or annual basis). UKRI could also facilitate the creation of tools that would allow researchers to assess the impact of using DRI, and prioritize lower impact options. For example, delaying the use of significant computing capacity – such as

when training an AI system - during periods of high renewable energy capacity could significantly reduce carbon. Standards and new pricing models that incentivize greener behaviour could, if adopted more widely by cloud providers, also create positive impacts beyond UKRI. UKRI could facilitate discussions on integrating net-zero targets into DRI, allowing researchers, industry experts and policymakers to exchange ideas, share success stories and collectively explore innovative solutions to address the environmental impact of DRI. Learning by doing is a key element in improving organisational capacity to respond to change.

Notably, UKRI has the potential to influence the direction of procurement practices in their supply chain. By prioritising green and innovative patterns in procurement decisions, UKRI can encourage suppliers to adopt sustainable practices, such as net-zero commitments. This approach can help to drive sustainability across supply chains and support the growth of sustainable and environmentally friendly technologies. Section 4 looks at the potential of procurement in greater detail.

5. In focus: Aligning procurement with UKRI's goal of net-zero DRI

One of the tools available to states and institutions to advance missions, direct investment and promote innovative solutions is procurement. Public procurement is the acquisition of goods and services by governments or public institutions. In the context of UKRI's DRI decarbonisation agenda, procurement stands out since it can tackle both the supply and consumption (demand) of DRI. To be more specific, procurement can create markets by providing a demand-side pull for new products and services, and can widen the ecosystem of companies able to access UKRI contracts. Changing how procurement is done can also increase the economic multiplier. By procurement we refer both to investments in DRI — for example, in cloud computing, accelerators, heterogeneous computing, technologies for heat reinvestment through more efficient cooling systems, recycled hardware and so on — and to the funding (grants) that UKRI provides to research that uses that research infrastructure.

It is acknowledged as one of the most effective demand-side instruments to mobilise investment and resources towards an objective of societal value (Bleda and Chicot 2019; Mazzucato 2020). Indeed, procurement budgets for one department can be four times as large as a state's entire innovation budget (Mazzucato 2020). In the UK, approximately a third of public spending is through procurement, worth almost £300 billion in 2019/20 (House of Commons 2022). Procurement has been recognised by the European Commission, for example, as an essential driver to achieve innovative and sustainable goals, and to direct public demand according to a mission-oriented approach (Mazzucato 2018a). As Perez (in Lember et al. 2013) writes, major societal challenges '…can only be healed through the intervention of the state as an active and creative agent of innovation for growth and widespread well-being. Among the many ways of government action in pursuit of such goals, innovation procurement seems to be a prime instrument. It is both a form of public investment that spurs economic activity and a way of stimulating private efforts in innovation directed at fulfilling social needs.'

If designed to properly address economic and social objectives, public procurement can not only contribute to stimulating innovation, but can foster the creation of new markets, the adoption of new technologies and the implementation of new services (Lember et al. 2013). Box 1 highlights this market-shaping potential using the case of the UK's Government Digital Service (GDS) procurement strategy.

UCL Institute for Innovation and Public Purpose is working with Camden Council in London, UK, to explore how their procurement policy could be redesigned to support four missions defined by the Camden Renewal Commission as part of the We Make Camden strategy. Early insights emphasise the importance of leveraging procurement to shape markets by building capabilities among suppliers and securing commitments to work in new ways; focusing on outcomes rather than specifying inputs or outputs; exploring place-based commissioning to drive collaboration between services that are co-located; adapting internal processes and governance to enable a different approach to procurement; and building organisational and individual capabilities (UCL Institute for Innovation and Public Purpose 2023). This last point is discussed in more detail in the next section.

Historically, commissioning of services has often focused on visible outputs (for example, the number of children attending a breakfast club) rather than the desired outcome (the number of children with healthy nutrition) - in part driven by the relative ease of collecting data. In the context of Camden, or other Local Authorities, the goal of outcome driven procurement for services would be to give providers the flexibility and freedom to achieve the outcomes of the service in whatever way they see fit. As the actor closest to the frontline, they are often in a better position to make strategic and tactical choices about delivery models and priorities than the commissioner.

However, outcomes commissioning for services carries risks of its own. If commissioners simply swap output metrics for outcome metrics, they risk creating perverse incentives that often lead to suppliers gaming data. This is driven in part by the fact that service outcomes are always nested within complex systems, in which no single organisation or service has full control over the outcome in question. Continuing the example above – even the best breakfast club in the world may not lead to an increase in the number of children with healthy nutrition if the food environment is declining in quality at the same time. Attempts to hold suppliers to account for changes in outcomes thus often lead to them being asked to take responsibility for factors outside their control, which provides a strong incentive to present data and information in a way that paints them in the best possible light.

Alternatives to this approach maintain a focus on outcomes as a shared purpose across system actors, but rather than using data for accountability emphasise the importance of sharing learning. The goal is to create a trusted relationship between commissioner and supplier that enables continual improvement and adaptation in the face of the ever-changing system(s) within which they are working (Knight et al, 2020). IIPP's work in Camden has also highlighted the importance of culture and attitudes to risk as a barrier to more progressive procurement practice. Whilst new processes (such as pre-commercial procurement) can have a real impact on procurement outcomes, it remains the case that for large organisations the values, goals and mindsets of the people working in central procurement teams is a critical enabler of change.

Table 1: Adopted and modified based on Institute for Innovation and Public Purpose (2023)

Characteristic	Opportunity	Organisational Capabilities	Individual Capabilities
Market shaping	▪ Reframing the government's role as an orchestrator ▪ Improving story telling & building a shared vision with suppliers and stakeholders ▪ Securing co-investment and commitment from partners ▪ A relational approach to supplier and business engagement & earlier engagement ▪ Proactively creating capabilities within the supply chain ▪ Embedding market engagement in senior directors' roles	▪ Ecosystem leadership and orchestration	▪ Communication, storytelling, relationship building, understanding differing markets, technologies, and communities.
Outcome based procurement	▪ Using agreed missions to prioritise and articulate public value outcomes ▪ Embedding mission outcomes into the procurement stage gate process, and ultimately into contracts ▪ New approach to measurement and evaluation that prioritises mixed and comparative methods to create confidence that outcomes are being delivered ▪ Stronger connection between monitoring and evaluation so that service is improved over time	▪ Developmental evaluation	▪ Data and analytics, patience, pragmatism, creativity, an inquisitive mind
Organisational change	▪ Embedding new values and mindsets through the onboarding process	▪ Reflective practice, double loop learning	▪ Collaboration, openness to new ideas,

	▪ Redesigning performance and appraisal processes to incentivise innovation ▪ Creating a forum for reflective practice on past commissioning and procurement projects	▪ Enabling leadership	communication, an entrepreneurial mindset

Procurement must be seen as a strategic tool. The procurement process can entail a pre-commercial stage; a stage for consulting all the actors involved with the aim of assessing procurement standards and procedures, and available products and services; and a stage for developing sustainable solutions. As in the UKRI Net Zero Digital Research Infrastructure project, this phase might include a scoping period, with the objective of defining clear and measurable goals for the mission. Within collaborative procurement processes, the pre-commercial phase will be followed by demonstration and coordination — further steps meant to translate the pre-commercial idea into a concrete proposal to be commercialised. In detail, the procurement process may include the following stages (Edquist and Zabala-Iturriagagoitia 2012):

1. the definition of a grand challenge, or the 'wicked' problem;
2. the translation of this challenge into clear missions;
3. the tendering process;
4. the award of contracts; and
5. the delivery of the new product or service.

Procurement itself can be of different types and can serve different purposes. A first useful distinction is between **product** and **functional** procurement. The first refers to the purchase of a product, or good, that already exists on the market. The second does not specify the exact product to be acquired, but defines the function it needs to perform (Enquist and Zabala-Iturriagagoitia 2020; Mazzucato, 2020). A second line of differentiation exists between **adaptive/incremental** or **developmental** procurement. These two forms of procurement both entail a degree of innovation, but the former only implies the adaptation of an existing product or service to a new context or market, while the latter involves the creation of a brand-new product, service or system and therefore carries the potential for more radical, path-breaking innovation (Edquist and Zabala-Iturriagagoitia 2012; Lember et al. 2013).

It is also important to outline types of procurement embodying a different scope or purpose. Two kinds of procurement are particularly relevant to this project and should be leveraged to face the grand challenges we are confronting today, including the need to respond to the pressing climate emergency. The first is public procurement for innovation and the second is green public procurement.

Public procurement for innovation (PPI) is a demand-side policy tool involving experimentation, and the formulation of innovative solutions to economic and societal problems. It can trigger

technological development, the creation of new markets and the commercialisation of products not yet available on existing markets (Mazzucato 2020). When it does not lead to the actual development of a new product, it still attempts to indirectly open up innovative possibilities, for example spurring innovation in technological or organisational capabilities, and thus allowing for learning and new knowledge accumulation (Lember et al. 2013). Within PPI, the procuring organisation can be the end-user of the new product or service, or act as a catalyst, for example by inducing the procurement of innovative products or solutions for the benefit of external users or buyers, or adopting a broader societal or supply chain perspective (Edquist and Zabala-Iturriagagoitia 2012). Innovation-oriented public procurement can lead to the creation of a 'lead customer' or a 'lead market' for an innovative product or service, incentivising the adoption or the diffusion of new technologies (Uyarra et al. 2020). It can contribute to re-shaping existing markets (for example by changing competition patterns) or to shaping and co-creating new ones. PPI is a key tool for implementing a mission-oriented innovation approach.

In relation to the UKRI Net Zero Digital Research Infrastructure project, PPI could be leveraged jointly with a group of research organisations or other partners to stimulate advancements in specific aspects of DRI that could lower carbon emissions, not only for UKRI, but on a market level. On its own, UKRI may not have significant market-shaping power. However, pooled procurement approaches could be used to enhance the demand-side pull for innovative products and services.

Green public procurement (GPP) is fundamental to the achievement of green missions and net-zero goals. GPP seeks to attach the use of procurement by public institutions to a series of green conditionalities, thus expanding the potential to attain wider public purpose and social value. The pressing climate emergency, with the need to pursue environmentally sustainable goals and work towards net-zero targets, has made this form of procurement extremely important — a crucial instrument to address the challenge of reducing carbon emissions and combatting global warming. In a tendering process, sustainable green public procurement means not necessarily opting for the lowest price of a product or service, but considering the overall sustainability and life cycle of what needs to be acquired (Mazzucato 2020; Sönnichsen and Clement 2020).

In this way, GPP can contribute to creating green markets, and to changing unsustainable consumption and production patterns (Cheng et al. 2018; Sönnichsen and Clement 2020). In relation to the UKRI Net Zero Digital Research Infrastructure project, GPP might range from giving preference to cloud computing solutions that are backed by a credible commitment to 100% renewable energy or purchasing energy-saving hardware to investing in accelerators and cooling systems, setting circular patterns in terms of recycling and waste management or imposing sustainability criteria in the selection of suppliers. Indeed, the main objective of GPP must be minimising environmental impact and waste, while reducing carbon emissions and investing in clean, energy-saving infrastructure.

GPP relates to a broader, burgeoning policy discussion about embedding conditions in public funding to better share risks and rewards, in particular between public and private actors. Broadly, conditions can be related to (1) access, where equitable and affordable access to the resulting products and services is ensured; (2) directionality, where firms' activities are directed towards ambitious goals, such as a green transition or improved labour market conditions; (3) profit-sharing,

where profitable firms share royalties or equity with government and may be incentivised to leverage their profits through acquisition of government shares; and (4) reinvestment, where profits gained are reinvested into productive activities and R&D for longer term benefit, avoiding financialisation.

Importantly, the effective design of mission-oriented public procurement depends on many factors, including economic, institutional and social variables. Some countries and institutions may achieve more successful outcomes than others. Sweden is, unsurprisingly, an example of excellent use of public procurement for innovation targeting ecological transition goals. Since 2003, the Scandinavian country has combined a strong legislative framework for a green transition with clear targets for net-zero goals and incorporated the use of green public procurement as a specific environmental policy tool. This included an increased share of overall procurement linked to environmental sustainability criteria, the definition of green contracts and support for public authorities adopting green procurement. Among the most successful examples of projects driven by green public procurement it is worth mentioning the conversion to 100% organic food in Malmö's public catering services and the extensive purchase of electric vehicles by the city of Stockholm (Mazzucato 2020). The city of Copenhagen represents another positive example, with its ambition to radically transform the energy system at a city level and become a carbon-neutral city by 2025. Its procurement process has a clear green objective and has, for example, focused on radical innovation in the context of the street lighting system. With the introduction of LED streetlights, energy consumption was reduced by 57 per cent, with a consequent decrease in the city's carbon footprint and maintenance costs (€1.6 million per year for an investment of €26 million) (Mazzucato 2020).

Besides these successful examples, there are, of course, contexts where the effective use of procurement is hampered by factors that can be, for example, financial, institutional or organisational in nature. Within the crucial pre-commercial phase, which can include research and development (R&D) and is essential to establish the scope of the mission, knowledge and capabilities are key to set a clear direction and define targets. In the case of innovation-oriented public procurement, the time and complexity involved in developing new strategies can constitute a significant obstacle (Mazzucato 2020). In addition, lengthy and cumbersome administration and regulations, and poor communication and coordination between different actors involved in the process represent frequent barriers. Both in the pre-commercial and tendering phases, technical and administrative capabilities are fundamental. In this regard, and as was the aim for the UKRI Net Zero Digital Research Infrastructure project, building multi-disciplinary teams of technical experts can be of great value.

In the context of UKRI's net-zero DRI strategy, procurement policy can have consequences for the consumption patterns of digital infrastructure by numerous stakeholders. Design of procurement policy should therefore take into account the possibility of rebound effects, for example those associated with private actors scaling up their consumption of digital infrastructure where policy is conducive to innovation in energy efficiency or researchers opting to shift to using private DRI facilities, perhaps at their base organisations.

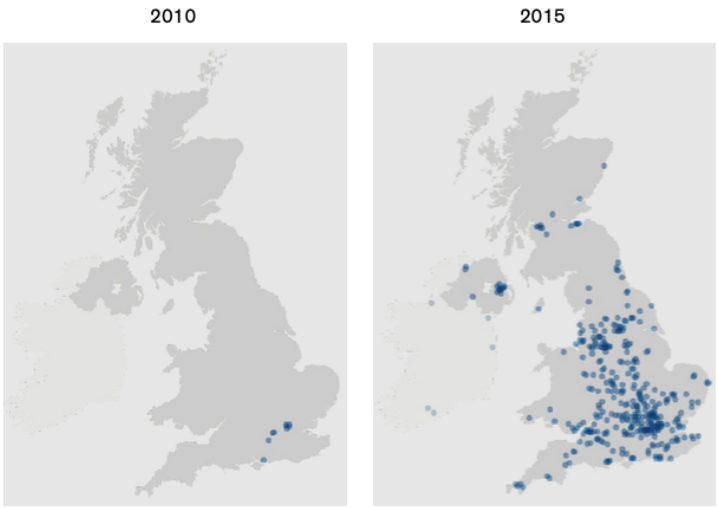
Overall, for mission-oriented, innovation-driven, green public procurement, factors that can determine success include the discretion and flexibility to shape procurement around broader societal goals, such as achieving carbon neutrality, as well as embedding environmental criteria across tenders and capabilities, including the cross-disciplinary, administrative and technical capabilities needed at all stages of the procurement cycle and within all actors involved in the process (Mazzucato 2020).

We follow this section by considering the capabilities needed within UKRI in order to implement a mission-oriented approach, including in the area of DRI procurement.

Box 1. Example: shaping markets through procurement

'Government Digital Service (GDS) was the team created in 2011 to lead the UK Government's digital transformation. A core part of their work was the creation of the Digital Marketplace, which is an online service for public sector organisations to find people and technology for digital projects. They made it easier for suppliers to sell to government — by simplifying framework applications, reducing the number of legal documents and engaging with potential suppliers, among other things — and as a result helped create a much more diverse supply base. By 2018, 92% of the 5100 suppliers on Digital Marketplace were small- and medium-sized enterprises (SMEs), and almost half of the £4.3 billion that had been spent through the Marketplace had gone to SMEs (OECD 2018). As the graphic below shows, increasing diversity also meant that suppliers from across the country were better able to access government contracts' (UCL Institute for Innovation and Public Purpose 2023).

UK Government IT suppliers: 2010 and 2015



Source: Mike Bracken, 2020

Dynamic capabilities for mission-oriented procurement

Implementing a strategic, mission-led approach to procurement is not easy. It requires a wide range of organisational and individual capabilities (UCL Institute for Innovation and Public Purpose 2023). Public-sector capacity is typically defined as the set of skills, capabilities and resources

necessary to perform policy functions, from the provision of public services to policy design and implementation.

Box 2. Public sector capacity and dynamic capabilities

More specifically, capacities and capabilities can be defined as follows:

- Adapting and learning in the face of incomplete, at times conflicting, information and radical uncertainty;
- Aligning public services and citizen needs;
- Governing resilient production systems and capabilities to foster symbiotic public-private collaborations and tapping into citizen innovation;
- Capacity to govern data and digital, including handling the 'infodemic' while balancing human rights protection; and
- Inter- and intra-governmental learning and coordination (including at different levels of government, for example federal and local, inter-ministerial and international).

(Mazzucato et al., 2021)

Crucial to implementing a mission-oriented approach is the broader context of experimentation and exploration. In particular, given the potential ripple effects that UKRI's net-zero efforts may have on the wider innovation landscape, it will be valuable to capture and share lessons, and to create dedicated spaces or processes for experimentation within broader organisational and institutional frameworks (Miedzinski, Mazzucato and Ekins 2019).

The development of mission-oriented policies requires the development of new types of dynamic capabilities inside public institutions that enable them to learn and experiment (Kattel and Mazzucato 2018). McLaren and Kattel (2022, 2) point out that even though, since the launch of its 2017 Industrial Strategy and introduction of the Industrial Strategy Challenge Fund (ISCF), UKRI has started to design policy interventions with a mission-oriented approach, its dynamic capabilities to realise such policies are 'not in place' and 'emerging *in spite of* institutional and wider structural challenges' (emphasis added). Developing these capabilities requires time and relies on the accumulated investments governments make in public institutions, infrastructure, human resources and public-private partnership design (Begovic et al. 2021).

Dynamic capabilities are critical for reacting to crises and change, re-configuring existing policies and implementing new practices (Kattel and Mazzucato 2018; Kattel 2022). In procurement, they can relate to procurement process design — including designing directionality into procurement policy and sending effective market signals — as well as evaluation, fostering new networks, effective collaboration with other procuring bodies and with suppliers, and embedding new solutions into established routines. In the case of UKRI DRI, policies can aim to embed directionality in order to achieve the goal of carbon neutrality (shaping routines); build communicative practices to engage other actors within and outside UKRI in order to inform UKRI DRI policy and share lessons from UKRI DRI as a case study (connecting routines); and constantly monitor policy outcomes to assess and learn from successes and failures (sense-making routines) (Kattel 2022).

6. Conclusion

Applying a mission-oriented innovation strategy to UKRI's endeavour of achieving net-zero objectives in the use of DRI must build on a systemic view of innovation and societal goals, where a wide range of stakeholders are involved in radical transformation. UKRI could play a pivotal role in terms of funding mission-oriented research and multi-disciplinary collaboration, in shaping sustainable research practices, and in the procurement of greener digital infrastructure along its supply chains.

As a small player, UKRI could focus on the possibility of demonstrating what DRI policies aligned with a net-zero mission could look like, and influencing governance patterns in the use of DRI, including through the standards it sets to manage the carbon footprint of its own operations and those of funded researchers, and through the directionality and conditions attached to its procurement of computing capacity. Here UKRI could explore the potential to collaborate with partners on green procurement for innovation to help push industry partners to accelerate the shift to net zero or carbon neutrality. UKRI and its partners could also push for credible, standardised energy consumption and carbon emissions metrics. This would enable 'apple to apple' comparisons to facilitate green procurement and enable researchers to make more carbon-sensitive decisions.

Importantly, as UKRI advances its net-zero strategies, it should consider how it fits within the broader UK innovation system, and how its investments and policy decisions relate to, influence and reinforce mission-aligned investments and the policies of other actors.

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