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WHAT THE GREEN REVOLUTION CAN LEARN FROM THE IT REVOLUTION:

A green entrepreneurial state

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Planning for an economy-wide overhaul

A Green New Deal is far from being only about renewable energy—it also requires innovative transformations across all sectors, one of the largest shifts ever attempted by humans. The IT revolution, one of the closest examples in terms of scale, can provide lessons—both positive and negative. The urgency for a green transition means these lessons should be learned now.

Moving to a greener low carbon economy means re-directing all sectors and all actors—public, private and civil society—towards economic growth in a sustainable and inclusive direction. Planning for this shift must acknowledge the complexity inherent in re-orienting our global economic and biophysical systems. This is particularly pertinent as economic thinking has been shaped for many decades by silo-ing environmental, social and governance issues into concepts like market failures and negative externalities. The idea is that policy should only intervene when there are clear market failures (Samuelson, 1954/1955). Yet while positive externalities can justify the investment in basic research, and negative externalities the design of carbon taxes, what is required for a green transition is a clear remit to shape and co-create markets.

A green transition cannot happen in one, isolated economy or nation-state; the entire global and interdependent system must shift in tandem. The globalised nature of production chains means that even products which are 'greener' at point of use, such as electric vehicles, require cobalt and lithium—non-renewable elements extracted in countries with loose child labour and human rights laws (Broom, 2019). Both private sector owners of these supply chains and public sector regulators must co-design the new

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system. Co-designing future systems must also take an intergenerational lens. The definition of 'long-termism' in many different markets—particularly financial—must be redefined, and unpredictable biophysical tipping points and feedback cycles must be anticipated and modelled in line with economic complexity models.

Our previous policy brief (IIPP PB 04) explored a Green New Deal, outlining how a market-shaping, mission-oriented approach should be adopted for green innovation policy and industrial strategy. A mission-oriented approach sets a clear, long-term, direction for change, and using this to bring together multi-sectoral actors to co-create markets. This brief acts as a sequel, and takes a historical approach to understand what we can learn from one of the most recent innovation revolutions—that of information technology—when developing market-shaping roadmaps for green growth.

Recommendations:

1. **Markets will not find the desired direction on their own**. Public policy and public investment are key to leading the way
2. Public investment is most effective when led by **ambitious and flexible mission-oriented public organisations**
3. Innovation and investment need to happen **across the entire innovation chain**, including both supply and demand
4. **Citizens can shape** the green transition from the start—as users, workers and systems-owners
5. **Patient finance is crucial for innovation**, and the short-termism and financialisation that has taken place in the IT and in the pharmaceuticals sectors should be avoided
6. Proactive regulation can help **overcome incumbency and lock-in effects**

Markets won't go green alone

The IT revolution would not have happened without early and directed risk-taking from the State

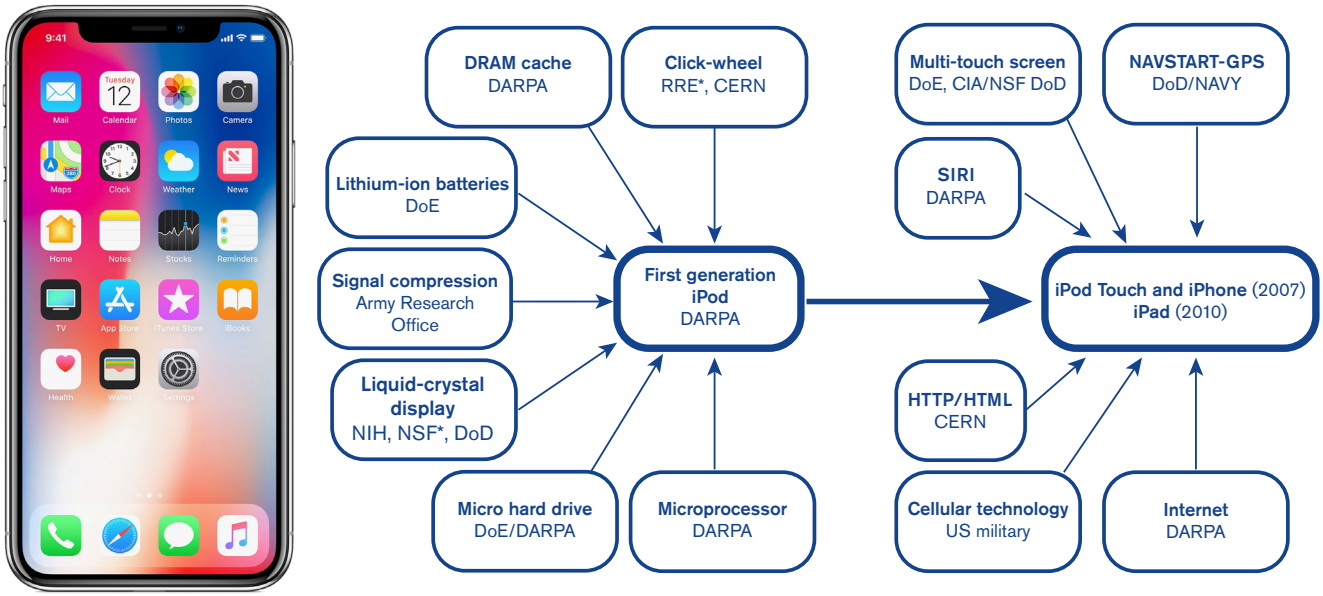
The information age began in the 1960s, propelling digital knowledge and data ownership into new forms of power—and paradigms of value creation—for the late 20th and early 21st centuries. The realisation of Moore's Law resulted in computer power doubling at a regular rate, alongside a halving of cost. This did not happen alone. Identifying the innovative potential of the silicon microchip in 1965 was bold. To bring its potential into being required both supply side and demand side policies—from basic research, to applied research, early stage patient financing, and demand led procurement policies.

The spread of information technology over the past 30 years has been one of the most rapid invention-innovation-diffusion processes in any technological revolution (Perez, 2002). But in its infancy, it was not clear that IT would take off—it took early-stage risk-taking by the public sector to make the business case clear for investment. Indeed, as has been shown by Mazzucato's *The Entrepreneurial State*, all the areas that make our smart products smart were funded by the public sector. The iPhone is a product of multiple publicly funded hardware and software innovations (fig 1). This did not mean that private initiative was not needed, but that entrepreneurial public organisations led the way which later crowded-in private enterprise.

Today, after half a century of public investment, the IT sector is flooded with private sector financing and enthusiasm, and attracts top talent. Leading tech firms are developing large R&D investments in cutting-edge technology like artificial intelligence, satellite technology and drones—far more than government bodies are investing, despite the clear security and governance implications for such innovation (Kattel, 2019). As innovation not only has a rate but also a direction (Mazzucato and Perez, 2015), a key question is how to broker, facilitate and govern interaction between these multi-agenda actors (Block, 2011).

The information revolution relied on the developmental state (Block, 2008). The starting-gun was fired on IT innovation investment by directed public sector actions. Between the 1970s and 1990s, a collaboration made up of the US's Defense Advanced Research Projects Agency (DARPA) and the UK's Post Office conceptualised, invested in and delivered the networking stations, operating systems and email programmes of the first high-speed digital networks in the US. These publicly funded agencies did not initially intend to go it alone—both AT&T and IBM were approached to co-lead the project but they declined, concerned that it would

Fig 1: State investment built the iPhone



*Royal Radar Establishment (RRE), National Science Foundation (NSF)

Source: Mazzucato (2013)

threaten their existing work. It was then in the 1980s at CERN (the public sector European Organization for Nuclear Research) that Tim Berners-Lee and Robert Cailliau implemented the first-ever successful HTTP (Mazzucato, 2013). Commercial and social applications became quickly evident and the private sector swiftly increased their investment appetite, but only after the public sector had proven the technologies' potential.

The nanotech sector similarly benefitted from decisive state decision-making in the late 1990s, when the US took a visionary stance through the development of the National Nanotechnology Initiative (NNI), shaping a long-term policy framework to support R&D in atomic, molecular and supramolecular research. Nanotech is now considered to be the next 'general purpose' technology, with applications across multiple sectors, becoming a foundation for economic growth (Mazzucato, 2013). The NNI programme works through allocating funding to participating federal agencies including the National Institutes of Health (NIH), the Department of Energy (DoE) and the Food and Drug Administration, to develop multi-sector expertise, and leverage distributed resources (NNI, 2019).

A diverse and dynamic set of instruments

Directed innovation programmes, and collaborative projects are just two levers available to the entrepreneurial, market-shaping public sector. Procurement policy is another valuable tool, which can be developed as part of a local or national industrial strategy, across multiple sectors (UCL MOIIS, 2019). When well-designed, procurement can help fuel bottom-up experimentation and multiple solutions to solve specific goals (Edler and Georghiou, 2007). The key is to not specify the solution but the outcome needed. State co-ordination on procurement can have other benefits, including information sharing between actors and the specialisation of smaller firms (Weiss, 1989).

State actors have also used loan guarantees, grants and prizes. The latter are highly applicable beyond the technical innovation arena, and social innovations are increasingly being spurred by prizes. The Finnish innovation agency Sitra launched Solution 100, with the aim of giving all citizens a chance to participate in tackling future challenges (Takala et al., 2018). Intangible national pride and tangible security incentives can be useful state levers. JF Kennedy's 1960s Moonshot, often cited as an archetype of cross-sectoral mission-oriented innovation, must be considered against the backdrop of Cold War politics and the Space Race (NASA History Office, 2013). A vital issue today is how to use the UN Sustainable Development Goals, and climate change more specifically, to drive the sense of urgency for missions.

Different government approaches and lever-pulling will result in a variety of outcomes: so actions must involve the use of multiple levers. In the UK and US support for the IT revolution was staunchly backed by wider industrial policy and remains so today. In the European Union, micro-

processing innovation was curtailed by a lack of joined-up public action—by laissez-faire public policy approaches, and late-coming specialist innovation programmes—even whilst the trajectories for technological growth were being established in the US (Dosi, 1981). Similarly in the green revolution, the whole gamut of government innovation stimulus must be brought into play: high-profile market-fixing levers such as carbon pricing and taxing must not be seen as a complete solution by themselves. They must be in the context of a wider innovation system to tilt the playing field in a green direction.

From hardware to software

Investing across the innovation chain: demand-pull and supply-push public policy

The IT revolution was not invested in as a 'computer business', and would not have gone anywhere if investment opportunities had been limited to monitors and mice. Instead, investment spanned the chain, from hardware to software, and from basic research (the manifesto behind the World Wide Web) to diffusion and deployment, including cable and wireless infrastructure. This culture of evolution-led investment led to the innovations in data, digital governance and artificial intelligence that we see today (fig 2). The role of institutional innovation hubs, such as the Fraunhofer Institutes in Germany, and the UK's Catapults, can promote such approaches (Mazzucato and McPherson, 2018).

Critically, the investments by public organisations in figure 2 were direct investments, not indirect. The latter, in the form of tax subsidies to business, often assume the desire to invest in the business community. The role of such direct public investments is precisely to lay the groundwork that increases the expectations of future growth opportunities and hence investment. In this sense they create 'additionality'.

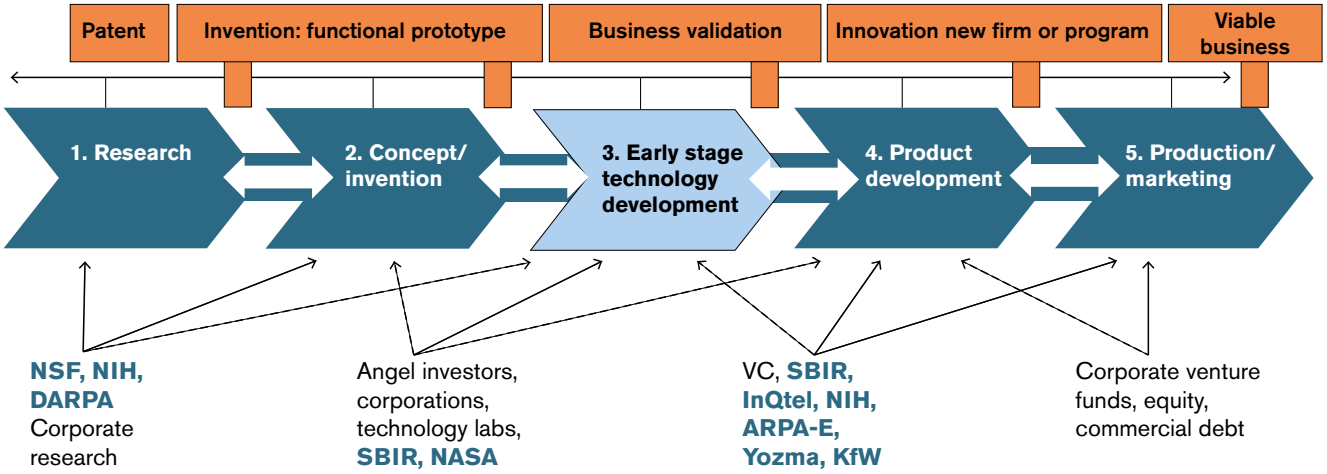
A focus on both supply and demand is vital for innovation investment planning (Mazzucato and Semieniuk, 2018b). Forward-thinking state approaches paved the way for the internet to be democratised through investment in infrastructure, and by enabling diffusion. In France, the government prepared for the arrival of internet in all homes by providing a terminal almost ten years before internet usage became widespread (Grubb, 2014). Such investment can also enhance regional equality and place-making agendas by decentralising innovation ecosystems.

Collaborative risk-taking

Organisational structures require re-imagining to support cross-chain and bottom-up innovation

Organisations that have successfully tackled ambitious, mission-oriented projects in the past have implemented structures that are flexible, adaptable, and able to foster bottom-up solutions. For the green transition, we need entirely new, flexible, agile and open-minded institutions and structures to take on uncertain innovation challenges. The Moonshot required many different sectors to innovate—from materials to nutrition and aeronautics, and bottom-up solutions. It also needed mission-driven organisations, such as NASA and DARPA.

Figure 2: Co-creating and co-shaping markets along the entire innovation chain



Author's addition of public agencies to underlying figure by Auerswald and Branscomb 2003. National Science Foundation (NSF), NIH, DARPA, Small Business Innovation Research Program (SBIR), ARPA-E

Source: Mazzucato (2015a)

Typical case studies of successful mission-oriented organisations include DARPA in the US Department of Defense (DoD) and ARPA-E in the US Department of Energy. These public organisations are driven by the need to find solutions to problems—providing long-term finance to those organisations 'willing' to experiment towards a goal. While these are research organisations, across the world patient finance for innovation also comes in the form of public venture capital (e.g. Yozma in Israel) or through investment funds of public banks (e.g. the European Investment Fund inside the European Investment Bank). Management of a mission-oriented system of innovation requires risk-taking and a specific type of leadership, governance frameworks, employee training and incentive structures. DARPA, for example, is characterised by small, proactive offices which are made up of an interdisciplinary scientific community, and given both budgetary autonomy and the autonomy to identify promising ideas (Azoulay et al., 2019; Fuchs, 2010). DARPA research activities take place outside of regular government, industry or academic activities, leading to a sense of freedom and novelty that attracts talented and mission-driven employees. It is vital to remember today that important private sector laboratories were often the result of healthy tensions between business and government. To retain its monopoly status, AT&T had to prove that it would reinvest its profits into long-run radical innovation—which it did through the creation of Bell Labs in 1925 (Mazzucato, 2015b).

Avoiding the financialisation trap

No more PLIPOs

Patience is also required inside the business community. Yet the clean technology sector is showing early signs of 'financialisation'. This is identifiable as both an influx of short-term capital into the sector, and a concentration of actors on moving funds away from R&D—which would finance new innovation—and towards share buybacks and dividends instead, actions which influence stock price and executive pay (Lazonick 2014). Financialised behaviour has long been a characteristic of sectors including pharmaceuticals and petroleum, which are the largest repurchasers of shares, often claiming these decisions are made due to a lack of new investment opportunities. And yet given that opportunities are abundant, especially around renewables and health care, it seems that the real bottleneck is the desire to please shareholders (Mazzucato, 2013).

Financialisation is also evidenced in the short-termism of the financial sector itself, for example the exit-driven investment mindset. The calling card for financialisation in the tech sector is the emphasis placed on Initial Public Offerings (IPOs) which have become a fetishised event in the Silicon Valley innovation model. The push to IPO earlier than ever in the product life-cycle has led to the improbable 'product-less IPO' (PLIPO) (Lazonick and Mazzucato, 2013). The venture capital which finances

CASE STUDY: Learning from ARPA-E

It was 'an absurdly high-powered team of brainiacs' that started at the US Advanced Research Projects Agency-Energy (ARPA-E) in the mid-2000s (Grunwald, 2012). The agency was specifically designed as a 'DARPA-clone', bringing mission-oriented investment to the energy sector (Bonvillian, 2018). In 2005, a cross-party coalition asked the US National Academies of Sciences, Engineering and Medicine to provide non-partisan direction on the vital challenges the US faced in science and tech leadership. The Intelligence Advanced Research Projects Agency (IARPA) was launched with an intelligence tech mandate in 2007.

ARPA-E takes on the same organisational mindset of DARPA—both expecting and tolerating failure. Like DARPA, ARPA-E does not set its own research agenda at 'top-down' level—instead it draws on the priorities set by industry experts and academics who are working on high-risk, cutting-edge technical solutions (Fuchs, 2010).

ARPA-E also takes on a financial multiplier role, with the core aim of developing high-potential, high-impact energy technologies that are too early for private sector investment (ARPA-E, 2019). Having provided $1.8bn in R&D funding to more than 660 projects since 2009, 136 ARPA-E projects have attracted more than $2.6bn in private-sector follow-on funding. But this is small scale funding compared to the billion-dollar budgets given to DARPA, partly stemming from the mandate of national security that underpins DARPA's innovation role. ARPA-E's budget is around 10% of DARPA's (Bonvillian, 2018). Perhaps as climate change, renewables innovation and national and international security become increasingly aligned, funding priorities will shift towards ARPA-E.

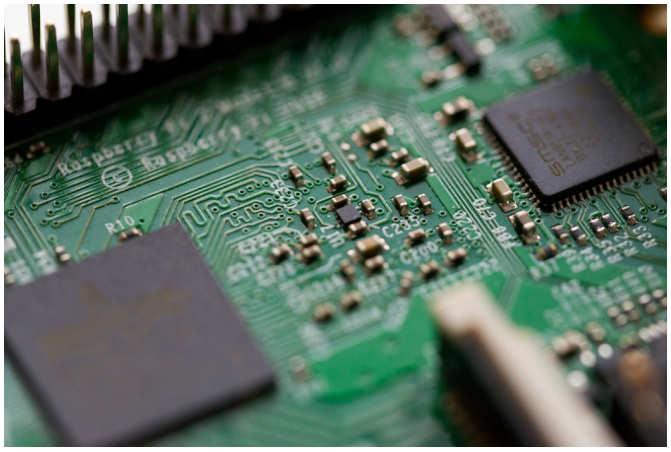
this behaviour is structured to seek return and exit investments in the short-run, and has been criticised for stalling the nascent clean energy sector through unsuccessful investments, and eventual company failures brought about through misaligned time horizons (Gaddy et al., 2016).

Instead, it is long-term patient finance that is needed for the green transition, due to the uncertain, high-risk nature of innovation. It must also be collective—from a variety of public and private sources, just as the agents carrying out innovation should be multiple collaborators (Mazzucato and Semieniuk, 2018a). A three to five year investment cycle does not match the increasingly long lifespan of a wind turbine array (25 years+) or of the innovation needed in e-mobility, natural capital development (such as rewilding programmes) or green infrastructure projects. Betting only on short-term private finance risks derailing the transition (Semieniuk and Mazzucato, 2018).

From micro to macro

Shifting financial regulation

A green revolution requires tilting the playing field, not levelling it, so that green behaviours are rewarded over brown ones. This includes taxation that favours the reduction of carbon across sectors. A green transition requires taxation to be moved away from salaries, and focused instead on materials and energy use, alongside measures to counteract widespread short-term, 'casino-type', financial activities (Mazzucato and Perez, 2015). In the real economy, tax incentives and disincentives can be designed to tackle high polluters, to decrease material content per product, and to encourage innovation around areas like waste and durability. Rather than removing taxes as 'impediments' to investment, we must instead retool tax policy to direct investment and innovation (Mazzucato and McPherson, 2018).



Source: Chris Ried | @cdr6934 | Unsplash

It also requires lining up fiscal, monetary policy, central banks and financial regulators in a green direction. With national mandates for maintaining financial stability, central banks were startled by Governor of the Bank of England Mark Carney's speech on 'The Tragedy of the Horizon' in 2015, which contrasted the misaligned timespans of short-term monetary and financial stability policies, with medium to long-term climate risks (Campiglio et al., 2018). Considering monetary policy—including quantitative easing and collateral frameworks—macro-prudential policy and credit allocation tools through the lens of a smooth and managed low-carbon transition could both reduce financial stability risks and uncertainty and help provide sufficient finance to achieve sustainable economic growth.

The realisation of a green economy is often portrayed as a costly endeavour, yet redirection to virtually unlimited energy sources and resource efficiency through circularity to close industrial loops permits economic efficiency to be raised when economies of scale are reached and the infrastructural foundation transformed (Mathews, 2019). These public innovation policies for structural transformation carry the potential of economic supermultipliers by crowding in private investments to new growth opportunities (Deleidi & Mazzucato, 2017). China is one country currently using the financial approaches to rapidly transform their economic system to realise first-mover advantages and the resulting efficiency and environmental gains (Mazzucato and Semieniuk, 2018a).

Who asked the public?

Social systems innovation is as important as technological and financial innovation

Green growth is more complicated than purely technological feats such as getting to the moon and back. It requires not only innovation in technical terms but also societal innovation and behavioural change (Mazzucato, 2018b). At the heart of this is the role of citizens. The question of 'who' —who will benefit from the green growth outputs; who takes on the 'transition risk'—should be foregrounded. Bringing trade unions and citizens' organisations to the table for open and early, rather than late and defensive, discussions on what 'green' means for their way of life is vital. IIPP's most recent report for the European Commission, *Governing Missions in the European Union*, addresses these key questions of 'who' and 'how' we should take on societal challenges (Mazzucato, 2019).

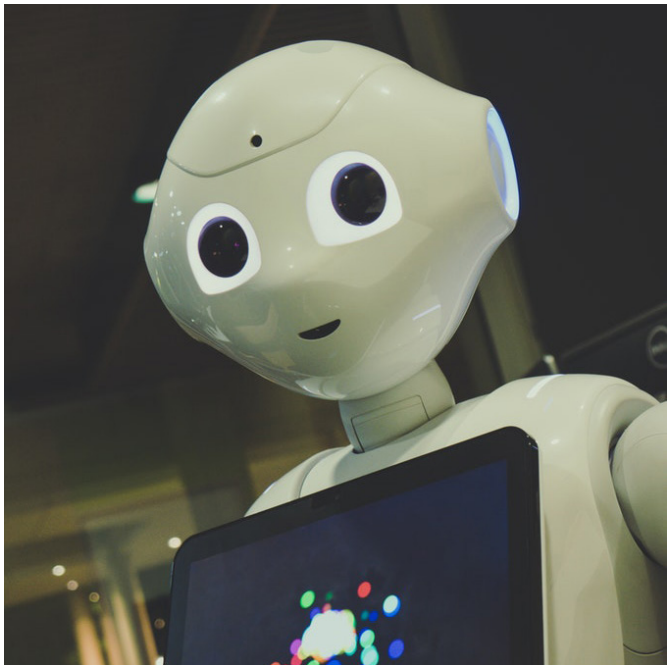
Citizen co-creation and public-value-oriented citizen engagement is something that the information technology revolution hasn't predicted or executed well. Understanding how to involve citizens both in the formation of missions and their implementation is key

to making them more resilient and radical (Leadbeater, 2018). Two significant overlooked outcomes of the IT revolution have been the consuming impact of social media, and its psychological impact, particularly on young people; and secondly, the role to be played by data science in accelerating the automation of the workplace. The green transition is already dealing with similar job security fears and must do better in bringing multiple groups to the table as shapers and stakeholders (Powell et al., 2018; ILO, 2015).

Another overlooked problem in IT has been the issue of ownership. Who owns data is just as important as how privacy is governed. Cities like Barcelona and Amsterdam are experimenting with new forms of ownership, for example through the DECODE project in Barcelona, which brings to the city 'a new social pact' in which citizens have control over the privacy and shareability of their data (Graham, 2018). Ownership is equally critical for the green revolution—for example in the arena of residential solar generation.

Citizen-orientation also means a mindset shift in thinking about high-carbon sectors, and about citizens as consumers. Many industry players are moving to consider energy and transit as services—thinking in terms of light-hours enjoyed and miles travelled, rather than megawatt hours used or petrol burned. The move made by the UK's Government Digital Service, from considering citizens as 'clients', customers or consumers to citizens as 'users' of their services, and subsequently taking a user-oriented approach to interface design, illustrates a successful shift in the IT sector. And citizens, of course, are also rights holders—the economics of human rights will likely need to be directed to deal with the issues both around data and renewable energy.

Movements which come from missions have the power to make markets, contesting and shaping the purpose of innovation (Leadbeater, 2018). This has been seen in particular in the Energiewende movement in Germany, which grew out of long-term environmentalist movements, and entailed a cross-sector economic transformation, notably in high-carbon industries such as steel (Mazzucato and McPherson, 2018). Linking consumer lifestyles and values to low-carbon components, such as low-carbon cement, will be key to increase the efficacy of people-driven movements which support the green transition. The marketing and communications sector should be harnessed to get consumers as excited about low-carbon embodied elements when they are in non-consumer sectors. The famous 'Intel Inside' jingle, alerting end-users to the presence of a branded processor, is a rare and learnable triumph of attention being drawn to components in an industrial process.



Source: Owen Beard | @owenbeard | Unsplash

It could be argued that the current interest in waste plastics is a comparable feat, in terms of user focus on the non-consumption section of product lifestyle. Between media-driven awareness raising, such as 'national treasure' broadcaster David Attenborough's focus on plastics in his TV show 'Blue Planet', and European legislation implementing charges for plastic carrier bags, awareness is growing and lifestyles are changing. Whilst shifts in consumer behaviour will often be adopted first either by high-earners or by niche interest groups (Geels, 2012), distribution, cost decreases and aspiration will lead these behaviours to spread over time to the wider population. The interconnection between products and lifestyles makes systemic change possible in both the production and services economies, influencing elements like health and social care, or finance, as much as consumer goods supply chains. This link is evident in the role played by mobile technology in swift service procurement—increasing demand for services such as ride-sharing and even beauty treatments. As new lifestyles develop through innovation, they become over time the model of 'the good life' (Perez and Murray-Leach, 2018).

Embedding carbon literacy, and with it the concept of the 'green good life', in a pan-societal curriculum leads to a transition that is co-created as an answer, not a problem, posed to livelihood questions such as the future of work, transit, and energy use (UCL IIPP/ MOIIS, 2018). 'Green New Deal' approaches link innovation through to improved jobs and increased life quality (Mazzucato and McPherson, 2018). The IT revolution could also offer a deployment and delivery opportunity for the green transition—Perez is optimistic that just as mass-production in the 1950s required the

suburbanisation trend in the residential sector in order to be fully deployed, so the IT revolution could use 'green' as a new direction for its full deployment (Perez, 2017).

The dangers of lock-in

Addressing incumbency effects

Multi-sector innovation necessarily takes place in a complex economic system. The core characteristics of complex systems include the impact of feedback loops, path-dependency, non-linear dynamics, endogenous risks, fundamental uncertainty and absence of optimality. These must be considered more fully when we come to monitoring and evaluating the opportunities that will lead us to a sustainable growth trajectory (Kattel et al., 2018).

For a green transition, brown innovation and investment must be curtailed in multiple sectors, and existing incumbency privilege removed. In the financial sector, investment is beginning to shift away from coal, oil and gas due to the increasing acknowledgement that in a future decarbonised society, it will not be profitable to exploit oil or use fossil fuels to generate electricity—these assets currently under management will be 'stranded', impossible to sell or repurpose.

However, incumbency privilege is knitted into existing systems. High-carbon sectors are inherently positioned to make long-term 'lock-in' decisions, such as building new coal-fired power stations, and to do so before incoming regulation prohibits it—fulfilling the so-called 'green paradox', in which the prospect of long-term pro-green regulation brings about short term pro-brown activity (such as pollution, or fossil fuel extraction) to avoid incoming penalties.

This defensive approach needs to be changed, and more positive feedback loops developed. Incumbent companies must realise a position for themselves 'to and through' the transition. In the internet revolution, communications giants were able to nimbly reposition themselves as data providers, largely due to the sales of intangible items—minutes, calls, data—through infrastructure that was relatively similar to what was already in place. The concept of dial-up internet, using existing telephone infrastructure to deliver a new service, is a good example of IT riding the coat-tails of the telecoms industry.

Getting citizen engagement right also means that people-as-employees, and therefore employees-as-institutions, will be activated and engaged to get involved in a mission-oriented approach to the green transition. An example of this is a scientist like Steven Chu, the Nobel Prize-winning physicist who was attracted to run the US Department of Energy—due to excitement about its impact—and who ended up having a big role in the 2009 stimulus program (Mazzucato, 2013). Companies like Shell and BP, as well as Google and Goldman Sachs, will become more attractive employers if they decide in favour of the green transition—and second-choice options if they do not. Finding a way for citizens to not only be engaged but to also find it an 'honour' to transform their own working lives to take part will be a key aspect of the green transition.

Conclusion

A green transition requires an economy-wide transformation that galvanises investment and innovation across all sectors. It must also be governed in ways that asks questions about both the rate of change, and also the direction of change, and how that direction can produce not only sustainable growth but inclusive growth. Growth which provides the opportunity to battle climate change and to ensure all people can benefit from the 'green good life'.

What is vital is that the green transition is chosen, designed, agreed, and directed by multiple participants. This is something that the information technology revolution did not have at its core. The challenges being faced today around automation and precarious employment, and around data ownership, were not foreseen by the actors driving the IT industry. The structure of the green transition must go further in anticipating these issues, and bringing about a dynamic, discursive governance, with different voices, such as trade unions, workers' co-operatives, and socially-responsible consumers, all at the table from the start. Mutualistic innovation partnerships must be struck between public, private, and third party actors to shape and lead the transition. There is momentum to design a new green way of life—we should take this opportunity to co-design one that is innovative, sustainable and inclusive.

Enquiries

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