CAP GEN

Capital Generation Partners

Capital Generation for a Sustainable Future

2021

Preface

There are three core tenets to our role as the stewards of long-term family capital; to preserve the value of capital, to grow it, and to do so in a way that aligns with our clients and our own values. In other words; to invest responsibly and wisely. There was a time in our industry, when this third tenet was seen as being at odds with the others; that in order to invest sustainably, for example, you might need to sacrifice returns. But today, not only has that view been challenged, it has been inverted; there is a boom in sustainable investing, with new ESG products constantly being churned out to meet surging market demand. Some fear this has the hallmarks of a new bubble. Last year alone European based ESG funds drew in €233 billion, almost double the figure for 2019.

But does this enthusiasm for all things green miss the bigger picture? Is there a more fundamental transition at play, and if so, how can investors ensure that they're on the right side of it? At CapGen, these are the kind of questions that we want to explore, and that is exactly what economist Dimitri Zenghelis has done so powerfully and convincingly for us in this extraordinary paper. He presents a vision that takes us far beyond ESG funds or the share prices of renewable energy stocks, to a more productive and innovative world where global economic growth is fuelled by cheaper, more efficient and (crucially) cleaner energy sources. What's more, investors have a pivotal role to play in enabling this transition.

At CapGen we talk about Responsible Wealth which encompasses risk, opportunity and purpose. We scrutinise the risks to the environment, society and portfolios that result from inadequate ESG measures. But as investors we are also alert to the opportunities that arise as a result of the seismic changes that are happening in our economy as we tackle climate change and other environmental and social challenges. And finally, our clients are keen to see their capital fulfil its purpose in providing long term, thoughtful backing to the investment opportunities which will transform our economy.

That is why this paper goes the heart of our role as investors. It clearly articulates the changing landscape of risks and by assessing assets which are likely to thrive in the 21st century and which are at risk of being devalued and stranded. We are not here to buy into fads. We exist to help families put their capital to work in a dynamic and evolving financial system; to back the technologies and sectors that will stand the test of time. That's what drives resilient financial returns, and powers economic growth in return. What you will find here is a clear explanation of the underlying technologies, institutions and behaviours shaping the transition to a sustainable future. It outlines a framework for investors to play their part in building it. It's a fascinating read, and we are delighted to share it with you.

Charlotte Thorne

Charlotte Thorne
Founding Partner, Capital Generation Partners

Executive summary

Will the world decarbonise? Yes. Investors must understand that this will happen and is already happening with impacts on every business on the planet. Companies' operations, supply chains and interdependencies with the wider economy and society at large will change, though some sectors are more exposed than others.

Growth is not only compatible for decarbonisation, it is a prerequisite. Sustainable growth will become the default business model across all business sectors. New technologies, new business models and new product markets are already driving significant decarbonisation. 'Degrowth' as a means to reduce emissions will fail. It will starve innovators of resources, perpetuate global poverty and sour the political appetite for change.

How will it happen? Transformative change is already gripping key global energy and transport sectors. Renewable energy and electric vehicles will become the norm within a few decades. .Almost all fixed energy source of energy consumption will be electrified while battery technologies, together with synthetic fuels, will increasingly dominate long distance haulage and aviation. Industry, land use, heat and agriculture will be transfigured. The precise details of every technological innovation cannot be second-guessed—but the drivers of innovation must be understood and harnessed.

It's likely to happen faster than we imagine and at less cost. There have been predictions of significant negative impacts on GDP as a result of the cost of decarbonisation. However, they rely on assumptions about the speed of adoption of new technologies which are neither corroborated by previous experience of technological change nor commensurate with the enormous scale of innovation being unleashed by a structural change of this magnitude. In fact, it is more likely that as each technology reaches a tipping point and as network effects accelerate adoption, the transition to a net zero carbon future will happen faster and at less cost than we can currently predict.

The net removal of greenhouse gases from the atmosphere by the second half of this century is not only achievable, it is more likely than many investors imagine. For all the hype over ESG, this remarkable prospect, and the shifting landscape of risk and opportunities it presents, is a long way from being fully priced in.

Investors are well-placed to support, and benefit from, a low-carbon transition. New technologies and infrastructure requirements will be capital intensive with relatively low operational costs. Consequently, these will provide appealing opportunities to investors. At the same time these opportunities, once realised, will boost innovation, efficiency and productivity with positive impacts on economies as a whole.

We are already witnessing increasing returns to scale in discovery and production in clean sectors. Improved battery technology, essential to ensure continual renewable energy supply given the intermittency problem of renewables (how to generate solar power when the sun isn't shining) will be one of the tipping points making the transition to renewables faster and cheaper than predicted.

This transition is already underway but will be accelerated and steered through policy and investor intervention. Once the clean innovation machine is kick-started, it will become self-reinforcing without need for policy support. In key sectors, that point has been passed leaving the way open for further positive cycles of investment intervention

The costs and benefits of attaining a low carbon future depend on decisions and investments made today. We present a risk-opportunity assessment framework, based on complexity science, to guide investors. In the meantime, it is clear that investors and economists alike should spend less time predicting the future and more time profiting from building it.

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01 / Introduction

There is only one growth path ahead, and that is a sustainable growth path. All the others will snuff themselves out.

The technological revolution which will accompany our response to the threat of climate change will affect all sectors. The dramatic system changes impacting the global economy, business sectors and society will have profound ramifications for investors. The risks and opportunities associated with the pace and scale of change, as the economic system is repurposed for the twenty-first century, are enormous and will re-shape how we value all assets.

After years of slow progress, clean innovation is leaving the carbon-economy in the dust. Regardless of climate impacts, the world is now going to have cheaper electricity and more productive cars thanks to the rise of resource efficient clean technologies. This is just the start of a revolution. The transition to net zero is now inevitable. Fossil fuel assets will continue to be devalued and left stranded. In anticipation of this transition, individuals, businesses, industries and policymakers are increasingly collaborating to create credible policy frameworks which steer expectations and guide behaviour. With sound good governance and strong leadership, there are profits to be had from facilitating and driving rapid and disruptive change.

02 / Decarbonisation is inevitable

In 2015, world leaders in Paris agreed to limit the rise in temperatures relative to preindustrial times to 2 degrees Celsius or below. Because it is the stock of greenhouse gases that causes global warming, not the annual emissions of flow into that stock, this means reducing carbon emissions by mid-century by at least 80% and decarbonising entirely in the second half of the century.

Keeping the global temperature stable at any level means transitioning to a net zero emissions world, because it is by definition the only way to stabilise the stock of greenhouse gases. In other words, the world will decarbonise. Humanity either does it the easy way and manages the transition to temperature stabilisation or nature does it for us by creating such a hostile climate that we depopulate and deindustrialise the planet.

A corollary feature of this process is that the speed at which we decarbonise matters, because it determines the temperature at which we ultimately stabilise. The longer the delay the higher the equilibrium temperature (barring costly accelerated reductions later on).

Achieving a global net zero economy by the second half of this century will be extremely challenging. Carbon from fossil sources is the source of energy which powers most of the world's economic activity, and has done for more than two hundred years, since the use of coal to fire steam engines first gave birth to the industrial revolution. It will require a complete repurposing of the global economy. This transition will affect all individuals and businesses either directly or indirectly.

The transition to a low carbon economy will inevitably mean that some assets are devalued or stranded, whilst other assets become increasingly valuable. The world is not running out of fossil fuels. There are at least 700 gigatons of carbon locked up in fossil fuel resources under the earth's crust. This is more than enough to roast the planet.

If we are to meet our climate targets consistent with a 2 degree temperature increase, a third of global oil reserves, half of gas reserves and over 80 per cent of current coal reserves should remain in the ground from 2010 to 2050 or, if they are burnt, the carbon emissions will have to be captured and stored. Securing a safe climate will affect oil companies' balance sheets.[1]

But it won't stop there. 'Downstream' carbon-intensive infrastructure such as refineries, transport infrastructure, carbon-intensive industries and power generation also risks being stranded.[2] Financial services heavily invested in fossil fuel entangled assets and markets will also be hit with the consequent concerns around systemic and sovereign risk.[3] The concept of "un-burnable carbon" highlights the risk caused by the financial exposure to stranded assets, which could be driven by policy, technological innovation or investors' decisions.

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[1] See McGlade and Ekins (2015) https://www.nature.com/articles/nature14016

[2] Pfeiffer et al, 2016. http://dx.doi.org/10.1016/j.apenergy.2016.02.093.

[3] Carbon entangled nations responsible for production and exports of fossil fuels or carbon intensive heavy industry will have a higher proportion of their national wealth at risk then wealthier more diversified countries. They also have on average more years of reserves than the major private oil and gas companies. They are therefore exposed to shrinking global demand. Because their institutions have been framed around fossil fuel production and export they will have more limited ability to diversify their economies in the face of change with government revenues being highly dependent on fossil fuel markets.

03 / Bad economics: how not to assess climate transition risk

Can the world afford to decarbonise in time? In its Fifth Assessment Report in 2014 the Intergovernmental Panel on Climate Change surveyed a range of Integrated Assessment Models (IAMs) and declared that stabilising global temperatures at no more than a 2 degree C warming would cost 2.9-11.4 % of global consumption in 2100 (Figure 1).

	Consumption losses in cost-effective scenarios[1]				Increase in total discounted mitigation costs in scenarios with limited availability of technologies				Increase in medium- and long-term mitigation costs due to delayed additional mitigation until 2030			
	[% reduction in consumption relative to baseline]			[percentage point reduction in annualized consumption growth rate]	[% increase in total discounted mitigation costs (2015–2100) relative to default technology assumptions]				[% increase in mitigation costs relative to immediate mitigation]			
									≤55 $GtCO_2eq$		>55 $GtCO_2eq$	
2100 Concentration [ppm CO_2eq]	2030	2050	2100	2010–2100	No CCS	Nuclear phase out	Limited Solar/Wind	Limited Bioenergy	2030–2050	2050–2100	2030–2050	2050–2100
450 (430–480)	1.7 (1.0–3.7) [N: 14]	3.4 (2.1–6.2)	4.8 (2.9–11.4)	0.06 (0.04–0.14)	138 (29–297) [N: 4]	7 (4–18) [N: 8]	6 (2–29) [N: 8]	64 (44–78) [N: 8]	28 (14–50) [N: 34]	15 (5–59)	44 (2–78) [N: 29]	37 (16–82)
500 (480–530)	1.7 (0.6–2.1) [N: 32]	2.7 (1.5–4.2)	4.7 (2.4–10.6)	0.06 (0.03–0.13)	N/A	N/A	N/A	N/A				
550 (530–580)	0.6 (0.2–1.3) [N: 46]	1.7 (1.2–3.3)	3.8 (1.2–7.3)	0.04 (0.01–0.09)	39 (18–78) [N: 11]	13 (2–23) [N: 10]	8 (5–15) [N: 10]	18 (4–66) [N: 12]	3 (−5–16) [N: 14]	4 (−4–11)	15 (3–32) [N: 10]	16 (5–24)
580–650	0.3 (0–0.9) [N: 16]	1.3 (0.5–2.0)	2.3 (1.2–4.4)	0.03 (0.01–0.05)	N/A	N/A	N/A	N/A				

Source: IPCC Fifth Assessment Report Working Group III, Summary for policymakers p15

These results are misleading. In fact, they're positively dangerous (even allowing for a chuckle at the comedy decimal place – a flagrant abuse of significant figures). As will become clear – they serve to delay action and raise costs.

After 80 years of employing the best brains and learning from, and investing trillions of dollars in, infrastructure technologies to extract and retain energy from the earth, sun, wind and sea, it seems implausible that this will be a more expensive way to generate energy — every year—than tying up labour resources digging up fuels from ever more remote locations, refining, transporting and burning them. And this comes even before consideration of the costs of a more hostile climate in the latter scenario. This is patently absurd. Such models cannot provide any kind of rational description of what the economy will be like nearly a century ahead.

Forecasting GDP two years ahead is challenging enough. The problem of forecasting fifty or a hundred years ahead arises from the approach adopted when running these projections. Economic models assume a unique equilibrium based on complete knowledge of the technologies, institutions and behaviours that underpin the economy. But this is both unrealistic and unhelpfully circular. The question of interest when trying to assess the cost of decarbonising by the end of the century is what *will* technologies institutions and behaviours look like? To presuppose this answer from the outset assumes away the most interesting questions about how socio-technological transformation occurs. It is not helpful in guiding investors.

Thomas Malthus in 1848 made false assumptions about the structure of the global economy. He assumed that technologies and processes would remain broadly unchanged, meaning that the world would run low on resources in the face of growing population and demand.[4] Constrained by methodology, economists are making the same mistake again.

[4] Malthus T.R. 1798. An Essay on the Principle of Population; John Stuart Mill, Principles of Political Economy. 1848; see also Meadows, D.H., Meadows, D.L., Randers, J. and Behrens III, W.W. (1972) The Limits to Growth: a Report for the Club of Rome's Project on the Predicament of Mankind. New York: Universe Books.

04 / The future will be what we build

The problem is not just one of spurious precision based on flawed assumptions. Deterministic forecasts fail to give an indication of the pathway necessary to deliver emissions reductions. The correct answer to the question 'what will it cost to decarbonise in the long run?' is 'it depends on the choices and actions we take today and forever after' (or, in wonk-speak, it is endogenous meaning it has a cause and origin internal to the system).

We don't know what the cost of decarbonising will be in terms of GDP in 2100, but we do know that it will be a lot lower if we manage that transition and start adjustment early. Understanding this dynamic process, and the fact that the evolution of our economy is pathdependent and cannot be predetermined, can guide investors and asset holders to manage the risks associated with a low carbon transition and help profitably make the world a better place (see section 11).

Nobel prize winning economist Paul Romer, an architect of the endogenous growth framework, focused on the dynamics of growth embodied in innovation, network effects and complementary feedbacks. He describes the difference between exogenous and endogenous growth theory as akin to the difference between 'complacent optimism' and 'conditional optimism':

"Complacent optimism is the feeling of a child waiting for presents. Conditional optimism is the feeling of a child who is thinking about building a treehouse. "If I get some wood and nails and persuade some other kids to help do the work, we can end up with something really cool." He continues *"What the theory of endogenous technological progress supports is conditional optimism, not complacent optimism… "Instead of suggesting that we can relax because policy choices don't matter, it suggests to the contrary that policy choices are even more important than traditional theory suggests."*

He is basically saying that the new technologies and institutions necessary to deliver a clean economy will not just drop out of the sky as 'manna from heaven'. They need to be designed and built. Once they are, the conditional probabilities relating to sectoral risks and opportunities all change.

“The correct answer to the question ‘what will it cost to decarbonise in the long run?’ is ‘it depends on the choices and actions we take today and forever after’”

05 / Understanding structural revolutions

Clearly, understanding structural change means going beyond predictions based on recent historic data. Anticipating structural change means understanding the processes that guide innovation in technologies, behaviours and institutions. The alternative is to be caught by surprise.

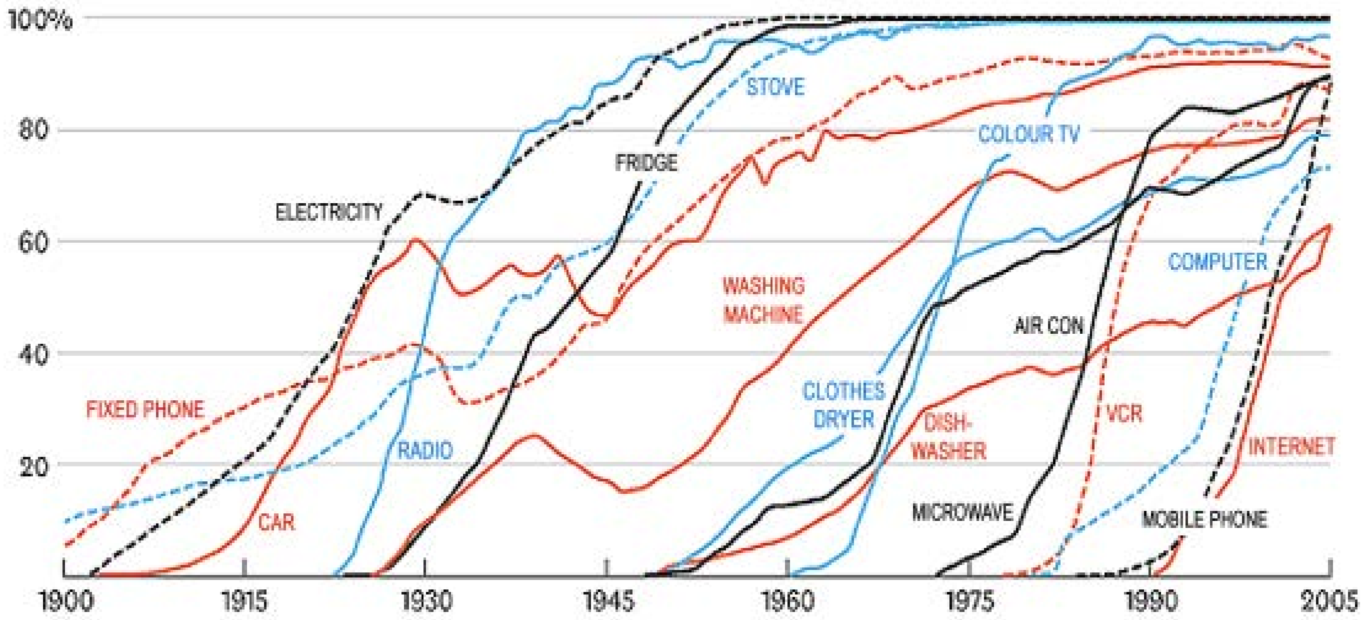
Figure 2 shows two pictures of traffic in the same stretch of New York's Fifth Avenue taken just over a decade apart. The yellow circle in the first marks the car. The yellow circle in the second marks the horse. Had an economist, or an IPPC modeller, been asked in 1900 to estimate the cost of transitioning from horse and cart to combustion engine vehicles and fuelling networks, they might well have given an astronomical figure (in the IPCCs case to a full decimal place of GDP). Yet clearly the investment was worth it and the efficiency savings to the economy substantial.

02 Transitions can be fast: this one may be faster

New York 1900: spot the car?

New York 1913: spot the horse?

03 Diffusion and adoption curves % US households

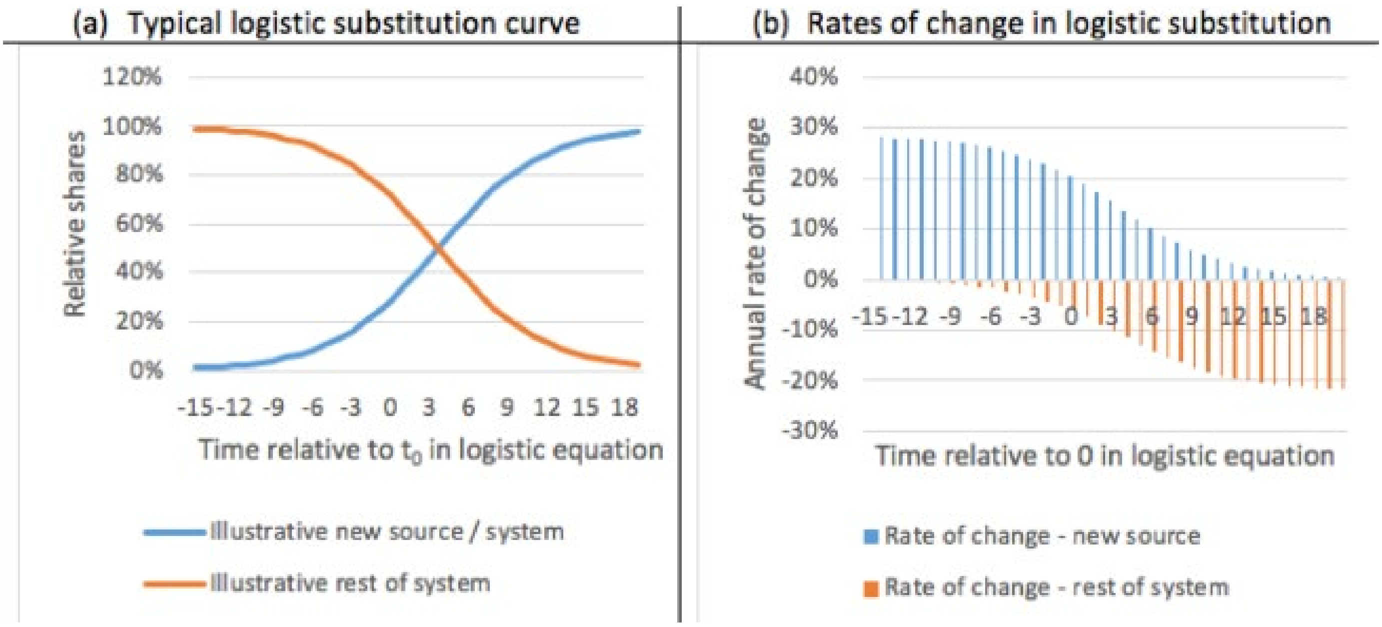


Source: http://www.nytimes.com/imagepages/2008/02/10/opinion/10op.graphic.ready.html

The deployment of new technologies associated with switching to superior networks, be they wells to piped water, horse to combustion engine, or kerosene to electricity, or a bunch of domestic appliances (Figure 3) have historically followed an s-shaped logistic curve.

Professor Michael Grubb at UCL explains that this is because systemic change means shifting entirely from one network to another. Early in the transition, change looks slow and limited to pioneers and early adopters. He argues that we are a decade away from inflection for some key clean technologies (close to the "-9" tick point in Figure 4, on the next page). At this stage, the growth of the new technologies such as renewables or electric vehicles is very rapid (double digit in recent years), but the bulk of the network is still comprised of incumbent technologies (chart (a)) which are only declining very slowly (chart (b)). Yet this is where most forecasters mistake a rapid and irreversible transition to an entirely new network for a slow and expensive evolution.

04 The schematic nature of network transitions



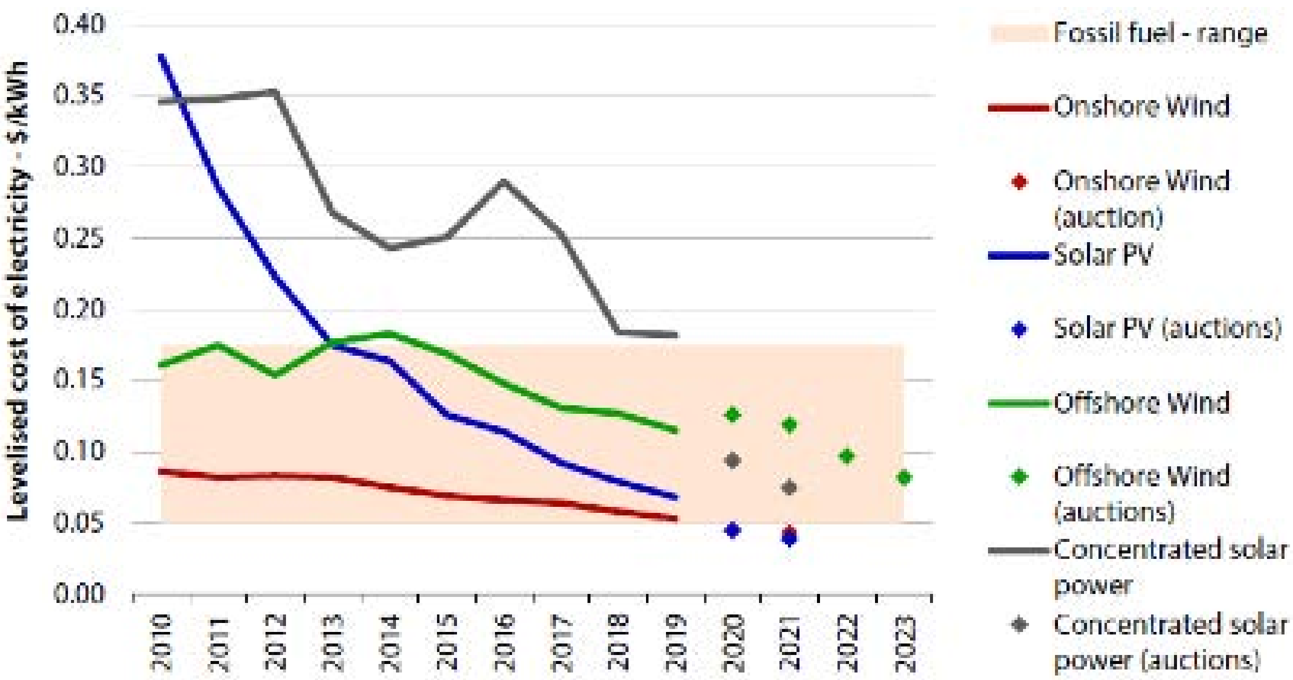
Source: Michael Grubb 2018

$$\text{deployment at time } (t) = \frac{MAX}{1 + ae^{-k(t-t0)}}$$

A. Electricity is rapidly going zero carbon

Renewable electricity technologies have witnessed remarkable cost declines over the last decade. The price of solar photovoltaic (PV) has fallen by 44% in the two years to the end of August 2017[5] and by 83% since 2010[6], a period over which the price of wind turbines dropped nearly 40%. These technologies are increasingly producing power that is cheaper than many coal- and gas-fired power plants (Figure 5).

05 Levelised costs of electricity (constant 2019 US dollars per kWh)



Source: CCC, 2020 https://www.theccc.org.uk/wp-content/uploads/2020/06/Reducing-UK-emissions-Progress-Report-to-Parliament-Committee-on-Cli.._-002-1.pdf

[5] Bloomberg New Energy Finance (2019) New Energy Outlook 2019 https://about.bnef.com/new-energy-outlook/
[6] https://www.linkedin.com/pulse/scenarios-solar-singularity-michael-liebreich/

But most renewables have a problem. They cannot be relied upon to deliver instantaneous dispatched energy. The sun doesn't always shine and the wind doesn't always blow. In the short run, dispatchable gas plants can bridge the gap. But in the longer term a zero carbon solution must be found in the form of either battery technologies or other storage technologies such as pump storage hydro-power or hydrogen created through water electrolysis generated by renewable energies (green hydrogen) or reforming natural gas gasifying coal, and capturing the CO2 emissions. The requirement for storage technologies increases system costs as the penetration of renewable energy into the electricity network grows.

Battery costs for electric vehicles have also decreased an extraordinary amount over the last decade.[7] In addition, grid interconnection to parts of the world where renewable energy is being generated, together with smart demand management responses such that energy demand is smoothed to match energy supply, also reduce the costs of intermittent renewable energies, allowing them to run at greater capacity.

With cheaper storage, growing demand-response capacity, business model innovation and smart policy design, renewable electricity generation has passed an unstoppable tipping point where, within the next few decades in most parts of the world, it can be dispatched at costs below those currently associated with fossil fuel generation.[8] Michael Liebreich, Senior Contributor and founder of Bloomberg New Energy Finance puts it this way:

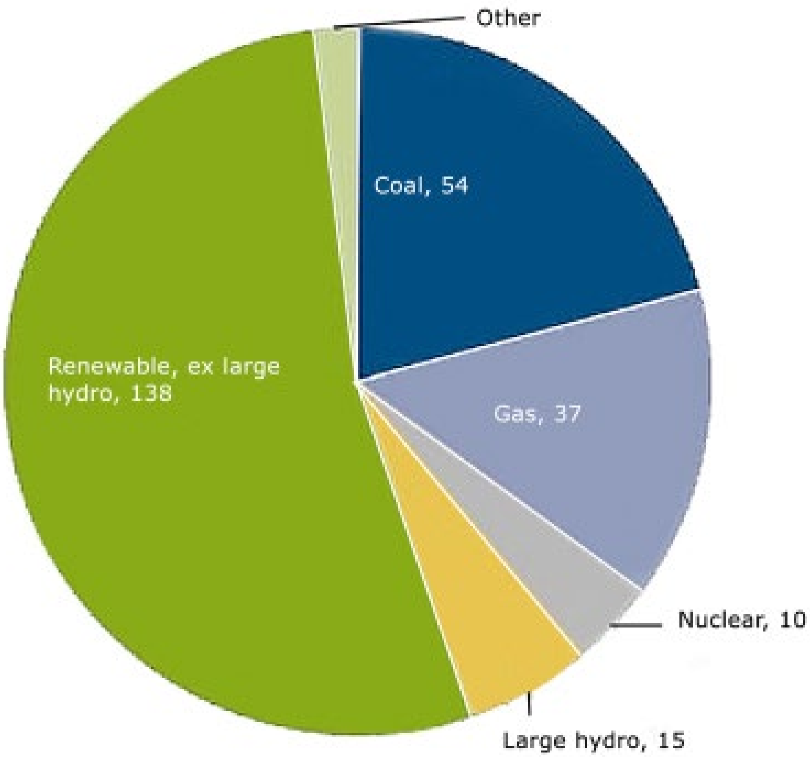
"Two decades ago everyone assumed that the cost of managing intermittency would soar after the first 5% of wind and solar entered the power mix; a decade ago we thought the inflection was 20%; now we know it is not this side of 40%. Modelling exercises around the world suggest that it is not until you reach 80% or more in any decently-connected grid that the cost of managing intermittency really starts to go vertical".

Liebreich, M. 2019: Peak Emissions Are Closer Than You Think – and Here's Why https://about.bnef.com/blog/peak-emissions-are-closer-than-you-think-and-heres-why/`

[7] Bloomberg New Energy Finance (2019) Battery pack prices fall as market ramps up with market average at 156 kWh in 2019

[8] This is the case even without the implementation of a carbon price (which would further accelerate the competitiveness of renewable energy sources).

06 Investment in generating capacity 2016, GW



Source: Bloomberg New Energy Finance

With the cost of generating zero carbon electricity falling so rapidly, it is perhaps no surprise that global investment in renewable generation, excluding nuclear and hydroelectricity, is already outstripping investment in coal, gas, and oil power (Figure 6).

The stock of generating capacity remains mostly fossil fuel based, but the investment flows are rapidly set to change that as old plant is retired. The IEA (2020) estimates that 'Renewables will overtake coal to become the largest source of electricity generation worldwide in 2025'. Over the next decade or so, and starting with the older and least efficient plant, it will be cheaper to scrap fossil fuel plants before the end of their working lifetime and replace them with renewables (see Section 12 for the implications of asset stranding).

B. Electric vehicles (EVs)

Many analysists see ample potential for further reductions in battery storage costs to $100/kWh by 2025.[9] This is a threshold below which electric vehicles are likely to be cheaper than conventional cars (in addition to savings afforded in running costs - at battery prices around $200 per KWh, the total cost of owning an EV is lower than the total cost of owning a combustion engine car, because the higher initial EV price is offset by lower running costs and lower energy costs).

These changes will transfigure global oil markets: buying an internal combustion engine car commits you to import $10,000 of gasoline over the lifetime of the vehicle; the solar equipment to power an EV will cost under $1,000. (https://carbontracker.org/reports/nothingto- lose-but-your-chains/).
In anticipation of this, the UK has banned the sale of new combustion engine vehicles after the end of this decade.

In 2017, China announced that five million electric vehicles would be sold by 2020.[10] China is one of the world's largest electric markets and this announcement prompted large automotive companies such as Ford and General Motors to establish goals to increase electric vehicle sales. The result of this saw nearly double the number of electric vehicles produced and sold in the first half of 2018, when compared to the same period in 2017. This investment was a significant contributor to the sharp reduction in the costs of electric vehicles, further increasing their marketability and appeal and allowing policymakers to introduce ambitious targets for banning combustion engine sales (from as early as 2030 in the UK).

[9] See Nykvist et al. https://ideas.repec.org/a/eee/enepol/v124y2019icp144-155.html
[10] See Kingo et al.: https://www.wemeanbusinesscoalition.org/blog/the-key-to-faster-zero-carbon-growth-harness-theambition-loop

C. Decarbonisation of other sectors

The clean revolution will not be limited to renewables and EVs, though these currently form the most significant wave. Electrification will proliferate, starting with land transport to encompass residential and industrial heating and industrial processes. The production of clean hydrogen and synthetic fuels like ammonia, which also experienced marked cost reductions, will eventually fuel long-distance transportation such as haulage, shipping and aviation and help decarbonise significant parts of heavy industry.

Great strides have been made towards improving efficiency. For example, LED lighting has gone from less than 5% of the global lighting market to 56% since 2014.[11] At the same time, coal has gone from supplying around 40% of UK electricity to under 5%.[12] Tackling hard to crack sectors such as aviation, shipping, heavy industry and agriculture requires a clear sense of direction and strategic planning, but even here there are efficiency gains to be had.[13]

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[11] https://www.grandviewresearch.com/industry-analysis/led-lighting-market

[12] OFGEM Electricity generation mix by quarter and fuel source. Available at: https://www.ofgem.gov.uk/dataportal/electricity-generation-mix-quarter-and-fuel-source-gb

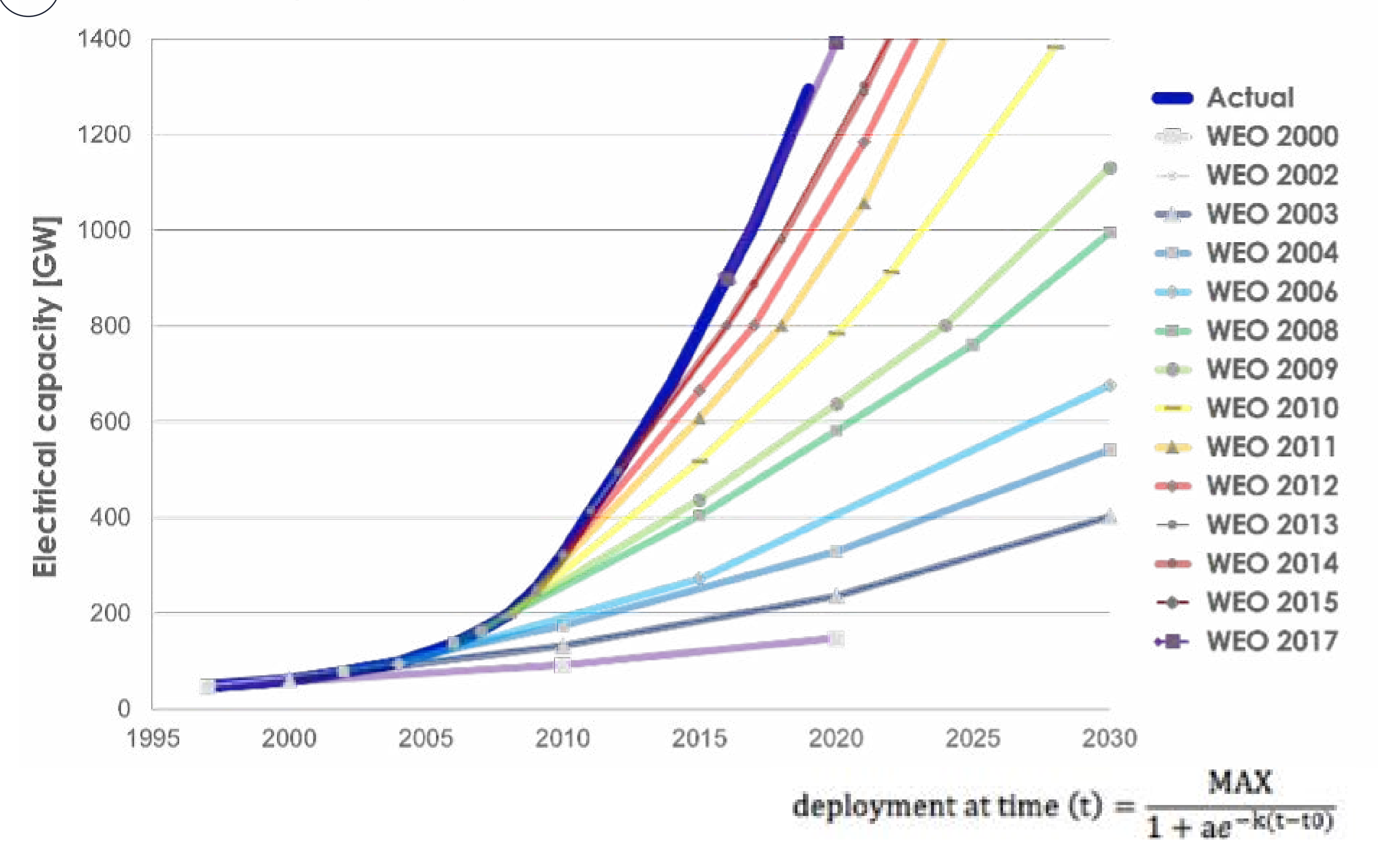
[13] Not all the innovations will be cost effective. In order to reach a net zero global economy some form of direct air capture to 'suck' carbon back out of the atmosphere or 'end-of-pipe' carbon capture and storage facilities will be required to squeeze that last bit of carbon out of annual emissions. These technologies usually require additional expensive kit; however, these costs can and will be cross subsidised by the gains from clean and resource efficient technologies.

06 / Time to expect the unexpected

Yet in spite of inevitable forces, investment in fossil fuel infrastructure continues, with China purportedly planning to build hundreds of coal fired power stations as part of its economic stimulus plan. So is the world transitioning or not? The difficulty associated with the conventional approach to forecasting such dramatic and large-scale transitions was outlined in section 4. Figure 7 illustrates this graphically. It shows the projections made by the International Energy Agency in their World Energy Outlook for renewable capacity excluding hydro power. This consists mostly of wind and solar technologies, but also geothermal, bioenergy and marine energy.

A notable feature of the last decade has been the astonishing declines in the cost of renewable and other clean technologies (see next section). As renewable costs collapsed, investment in renewable energy skyrocketed, with capacity doubling every four or five years (bold blue line). The thin coloured spidery lines fanning off the blue line represent sequential years' predictions of renewable energy capacity as expressed in the World Energy Outlook (WEO) for that year. Not only did capacity projections fall well short of actual outturns, they did so systematically year after year after year after year. The intent here is not to pillory the International Energy Association - this is perhaps the most authoritative and analytically informed body on energy issues on the planet. The point is to graphically illustrate the innate difficulty associated with projecting energy transitions.

07 Renewable capacity, ex-hydro



Source: Energy Watch Group 2015 and authors estimates based on IEA WEOs
https://energywatchgroup.org/wp-content/uploads/2018/01/EWG_WEO-Study_2015.pdfs_.pdf

The problem the IEA faced is this. One of the key reasons renewable capacity grew faster than expected was because costs fell sharply. But costs fell sharply because capacity expanded. Like everyone else, the IEA overestimated renewable costs and underestimated deployment. Several key amplifying feedback mechanisms were missed:

01

Learning effects

A key reason for the sharp reduction in costs is learning-by-doing and experience because of rapidly expanding deployment. With deployment, lessons are learned on how to manufacture, distribute, instal, run and maintain equipment more efficiently.

02

Economies of scale in production and distribution

Costs also come down because of the unit cost benefits accrued from larger production and distribution networks. This reflects large, fixed costs where, once the initial fixed costs have been incurred, low unit costs encourage increased output.

03

Network and coordination effects

This is closely related to economies of scale, but reflects the greater advantages of moving in tandem with others, such that the gains are higher the more economic agents are taking similar action. Sometimes the networks involve spill-overs across sectors. Give people more computers, they come up with better things to do with them and more software which increases the value of getting more computers.

04 Sector spill-overs

Not only have sustainable technologies been shown to have predictably higher cost-reducing learning rates, they have been shown to have positive productivity spill-overs into other sectors of the economy. Using data on 1 million patents and 3 million citations, Dechezlepretre et al. (2014) suggest that productivity enhancing spill-overs from low-carbon innovation are over 40 percent greater than from conventional technologies (in the energy production and transportation sectors).

05 Social and institutional feedbacks

Social norms can be defined as the predominant behaviour within a society, supported by a shared understanding of acceptable actions and sustained through social interactions (Ostrom 2000). Social feedbacks help make norms self-reinforcing and therefore stable. Formal institutions struggle to enforce collectively desirable outcomes without popular support. Acceptable standards of behaviour and social norms are the sources of law and ultimate drivers of legislative change (Posner 1997).

06 Expectations

People's changing expectations with shape the nature and pace of change. Perception of new technologies as superior leads to behaviour change which itself facilitates their successful adoption. Most obviously, investment in the technologies and in supporting infrastructure and networks increases. Social norms also change and new political institutions such as ministries, agencies and business and trade union lobbies are created. These are accompanied by supportive policies, in the case of carbon, these include carbon taxes, deployment support and new standards and regulations which are being deployed globally. Insights from social psychology suggest that solving coordination problems requires building expectations into models and generating 'common knowledge' as an expectation anchors (Thomas et al. 2014).

The role coordinated shifts in expectations play in driving transformational change is now widely recognised. Social psychologists talk of cascades of information and shifts in the perception of 'common knowledge'. Nobel Prize winning economist Robert Shiller refers to contagious narratives driving global events in what he famously labelled 'narratives economics'. Game theorists refer to 'strategic complementarities', whereby the payoff to adopting a new behaviour or investing in a new technology is a function of the number of others who do likewise. For example, a policymaker, business or individual is more likely to invest in clean technologies if they feel everyone else will. This is because with everyone else investing, they would expect costs to fall, finance to go from niche to mainstream, and new markets to open up.

Economic models cannot handle the instability these amplifying feedbacks imply, so they are mostly ignored. The result is that forecast cost of these transformative technologies are overstated. This has posed problems globally. The regular assertion by economists and others that environmental action is likely to be prohibitively expensive becomes self-fulfilling. By helping set expectations it delays political action and investment that might lead to deployment and innovation which, in turn, would reduce future costs. Economists often don't just get the future wrong, they make the future wrong.

Thankfully, expectations are showing signs of tipping. The perception that 'green' conflicts with growth is not only being challenged, it is being turned on its head. A recent Oxford study of 231 global finance ministry and central bank officials and senior economists showed that investments with the highest economic growth potential are in many cases thought to be the cleanest and most sustainable.[9] Post COVID-19 recovery and stimulus packages, could accelerate these trends as government funds are invested in resilient and sustainable infrastructure.[10]

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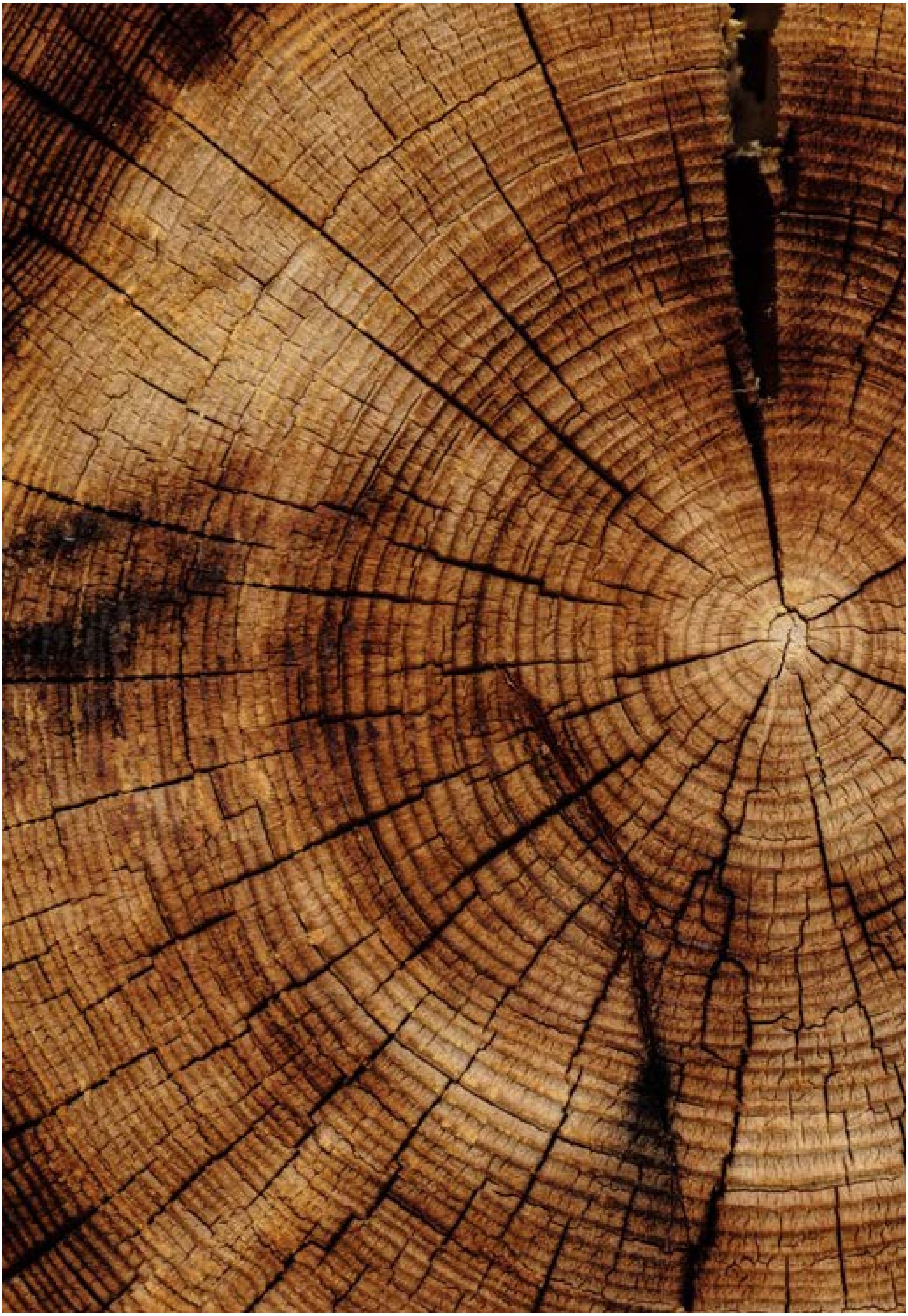
[9] Highest scoring sectors include clean R&D spending, clean energy infrastructure, connectivity infrastructure, building upgrades and energy efficiency and investment in green spaces.

[10] Sustainable, resilient and inclusive investments have some very appealing short- and long-run characteristics in a recession. In the short run, clean energy infrastructure (such as insulation retrofits and building wind turbines, broadband networks, rolling out EV charging infrastructure, plant trees, restore wetlands) is labour intensive but not susceptible to offshoring or imports (Pollin et al. 2008). Consequently, they impart high short run multipliers (Houser et al. 2009, Jacobs 2012). In the long term, the economic multipliers are also high, as the operation and maintenance of more productive renewable technologies makes them less labour-intensive, and energy cost savings are passed to the wider economy (Blyth et al. 2014), (Hepburn et al 2020).



07 / Innovation and knowledge the key to sustainable prosperity

The inevitability of global decarbonisation and the resource-efficient shift makes it close to a one-way bet which can guide actions and help overcome strategic complementarity problems outlined in section 5.[21] Innovation provides society the opportunity to boost productivity and reduce environmental stress by getting more out of the limited resources we have. Knowledge is the key driver of the growth in total factor productivity and will direct the increasingly valuable 'weightless' economy.

In 1975 around 20% of the value of listed companies was intangible - the ideas, processes and networks that a company has nurtured. By 2015, that level had risen to around 80%. Ideas are weightless and it is these that will increasingly deliver value in the future.

The low-carbon transition is one of many 21st century secular megatrends. The world economy is entering the fourth industrial revolution.[22] The new economy will be shaped by productivity boosting innovation utilising digital platforms. AI, automation, ubiquitous sensors, machine learning, big data, the internet of things, nanotech and biotech revolutions have already delivered significant disruption. These technologies face high costs barriers to deployment and may not be fully competitive today, but they all benefit from the same economics of scale in production and discovery as low carbon innovation. Indeed, they are complementary to the low carbon transition and their combined impact will transfigure the electrical system and unlock sweeping changes to the efficiency with which resources are used.

We cannot know with any certainty what the world will look like in 2050, nor how new systems will evolve. We do, however, know the sources of greenhouse gas emissions and the processes that generate innovation and behavioural change which can steer the economy towards a zero carbon future. This means understanding new risks and opportunities and, by applying conditional optimism, using finance to help steer, design and build the future.

[21] See Zenghelis, D. (2020) https://www.lombardodier.com/contents/corporate-news/responsiblecapital/2019/november/can-we-be-green-and-grow.html?skipWem=true
[22] See https://www.pwc.co.uk/services/sustainability-climate-change/insights/innovation-for-earth.html

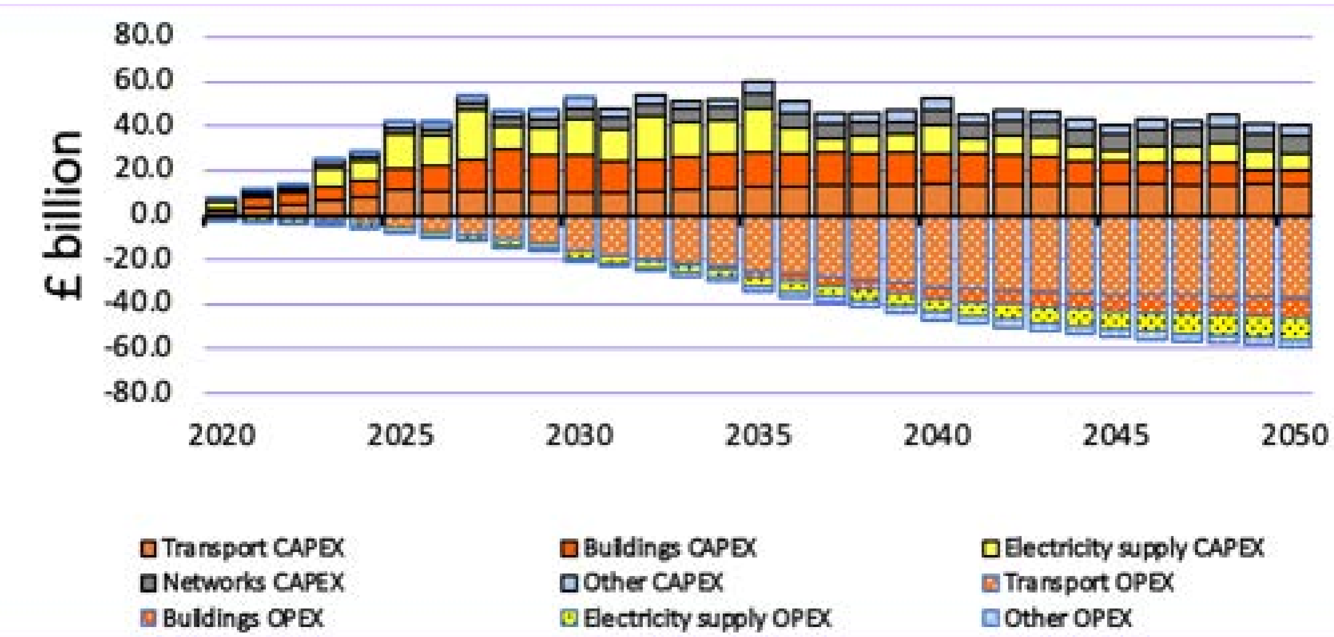
08 / The call for capital

The clean economy affords profitable new investment opportunities for private capital. It will require substantial capital expenditure in the form of upfront investment, but much less in the form of operational costs relative to fossil generation. This is because once the equipment is in place the energy source does not have to be mined, transported and burnt, but instead can be obtained at minimal cost from sun, wind and other natural sources.

In the UK the Committee on Climate Change has forecast that, with time, the reduction in operating costs associated with reaching net zero is likely to offset the additional capital cost requirement (Figure 9) as efficiencies are passed on to consumers and industries. The Committee therefore concluded that the costs of delivering a net zero economy to the UK by 2050 could be zero (even excluding the significant co-benefits discussed above and the avoidance of the worst climate risks).

Here, we can see the full impact of the UK Net Zero transition on operating expenses versus capital expenditure. While embedding new systems and technologies does incur an initial cost, those costs are likely to be offset by the ongoing reduction in operating costs, helping to boost profits over the longer term:

09 CAPEX and OPEX impact of UK Net Zero transition



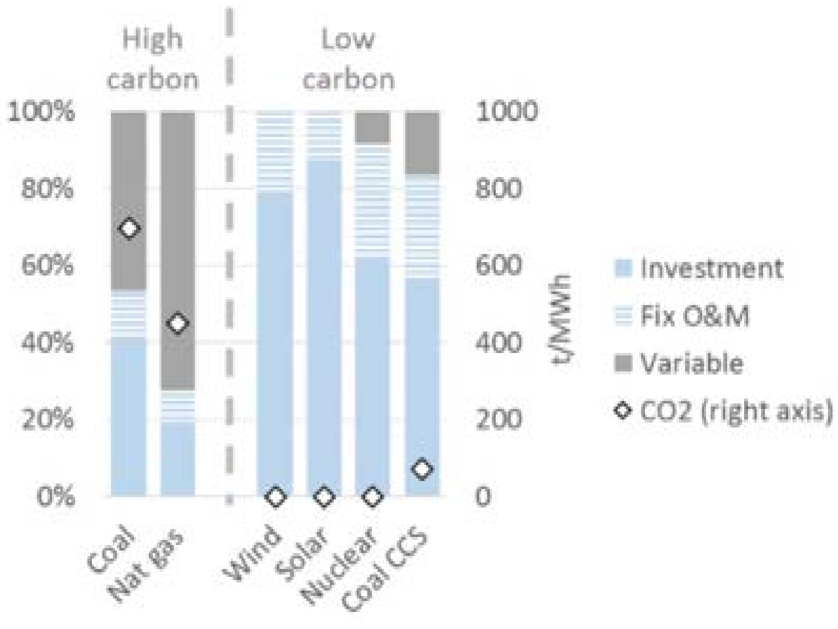
Source: Committee on Climate Change, 2020

The significance of the UK's net zero plans cannot be overstated. The country that brought the world the industrial revolution based on the burning of fossil fuels which has powered the global economy thought the last two centuries plans, within a matter of decades, to completely decarbonise its economy.

Cheaper (zero carbon) electricity will raise the returns to electrifying all areas of the economy. This will require huge investment in the power grid. An additional US$800 billion per year is required to decarbonise the global economy, the bulk of it associated with electrical power, but also including buildings, and clean transport infrastructure. By comparison, the world is expected to invest about US$60 trillion on infrastructure in the decade up to 2030.

This makes for an enhanced role for financial and capital markets (Figure 10). Indeed, from a macroeconomic perspective, it affords a great opportunity for private capital. Private sector investors in the advanced economies have, in recent decades, seen limited opportunities for productive investment. Facing few attractive options on where to put their money, they have though it paid an ever diminishing (in real terms negative) rates of interest.[23] It is this enduring surplus of desired net saving over desired investment which has pushed global neutral real interest rates to below zero.[24] The low carbon economy provides a conduit to generate future returns to investors by boosting the productive capacity and resilience of the global economy.

10 Finance will be key: Clean energy will be capital intensive



Source: Hepburn, 2017. INET Oxford

[23] See Lukasz and Summers (2019) https://www.nber.org/papers/w26198

[24] The term neutral refers here to the rate that would prevail when the economy is operating close to capacity, not requiring either a tight/loose monetary stance to contain/stimulate demand. It reflects underlying structural factors shaping preferences for desired savings and investment, rather than cyclical positions dictated by policy rates. It reflects a countries equilibrium real rate of interest in the long run. According to Lukasz and Smith 2015, lower expectations for trend growth and shifts in desired savings and investment have driven a 400bps of the 450bps decline in the global long-term neutral rate since the 1980s See Stern and Zenghelis (2021) https://www.lse.ac.uk/granthaminstitute/wpcontent/ uploads/2021/03/Fiscal-responsibility-in-advanced-economies-through-investment-for-economic-recovery-fromthe- COVID-19-pandemic-1.pdf

09 / The need for credible intervention to steer change

The road to net zero will not be smooth. Even where the benefits of change are clear and tangible, important barriers prevent implementation. Strong inertia in behaviours and processes as well as high switching costs make it initially difficult to shift the innovation system from incumbent dirty to clean technologies. New innovation is always risky and may not succeed. Firms tend to direct innovation toward what they are already good at[25] while scientists work in sectors and regions where similar research is undertaken[26] using similar production capabilities. Innovation can be thought of as 'path-dependent'.[27]

Large-scale change will generate winners and losers, and the losers will suffer dislocation and, understandably, lobby hard to resist change. This understanding is not new. Back in the mid-16th century, Machiavelli wrote in "the Prince" (1532)

"The prince will find many enemies among those who oppose change. On the other hand, the prince will find the supporters of change to be passive because people generally do not want to trust something until it is firmly established."

[25] See Aghion et al, 2016 https://dash.harvard.edu/handle/1/27759048
[26] See Hidalgo et al, 2016 https://arxiv.org/ftp/arxiv/papers/0708/0708.2090.pdf
[27] See Aghion et al (2024) http://www.lse.ac.uk/GranthamInstitute/wpcontent/uploads/2014/11/Aghion_et_al_policy_paper_Nov20141.pdf

“Whether one cares two hoots about the climate, the world is set to experience cheaper electricity and more efficient and drivable vehicles compared with the incumbent fossil fuel alternatives. The market alone would never have delivered this and no economists, to the author’s knowledge, ever predicted it.”

A quick scan of the global political economy tells us that these concerns need to be carefully managed if they are not to generate delay, backlash, resistance and resource wastage. Countries which still plan to build coal plants do so for predominantly political reasons (preserving jobs in the coal mining and generation) rather than economic reasons. Ensuring a just transition will be crucial for maintaining social cohesion and economic justice and enabling the climate transition to unfold.[28] This requires enabling institutions that reskill, retool and compensate affected workers to secure the skills and jobs necessary to enable those affected by change to participate in the 21st century economy.[29] Regional transition funds can help the local economy dependent on fossil fuels diversify.

Another key insight is that public intervention is often necessary to overcome the hurdles of adjustment early in the transition and shift the economy to a superior system. This in turn relies on coordinating expectations.[30] Credible policy intervention can provide investors and companies with greater clarity and confidence that a low carbon future will be a profitable one. Once they reach a tipping point, expectations can transition rapidly to the new equilibrium, technologies are enabled to switch quickly from one network to another.[31] Public intervention is a driver of change, as well as a consequence of it. For example, flourishing low carbon business interests lobby for policies which promote clean investment and penalise emissions. This further amplifies the reinforcing feedback and drives forward the phase change to a new equilibrium.

As a result, public policy and national regulators are increasingly implementing and enforcing actions that incentivise or force businesses to reduce their carbon footprint and positively contribute to greener growth. These include carbon pricing, more stringent regulation and support for R&D and deployment. At the same time, as new technologies and processes begin to competitively undercut old ones and render them redundant, this has the potential to transform the competitiveness of markets, especially as significant R&D and deployment shifts to low carbon sectors.

Policy to support clean innovation needs to be strong, but perhaps only temporary. One influential study[32] argues that once the "clean innovation machine" has been "switched on and is running," it can be more innovative and productive than the conventional alternative, with a positive impact on GDP.[33] Instead of a uniform global carbon price, this might augur for targeted policies focussing on currently expensive technologies with greater potential for future innovation. Rather than working along an abatement cost schedule picking off the cheapest options first, it might make better sense to start with some of the most expensive technological options to bring their costs down faster.[34] Business can work with government to attract funds to support R&D and demonstration of critical technologies and new business models (for example in fuel cells, hydrogen and ammonia technologies, carbon capture and storage and biomass).

Whether one cares two hoots about the climate, the world is set to experience cheaper electricity and more efficient and drivable vehicles compared with the incumbent fossil fuel alternatives. The market alone would never have delivered this and no economists, to the author's knowledge, ever predicted it.

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[28] See European Commission, (2020)https://ec.europa.eu/regional_policy/en/newsroom/news/2020/01/14-01-2020-financing-the-green-transition-the-european-green-deal-investment-plan-and-just-transition-mechanism
[29] See Robins et al., (2019) http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/09/Financing-inclusiveclimate-action-in-the-UK_An-investor-roadmap-for-the-just-transition_POLICY-REPORT_56PP.pdf
[30] For example, solar PV innovation relied initially on NASA's and Bell Labs' early investment and, after decades of research and development, targeted intervention such as Germany's feed-in-tariff and Japan's metering policies. Eventually, reduced costs incentivised China to fabricate low low-cost solar panels in anticipation of market opportunities.
[31] Krugman, P., 1991 'History Versus Expectations' The Quarterly Journal of Economics, Vol. 106, No. 2. May, pp. 651-667.
[32] See Acemoglu et al. (2012) https://www.aeaweb.org/articles?id=10.1257/aer.102.1.131
[33] See Zenghelis (2019) https://journals.sagepub.com/doi/10.1177/002795011925000118
[34] See Vogt-Schilb et al., 2018 https://www.sciencedirect.com/science/article/pii/S0095069617308392

10 / New modelling approaches required

These reinforcing feedbacks and complex dynamics make modelling and forecasting the cost of systemic non-marginal energy transitions fiendishly difficult. Conventional economic models cannot deal with the multiple equilibria these feedback dynamics imply and consequently they systematically overstate the costs of decarbonisation and downplay the opportunities.[35] This underlines the preposterous outcomes presented by the IPCC in their Summary for Policymakers outlined at the start of this paper.

It is no coincidence that, to the author's knowledge, not a single economic model predicted the sharp falls in the costs of renewables or battery technologies over the past decade. Models also miss the importance of early public intervention to tilt the economy onto a new, more productive, path. They understate the degree to which leadership matters.

This is not to disparage the use of models. Models are essential tools in helping us examine theoretical and empirical behavioural relationships too complex to assess in one's head. They force the modeller to explicitly articulate assumptions and relationships and help us understand the workings of the world. But their limitations need to be recognised.[36] The difficulty stems from the genuine futility of making long term predictions in a dynamic system subject to cumulative uncertainty.

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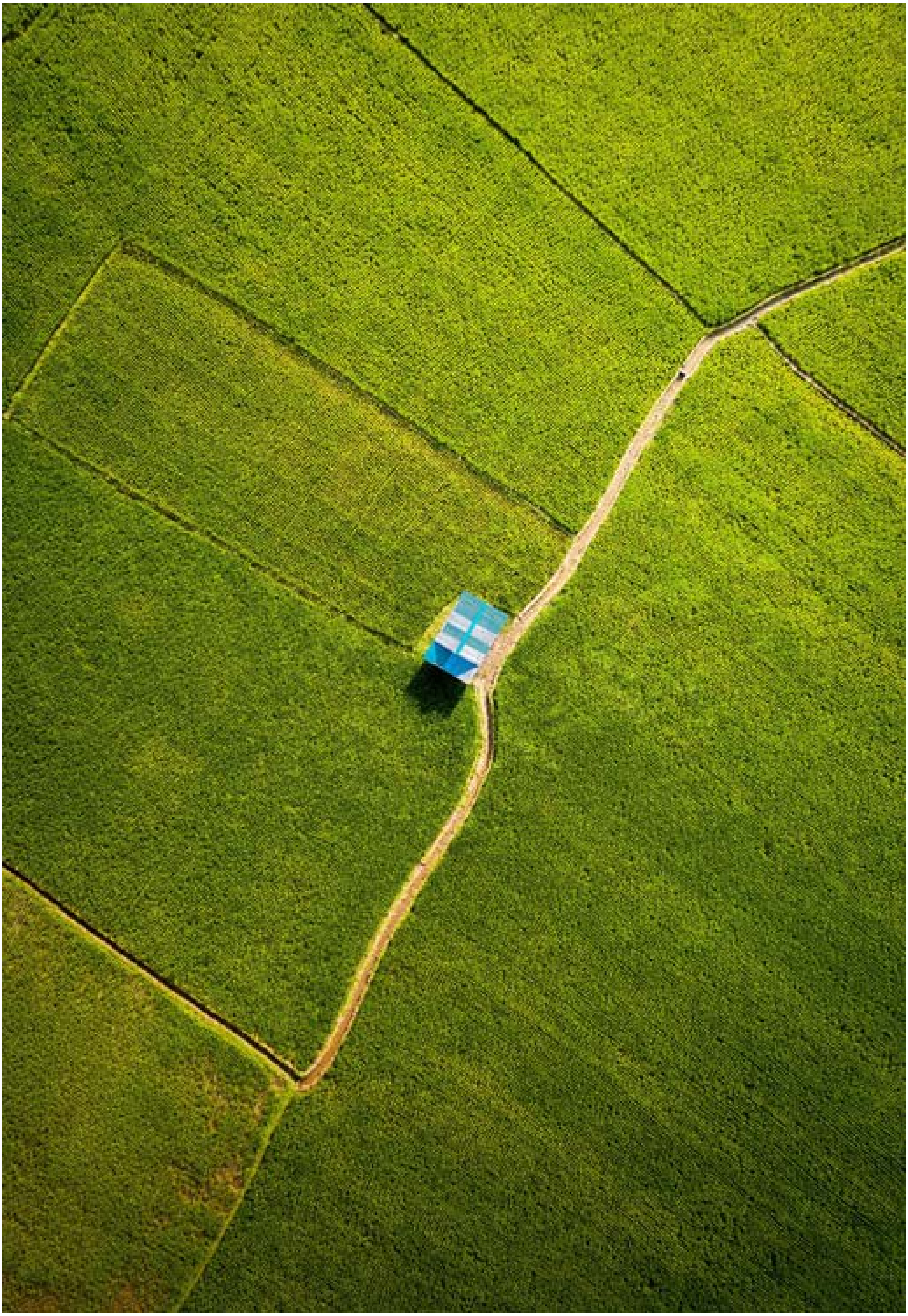
[35] See Zenghelis (2019). https://www.lombardodier.com/on-off
[36] See Zenghelis (2017) https://www.wri.org/climate/expert-perspective/role-modelling-and-scenario-development-longterm-strategies *April 2020, survey of 231 finance ministry/central bank officials/senior economists (representing 53 countries incl. all G20): perspectives on COVID-19 fiscal recovery packages (Hepburn, C., O'Callaghan, B., Stern, N., Stiglitz, J., and Zenghelis, D., 2020)



A recent study* on the process of change defined a risk-opportunity assessment (ROA) framework, based on complexity science, to guide policy-makers and investors.[37] They concluded:

01 Models based on inappropriate assumptions will not provide helpful input to such an analysis.

02 The expected value of (non-marginal dynamic) outcomes cannot be reliably calculated.

03 Policy action in these conditions is about 'steering' in an uncertain, changing environment, rather than about 'optimising' an outcome in a world of certainty.

04 It is therefore processes –the likely direction, rate, and magnitude of change –that should be the focus of analysis.

[37] See http://eeist.co.uk/output/

05 The preferred option is determined by the decision-maker based on a qualitative judgment of the scale of the opportunities and risks, compared to the cost of the intervention.

06 This will necessarily be a subjective judgment (since it incorporates a weighing of outcomes in different dimensions), informed by an objective assessment of likelihood and magnitude of possible outcomes in each of the relevant dimensions.

07 A clear statement of the reasoning behind the decision is recorded including the decision-making body's assessment of the risks and opportunities in their various dimensions. (This can be helpful for transparency and for learning from experience).

They describe ROA as a generalisation, "in fact possibly the only self-consistent generalisation one can make, of cost-benefit analysis when in the presence of dynamics and strong path-dependence in the economy, of fundamental uncertainty and heterogeneity of stakeholders".

11 / Opportunity breeds collaboration

The reality is that self-interest, not shared sacrifice for the greater good, breeds cooperation and helps overcome expectations inertia. It unlocks the proverbial tragedy of the commons whereby agents have an incentive to 'free ride' on the actions of others, leading to a race to the bottom characterised by collective inaction. The big innovation of the Paris Agreement is that it dropped the language of 'burden-sharing' and focussed instead on nationally determined voluntary contributions.[38] This important change in outlook in turn builds on a growing evidence of the opportunities associated with a low-carbon transition.[39]

Policymakers have increasingly sought to proactively identify potential co-benefits during the policy design stage and shape implementation criteria to maximise impact. Greater efficiency saves money and reduces pressure on resource prices. (King 2012, HSBC 2012). Local air pollution costs 6.2% of global economic output and can be markedly reduced by decarbonising electricity and vehicles.[40] Urban congestion and improved health outcomes result from better urban planning, Cost saving are available in the way we manage water, food and land and there are opportunities even in aviation, shipping and industry.[41]

The Global Commission on the Economy and Climate estimated that "at least half and possibly as much as 90%" of the global emissions reductions required to meet a 2 degree target could generate net benefits to the economy. The IMF recommends fossil fuel pricing on economic grounds.[42] Countries and companies that successfully invest early in green capabilities, have been shown to have greater success in diversifying into future clean product markets.[43]

Expectations of a better future drive innovation in new sectors, sufficient to overcome hurdles inhibiting change.[44]

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[38] United Nations (2020) The Paris Agreement

[39] The Grantham Research Institute on Climate Change and the Environment and The Centre for Climate Change Economics and Policy (December 2014) Taming the beasts of 'burden-sharing': an analysis of equitable mitigation actions and approaches to 2030 mitigation pledges

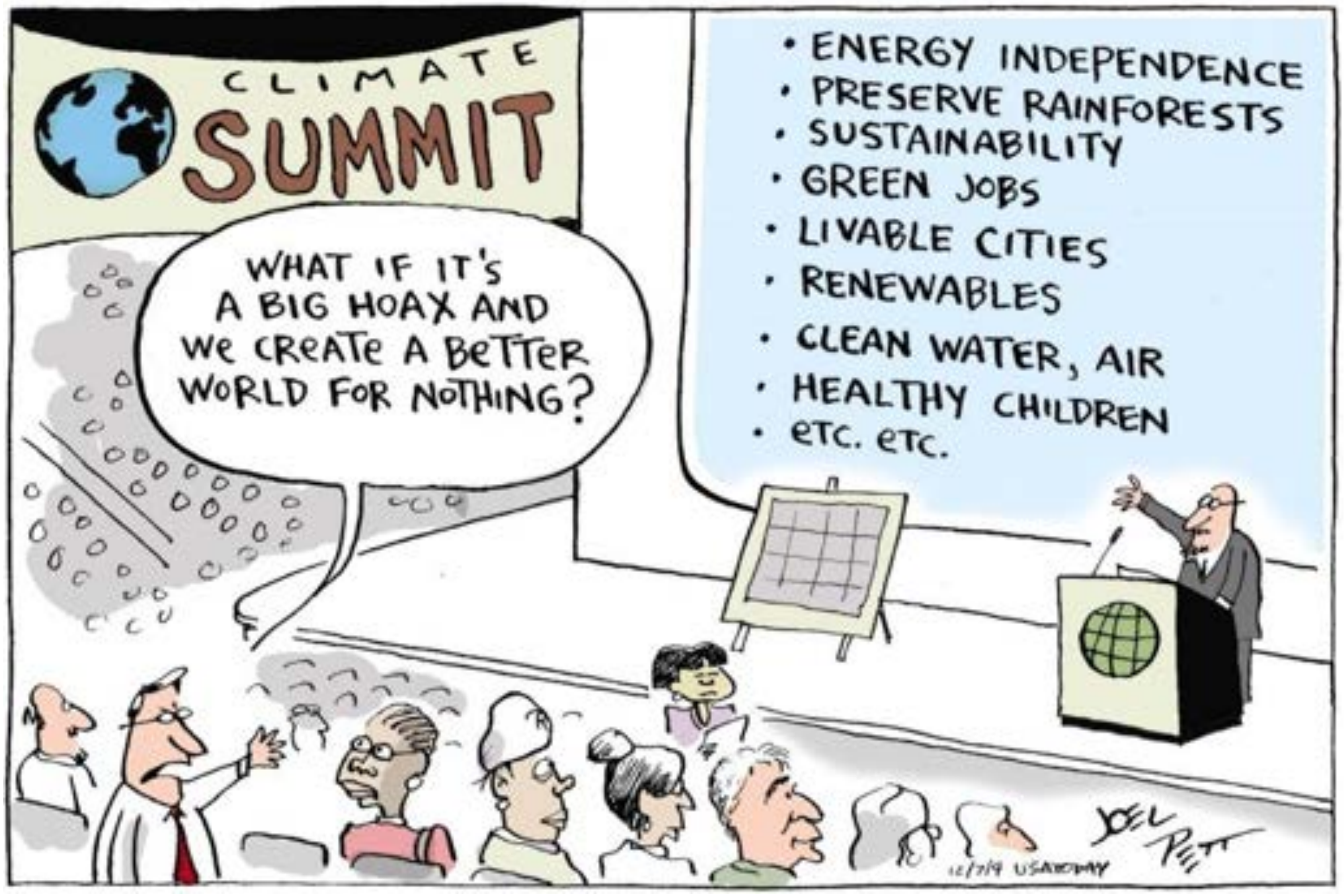
[40] See Landrigan et al. (2018) https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)32345-0/fulltext

[41] See Energy Transition Commission https://www.energy-transitions.org/publications/mission-possible/

[42] See IMF (2019(https://www.imf.org/en/Publications/Policy-Papers/Issues/2019/05/01/Fiscal-Policies-for-Paris-Climate-Strategies-from-Principle-to-Practice-46826

[43] See Hepburn and Mealy (2017) https://www.researchgate.net/publication/333039741_Transformational_Change_Parallels_for_addressing_climate_and_development_goals

[44] See Zenghelis (2019) https://www.bennettinstitute.cam.ac.uk/blog/mind-over-matter-how-expectationsgenerate-wealth/



Source: © Joel Pett http://aries.mq.edu.au/images/Copenhagen-Pett.jpg

"A critical mass of attitudes, technologies, and actors can lead to system-wide transformation away from hydrocarbons. Network effects, economies of scale, and bandwagon dynamics can create self-reinforcing feedback loops such that a small push in the right direction can have outsized impacts."

Report of the Policy Advisory Group of the Committee on Climate Change, 2020

This explains why, even when the necessity for change is clear and the opportunities apparent, structural shifts can progress frustratingly gradually and then suddenly, as Ernest Hemingway might describe it. Anyone who has followed the climate policy debate over the years will at many times have felt disheartened by its progress. Then suddenly, after decades of inaction and inertia, there come a series of rapid and inexorable shifts to new networks, much as we are seeing in renewable energy and cars.

12 / Assets will be created; assets will be destroyed

Misjudging the pace and scope of decarbonisation poses an immediate threat to all businesses. Transition risk,[45] associated with keeping up with rapidly changing policies, markets, technologies, social norms and consumer tastes, will disrupt business models and drive major valuation gains and losses across the economy.

On top of technology and policy risk, highlighted above, comes litigation liability risks. People are taking to the courts to seek recompense and justice against private and public organisations who knowingly undertook activities which undermined people's livelihoods. This process of holding businesses accountable for greenhouse gas emissions will increasingly undermine the future viability of companies in this sector and jeopardise shareholder value.[46] In the last six years there has been a more than doubling of global climate laws to 1,900.[47] The public sector is also being sued. There are currently 25 climaterelated lawsuits brought against governments or their representatives. Successful litigation against the Netherlands, forcing accelerated emissions cuts, marks the start of a growing trend.

As these risks proliferate, they can quickly devalue the physical, human and intangible assets of slow-moving companies – or render them stranded.[48] Outdated infrastructure, skills and ideas will become a liability. The anticipation of this is affecting asset prices today, even as fossil fuels continue to play an active role in the economy. At the same time, investor attention is focusing on having companies explicitly articulate a strategy to manage their future exposure to these risks by building a business model that is resilient to, and profitable in, the low carbon, resource-efficient economy of the twenty-first century.

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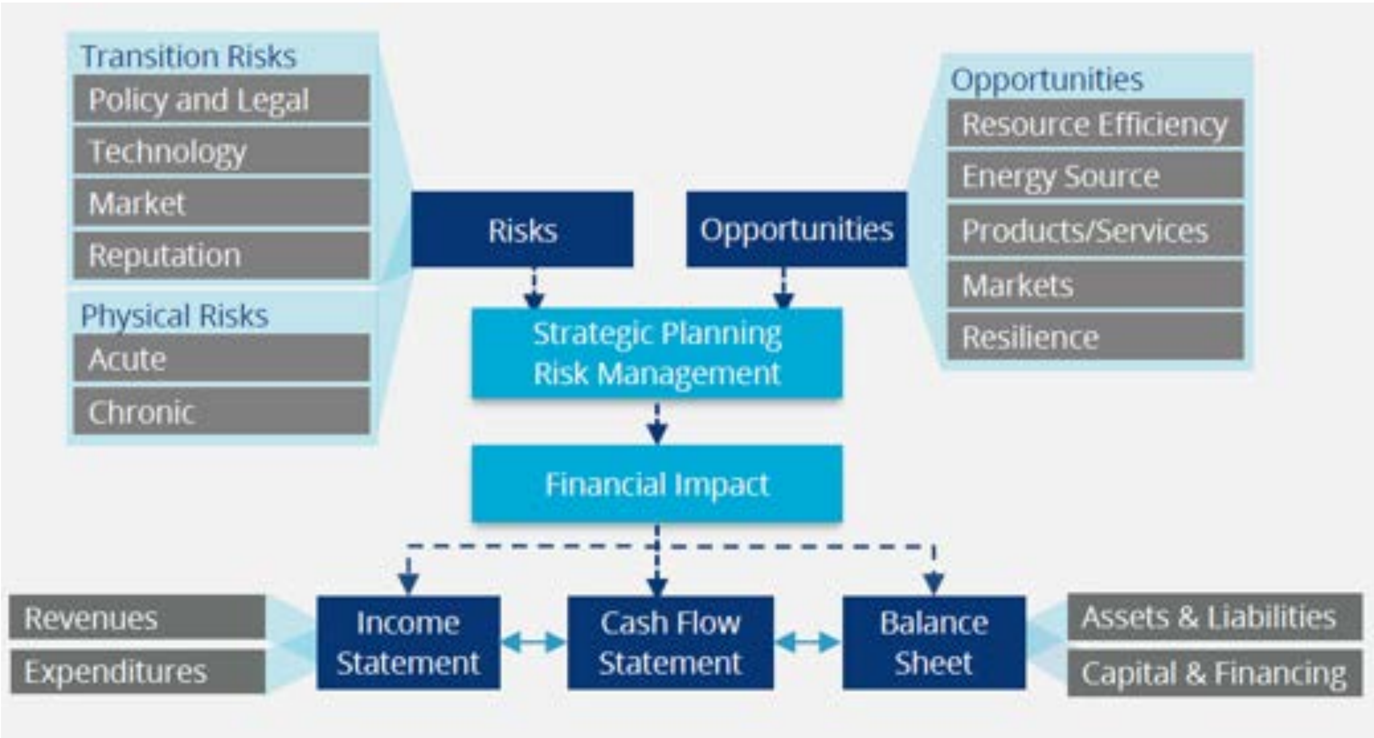
[45] See Task Force on Climate-related Financial Disclosures (2019) https://assets.bbhub.io/company/sites/60/2020/10/2019-TCFD-Status-Report-FINAL-0531191.pdf

[46] In October 2019, Massachusetts joined New York in suing Exxon Mobile for allegedly hiding its knowledge of climate change and misleading investors on its financial impact. Cities and counties in New York, California, Colorado, Washington and Maine have filed civil lawsuits against oil and gas companies.

[47] At the time of writing, over 1200 climate-related litigation cases had been reported in the US, and over 400 in the rest of the world. See Climate Change Laws of the World. (2020) https://climate-laws.org/

[48] See McGlade and Ekins (2015) https://www.nature.com/articles/nature14016 and also Pfeiffer et al, 2016. http://dx.doi.org/10.1016/j.apenergy.2016.02.093

11 Disclosures are to be forward looking and address risks and opportunities on P&L AND balance sheet



Source: Hepburn, 2017. INET Oxford

A recent paper steered by Janet Yellen and Mark Carney succinctly summarised how the financial system might accelerate and amplify the effectiveness of public policies:

“By factoring a forward-looking assessment of future climate policies into today’s insurance premia, lending decisions, and asset prices, the financial system pulls forward the adjustment to a net-zero economy. By assessing the impact of policies in a systematic way, it can ensure that climate policies inform the allocation of capital across all sectors of the economy.”

It is worth noting that the structural revolutions can be non-linear with regards asset valuations. Expectations have been shown to at first take time to 'catch up with reality' before over-reaching and systematically running away with themselves. Carlota Perez also describes 'technological revolutions' involving general purpose technologies (which transforms the whole of the economy – such as steam, electricity or cars) as following the well-known innovation 'S' curve.[49] She describes five great surges of development in the last three centuries, each wave lasting some 50-60 years. The most recent, the age of information and communications technology, can be dated from the 1970s. The low carbon revolution constitutes the latest such wave.

Perez splits this familiar take off, acceleration deployment and saturation curve into two broad periods: 'installation' and 'deployment'. She characterises the transition between the two phases as being marked by financial crisis. The installation period features a financial bubble, over-investment and a subsequent collapse, but only after the surge of investment establishes the necessary infrastructure (roads, canals, railways, cable etc). Out of the ashes emerges a 'deployment' period, in which the new networks become mature. In this second period, finance plays a diminished role to 'production capital', backed by a more interventionist state, which takes a lead in pushing the technology to saturation.

In this framing, clean technologies will experience an unsustainable investor bubble, and subsequent crash. This is true even though they offer the best prospect of safeguarding future value, as they will define the economy of tomorrow.

Market expectations and expectations in general are belatedly catching up with the technological and behavioural revolution. Governments and businesses alike are seeking to invest in future-proofed assets that offer the greatest risk-adjusted returns in the carbonconstrained markets of the future.

For policymakers, this means public investment, policy frameworks and institutions designed to guide investors into clean sectors. There will be a need to ensure fiscal and monetary policy work together to guide liquidity and savings towards the growth of productive sectors.[50] It will also require a new breed of investor, with the confidence to influence every step of the transition to a thriving low carbon and resource efficient economy. It is leaders in finance and business, working with government who will fund, design and build this cleaner, more resilient and productive future. They stand to profit greatly by moving beyond the old model of growth that has proved insufficiently productive, environmentally unsustainable and socially divisive.

In the short run, the prospect of interest rates rising from historic lows means the net present value of discounted future cash flows from new intangible-rich sectors such as tech and green will shrink, undermining their valuations relative to traditional value stock. In the medium term, the global clean revolution is unlikely to unfold without speculative bubbles. But if you take the view that change is happening, there is a huge long-term buy opportunity from investing in sustainable sectors still seen as exotic, while shunning high carbon sectors whose assets may be left devalued or stranded. While the rest of the pack catch up on their understanding, there is money to be made in greening the economy.

[49] See http://www.carlotaperez.org/downloads/reviews/Mennis_review_newv2.pdf
[50] See Stern and Zenghelis (2021) https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/03/Fiscalresponsibility-in-advanced-economies-through-investment-for-economic-recovery-from-the-COVID-19-pandemic-1.pdf

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