

# STRESSFUL TESTS

**Banks need to recognise that climate risks are bigger and more pressing than the central banks' stress test scenarios suggest , says Mark Cliffe**

*By Mark Cliffe*

Central banks, supervisors and regulators are turning up the heat on banks and insurers to confront the risks arising from climate change. Many, mostly in Europe and Asia, are conducting 'stress tests' over the coming months. These stress tests are meant to show the impact on the financial institutions' capital adequacy stemming from different pathways for global warming and climate policy responses. While regulators note that the tests are exploratory<sup>1</sup>, the signs are that they will not be stressful or shocking enough to make much difference the financial institutions' behaviour.

Early pilot studies largely echo the European Central Bank, which, looking out to 2050, misleadingly suggests that a 'hot house' scenario would be barely more damaging to the economy or financial system than scenarios involving policies that that deliver on 'Net Zero' pledges to cut green house gas emissions. The ECB's recently released [pilot stress test](#)<sup>2</sup> estimated that the 'hot house' scenario of 3 C of global warming would result in a fall in GDP output of less than 5% (0.2% p.a.) relative to current trends, compared with just under 2% (0.1% p.a.) if 'Net Zero' is implemented in an orderly fashion . Meanwhile, the 'hot house' would result in a barely noticeable increase in the probability of default (PD) on corporate loans to 2.3% compared with 2.1% under Net Zero.

The modesty of official projections of the financial risks from climate change look especially odd in the light of recent events. The violent disruption from the Covid 19 pandemic, the volatility in the global economy and markets – not least in energy – have coincided with unprecedentedly damaging weather events

and climate scientists on the [UN's Intergovernmental Panel on Climate Change \(IPCC\)](#)<sup>3</sup> declaring a "code red for humanity". Consider that last year alone global GDP fell 3.5%, more than 6% below trend, in other words more than the cumulative damage that the ECB suggested would occur over the next three decades in its hot house scenario. Exceptional though the past year has been, it will surely prompt Bank boards to take a sanguine view of the ECB's estimates.

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What makes this doubly curious is that the central banks are making the right noises on the need for swift climate action. "[Urgent action is not an option; it is an imperative](#)", according to Frank Elderson of De Nederlandsche Bank (DNB), who chairs the Network of Central Banks and Supervisors for Greening the Financial System (NGFS)<sup>4</sup>. Yet while they partly acknowledge some of the limitations of their pilot projects, the urgent tone of

their rhetoric is not reflected in their scenarios. Their scenarios have so far been based on assumptions and models which ignore or downplay crucial elements of climate risk, notably the rising frequency of extreme weather events, and critical triggers, tipping points and interdependencies between the climate, the economy, politics, finance and technology.

As a result, they underplay the potential downside risks that might plausibly challenge the health not just of vulnerable financial institutions, but the system as whole, and potentially on a horizon far shorter than 30 years ahead. In other words, they fail to provide the stress that would prompt urgent action. This point is reinforced by the fact that they also downplay the opportunities, or the upside risks, that stem from the transition to Net Zero by continuing to underestimate the pace of technological change.

## An urgent rethink is required

The NGFS is committed to developing and sharing best practice on climate risk management<sup>5</sup>. The Bank of England, like the ECB, is building on NGFS-developed scenarios for its [stress tests of banks and insurers](#) next year<sup>6</sup>. They have made commendable progress on translating the macro scenarios into financial risk, for example by employing large data sets to model credit risk down to the firm or location level<sup>7</sup>. But the indications are that fundamental limitations of their approach are not about to be addressed.

The Bank for International Settlements (BIS), aka ‘the bank for central banks’, highlighted the challenges last year in a report entitled ‘[The Green Swan](#)’<sup>8</sup>. It has called for an ‘epistemological rupture’, essentially a complete rethink, in the approach to climate risks, which involve “*interacting, nonlinear and fundamentally unpredictable environmental, social, economic and geopolitical dynamics*”. As yet, there is little sign of progress on this.

So how can central banks change their approach to stress test scenarios to inject more urgency into the responses of

financial institutions? It is essential that they highlight that there are a much broader range of outcomes than they have so far suggested, and acknowledge that the risks are heavily skewed to the downside. There are four important ingredients that should drive this urgent rethink.

### **1. Focus on shorter time horizons. Action is needed now to head off long term existential threats.**

So far central banks and the financial services industry have tended to view climate risk as predominantly a long term problem. Climate scientists warn that the damaging effects of global warming will continue to build up over the coming decades even if we succeed in reaching ‘Net Zero’. This reflects the fact that the climate responds with a lag not to the rate of green house gas emissions, but the stock of past emissions. Moreover, if we fail to achieve Net Zero, large parts of the planet would become unliveable later in the century. This dire threat underlies policy makers’ desire to encourage financial institutions and other businesses to confront these long term risks.

The central banks’ climate risk scenarios stretching out to 2050 and beyond have certainly driven home the wholesale transformation needed to decarbonise the economy. Using ‘integrated assessment models’ (IAMs), they have modelled how rising prices on carbon emissions (and greenhouse gases in general) could eliminate fossil fuels from the energy mix, but perhaps for a small proportion offset by carbon removal processes. The rush by financial institutions to sign up to commit to 2050 Net Zero targets shows how they have taken this message on board<sup>9</sup>.

However, the central banks’ long term scenarios shed little light on how to operationalise these Net Zero commitments. This will require shorter term scenarios that set out the potential paths over the next few years<sup>10</sup>. This will enable financial institutions to embed climate change into their business plans, which rarely stretch beyond five years. The need for this is pressing, because



it is generally recognised that the world needs to mobilise now if Net Zero is to be achieved; indeed, the developed world is aiming to be around half way there by the end of the decade.

Indeed, switching from a 30 year horizon to 2025 or 2030 will necessitate changes to their scenario designs that force them to confront the other three ingredients of the necessary rethink. A crucial, and ironic, aspect of this is that on a sub-10 year horizon the main driver of climate risk scenarios is not the climate itself, since global warming and increased extreme weather events are already largely ‘baked in’. Rather attention is thrown onto the

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transition risks surrounding what action we collectively take, which shifts the spotlight on politics and policy, technology and markets, and finance and behaviour. In the process, this shift would confirm that climate risks are both bigger and more pressing than the central banks’ modelling indicates.

## **2. Stop ignoring or downplaying crucial risks.**

The central banks make no secret of the limitations of the modelling behind their long term climate scenarios. Extreme weather events, political disruptions, financial markets, behavioural and technological change are all aspects that are difficult to capture. Given the complexity of the problems and the absence of much of the required data it is understandable that they should try to simplify the exercise by steering away from them. But the old aphorism “*All models are wrong, but some are useful*” begs the question of whether the simplifications that the central bank modellers are making are leading us astray.

It is hard not to conclude that by assuming away, ignoring or downplaying crucial risks they are substantially understating the range of possible outcomes. At the core of the [scenarios produced by the NGFS<sup>11</sup>](#), and adapted by member central banks, are a range of integrated assessment models (IAMs) which produce pathways for emissions, global temperature and energy mix pathways. On some variables, the IAMs produce very different results, so the first simplification is average these out.

The IAMs examine physical risks through the lens of rising global temperatures, which are assumed to damage productivity. Other chronic, or sustained, physical risks such as rising sea levels and acute risks, comprising extreme weather events such as storms and floods, are not directly modelled. This is a serious drawback since, as the Intergovernmental Panel on Climate Change (IPCC) recently underlined, such events will become

more frequent, intense, persistent and more widespread, even if uncertainty over their precise timing and location will remain.<sup>12</sup> Aside from the direct costs of such events, the rising costs of adaptation investments, and the subsequent potential benefits, are ignored. So too is the collateral damage wrought on other aspects of the natural environment, such as the loss of biodiversity, natural resources, water or air quality.

The shortcomings are particularly serious for ‘business as usual’ scenarios where policy fails to curb emissions and global warming rises beyond 3 degrees. These scenarios would lead to dramatically higher increases in both chronic and acute physical risks, as well as the associated adaptation costs.

Physical risks aside, other important risk drivers are missing from the NGFS scenarios. It noted in June that “there are other uncertainties that are not captured due to modelling simplifications such as behavioural change, policy heterogeneity and market allocation of capital”. Yet such factors could have a profound impact on the outlook.

The fact that finance is absent from the IAMs is particularly troubling, given the massive shifts in capital flows that are required. This could create frictions that the models ignore.

Central bank climate scenarios make the simplifying assumption that climate policy is reflected solely by prices on carbon emissions. Carbon pricing is used as a proxy for regulations and other non-price-based policies. This makes it easier to model the energy transition, but overlooks the enormous political frictions, domestically and internationally, that would arise from sharp carbon price increases.

Central banks, who are ultimately answerable to their governments, are understandably wary about making explicit assumptions about dramatic political or policy changes. But the awkward truth that the Net Zero challenge is intrinsically political. Since climate change stems from market failure to price carbon emissions adequately, the path towards Net Zero will depend heavily on when, where and how governments

*Tipping points mean that existential threats could be closer than linear modelling suggests*

step in to change market behaviour and stimulate the required innovation and investment.

The capping and then winding down of fossil fuel-based activities will create many losers as asset values fall and jobs are lost. Redistributing some of the benefits of the greening of the economy to compensate them will require deft political handling, which has so far been lacking. Meanwhile, the uneven distribution of both physical climate damages and fossil fuel production threatens geo-political conflict which in extremis could trigger wars and mass migrations. None of this features in the scenarios published by the central banks.

## **3. Recognise the importance of non-linear dynamics in accelerating change, for good or ill.**

It is problematic enough that the central banks stress test scenarios exclude or downplay some crucial risk factors. What is worse is

that they fail to capture the degree to which climate change, and the action to counter it, will be messy and disruptive.

The models that the central banks employ portray worlds in which change is generally smooth, linear and orderly. True, the NGFS has a ‘disorderly’ scenario, but this incorporates represents merely a one off delay of policy action to 2030, after which their models revert to smoothly transitioning towards ‘Net Zero’. Yet the reality is that climate change, and its human causes and responses do not progress smoothly, but with non-linear changes that are often dramatic and unexpected.

In the midst of unprecedented change, historic data is of limited use, and models will be prone to make errors that grow exponentially worse the further out you look. The concept of ‘VUCA’, the acronym for volatile, uncertain, complex and ambiguous, is particularly apt for climate change, and it makes quantifying scenarios hazardous. It also points to a far wider range of outcomes than the central banks have so far suggested. As a report from the Grantham Research Institute put it “*A stress test that does not include the low probability, high impact consequences of climate change is not strictly a stress test*”<sup>13</sup>

This is all the more reason for central banks to switch their focus to climate-related financial risks that may arise on the shorter, sub 5 year, horizons used in traditional stress tests. Beyond that, scenarios become progressively less useful. Attempts to produce detailed quantification down from a country and sector level to a local and business level on a multi-decade basis are liable to descend into a “number theatre” of colossal databases of useless data. In the spirit of Carveth Read, who said “*it is better to be roughly right than precisely wrong*”, numbers attached to long term scenarios should be seen as illustrating their narratives rather than the basis for financial planning, still less financial regulations.

Over the next few years, as described earlier, uncertainty around financial risks will stem more from the transitional

risks around human action than from the climate itself. That said, scientists are increasingly concerned that rising physical risks are bringing the climate and environment closer to critical thresholds, or tipping points, which lead to sudden accelerating change and potentially irreversible damage. A notable example of this is the sudden melting of polar ice caps, which threaten higher sea levels, accelerated coastal erosion, flooding and storm surges. Such tipping points mean that existential threats could be closer than linear modelling suggests.<sup>14</sup>

The linear models at the heart of the central banks’ scenario methodology also fail to capture crucial non-linearities around changes in prices, politics, technology and behaviour. The responses to the Covid-19 pandemic are a vivid illustration of the failure of forecasters to capture the potential for disruptive volatility and shocks that can crystallise long term risks into immediate damage and catalyse lasting changes in behaviour. Consider how the plunge in oil prices prompted BP and other major oil companies to write off billions from the value of their reserves and announce more ambitious targets for their renewable energy investments. It is not just the physical world that is subject to tipping points.

Central banks are certainly conscious of the volatility of energy and asset markets. Yet the IAMs that they have at the centre of their scenario modelling ignore the fact that in these markets price volatility is a feature, not a bug. The recent surge in natural gas prices, which has seen wholesale prices in Europe and Asia jump five-fold over the past year, may affect market behaviour, public policy and investment for years to come. In other words, peaks and troughs in prices can accelerate changes. Sadly, this is not yet factored into central bank modelling:

*“The future pathways of commodity prices are highly uncertain [...] mitigation scenarios [do] not capture the full range of outcomes. Pathways do not*



*account for the possibility of 'sell-off' behaviour from producers, or other volatility between 5-year time steps." NGFS June 2021.*

Politics, and with it policy, has its own distinctive non-linearities. For long periods, governments may resist change fearing a popular backlash from those who stand to lose out from it. Then periodically, sudden shifts emerge as pent-up pressures for change burst through following changes of government or shocks such as recessions, natural disasters or international conflicts.

The swings in climate policy in the US make this point very clearly. President Biden has dramatically reversed US climate policy away from the denialism of President Trump, to an approach even more activist than that of President Obama. For building scenarios, the good news here is that at least there is a predetermined electoral cycle - the 2024 election already

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looms large. Moreover, the outcomes are – usually - binary. But the bad news is that while we have some sense of timing around alternative scenarios, the scale of the policy shifts that they could trigger is a much tougher call: would a future Trumpian President withdraw from the Paris Climate Accord again?

#### 4. Adopt a systemic approach

The fourth ingredient of the needed rethink on climate risk is to address the complex interactions between the drivers and impacts of climate change. Earth systems and the economic, financial, political and social systems are interdependent in a way that can lead to complex feedbacks. This provides another reason why linear modelling may fail to capture the pace and scale of change. Complex systems have emergent properties, or unexpected behaviours, which are hard to predict from the individual parts of the system. As Professor [Tim Jackson](#) puts it:

*"Three features of the [Net Zero] transition—rapid structural change, massive investment shifts and 'post-normal' behaviours—mean that conventional equilibrium or partial equilibrium models aren't much help to us. They assume too much homogeneity in behaviour. They have little or nothing to represent the complex structure of financial balance sheets through which transition risks may be propagated. And they are likely to miss the dynamic feedbacks that occur between the real and the financial economy"<sup>15</sup>*

Adopting a systemic perspective to climate risk is challenging, particularly as it must factor in positive feedback loops and tipping

points that may compound the errors on long term projections. This is where the scenario approach can help. It starts not with detailed quantification and modelling, but by focusing on the factors that are most uncertain and impactful. It then aims to develop structured, plausible and revealing narratives based on how these factors might relate to one another.

Unfortunately, the central banks have made limited progress in developing a more systemic approach to their climate scenarios. The most obvious problem is that their scenarios focus squarely on the consequences of climate change while ignoring its causes. Climate change is not happening in isolation: different paths for economic growth, policy, technology, and consumer behaviour would result in different paths for emissions and the climate, which would then feedback into different paths for climate risks.

To take an example, varying the baseline of global GDP growth by merely +/-0.2% p.a. would result in a cumulative change of over +/-5% by 2050. This would itself double the range of variation seen in the ECB's pilot scenarios. Aside from flowing through into energy demand and carbon emissions, this would open up different pathways for policy, investment and market prices. This is before we even begin to build in the likelihood of upswings and recessions into the narratives. Indeed, such cyclical shocks, which are at the heart of traditional solvency stress tests, arguably should be a critical component of climate-related stress tests as well.

Meanwhile, physical and transition risks are still largely treated separately in the central banks' exercises. Yet it is clear that increased extreme weather events are already increasing the social and political pressure for action. Having experienced the damage from climate change first hand, people are more inclined to support remedial policy action and change their behaviour. Conceding that the central banks are not capturing such tipping points, the NGFS notes that "*Studies that have assessed the potential impacts from tipping points on policy responses find that emissions prices should be up to eight times higher*"<sup>16</sup>.

It is easy to see how the uneven damage from climate change could generate conflict. As [Gernot Wagner](#) puts it, "*For good reason, the green transition is viewed as a matter not just of energy but of geopolitics. We are undergoing a historic shift from petrostates to 'electrostates'*"<sup>17</sup>. This could heighten risks from policy clashes, leading to protectionism, weaker growth, higher inflation, higher interest rates, and reduced investment and innovation.

Again, the central banks' scenarios have not accounted for such possibilities. They look solely at the macro-economic and financial damage from physical climate change and the impact of transition.

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On top of this, it is possible to envisage strong feedback loops between politics, policy incentives, technological progress, financial flows and consumer adoption. On the negative side, a rush for the exit could lead to a sudden stranding of fossil fuel assets as prices crash, creating an economic and political crisis. On the positive side, climate policies including carbon pricing, regulation and public investment could catalyse private investment and innovation, rapidly driving down costs and prices, stimulating consumer demand while improving financial returns.

A more realistic perspective, recognising the emergent properties of complex systems, would point to a far wider range of outcomes. This is because of the path dependency of outcomes, whereby 'one thing leads to another', such as how a change of government leads to a new policy direction. So instead of a linear interpolation of a long term forecast, this calls for an iterative 'decision tree' progression of short term scenarios, allowing for shocks to create new paths. Since this rapidly multiplies the possibilities, producing longer term scenarios requires models that can handle more complex computations or more simplified qualitative analysis.

## Conclusion

There is no doubt that the central banks, supervisors and regulators recognise the urgency of climate change. This is why they are conducting stress tests on the financial risks that it poses to the banks and other financial institutions. Sadly, the signs are that the scenarios that they are providing for this purpose will not be stressful or shocking enough to make much difference the financial institutions' behaviour. Perhaps inadvertently, they risk fostering complacency.

Despite their justified humility about their current modelling, the central banks' scenarios suggest that climate risk will make little difference to growth or financial losses even on a 30 year horizon. In the ECB's case, the cumulative total difference in GDP between their business-as-usual 'hot house' scenario and an orderly policy 'Net Zero' scenario is barely 3%. This is despite escalating physical risks and the dramatic transformation in the economy that decarbonisation will entail. This modest range of variation is against the basic essence of the scenario method, which is to explore a wide enough range of possibilities to provide strategic insights.

If the central banks wish to inject the needed urgency into the financial institutions' embrace of climate risk the next phases of their stress testing exercises will have to rise to the challenge set by the BIS for an 'epistemological rupture'. There are four ingredients that could feed into the rethink required.

First, given the urgency, the scenarios should be on shorter time horizons of five years or less, in line with traditional solvency stress tests and the planning horizons of the financial institutions. The financial sector is already well on the way to be fully signed up to being 'Net Zero' by 2050, so the challenge is to operationalise this now and to recognise that the financial risks and opportunities are far larger and more immediate than the central bank scenarios suggest. The ECB's latest announcement that next year's stress test will incorporate policy and weather shocks in 2022 is therefore a welcome step forward.

Second, the scenarios need to incorporate crucial risks which they have so far assumed away or downplayed. Extreme

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weather events, political disruptions, policy shifts, financial markets, behavioural and technological change are all aspects that are difficult to calibrate and model. But failing to account for them severely reduces the realism and usefulness of the scenarios for stress testing purposes. By limiting the time horizon to no more than five years, it should be possible to capture more of these factors in scenarios which reveal a broader and more meaningful range of outcomes.

Third, the scenarios need to acknowledge that fact the risks are non-linear, making the likelihood of extreme outcomes far more likely. The central banks' models yield smooth orderly changes and fail to capture the risk that the climate may breach thresholds beyond which damages may accelerate and become irreversible or existential. Although tipping points are perhaps not so likely for the physical climate if we step back from a thirty to a five year horizon, they are still eminently possible for transitional climate risks. Socio-political disruptions, policy shifts and market spikes and crashes could all feature in more illuminating short term scenarios.

Fourth, the scenarios need to acknowledge the complexity of the interactions between the drivers and impacts of climate change. Earth systems and the economic, financial, political and social systems are interdependent in a way that can lead to complex feedbacks. These could either delay or accelerate change in a way that the central banks' conventional linear models do not capture. This adds layers of uncertainty which argues for embracing the precautionary principle by making assumptions that result in a broader range of outcomes.

But the scenario method provides room to develop plausible narratives around these interactions. The pandemic has provided a timely lesson in how nature can trigger rapid changes in human behaviour, whether it be politics and policy, markets and innovation, or social norms and consumer behaviour. In the case of climate change, official forecasts continue to underplay the fact that the costs of renewables are falling, partly through policy support, in a way that is triggering tipping points in business and consumer demand.

On the flipside, the central banks also understate how policy inertia or missteps could crystallise longer term financial risks from stranded fossil fuel assets and labour well before 2030, let alone 2050. It is time to inject some real stress into their climate stress tests.

## Notes

1. A key feature is that the stress tests are based on forward-looking scenarios using a suite of forecasting models rather than traditional backward-looking probabilistic risk models.
2. ‘Economy-wide climate stress test Methodology and results’, ECB, September 2021 <https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op281~05a7735b1c.en.pdf>
3. UN Intergovernmental Panel on Climate Change (IPCC) AR6 Climate Change 2021: The Physical Science Basis <https://www.ipcc.ch/report/ar6/wg1/>
4. All the way to zero: guiding banks towards a carbon-neutral Europe’ Keynote speech by Frank Elderson, April 2021 <https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210429~3f8606edca.en.html> . In his latest speech he followed up with a call for legally-binding transition plans, including verifiable milestones: ‘Overcoming the tragedy of the horizon: requiring banks to translate 2050 targets into milestones’, October 2021 <https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp211020~03fba70983.en.html>
5. For its latest survey of progress see ‘Scenarios in Action A progress report on global supervisory and central bank climate scenario exercises’ NGFS, October 2021. <https://www.ngfs.net/en/scenarios-action-progress-report-global-supervisory-and-central-bank-climate-scenario-exercises>
6. ‘Key elements of the 2021 Biennial Exploratory Scenario: Financial risks from climate change’ Bank of England, June 2021
7. <https://www.bankofengland.co.uk/stress-testing/2021/key-elements-2021-biennial-exploratory-scenario-financial-risks-climate-change>
8. The ECB’s notes that its “economy-wide stress test has made significant advancements [...] largely thanks to the creation of an unprecedented database that combines climate and financial information for millions of firms worldwide”. ECB Sep 2021 *ibid.*
9. ‘The Green Swan’, Bank for International Settlements (BIS), January 2020 <https://www.bis.org/publ/othp31.pdf>
10. See, for example, the recently created Glasgow Financial Alliance for Net Zero: <https://www.gfanzero.com/>
11. An interesting early exception to the central banks’ preference for long term scenarios is the De Nederlandsche Bank, which produced a set of 5 year scenarios in 2018: ‘An energy transition risk stress test for the financial system of the Netherlands’ [https://www.dnb.nl/media/pdnpdalc/201810\\_nr\\_7\\_-2018-\\_an\\_energy\\_transition\\_risk\\_stress\\_test\\_for\\_the\\_financial\\_system\\_of\\_the\\_netherlands.pdf](https://www.dnb.nl/media/pdnpdalc/201810_nr_7_-2018-_an_energy_transition_risk_stress_test_for_the_financial_system_of_the_netherlands.pdf)
12. ‘Climate Scenarios for central banks and supervisors’, NGFS, June 2021 [https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs\\_climate\\_scenarios\\_phase2\\_june2021.pdf](https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf)
13. As US Federal Reserve Governor Lael Brainard hinted at more severe damage recently when she noted, “These cumulative and chronic changes could have economic effects that differ substantively from the historic experience, for example, if they contribute to shifts in the location of economic activity or the sectoral composition within a region.” <https://www.federalreserve.gov/newsevents/speech/brainard20211007a.htm>
14. ‘The new climate scenarios for central banks and supervisors’ Grantham Research Institute on climate change and the environment, June 2020
15. <https://www.lse.ac.uk/granthaminstitute/news/the-new-climate-scenarios-for-central-banks-and-supervisors/> 4/6
16. The NGFS scenario portal notes that “Tipping points and impacts from extreme weather events are not accounted for”. <https://www.ngfs.net/ngfs-scenarios-portal/>
17. ‘Modelling Transition Risk’, Professor Tim Jackson February 2021 <https://cusp.ac.uk/themes/aetw/blog-tj-modelling-transition-risk/>
18. my emphasis] BIS July, *ibid*
19. ‘The Climate Tipping Point We Want’ Gernot Wagner, Project Syndicate, May 2021 <https://www.project-syndicate.org/commentary/climate-action-increasingly-cheaper-than-inaction-by-gernot-wagner-2021-05>