

POTENTIAL USE OF PLANETARY BOUNDARY THINKING IN THE UK

A Schumacher Institute Challenge Paper – December 2017

Fred Barker, Senior Research Fellow

Introduction

- 1 The planetary boundary (PB) concept is based on a set of nine boundaries for critical processes that regulate the functioning of the earth's ecosystems at a global level¹. The concept posits that crossing these boundaries takes us into 'zones of uncertainty', with potential risks of reaching thresholds or tipping points that could generate abrupt or irreversible changes on a large scale, or of substantially eroding the resilience of the earth's eco-systems. Although the importance of operating within PBs is increasingly recognised in policy circles², the EU³, national governments⁴, and businesses⁵, the concept has not yet been systematically applied in the UK by Government or other public bodies. Given the Government's commitment to produce a 25 Year Environment Plan, and a Resources and Waste Strategy, it seems timely to consider how PB thinking might be used to inform UK policy development and decision-making. This paper is intended to prompt discussion about meeting that challenge.

- 2 The structure of the note is as follows:
 - Firstly, it provides explanation of the concept, associated research and how it is being, or could be, applied.
 - Secondly, it provides a summary of key relevant policy developments in the UK and of associated research.
 - Thirdly, it provides a preliminary discussion about what PB thinking might add.
 - Finally, it suggests some initial conclusions.

¹ Rockström J, et al, 'A Safe Operating Space for Humanity', *Nature* 461, pp.472-475, 2009.

² See in particular the discussion on the need to operate within planetary boundaries in the interim report of the Commission on Economic Justice, 'Time for Change: A New Vision for the British Economy', IPPR September 2017, p68-71, <https://www.ippr.org/cej>. The planetary boundaries concept also informed the UN's new global development framework: 'Transforming our World: the 2030 Agenda for Sustainable Development', which sets out 17 Sustainable Development Goals and 169 targets. All nine of the boundary processes are addressed in some way, either as the focus of a goal or included in specific targets. See <https://sustainabledevelopment.un.org/post2015/transformingourworld>.

³ The planetary boundaries concept has informed the 7th Environment Action Programme ("Living well, within the limits of our planet"), which sets priorities for EU environmental policy to 2020. <http://ec.europa.eu/environment/action-programme/>.

⁴ The concept now forms an integral part of the Integrated Environmental Programme 2030 of Germany's Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. Respecting the boundaries is framed as the central challenge for German environmental politics. See Keppna B et al, 'Making the Planetary Boundaries Concept Work', International Conference, Co-hosted by the German Federal Ministry for the Environment, April 2017. https://pb-conference2017.de/sites/pb-conference2017.de/files/documents/conference_input_paper_pbconf2017_web.pdf.

⁵ See, for example, Unilever's approach to using the planetary boundary concept in Sim S et al, 'The Role of Science in Shaping Sustainable Business: Unilever Case Study', in Clift R et al 'Taking Stock of Industrial Ecology', 2016.

Development and Use of the Planetary Boundary Concept

Introduction to the Concept

- 3 The concept of PBs was introduced in 2009 by Johan Rockström and colleagues⁶, with an important update in 2015 (the ‘Steffen update’)⁷. The nine boundaries relate to climate change, ocean acidification, ozone depletion, novel entities (e.g. chemical pollution), aerosol loading, biosphere integrity (focusing on biodiversity loss), biogeochemical flows (focusing on nitrogen and phosphorus cycles), freshwater use and land-system change. If we stay within the boundaries (the ‘safe zone’), the concept suggests a very low probability of crossing a critical threshold or substantially eroding the resilience of the earth’s eco-systems. The concept applies the precautionary principle so that the PB is set at the “safe” end of the zone of uncertainty. The buffer between a boundary and a potential threshold or tipping point allows for knowledge gaps and uncertainties and in principle gives society time to respond to early warning signals.

The 2015 Update

- 4 After amending the quantification of most of the PBs in the light of recent research, the Steffen update concluded that we have crossed four of the boundaries into ‘zones of uncertainty’ (climate change, biosphere integrity, biogeochemical flows and land-system change), and that for two of these (biosphere integrity and biogeochemical flows) we have moved beyond the ‘zones of uncertainty’ into ‘high risk zones’. The update also made the following key points:
- Climate change and biosphere integrity should be considered ‘core’ boundaries, each of which has the potential on its own to drive the Earth system into a new state should they be substantially and persistently transgressed. These core boundaries are connected to, and regulated by, the other boundaries. The crossing of one or more of the other boundaries may seriously affect human well-being and may predispose the transgression of a core boundary, but does not by itself lead to a new state of the Earth system.
 - The boundaries operate interdependently, which has profound implications for global sustainability because it requires multiple interacting environmental processes to be addressed simultaneously (eg stabilizing the climate system requires sustainable forest management and stable ocean ecosystems).
 - For four boundaries – climate change, ocean acidification, atmospheric ozone depletion, and systemic chemical pollution - the absolute magnitude of anthropogenic emissions is what determines the overall impact, and it does not substantially matter where on Earth the emissions are generated. For the other five boundaries - biosphere integrity, biogeochemical flows, land-system change, freshwater use, and atmospheric aerosol loading – there are strong regional operating scales, dependent on conditions. Regional level boundaries (as well as globally aggregated boundaries) are identified for the first four of these boundaries.
 - Although the PB framework is not designed to be “downscaled” or “disaggregated” to national or local levels, PB thinking could be applied at those levels. The concept is meant to complement, not replace or supersede, efforts to address local or national ecosystem issues.

⁶ Rockström J, et al, ‘A Safe Operating Space for Humanity’, Nature 461, pp.472-475, 2009.

⁷ Steffen W, et al, ‘Planetary Boundaries: Guiding Human Development on a Changing Planet’, Science, 13 February 2015: Vol. 347 no. 6223.

A 2017 Overview

- 5 The key input paper to a 2017 international conference on ‘Making the Planetary Boundaries Concept Work’⁸ provides a high-level overview of the ‘state of the art’ with respect to PB research. This includes:
- The impact of the four PB transgressions is not yet fully understood⁹. For climate change, the impact has been researched in detail, whereas for other PBs (eg land system change) the impact is understood but has not been fully quantified, and for other processes (eg biosphere integrity) the system response is not well known¹⁰.
 - Some of the impacts of planetary boundaries transgression are irreversible (eg loss of biosphere integrity), and others appear to be at least partly reversible (eg biogeochemical flows and land system change). Irreversibility means that these boundaries should be particularly high priority.
 - For some of the boundaries, control variables have not yet been defined or fully quantified (novel entities; atmospheric aerosol loading; functional diversity as an indicator for biosphere integrity), but there are ongoing efforts to further define and quantify them.
 - Taken together, the interacting processes that underlie the planetary boundaries regulate the physical functioning of the Earth system. The processes interact in complex ways, presenting challenges for their quantitative analysis and constraining the capacity for scientific prediction of change.

National Operationalisation

- 6 Based on a review of existing studies that seek to translate the PB framework to specific national or regional contexts, a 2016 paper by Tina Häyhä and colleagues discusses a framework for operationalising the PB concept at the national level¹¹. The paper observed that there had been little consistency in approaches so far, and proposed that:

⁸ Keppna B et al, ‘Making the Planetary Boundaries Concept Work’, International Conference, Co-hosted by the German Federal Ministry for the Environment, April 2017. https://pb-conference2017.de/sites/pb-conference2017.de/files/documents/conference_input_paper_pbconf2017_web.pdf

⁹ Van Vuuren D et al, ‘Horses for courses - analytical tools to explore planetary boundaries’, *Earth System Dynamics* 7:1, 2016, p 267–279. This paper provide a systematic categorization of key PB research questions and identifies the strength and weaknesses of different research areas, focusing specifically on different types of models. The paper argues that more interdisciplinary research is need.

¹⁰ As Van Vuuren et al point out, there has been debate about whether all PB issues are associated with abrupt planetary tipping points. They suggest that some processes (eg biodiversity loss) are primarily associated with incremental change at a local level, with a possibly weak causal connection to large-scale change. See, in particular, the exchange between Brook BW et al, ‘Does the terrestrial biosphere have planetary tipping points?’, and Hughes TP et al, ‘Multiscale Regime Shifts and Planetary Boundaries’, *Trends in Ecology & Evolution*, July 2013, Vol. 28, No. 7. Hughes et al point out that although the Planetary Boundaries framework has never claimed to postulate a planetary-level biosphere tipping point, there is scientific evidence suggesting that there may, after all, be such a tipping point.

¹¹ Häyhä T, et al, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, 2016, p 60–72. The paper reviews studies for Sweden, South Africa, Switzerland, two regions of China, Finland and the European Union. Table 4 in the paper provides a useful overview of the strengths and limitations of each study.

- Three dimensions for bridging across scales – the biophysical, socio-economic and ethical – should be considered¹². For each dimension, the paper reviewed available analytical tools, and then addressed a range of integrative techniques.
- On the biophysical scale, different bridging methods will be needed according to the dominant geographic scale of the boundary system in question. For the four PBs where the absolute magnitude of emissions is what determines the overall impact, national allocation of the planetary ‘safe operating space’ can be done in a ‘top down’ way (as a starting point, on the biophysical scale, by sharing the global ‘budget’ on a per capita basis). For the other five PBs, where local conditions play a crucial role in determining the level of sustainable use or tolerable emission, a more integrated approach is needed which takes account of (a) local vulnerabilities, critical loads and potential ecological ‘hotspots’, and (b) the regional level boundaries identified by Steffen et al that relate to the way sub-global dynamics affect the functioning of the Earth system as a whole¹³.

7 The 2016 Häyhä paper also observed that the connection on the biophysical scale between top-down and bottom-up approaches is still scientifically tentative, thereby presenting a major challenge for national operationalisation of the PBs associated with geographically heterogeneous processes. The paper argued that developing understanding of this connection should be an international research priority. It also pointed out that these PBs have only recently been seen as global problems as a result of scientific insights about earth system dynamics and global socio-economic connectivity. As such, these PBs may not show up as nationally important issues if only territorial approaches are applied, and it might take a more in-depth life cycle or consumption-based analysis to show where there is a substantial national responsibility.

A Preliminary UK Study

8 In 2015 Oxfam published a preliminary study to begin the process of identifying which PBs might be useful for incorporation into a national UK analysis¹⁴. This study also addressed areas of life that might constitute a social floor below which no one in the UK should fall¹⁵. Although provisional in nature, the picture painted by the Oxfam research is stark: inequalities in the

¹² The biophysical dimension deals with the geographical scales of the planetary boundaries processes and their interactions. The socio-economic dimension addresses the sub-global links created by production and consumption patterns and through international trade. The ethical dimension addresses equity in sharing the global safe operating space and recognizing the differences between countries’ rights, abilities, and responsibilities. For the socio-economic dimension see also, for example, WWF, ‘Risky Business: Understanding the UK’s Overseas Footprint for Deforestation Risk Commodities’, October 2017.

¹³ Steffen W, et al, ‘Planetary Boundaries: Guiding Human Development on a Changing Planet’, *Science*, 13 February 2015: Vol. 347 no. 6223. More recently, it has been argued that only climate change is truly planetary in scale, and that the other boundaries need to be quantified at a range of geographic scales—local, regional and planetary—defined by natural phenomena rather than political boundaries. See Clift R et al, ‘The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains’, *Sustainability*, 9, 279, 2017, p15.

¹⁴ Sayers M and Trebeck K, ‘The UK Doughnut: A Framework for Environmental Sustainability and Social Justice’, Oxfam Research Report, February 2015, <http://policy-practice.oxfam.org.uk/publications/the-uk-doughnut-a-framework-for-environmental-sustainability-and-social-justice-344550>.

¹⁵ The combination of environmental ceiling (outer ring) and social floor (inner ring) has become known as the Oxfam Doughnut model. The area between the outer and inner rings represents a safe and just space within which to exist. The model was introduced by Kate Raworth in 2012, see ‘A Safe and Just Operating Space for Humanity’, Oxfam Discussion Paper, February 2012. Raworth has subsequently developed a “roadmap for bringing humanity into the safe and just operating space”, see ‘Doughnut Economics: Seven Ways to think like a 21st Century Economist’, Random House, 2017.

distribution of the UK's wealth are causing deprivation across many social indicators, and the UK appears to significantly overstep proposed boundaries in nearly all of the environmental domains identified¹⁶.

- 9 The Oxfam study was not included in the 2016 review of national or regional studies by Häyhä and colleagues, but it is clear that it displays several of the limitations of these other studies. In particular, it uses an exclusively top down approach for some of the spatially heterogeneous PBs (nitrogen cycle and land system change) and wholly locally based alternative measures for others (biodiversity, phosphorus cycle and chemical pollution). The bulk of the research was also undertaken before the updated quantification of PBs in the 2015 Steffen paper. As such, its initial findings on national environmental boundaries should be treated with a degree of caution. Nonetheless, the study represents a constructive starting point, and should be taken into account – alongside the framework proposed by Häyhä and colleagues - in further research to operationalise the PB concept in the UK.

Identifying Principles of PB Thinking for Use at a National Level

- 10 Pending the commissioning of this research, and subsequent identification of specific UK limits and targets linked to the PBs, a high level approach to applying PB thinking in the UK could perhaps be based on applying key PB principles. A set of key points was recently articulated in the input paper to the international conference on 'Making the Planetary Boundaries Concept Work'¹⁷. Using these as a starting point, a potentially appropriate set of principles for the purposes of this paper might be to:

- 1) Place the core PB issues of climate change and biosphere integrity centre-stage and ensure consideration of all PB issues
- 2) Strive for integration, focus on synergies and minimise trade-offs
- 3) Be truly precautionary and develop a target-oriented approach
- 4) Strive for coherence across sectors, scales, and governance levels
- 5) Adopt a transdisciplinary approach, co-developing actions with relevant stakeholder groups.

An initial application of these principles is discussed below, in the section 'What PB Thinking Might Add in the UK'.

The Nature of Specific PBs

- 11 In order to explore the application of these principles in the UK, it is first necessary to outline the nature of specific PB issues. In this paper, we focus on three of the PB issues where researchers argue we have crossed into 'zones of uncertainty', and which should align with topics addressed in the UK's forthcoming 25 Year Environment Plan. The three PB issues are biosphere integrity, land-system change and biogeochemical flows. This focus is consistent with the need to extend the scope of global change policy beyond climate change to address other global destabilising pressures. An introduction to each of the three PB issues is as follows:

¹⁶ Sayers M and Trebeck K, as above. See, in particular, Figure 15 and Table 7 for a summary of the UK's transgression of 'environmental ceilings'.

¹⁷ Keppna B et al, 'Making the Planetary Boundaries Concept Work', International Conference, Co-hosted by the German Federal Ministry for the Environment, April 2017. https://pb-conference2017.de/sites/pb-conference2017.de/files/documents/conference_input_paper_pbconf2017_web.pdf

- **Biosphere integrity:** this PB issue is primarily about **biodiversity loss** (the decline in the number and variety of living species), which damages the integrity of ecosystems, reduces resilience and undermines the capacity of eco-systems to provide food, fuel and fibre, and to sustain life¹⁸. The issue should be accorded a high priority because it is a core boundary and involves irreversible change. Interim control variables that define the PB relate to genetic and functional diversity (extinction rates and Biodiversity Intactness Index respectively)¹⁹. Operationalisation of the PB at a national level should take account of local conditions²⁰.
- **Land-system change:** this is about **converting land for human use** (such as forests and wetlands into cities, farmland and highways). This depletes the earth's carbon sinks, destroys wildlife habitats, and undermines the land's role in recycling water, nitrogen and phosphorous. Land-system change has a major impact on biosphere integrity²¹. The control variables that define the PB relate to the area of forested land as a % of original forest cover (global) and the area of forested land as a % of potential forest (biome specific). Operationalisation of the PB at a national level should take account of local conditions.
- **Biogeochemical flows:** this focuses on **nitrogen and phosphorous loading** (primarily the run off of nitrogen and phosphorous from agricultural fertilisers into rivers, estuaries, lakes and oceans). This can cause algae blooms that kill off other aquatic life and threaten aquatic eco-systems, thereby impacting directly on biosphere integrity. Human generated nitrogen flows can also impact on drinking water quality, air quality and climate change²². Some NGOs and researchers point out that this PB issue has received less attention than might be expected, given its importance to sustainable food systems²³. The control variables that define the PB relate to flow from freshwater systems into the oceans (P global), flow from fertilisers to erodible soils (P regional) and industrial/intentional biological fixation (N global). These PBs are challenging to operationalise at a national level because they involve spatially heterogeneous processes.

Policy and Evidence-Base Developments in the UK

The Clean Growth Strategy, 25 Year Environment Plan and Resources and Waste Strategy

12 In October 2017, the UK Government published its Clean Growth Strategy (CGS)²⁴. As part of a wide ranging package of measures to “keep us on track to meet our carbon budgets” and “accelerate the pace of ‘clean growth’”, the strategy proposes ways of “enhancing the value

¹⁸ See for example Cardinale B J et al, ‘Biodiversity Loss and its Impact on Humanity’, Nature, Vol 486, 7 June 2012, for a review of two decades of research about how biodiversity loss influences ecosystem functions and services.

¹⁹ Steffen W, et al, ‘Planetary Boundaries: Guiding Human Development on a Changing Planet’, Science, 13 February 2015: Vol. 347 no. 6223.

²⁰ See the discussion of the practicality of applying biosphere integrity indicators in Clift R et al, ‘The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains’, Sustainability, 9, 279, 2017.

²¹ Newbold T et al, ‘Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment’, Science, Vol 353, Issue 6296, 15 July 2016.

²² WWF, ‘Living Planet Report 2016’, p67.

²³ Erisman J W, et al, ‘Nitrogen: too much of a vital resource’, Science Brief, WWF Netherlands, 2015, and Hoppe T, et al, ‘System Merits or Failures? Policies for Transition to Sustainable P and N Systems in the Netherlands and Finland’, Sustainability 2016, 8, 463.

²⁴ HM Government. ‘The Clean Growth Strategy: Leading the Way to a Low Carbon Future’, October 2017, <https://www.gov.uk/government/publications/clean-growth-strategy>.

and benefits of our natural resources” (which it states are responsible for 15% of UK emissions). This includes:

- designing a new system of future agricultural support to focus on delivering better environmental outcomes, including addressing climate change more directly;
- establishing a new network of forests in England including new woodland on farmland, and funding larger-scale woodland and forest creation, in support of a commitment to plant 11 million trees, and increase the amount of UK timber used in construction;
- working towards an ambition for zero avoidable waste by 2050, maximising the value extracted from resources, and minimising the negative environmental and carbon impacts associated with their extraction, use and disposal;
- publishing a new Resources and Waste Strategy to make the UK a world leader in terms of competitiveness, resource productivity and resource efficiency; and
- investing £99 million in innovative technology and research for agri-tech, land use, greenhouse gas removal technologies, waste and resource efficiency.

It is the Government’s stated intention to set out further details in its forthcoming 25 Year Environment Plan.

14 The CGS describes its ambition in relation to natural resources in the following way:

We want low emission, highly productive land while ensuring we hand our environment on to the next generation in a better state than we found it. As part of this, we want the UK to become a world leader in terms of competitiveness, resource productivity and resource efficiency: maximising the value we extract from our resources, and minimising the negative environmental and carbon impacts associated with their extraction, use and disposal. We will work toward achieving zero avoidable waste by 2050.

Whilst this represents a welcome step in the right direction, the question arises of just how ambitious the ambition - to “hand our environment on to the next generation in a better state than we found it”- should be? This paper suggests that an important part of the answer is that the scale of the ambition should be commensurate with making an appropriate and equitable contribution to returning the planet to, and staying within, a safe operating space. To identify what this means in practice would require the identification of specific UK limits linked to the PBs (paras 6-11 above). In the absence of such limits, this paper makes initial comments on the approach in the UK, based on the principles of PB thinking outlined above. Before doing this, information is outlined about the way the paper’s three PB issues are addressed in UK policy and evidence base developments.

Addressing Biosphere Integrity in the UK

15 Biosphere integrity and biodiversity loss are not central concerns within the CGS’s chapter on enhancing the value and benefits of natural resources. In fact, the term ‘biosphere integrity’ does not appear, and the word ‘biodiversity’ appears just twice. The first time is in relation to the assessment of ‘natural capital’ impacts that informed the strategy:

Increasing forestry cover can have a number of benefits to natural capital including creating new habitats for animals and reducing flood risk. Likewise changes to farming practices can reduce the demands placed on natural resources and aid biodiver-

sity. However, context is very important when changing land use. For example benefits vary by species of tree planted, or the previous use of land converted to produce less emission intensive crops.²⁵

The second time the word ‘biodiversity’ appears is in relation to the CGS’s ‘bio-resource’ evidence base, as a constraint on land available for energy crops.

16 Should alarm bells be ringing about this lack of consideration of biodiversity? In principle, this should not be the case, as there is a wealth of advice, evidence and proposals that can be drawn upon to address biodiversity in the 25 Year Environment Plan, including:

- The advice of the **Natural Capital Committee (NCC)**, set up to advise the Government on how to meet its objective of ensuring “we hand our environment on to the next generation in a better state than we found it”²⁶. The Committee proposes a range of biodiversity-related goals that could be included in the Plan’s vision, including ensuring that: “wild species and habitats are thriving and populations are restored and enhanced to levels that are sustainable into the future despite the challenges from climate change and increasing pressures from built infrastructure”. It also proposes biodiversity related investments, including to: “develop and implement a national network of conservation areas to provide bigger, better and more joined up habitats, including more nature reserves”.
- The evidence base provided by the UK **National Ecosystem Assessment Follow-on (NEAFO)**, a UK Government and Research Council sponsored project which aimed to: further understanding of the economic and social value of nature; develop tools and products to operationalise the Ecosystem Approach; and support the inclusion of natural capital in the UK’s National Accounts²⁷. As such, the project report explains that the underlying aim is to manage ecosystems in a way that maintains or enhances their resilience, and the valuable flow of services they provide, rather than to maximise biodiversity conservation per se as a moral imperative. NEAFO proposed use of The Convention on Biological Diversity Ecosystem Approach to ensure a holistic, integrated way of looking at interacting economic, social and environmental consequences throughout the policy-making process, and to embed knowledge of ecosystems into decision-making²⁸. Specifically on biodiver-

²⁵ HM Government. ‘The Clean Growth Strategy: Leading the Way to a Low Carbon Future’, October 2017, p157, <https://www.gov.uk/government/publications/clean-growth-strategy>.

²⁶ Natural Capital Committee, ‘Advice to Government on the 25 Year Environment Plan’, September 2017. The Committee explains that: “A natural capital approach to the environment brings established economic and accounting methods for public and private assets together with the best natural science understanding. Properly measured and accounted for, the approach brings disparate activities and their consequences together into a single strategic perspective that addresses the complexity and long-term nature of making the most of our natural capital.” The importance of utilising natural capital and ecosystem services thinking in policy making is highlighted in Guerry A D et al, ‘Natural Capital and Ecosystem Services: from Promise to Practice’, Proceedings of the National Academy of Sciences, June 2015. For a critical perspective on the extent to which a natural capital approach can capture key dimensions of value (eg to place), see O’Neill J, ‘Life Beyond Capital’, CUSP, October 2017.

²⁷ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014. See also the ‘UK National Ecosystem Assessment Five Years On’, Ecosystems News, Issue 13, Summer 2016.

²⁸ The UK NEAFO found that the full potential of the Ecosystem Approach is rarely realised, partly due to a failure to fully use all of its 12 principles. The NEAFO report observes that there is often selective use of a subset of the 12 principles at the expense of the other principles and the benefits they can provide. For example, the emphasis on maintaining ecosystem services (Principle #5), often comes at the expense of principles on decentralising to the lowest appropriate level (Principle #2), recognising thresholds and functional limits (Principle

sity, NEAFO concludes that a key requirement is to integrate its objectives with other sectors: “In a changing world, the response options the UK NEAFO identifies as most viable in achieving this are greenspace and ecological networks, agri-environment schemes, and partnerships”²⁹.

- The research being undertaken within the UK’s **Biodiversity and Ecosystem Service Sustainability programme** (BESS), a six-year (2011-2017) NERC research programme, designed to answer fundamental questions about the functional role of biodiversity in key ecosystem processes and the delivery of ecosystem processes at the landscape scale³⁰.
- The good practice guidance on **‘Biodiversity Net Gain’**, prepared by IEMA, CIRIA and CIEEM, to help professionals and UK industry achieve ‘Net Gain’ targets for biodiversity³¹.
- The proposals put forward by the Wildfowl and Wetlands Trust (WWT) in its report, **‘Nature’s Way: the Environment for Success’**³². These include a call for clear, legally-binding objectives, three of which relate directly to biodiversity: ensuring wildlife is more diverse and abundant by 2040 (with species targets to increase the abundance of species and save the most threatened); creating a network of healthy habitats across the UK (so that by 2040 all protected sites would be in favourable condition, connected by a national network of functioning wildlife corridors); and contributing to a sustainable earth (including meeting international obligations on halting biodiversity loss by reflecting them in UK law). The report adds that the 25 Year Environment Plan “should set in motion an ambitious programme of habitat creation and restoration, from small networks of green and blue spaces in our cities, to landscape-scale restoration around our coasts and countryside.”

Addressing Land-System Change in the UK

- 17 Although the term ‘land-system change’ does not appear in the CGS, the strategy is replete with references to land use and notable for the proposals about increasing tree cover, which relate directly to the control variables outlined by Steffen and colleagues for this PB (para 11 above). The proposals include: increasing tree cover in England by 180,000 hectares from 9.8 per cent to 11 per cent (including 130,000 hectares of new woodland and plans for farmers to plant more trees across the country); during the 2020s, accelerating the rate of tree planting, working towards a 12 per cent tree cover aspiration by 2060; and designing woodland creation incentives that attract more landowners and farmers to plant on marginal land, including through agroforestry and bioenergy production, to help diversify land-based businesses and enhance the farmed environment.

#6), taking a long-term view (Principle #7), and accepting that change will happen and recognising lag effects (Principle #9).

²⁹ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014, p59.

³⁰ See <http://www.nerc-bess.net/what-is-bess/>, and associated research, including: Oliver T H et al, ‘Declining resilience of ecosystem functions under biodiversity loss’, Nature Communications, December 2015, and ‘Are existing biodiversity conservation strategies appropriate in a changing climate?’, Biological Conservation, January 2016; Newton A C, ‘Biodiversity Risks of adopting Resilience as a Policy Goal’, Conservation Letters, September/October 2016; and BESS, ‘Feeding a Growing Planet – Meeting the Challenge of Biodiversity and Food Security’, Synthesis Note 2016.

³¹ CIEEM, CIRIA, IEMA, ‘Biodiversity Net Gain: Good practice principles for development’, 2016.

³² WWT, ‘Nature’s Way – the Environment for Success: Practical Proposals for the Government’s 25 Year Environment Plan’, October 2017.

18 As with the issue of biodiversity, It is illuminating to view these proposals in the context of wider advice, evidence and proposals:

- The advice of the **NCC** includes a potential land-use goal: “Everyone has access to local greenspace and recreation and can benefit from the physical and mental health benefits it provides. Specific targets should be set, for example, one hectare of local nature reserve per 1000 people, two hectares of natural greenspace within 300 metres of where they live, and a 20 hectare site within two kilometres.” It also suggests a series of land-use related investments, including: increasing woodland by at least 250,000ha by 2040; restoring peatland systems, particularly in upland areas, to favourable condition; restoring natural hydrological processes including wetland creation; significantly expanding green spaces and outdoor recreation areas, especially in and around urban and well populated areas; and designating new national parks to protect and enhance natural capital and cultural heritage³³.
- The evidence base provided by **NEAFO** includes a spatially and temporally explicit integrated land use model, which “shows the benefit of designing policies that are flexible and can be adapted to regional and local contexts”. The model provides a ‘spatially targeted’ process which allocates scarce resources to those locations which maximise pre-set objectives. NEAFO used the model to undertake a case study on the potential for establishing new forests, looking at the impact across agriculture, timber, water quality, greenhouse gases, recreation and biodiversity. Study outputs included a targeted ‘Social Value’ driven planting policy in which the model selects planting locations that take into account the full sweep of benefits and impacts generated by afforestation, including market priced and non-market goods for which economic value can be estimated (eg greenhouse gas emissions). According to NEAFO, this results in woodlands being located away from vulnerable organic soils and close to areas that yield higher recreational values. Analysis of the impacts of non-market goods which could not be given robust economic values (e.g. biodiversity and water quality) shows that water quality and woodland bird species richness are also enhanced when the value of all goods and services are considered³⁴.
- For **the WWT**, the 25 Year Environment Plan: “should include ambitious goals for creation and restoration of all kinds of natural marvels: wetlands, woodlands, uplands, lowlands, grass, heath, rock and shore. For example, there is a strong economic case for creating or restoring 100,000 hectares of wetland, with benefit to cost ratios of up to 9:1.”³⁵ According to WWT, the case for wetland creation and restoration includes that: upland wetlands can slow and store flood waters; farmland wetlands can filter out pollutants from water more cheaply than chemical methods; urban wetlands, like sustainable drainage systems, can help to make communities more resilient to flood risk; and that, inch for inch, UK wetlands like peat can store more carbon than the Amazon rainforest.

³³ Natural Capital Committee, ‘Advice to Government on the 25 Year Environment Plan’, September 2017. The NCC advice is informed by the economic analysis in EFTEC, ‘The Economic Case for Investment in Natural Capital in England’, Final Report for the NCC, January 2015.

³⁴ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014, p53.

³⁵ WWT, ‘Nature’s Way – the Environment for Success: Practical Proposals for the Government’s 25 Year Environment Plan’, October 2017.

The WWT also highlights the importance of investment in green infrastructure in urban areas³⁶.

Addressing Biogeochemical Flows in the UK

- 19 Although the term ‘biogeochemical flows’ and the word ‘phosphorus’ do not appear in the CGS, the strategy contains a range of proposals relating to fertilisers, agricultural practices, and resources and waste management which could in principle address this PB issue. These include: working with industry to encourage the use of low-emissions fertiliser; developing affordable low carbon fertiliser products to reduce and replace fertilisers; exploring the potential for bio-stimulants to improve nutrient use efficiency; exploring the viability of fertiliser production by recovering nutrients from wastes and other organic materials; reducing the costs of resource use in crop and livestock production by improving our understanding of crop soil interactions and exploring the potential of robotics and precision farming technologies; and developing a Resources and Waste Strategy to maximise resource productivity, reduce waste in our energy and resource systems, promote well-functioning markets for secondary materials and incentivise producers to design better products.
- 20 On the face of it, these CGS proposals hold potential for adoption of a more comprehensive and systematic approach to nitrogen and phosphorus cycles than the current approach in the UK, which is based largely on the requirements for pollution control set out in EU Nitrates and Water Framework Directives. The UK approach to these requirements is as follows:
- Nitrates Directive: this is intended to reduce water pollution caused by nitrates from agricultural sources. A UK review of requirements and evidence in 2007 resulted in the designation of 62% of England as **Nitrate Vulnerable Zones (NVZs)** and introduced a strengthened range of measures in the Nitrates Action Programme that farms within NVZs must comply with. A national consultation took place in 2011-12, which included review of whether Action Programme measures should be applied throughout the whole of England. Although recognising that the latter approach would enable nitrates to be considered as part of a wider, more integrated approach to improving the sustainability of agriculture, the Government concluded that the balance of the argument was in favour of retention of discrete NVZs³⁷. Most recently, NVZs for 2017 to 2020 started on 1 January 2017, covering about 58% of land in England, including new areas of NVZs, and excluding areas that have been de-designated³⁸. DEFRA guidance explains how the requirements for storing and using manufactured nitrogen fertilisers and organic manure should be followed within NVZs³⁹.
 - Water Framework Directive: this introduced requirements to help protect and improve the ecological health of rivers, lakes, estuaries and coastal and ground waters. Implementation of the Directive in the UK is underpinned by the use of environmental standards to inform risk assessment and identify the scale of improvements needed.

³⁶ WWT, ‘Nature’s Way – the Environment for Success: Practical Proposals for the Government’s 25 Year Environment Plan’, October 2017, p30. See also, for example, Secretariat of the Convention on Biological Diversity, ‘Cities and Biodiversity Outlook’, 2012, Montreal.

³⁷ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/89434/nitrates-government-response.pdf.

³⁸ <https://www.gov.uk/guidance/nutrient-management-nitrate-vulnerable-zones>.

³⁹ <https://www.gov.uk/guidance/using-nitrogen-fertilisers-in-nitrate-vulnerable-zones>.

DEFRA published details of new and updated environmental standards in 2014⁴⁰. These include standards for phosphorus in rivers, which are specific to particular conditions at a site. This approach is designed to take account of the natural variation of nutrient concentrations along rivers and site-to site differences in the ecological response to elevated concentrations. Based on an initial assessment of 804 sites in the UK, DEFRA estimated that the combined effect of the proposed new standards would be to classify 52% of river sites as worse than good status as a result of phosphorus enrichment. However, DEFRA advice is that: “Because we cannot be sure the standards are precisely matched to the ecology at any individual site, the proposal is not to seek costly action to reduce phosphorus concentrations at individual sites without appropriate ecological evidence of nutrient-related impacts.”⁴¹ For those river sites where evidence of impacts is available, one way of achieving the relevant standard for phosphorus concentration is to control the level of phosphorus in treated wastewater discharged into the environment. Historically, this has been done using chemical dosing (with iron salts). Water companies are looking at opportunities for increased adoption of technologies such as biological nutrient removal (BNR)⁴². This micro-organism based approach can be used to remove most of the phosphorus in the wastewater, and the resultant sludge can then be used as fertiliser or be processed to recover phosphorus in a purer form. Note, however, that wastewater treatment can only go so far as it only contains a maximum 20% of the phosphorus that is used (much of the rest ends up in agricultural run-off). Further incentivising farmers to reduce their nitrogen discharges could also have a significant impact on phosphorus loads, as each is intrinsically tied to the other⁴³.

21 In order to begin to identify how the CGS proposals relating to fertilisers, agricultural practices, and resources and waste management might specifically address nitrogen and phosphorus cycles, it is necessary to look to the wider NGO and research literature, as the issue is not considered in NCC advice to Government on the 25 Year Environment Plan, nor in the NEAFO, and only obliquely in the WWT proposals (in relation to the benefits of wetland). Key points from the wider literature include:

- Nitrogen cycle: in the light of the transgression of the N planetary boundary, a 2015 WWF science brief argues that immediate action is needed to reduce the use of nitrogen and better manage losses⁴⁴. It suggests that the “most effective and integrated solutions comprise increasing nitrogen use efficiency in agriculture, reducing waste in the food chain, promoting diets with less animal protein in developed countries, and a shift from fossil fuels to sustainable renewable energy sources.” More specifically, in relation to agriculture, the WWF brief argued that the most important general approaches include: substituting N-fertilizer by natural alternatives such as biological fixation (eg using by using leguminous crops in rotation); closing the nutrient cycle and preventing loss of nutrients (eg by balanced nutrients per crop), and adopting agro-ecology principles (eg by making use of natural processes, strengthening functional biodiversity and protecting the ecosystem services that the farm depends on).

⁴⁰ DEFRA, ‘Water Framework Directive implementation in England and Wales: new and updated standards to protect the water environment’, May 2014.

⁴¹ DEFRA, ‘Water Framework Directive implementation in England and Wales: new and updated standards to protect the water environment’, May 2014, para 5.1.7.

⁴² https://www.ukconstructionmedia.co.uk/news/amp6-phosphorus-removal/?sector_id=3477.

⁴³ https://www.ukconstructionmedia.co.uk/news/amp6-phosphorus-removal/?sector_id=3477

⁴⁴ Erisman J W, et al, ‘Nitrogen: too much of a vital resource’, Science Brief, WWF Netherlands, 2015,

- Phosphorus cycle: an additional important motivation for systematically addressing the phosphorus cycle is a concern about ‘peak phosphorus’. The Soil Association drew attention to this in a 2010 report, pointing out that “the supply of phosphorus from mined phosphate rock could ‘peak’ as soon as 2033, after which this non-renewable resource will become increasingly scarce and expensive.”⁴⁵ For the Soil Association, this recognition strengthened arguments for switching to: organic and agro-ecological farming practices, diets with less meat and more organic foods and, in the longer-term, more ecological sanitation systems to allow greater use of human excreta as a resource. The combination of resource challenge and ecosystem impacts of phosphorus loading is also recognised by other agriculture stakeholders and researchers in the UK. This recognition has informed a range of research, leading to conclusions that there is a need for: further intensive research into ‘feeding the crop, not the soil’, and for planning a transition to this new strategy⁴⁶; greater recognition of the need for phosphorus source control and lowering soil fertility⁴⁷; large scale reduction in phosphorus fertiliser use to limit the detrimental effects of climate change on average winter phosphorus loads⁴⁸; and development of a circular economy for phosphorus, focusing on closing the cycle through improved use, recovery and recycling.⁴⁹

What PB Thinking Might Add in the UK

- 22 Having outlined relevant policy and evidence base developments in the UK, what points can now be made about what PB thinking might add in the UK? This is discussed in this section by reference to the five principles suggested above (para 10).

Place the Core PB Issues of Climate Change and Biosphere Integrity Centre Stage and Ensure Consideration of all PB Issues

- 23 With the 2008 Climate Change Act the UK became the first country to set legally-binding targets for reducing carbon emissions and, more recently, the CGS sets out how the Government intends to meet the so-called 5th carbon budget, seeking to limit the UK’s annual emissions to 57% below 1990 levels by the year 2032. Although there are a range of views on whether the CGS goes far enough⁵⁰, it is clear that climate change is being substantively addressed in the UK. According to the WWT, the forthcoming 25 Year Environment Plan provides opportunity “to do for our environment what the Climate Change Act did for carbon—setting long-term, legally-binding objectives that can drive action and investment across Government and the private sector, putting the UK at the forefront of environmental action”⁵¹. However, it is not currently clear to what extent biosphere integrity (biodiversity) will be addressed in that Plan.

⁴⁵ Soil Association, ‘A Rock and Hard Place – Peak Phosphorus and the Threat to our Food Security’, 2010.

⁴⁶ Sylvester-Bradley R, et al, ‘Improving the sustainability of phosphorus use in arable farming – ‘Targeted P’, Final Report of Sustainable Arable LINK Project LK09136, AHDB, 2017. This the final report of a 5 year DEFRA sponsored research programme exploring technologies to support a more efficient and sustainable strategy for phosphorus use on UK arable land.’

⁴⁷ Withers P J A, et al, ‘Reducing soil phosphorus fertility brings potential long-term environmental gains: A UK analysis’, Environmental Research Letters 12, 2017.

⁴⁸ Ockenden M C, et al, ‘Major agricultural changes required to mitigate phosphorus losses under climate change’, Nature Communications 8:161.

⁴⁹ Nesme T and Withers P J A, ‘Sustainable strategies towards a phosphorus circular economy’, Nutr Cycl Agroecosyst, 104, 2016.

⁵⁰ See, for example, the views of [Regen SW](#), the [Green Alliance](#) and [Carbon Brief](#).

⁵¹ WWT, ‘Nature’s Way – the Environment for Success: Practical Proposals for the Government’s 25 Year Environment Plan’, October 2017, p10.

As outlined above (para 15), biodiversity loss is not a central concern within the CGS's chapter on enhancing the value and benefits of natural resources. However, there is a wealth of advice, evidence and proposals that should be drawn upon to address biodiversity substantively in the Plan, including from the Natural Capital Committee, the National Ecosystem Assessment Follow-On, Research Council programmes and NGO proposals (para 16). In this context, PB thinking underlines the need to ensure that these and other relevant sources are drawn upon to substantively address biodiversity in the 25 Year Environment Plan.

- 24 For illustrative purposes, this note has focussed on three PBs and the ways in which they are being addressed in the UK. This consideration needs to be extended to other PBs (ocean acidification, novel entities, aerosol loading and freshwater use)⁵². In the interim, it is clear that land-system change will be substantively addressed in the 25 Year Environment Plan (para 17), and that there is a significant body of supporting advice, evidence and methodologies that can be drawn upon, including the integrated land-use model developed through the NEAFO (para 18). On nitrogen and phosphorus loading the position is less clear cut, although there is potential for the issues to be addressed substantively in the Government's proposals relating to fertilisers, agricultural practices, and resources and waste management (para 19). These proposals provide an important opportunity to address nitrogen and phosphorus cycles systemically, going beyond the current pollution control approach (para 20), and utilising a Circular Economy perspective (para 21).

Strive for Integration, Focus on Synergies and Minimise Trade-Offs

- 25 The need for systemic thinking and practice underpins the key elements of the second PB linked principle: that is, to strive for integration, focus on synergies and minimise trade-offs. It also features prominently in the Ecosystems Knowledge Network's reflections on the NEAFO 'five years on':

The language of ecosystem services is gaining more popular and public policy traction... It remains a personal mission to ensure that policy-makers, academics and anyone else using the term actually spot the word 'system' barely concealed within the word 'ecosystem'. Using the term 'ecosystem service' to describe managing one benefit from nature in isolation is not in the spirit of the ecosystem approach. Instead, it is old-school reductionism dressed up in new, ill-fitting clothes.⁵³

The research literature contains case studies of the sorts of risks that can arise including, for example, using resilience to climate change as a pretext for promoting 'pro-timber' forest management to the detriment of biodiversity⁵⁴, and the development of nature conservation plans for threatened species without explicit consideration of the projected impacts of climate change⁵⁵. In the light of the PB approach the need to think systemically is clear.

⁵² With the phasing out of ozone-depleting substances, the ozone PB is an example where, after a boundary has been transgressed regionally, humanity has taken effective action to return the process back to within the boundary.

⁵³ Everard M, 'Life after the UK National Ecosystem Assessment', Ecosystems News, Issue 13, Summer 2016, p 5.

⁵⁴ Newton A C, 'Biodiversity Risks of Applying Resilience as a Policy Goal', Conservation Letters, September/October 2016, 9(5), 369–376.

⁵⁵ Oliver T H et al, 'Are existing biodiversity conservation strategies appropriate in a changing climate?', Biological Conservation 193, 2016, p17–26.

26 The CGS does not indicate the extent to which systemic thinking and practice will inform the 25 Year Environment Plan. There is a strong commitment to a thorough going ecosystems approach in the NEAFO evidence base. More specifically, the NEAFO places the need for integration, and consideration of synergies and trade-offs, centre stage in its Ecosystems Services Conceptual Framework, associated tools, scenarios and case studies⁵⁶. This is then reflected, to a degree, in the NCC's recognition that the achievement of eco-system goals are inter-linked and that a coherent, integrated programme of work across those goals is needed⁵⁷. In this context, the second principle that arises from PB thinking serves to underline the importance of an approach that is already built into to the UK evidence base, and reflected in advice to Government. This approach now needs to be infused throughout the 25 Year Environment Plan (and inform the forthcoming Resources and Waste Strategy).

Be Truly Precautionary and Develop a Target-Oriented Approach

27 The UK's ambition to "hand our environment on to the next generation in a better state than we found it" begs the question how much better? The answer could range from a wholly inadequate, 'a little less unsustainable than before', through to a truly precautionary (and equitable) approach with evidence-based limits and targets linked to planetary boundaries and, for geographically heterogeneous processes, assessment of local vulnerabilities, critical loads and ecological 'hotspots' (see paras 6-9 above). As noted above, the PB approach is inherently precautionary, using value judgments in setting the boundaries within the range of uncertainty between 'safe' and 'dangerous', and informed by scientific evidence on the likely resilience of various of the Earth's systems in response to environmental pressures. Derivation of national limits and targets⁵⁸ should be similarly precautionary through linkage to the PBs and, in addition, for geographically heterogeneous processes, through evidence informed judgments to avoid local tipping points or thresholds (see para 31 below)⁵⁹.

28 There is little to suggest in the CGS's chapter on enhancing the value and benefits of natural resources that a truly precautionary approach will be taken in the 25 Year Environment Plan. Indeed the word 'precautionary' is not mentioned in that chapter. This should perhaps be seen in the context of concerns that the UK Government could create loopholes in environmental law as part of Brexit. In response, a coalition of 28 environment and wildlife organisations is calling for environmental legal principles – including the precautionary principle - to

⁵⁶ 'UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings', UNEP-WCMC, LWEC, 2014. See in particular Figure 2 for the Ecosystem Services Conceptual Framework, Figure 6 for 'Negotiation and Trade Off Analysis Support', and p38 for case studies and scenarios.

⁵⁷ Natural Capital Committee, 'Advice to Government on the 25 Year Environment Plan', September 2017. The NCC's Third Report to Government (2015) highlights the importance of synergies between natural capital investments, paras 5.0.4-5 and 5.2.2-3, as does the economic analysis informing the NCC's advice, EFTEC, 'The Economic Case for Investment in Natural Capital in England', Final Report for the NCC, January 2015, section 5.

⁵⁸ EFTEC refer to the distinction between limits and targets as follows: "Targets may be determined by society in different ways (through laws or in aspirational goals) and reflect a variety of factors. These factors can include the possibilities of crossing thresholds, with some targets reflecting 'safe limits' to avoid deterioration of natural capital reflecting what society may judge to be an acceptable risk of crossing thresholds, given the available evidence. In other cases, targets may be more 'aspirational'." See, EFTEC, 'The Economic Case for Investment in Natural Capital in England', Final Report for the NCC, January 2015, section 1.2.5, p11.

⁵⁹ In this spirit, Clift R et al propose a precautionary 'distance from boundary' approach, 'The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains', Sustainability, 9, 279, 2017, p16.

be put into domestic law through EU Withdrawal Bill amendments to ensure that they are binding and enforceable⁶⁰.

- 29 Although the CGS chapter on natural resources does contain some references to targets (eg on zero avoidable waste, para 12, and tree planting, para 17 above), these do not appear to be informed by an explicit commitment to a precautionary approach. Instead, the Government is espousing a business-led approach to environmental target setting, as explained in the following statement from the CGS:

The UK has some of the most dynamic and innovative businesses working on using our natural resources more efficiently. Government will work with them to deliver smart and ambitious regulation and targets to help us meet new environmental demands while also driving growth from these sectors.⁶¹

- 30 The NCC's advice to Government on the 25 Year Environment Plan is not explicit about the need for a precautionary approach. As indicated above (paras 16 and 18), the NCC suggests a series of goals, which should "be specific, measurable and ambitious, while also being closely linked to improving human health, wellbeing and the economy". A strong emphasis in the NCC's approach is the argument that the decline in natural capital must be reversed so that economic growth can be sustained, with the committee highlighting the "sheer scale and urgency of the task"⁶². In its third report, this perspective led the NCC to argue that "carefully planned investments in natural capital, targeted at the best locations, will deliver significant value for money and generate large economic returns"⁶³. It illustrated the argument by reference to case studies which showed a strong economic benefit for, for example, woodland planting, peatland restoration and wetland creation. The NCC's third report also sets out its proposed approach to developing targets "for determining how much natural capital needs to be secured"⁶⁴. It suggests that a combination of three strands of assessment is required: scientific analysis of relationships between assets and benefits (which it suggests is particularly important where thresholds may be present); economic assessment for example using cost benefit analysis; and identification of societal desires and preferences. With regard to the 'scientific analysis' strand, based on its preliminary work, the NCC advises that a 'risk register' should be developed so that the actual or potential benefits that are at greatest risk can be identified⁶⁵. This approach is augmented in the NCC's advice on the 25 Year Environment Plan, with the recommendation that to address data gaps and inconsistencies in analytical approaches across agencies the Plan should take forward a comprehensive '**State of the Environment**' report, including opportunities for its improvement, which should be completed by the end of 2019. The NCC advice on the Plan also highlights that its list of 12 goals "covers some of the most critical areas requiring action" but that "there are others where specific and measurable goals should be developed". The NCC's espousal of a 'risk register' approach,

⁶⁰ See <https://www.wwt.org.uk/news/all-news/2017/11/wwt-news/government-creating-gaping-brexite-environmental-legal-loopholes-warn-charities/> and <https://greenallianceblog.org.uk/2017/11/16/this-parliamentary-debate-was-a-significant-moment-for-the-uks-environment/>.

⁶¹ HM Government. 'The Clean Growth Strategy: Leading the Way to a Low Carbon Future', October 2017, p105.

⁶² Natural Capital Committee, 'Advice to Government on the 25 Year Environment Plan', September 2017, p4.

⁶³ NCC, 'The State of Natural Capital', 3rd Report to Government, 2015, p3.

⁶⁴ NCC, 'The State of Natural Capital', 3rd Report to Government, 2015, p18, 29-31.

⁶⁵ This advice builds on the EFTEC analysis, which suggests that a risk register approach should be used to inform a risk criterion in economic assessment, thereby helping to "balance at least to some extent" the possibility of bias against biodiversity benefits, EFTEC, 'The Economic Case for Investment in Natural Capital in England', Final Report for the NCC, January 2015, sections 4.2-4.3.

combined with proposals for further assessment and goal articulation, appears to offer opportunity for building in a PB informed approach to limits and targets, as proposed above (paras 6, 9 and 27). In principle, this might provide a way of further integrating precautionary and economically motivated approaches to natural capital.

- 31 The NEAFO initiative and findings were explicitly guided by the precautionary principle: “Given that there is scientific uncertainty about how some ecosystems and their services may be adversely affected by human development, a precautionary approach to decision-making is needed⁶⁶. In addition, principle 6 in the NEAFO’s Ecosystem Approach is about “recognising thresholds and functional limits”. This principle was reflected in the NEAFO’s procedure for assessing the condition of any natural capital asset, called the Natural Capital Asset Check (NCAC). This explicitly recognises that there may be thresholds in the relationships between assets and their benefits. The NCAC therefore incorporated precautionary ‘red flags’ which warn about the unsustainable use of natural capital assets and threshold risks⁶⁷. According to the NEAFO: “Thresholds can arise from both sudden changes to ecosystems, or from slower changes. Threshold crossing can affect ecosystems directly (for example, the collapse of fish stocks), or the ability of natural capital to recover, for example, the over abstraction of a water table.” The importance of regional and local thresholds and tipping points is also recognised in the wider UK-based research literature⁶⁸. In principle, it therefore appears that NEAFO’s NCAC, and other UK-based research, could provide an important input to deriving PB linked limits and targets for geographically heterogeneous processes which require a bridging between global (top-down) and local (bottom-up) approaches (see paras 6 and 7 above).

Strive for Coherence across Sectors, Scales, and Governance Levels

- 32 In its central concern about meeting future carbon emission targets, the CGS clearly demonstrates a commitment to work across sectors, scales and governance levels. Indeed, the CGS is itself structured around key sectors, including business and industry, homes, transport, power and natural resources. The CGS also conveys a challenging aspiration for coherence of approach across the CGS, 25 Year Environment Plan, Industrial Strategy⁶⁹ and Resources and Waste Strategy. It also recognises the importance of regional and local actions, with corresponding commitments to working with devolved administrations, local leaders and a new ‘Local Energy Contact Group’⁷⁰. On governance, the CGS includes commitments to: reinstate a regular Clean Growth Inter-Ministerial Group responsible for monitoring the implementation of this Strategy and driving clean growth policies; and to use the “Emissions Intensity Ratio” to report annually on performance in delivering GDP growth and reduced emissions⁷¹. It is not yet clear whether a strong focus on achieving coherence across sectors, scales and

⁶⁶ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014, p8

⁶⁷ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014, p22-23.

⁶⁸ See, in particular: the Research Council ‘Valuing Nature’ project ‘Identifying UK Ecosystem Tipping Points’ outlined at <http://valuing-nature.net/modelledTP>; Benton T G, et al, ‘Environmental tipping points and food system dynamics: Executive Summary’, the Global Food Security programme, UK, 2017; and Clift R et al, ‘The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains’, Sustainability, 9, 279, 2017.

⁶⁹ The recent Industrial Strategy White Paper indicates that the Government has made a start in addressing this aspiration, HM Government, ‘Industrial Strategy: Building a Britain Fit for the Future’, Cm 9528, November 2017. See in particular the statement about the need to enhance natural capital and the role of the Environment Plan (p135), and the box about natural capital and the circular economy (p148).

⁷⁰ HM Government, ‘The Clean Growth Strategy: Leading the Way to a Low Carbon Future’, October 2017, p11 and p119.

⁷¹ HM Government, ‘The Clean Growth Strategy: Leading the Way to a Low Carbon Future’, October 2017, p16.

governance levels will inform the 25 Year Environment Plan. As outlined below, this strong focus is evident in NCC advice and in the NEAFO evidence base.

- 33 In setting out its advice to Government on development and implementation of the 25 Year Environment Plan, the NCC stresses:

It will be the responsibility of Defra to lead the work, liaising closely with other government departments, so that the Plan joins seamlessly with other cross government initiatives like the Industrial Strategy and the Clean Growth Plan. In addition local councils, private industry, the voluntary sector, NGOs and researchers will also have a key role to play. If this is to be a genuinely transformative plan, as we think it should, then everyone will need to play their part.⁷²

One mechanism recommended by the Committee that would serve to increase coherence across sectors is the introduction of a “natural capital net gain principle” in: the planning regime for housing and infrastructure; the pollution prevention and control regulatory regimes; and public procurement contracts. According to the Green Alliance, “this would turn developers and industry into agents of environmental restoration”⁷³. The NCC advice also highlights that “the Plan will only succeed if its delivery is supported by appropriate governance, accountability and implementation structures”. To this end, the Committee proposes that: the Plan should be placed on a statutory footing to enable greater traction across government and its agencies; there be a single authority with statutory responsibility for its delivery, with a focus on integrated and coherent decision-making; delivery must be coordinated across spatial and administrative boundaries both national and local, and over time; and a separate body should be given a statutory responsibility to report on progress⁷⁴.

- 34 The NEAFO is strong on the need for, and ways of achieving, coherence across sectors, scales, and governance levels. In particular, it seeks to map the relationships between ecosystem services and major sectors of the economy, provides information and tools to help decision-makers across all sectors, and assesses the barriers and opportunities to embedding the Ecosystem Services Framework into appraisals at the *micro* (individual), *meso* (institutional) and *macro* (socio-political) scales. The NEAFO also contains a review of the effectiveness of a wide range of options for sustainably delivering ecosystem services, including direct economic incentives and market based schemes⁷⁵. The issue of governance is also centre-stage in the Framework, with a particular emphasis on the need for Adaptive Management, which is about “making policies and decisions that allow us to change our responses as our knowledge grows and we learn from our successes and failures”⁷⁶.

⁷² Natural Capital Committee, ‘Advice to Government on the 25 Year Environment Plan’, September 2017, p3.

⁷³ Tipper W A, ‘Three things you should know about the Natural Capital Committee’s advice on the 25 year plan for the environment’, Inside Track, 10 October 2017.

⁷⁴ Natural Capital Committee, ‘Advice to Government on the 25 Year Environment Plan’, September 2017, Chapter4.

⁷⁵ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014, section 1.4.8 and Figure 20. At some point in the future, it might be anticipated that appropriate combinations of options would provide an area for closer integration between Industrial Strategy and the Environment Plan. See also Francis A, ‘New Markets for Land and Nature: How Natural Infrastructure Schemes could Pay for a Better Environment’, Green Alliance, 2016, and Tipper W A et al, ‘Natural Infrastructure Schemes in Practice: How to create new markets for ecosystem services from land’, Green Alliance, 2017.

⁷⁶ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014, p11-12.

35 With regard to the 4th PB-related principle, the NCC advice and NEAFO evidence therefore provide a strong base from which to work in preparing the 25 Year Environment Plan. However, with the exception of the treatment of climate change, there is a clear missing scalar dimension – the global. A key way of addressing this omission - by operationalising the PBs in the UK - is outlined in paras 6-9, 27, and 30-31 above.

Adopt a Transdisciplinary Approach, Co-Developing Actions with Relevant Stakeholder Groups

36 There is little available information to suggest that such an approach will be taken in preparation of the 25 Year Environment Plan. However, the Plan will build on the advice of the NCC⁷⁷, which in turn draws on the evidence base of the NEAFO, which was based on a transdisciplinary approach:

The work of the UK NEAFO was highly interdisciplinary and was conducted and peer-reviewed by more than 150 experts. The time these experts generously dedicated to the project is very much appreciated. The co-chairs and authors were supported by a management structure that consisted of: (i) a Funders Group which included representatives from the project's funders; (ii) an Expert Group which comprised leading experts from a range of disciplines who peer-reviewed and guided the outputs of the project; (iii) a Stakeholder Group which included representatives from the public, private and voluntary sectors who helped with developing tools, external communications, and provided evidence on the application and implications of the project's findings ...⁷⁸

The NEAFO is also clear about the value of a transdisciplinary Ecosystem Approach in policy making and that effective stakeholder engagement is central to successful implementation⁷⁹.

Some Initial Conclusions

37 The NCC advice to Government on the 25 Year Environment Plan includes the following proposed goal:

(That) ... the country makes a net positive contribution to the global environment, including being among the leading nations in terms of contribution to global environmental commitments and an ever decreasing international impact.⁸⁰

One substantive way in which this goal could be achieved is by using PB thinking to support and inform development of the Plan⁸¹.

⁷⁷ The membership of the 7 strong NCC is a mixture of eminent economists and environmental scientists, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/518533/ncc-members.pdf.

⁷⁸ 'UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings', UNEP-WCMC, LWEC, 2014, p8.

⁷⁹ 'UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings', UNEP-WCMC, LWEC, 2014, p5, 8, 48 and 76.

⁸⁰ Natural Capital Committee, 'Advice to Government on the 25 Year Environment Plan', September 2017, p5.

⁸¹ As recently highlighted by Rockström and colleagues, the PB framework provides a complement to the myriad methods and approaches for ecosystem management by providing an Earth system-level framing. They stress that the framework is not intended as a replacement for ecosystem management approaches but a complement that takes Earth system considerations into account. See <http://www.stockholmresilience.org/research/research-news/2017-11-20-a-fundamental-misrepresentation-of-the-planetary-boundaries-framework.html>.

38 This Challenge Paper has provided an initial discussion about how this might be done, in particular by building on the extensive groundwork that has already been laid through the advice of the NCC and the evidence base of the NEAFO. More specifically, the paper has reviewed what PB thinking might add in the UK, by reference to five suggested principles. The key points that have emerged in relation to each of these principles are:

- i. ***Place the core PB issues of climate change and biosphere integrity centre-stage and ensure consideration of all PB issues:*** Although climate change is being substantively addressed, it is not clear to what extent biosphere integrity (biodiversity) will be addressed in the 25 Year Environment Plan. Its lack of consideration in the CGS chapter on enhancing the value and benefits of natural resources is not an encouraging sign. PB thinking underlines the importance of drawing upon the wealth of advice, evidence and proposals that exists in the UK to substantively address biodiversity substantively in the Plan. On land-system change, it is clear that this will be substantively addressed, and there is a significant body of supporting advice, proposals and evidence that can be drawn upon. On nitrogen and phosphorus loading the position is less clear cut, although there is potential for the issues to be addressed substantively in the Government’s proposals relating to fertilisers, agricultural practices, and resources and waste management. These proposals provide an important opportunity to address nitrogen and phosphorus cycles systemically, going beyond the current pollution control approach, and utilising a Circular Economy perspective. Finally, for illustrative purposes, this note has focussed on three PBs and the ways in which they are being addressed in the UK. This consideration needs to be extended to other PBs (ocean acidification, novel entities, aerosol loading and freshwater use).
- ii. ***Strive for integration, focus on synergies and minimise trade-offs:*** It is not clear to what extent the need for systemic thinking and practice will inform the 25 Year Environment Plan. There is a strong commitment to a thorough going ecosystems approach in the NEAFO evidence base. More specifically, the NEAFO places the need for integration, and consideration of synergies and trade-offs, centre stage in its Ecosystems Services Conceptual Framework, associated tools, scenarios and case studies. This is then reflected, to a degree, in the NCC’s recognition that the achievement of eco-system goals are inter-linked and that a coherent, integrated programme of work across those goals is needed. In this context, PB thinking serves to underline the importance of an approach that is already built into to the UK evidence base, and reflected in advice to Government. This approach now needs to be infused throughout the 25 Year Environment Plan (and inform the forthcoming Resources and Waste Strategy).
- iii. ***Be truly precautionary and develop a target-oriented approach:*** Although the Government wishes to “hand our environment on to the next generation in a better state than we found it”, there is little to suggest in the CGS’s chapter on enhancing the value and benefits of natural resources that a truly precautionary approach will be taken in the 25 Year Environment Plan. The CGS chapter on resources does contain some references to targets, but these do not appear to be informed by an explicit commitment to a precautionary approach. Instead, the Government is espousing a business-led approach to environmental target setting. Nonetheless, opportunities may arise from the NCC’s advice to Government. In particular, the Committee’s espousal of a ‘risk register’ approach, combined with proposals for a comprehensive ‘State of the Environment’ report, including opportunities for its improvement, might offer opportunity for building in a PB informed approach to limits and targets. In principle, this could provide a way of further integrating

precautionary and economically motivated approaches to natural capital. It is also likely that the NEAFO's Natural Capital Asset Check, and other UK-based research, could provide an important input to deriving PB linked limits and targets for geographically heterogeneous processes which require a bridging between global (top-down) and local (bottom-up) approaches.

- iv. **Strive for coherence across sectors, scales, and governance levels:** In its central concern about meeting future carbon emission targets, the CGS clearly demonstrates a commitment to work across sectors, scales and governance levels. However, it is not yet clear whether a similar commitment will inform the 25 Year Environment Plan. Nonetheless, a focus on these requirements is evident in NCC advice and in the NEAFO evidence base, thereby providing a strong base from which to work in preparing the Plan. In particular, the NCC advice includes proposals to introduce a “natural capital net gain principle” in planning and regulatory regimes, and for appropriate governance, accountability and implementation structures. The CGS also conveys a challenging aspiration for coherence of approach across the CGS, 25 Year Environment Plan, Industrial Strategy, and Resources and Waste Strategy. Note, however, that with the exception of the treatment of climate change, there is a clear missing scalar dimension – the global. A key way of addressing this omission would be by operationalising the PBs in the UK.
- v. **Adopt a transdisciplinary approach, co-developing actions with relevant stakeholder groups:** There is little available information to suggest that such an approach will be taken in preparation of the 25 Year Environment Plan. However, the Plan will build on the advice of the NCC, which in turn draws on the evidence base of the NEAFO, which was based on a transdisciplinary approach. The NEAFO is also clear about the value of a transdisciplinary Ecosystem Approach in policy making and that effective stakeholder engagement is central to successful implementation.

39 It is the contention of this Challenge Paper that the most substantive way in which PB thinking could add to the approach being taken in the UK is through a focus on the third principle above - being truly precautionary and developing a target-oriented approach. Much valuable groundwork has already been laid, including:

- proposals for how to translate the PB framework to specific national or regional contexts, based on a review of existing studies that have sought to achieve this (paras 6-7 above);
- the NCC's recommendation that a State of the Environment report be prepared, and its proposed approach to developing targets, including development and use of a 'risk register' (para 30); and
- the NEAFO's Natural Capital Asset Check, and other UK-based research, which could provide important input to deriving PB linked limits and targets for geographically heterogeneous processes which require a bridging between global and local approaches (paras 31).

A key need now is to bring these strands together in a programme of research that identifies PB linked limits and targets for the UK (see Annex A).

40 As a final point for discussion, further PB thinking could in principle be injected into a 'mission' based approach to 'Grand Challenges', of the sort proposed in the Industrial Strategy White Paper. This uses one PB-related issue – the need to reduce carbon emissions – to illustrate the approach:

Where appropriate, teams will develop ‘missions’ to tackle the Grand Challenges. They involve tackling specific problems, such as reducing carbon emissions by a given percentage over a specific year period, using well defined and concrete goals to allow progress to be monitored and assessed, and the option to change course when appropriate.⁸²

This thinking has been elaborated by the Commission on Economic Justice (CEJ) in its recent discussion paper on Industrial Strategy. It proposes a mission to “reduce the UK’s environmental footprint to levels consistent with global sustainability by 2040”, covering decarbonisation, the circular economy and sustainable natural capital. It further suggests that: “Each mission or sub-mission would be implemented through three steps: on the demand side, the establishment of a long-run goal and a broad plan for meeting it; on the supply side, a set of support policies and associated spending.”⁸³ The CEJ uses the ‘decarbonisation’ mission to illustrate how this might work. This example is used in Annex B below (‘Potential PB-Related Missions’), along with the three other PB issues considered in this paper. The Annex provides pointers to how biosphere integrity and land-system change PBs might be addressed in a ‘sustainable natural capital’ mission, and biogeochemical flows in a ‘circular economy’ mission.

⁸² HM Government, ‘Industrial Strategy: Building a Britain Fit for the Future’, Cm 9528, November 2017, p35.

⁸³ Jacobs M et al, ‘Industrial Strategy: Steering Structural Change in the UK Economy’, IPPR Commission on Economic Justice, Discussion Paper, November 2017, p16-17.

Annex A: Response to NERC Call for ‘Environmental Evidence for the Future’

The material in this Annex formed the basis of a submission in response to NERC’s autumn 2017 call for evidence on “key knowledge gaps and evidence needs pertaining to future environmental policy and practice challenges”⁸⁴. NERC stated that responses would “inform the scope of a proposal for a future large-scale transformative programme that will look to address priority future research and innovation needs”.

The call asked for three key questions to be addressed:

- What is the knowledge gap that could provide evidence to address the challenge?
- What is the research need?
- What key capabilities and skills are needed?

Knowledge Gaps

- What would constitute an appropriate and equitable UK contribution to returning the planet to, or keeping it within, a safe operating space, as defined by international research on key planetary boundaries (PBs), including ocean acidification, novel entities (e.g. chemical pollution), aerosol loading, biosphere integrity (focusing on biodiversity loss), biogeochemical flows (focusing on nitrogen and phosphorus cycles), freshwater use and land-system change?⁸⁵
- What would constitute precautionary and equitable limits in the UK, taking into account the control variables proposed in the research literature for the above planetary boundaries and, for those boundaries where local conditions play a crucial role in determining the level of sustainable use or tolerable emission, taking into account local vulnerabilities, critical loads and potential ecological ‘hotspots’?⁸⁶
- For those boundaries where local conditions play a crucial role, there are gaps in understandings of the biophysical connections between (a) local vulnerabilities, critical loads and potential ecological ‘hotspots’ and (b) the regional level PBs that relate to the way sub-global dynamics affect the functioning of the Earth system as a whole.⁸⁷

Research Needs

- Identify and apply the most appropriate methodologies for translating the PB framework to the UK, drawing on available reviews of studies that have sought to achieve this in various national and regional contexts.⁸⁸

⁸⁴ <https://www.eefi.ceh.ac.uk/>. The deadline for submissions was 4 December 2017.

⁸⁵ Rockström J, et al, ‘A Safe Operating Space for Humanity’, *Nature* 461, pp.472-475, 2009, and Steffen W, et al, ‘Planetary Boundaries: Guiding Human Development on a Changing Planet’, *Science*, 13 February 2015: Vol. 347 no. 6223.

⁸⁶ Häyhä T, et al, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, 2016.

⁸⁷ Steffen W, et al, ‘Planetary Boundaries: Guiding Human Development on a Changing Planet’, *Science*, 13 February 2015: Vol. 347 no. 6223, and Clift R et al, ‘The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains’, *Sustainability*, 9, 279, 2017.

⁸⁸ Häyhä T, et al, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, 2016, Van Vuuren D et al, ‘Horses for courses - analytical tools to explore planetary boundaries’, *Earth System Dynamics* 7:1, 2016, p 267–279, and Clift R et

- By developing understandings of the three dimensions for bridging across scales – the biophysical, socio-economic and ethical.⁸⁹ For the biophysical dimension (for PBs where local conditions play a crucial role in determining the level of sustainable use or tolerable emission), by developing understandings of the connections between (a) local vulnerabilities, critical loads and potential ecological ‘hotspots’, and (b) the regional level PBs that relate to the way sub-global dynamics affect the functioning of the Earth system as a whole, so that an integrated approach to identifying UK limits and targets can be developed.⁹⁰
- In order to develop understandings of the biophysical connections between local and regional levels, draw on the UK National Ecosystem Assessment’s Natural Capital Asset Check, and other UK-based research, to provide a critical input on local vulnerabilities, critical loads and potential ecological ‘hotspots’.⁹¹

Key Capabilities and Skills

- Scientific expertise in each of the PBs [climate change, ocean acidification, ozone depletion, novel entities e.g. forms of chemical pollution, aerosol loading, biosphere integrity (focusing on biodiversity loss), biogeochemical flows (focusing on nitrogen and phosphorus cycles), freshwater use and land-system change].
- Economic expertise in decarbonisation, circular economies, and assessment and valuation of natural capital, ecosystem services and the sub-global links created by international production and consumption patterns and international trade.⁹²
- Expertise in questions relating to the equitable sharing of the global safe operating space, recognizing the differences between countries’ rights, abilities, and responsibilities.⁹³
- Knowledge and experience of a transdisciplinary approach, including interdisciplinary working and effective stakeholder engagement.

al, ‘The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains’, *Sustainability*, 9, 279, 2017.

⁸⁹ Häyhä T, et al, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, 2016.

⁹⁰ Steffen W, et al, ‘Planetary Boundaries: Guiding Human Development on a Changing Planet’, *Science*, 13 February 2015: Vol. 347 no. 6223, and Häyhä T, et al, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, 2016.

⁹¹ ‘UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings’, UNEP-WCMC, LWEC, 2014; Benton T G, et al, ‘Environmental tipping points and food system dynamics: Executive Summary’, the Global Food Security programme, UK, 2017; the Valuing Nature project ‘Identifying UK Ecosystem Tipping Points’, outlined at <http://valuing-nature.net/modelledTP>; and research being undertaken within the UK’s Biodiversity and Ecosystem Service Sustainability programme, eg Oliver T H et al, ‘Declining resilience of ecosystem functions under biodiversity loss’, *Nature Communications*, December 2015 and Newton A C, ‘Biodiversity Risks of adopting Resilience as a Policy Goal’, *Conservation Letters*, September/October 2016.

⁹² For the latter see WWF, ‘Risky Business: Understanding the UK’s Overseas Footprint for Deforestation Risk Commodities’, October 2017.

⁹³ Häyhä T, et al, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, 2016.

Annex B: Potential Planetary Boundary Related Missions

[Note: consideration also needs to be given to applying this approach to the PBs based on ocean acidification, novel entities, aerosol loading and freshwater use]

Earth System Process (and Mission)	Planetary Boundary ⁹⁴	UK Limits, Goals and Targets	Strategies and Plans
Climate change (and decarbonisation)	Control variable: atmospheric CO ₂ concentration, ppm PB: 350 ppm CO ₂ Zone of uncertainty: 350–450 ppm Current value: 398.5 ppm CO ₂	<ul style="list-style-type: none"> - Climate Change Act 2008: reduce greenhouse gas emissions by at least 80% by 2050 (on 1990 levels) - Paris Climate Agreement 2015: zero net emissions after 2050 - CC Act requires adoption of intermediate targets every five years, set 15 years ahead ('carbon budgets' setting a limit on total emissions in five-year periods). 	<ul style="list-style-type: none"> - CC Act requires government to produce plans for meeting Carbon budgets. - The most recent – the October 2017 Clean Growth Strategy (CGS) – covers the period to 2032. This sets out expected emission reductions in power, heat, buildings, transport, industry and agriculture, and identifies the policy framework to incentivise, encourage and require reductions.
Change in biosphere integrity (and sustainable natural capital)	Interim control variables: genetic diversity (extinction rate) and functional diversity (Biodiversity Intactness Index (BII)) Genetic diversity (GD) PB: less than 10 extinctions per million species-years (E/MSY) GD Zone of uncertainty: 10–100 E/MSY GD current value: 100–1000 E/MSY BII PB: maintain at 90% BII zone of uncertainty: 90–30%	<ul style="list-style-type: none"> - Work is needed to identify: (a) precautionary and equitable UK limits (taking into account genetic and functional diversity PBs, and any UK-based threshold risks); and (b) UK 'current values' compared to these limits. - The UK limits and current values should inform judgement of the adequacy of currently proposed and future UK biodiversity goals and targets. 	<ul style="list-style-type: none"> - There is an opportunity for the forthcoming 25 Year Environment Plan to set out how goals and targets will be achieved. - Informed by a 'natural capital' approach, the NCC proposes biodiversity related investments, including to: "develop and implement a national network of conservation areas to provide bigger, better and more joined up habitats, including more nature reserves"; and "develop and implement

⁹⁴ From Steffen W, et al, 'Planetary Boundaries: Guiding Human Development on a Changing Planet', Science, 13 February 2015: Vol. 347 no. 6223

	<p>BII current value: 84%, applied to southern Africa only</p>	<ul style="list-style-type: none"> - There is an opportunity for the forthcoming 25 Year Environment Plan to set out biodiversity goals and targets. - Currently proposed goals and targets include: ensuring that “wild species and habitats are thriving and populations are restored and enhanced to levels that are sustainable into the future despite the challenges from climate change and increasing pressures from built infrastructure” (Natural Capital Committee NCC); and ensuring wildlife is more diverse and abundant by 2040 (with species targets), creating a network of healthy habitats across the UK, and meeting international obligations on halting biodiversity loss (Wildfowl and Wetlands Trust WWT). 	<p>a comprehensive network of marine protected areas”.</p> <ul style="list-style-type: none"> - The NCC also proposes a natural capital ‘net gain principle’ within: the spatial planning regime for housing and infrastructure; the environmental pollution prevention and control regulatory regimes; and public procurement contracts. - The NEAFO observes that biodiversity objectives should be integrated across other sectors, including through greenspace, ecological networks, and agri-environment schemes. - The WWT states that the 25 Year Environment Plan “should set in motion an ambitious programme of habitat creation and restoration, from small networks of green and blue spaces in our cities, to landscape-scale restoration around our coasts and countryside.”
<p>Land-system change (and sustainable natural capital)</p>	<p>Control variables: global – area of forested land as % of original forest Cover; biome – area of forested land as % of potential forest Global PB: 75% Global zone of uncertainty: 75–54% Global current value: 62% Biome PB: tropical 85%; temperate 50%; and boreal 85% Biome zone of uncertainty: tropical 85–60%; temperate 50–30%; and boreal: 85–60%</p>	<ul style="list-style-type: none"> - Work is needed to identify: (a) precautionary and equitable UK limits (taking into account biome PBs, the composition of UK woodland, and other relevant local factors); and (b) the UK ‘current values’ compared to these limits. - The UK limits and current values should inform judgement of the adequacy of current goals and targets for new tree planting, which have been established primarily through economic assessment 	<ul style="list-style-type: none"> - It is expected that the forthcoming 25 Year Environment Plan will set out how current goals and targets will be achieved. - Informed by a ‘natural capital’ approach, the NCC proposes land-use related investments, including to Increase woodland by at least 250,000ha by 2040. The NCC also proposes a natural capital ‘net gain principle’ (see above).

		<p>of the case for investment in this category of 'natural capital'.</p> <ul style="list-style-type: none"> - Current goals and targets include: increasing tree cover in England by 180,000 hectares from 9.8 per cent to 11 per cent (including 130,000 hectares of new woodland and plans for farmers to plant more trees across the country); and, during the 2020s, accelerating the rate of tree planting, working towards a 12 per cent tree cover aspiration by 2060 (Clean Growth Strategy). 	<ul style="list-style-type: none"> - The Plan could draw on the NEAFO integrated land use model, which "shows the benefit of designing policies that are flexible and can be adapted to regional and local contexts". The model provides a 'spatially targeted' process which allocates resources to locations which maximise the achievement of objectives across eg agriculture, timber, water quality, greenhouse gases, recreation and biodiversity. - The Plan could also draw on NEAFO's review of the effectiveness of options for sustainably delivering ecosystem services, including direct economic incentives and market based schemes.
<p>Biogeochemical flows (and circular economy)</p>	<p>Control variables: P global – P flow from freshwater systems into the ocean; P regional – P flow from fertilizers to erodible soils; and N global – industrial and intentional biological fixation of nitrogen Global P PB: 11 Tg/yr Global P zone of uncertainty 11–100 Tg/yr Global P current value: 22 Tg/yr Regional P 6.2 Tg/yr mined and applied to erodible (agricultural) soils Regional P zone of uncertainty: 6.2-11.2 Tg/yr</p>	<ul style="list-style-type: none"> - Work is needed to identify: (a) precautionary and equitable UK limits (taking into account global and regional PBs for P, the global PB for N, and any UK-based threshold risks); and (b) the UK 'current values' compared to these limits. - The UK limits and current values should inform identification of UK phosphorus and nitrogen goals and targets, which should be included in the forthcoming 25 Year Environment Plan, and/or Resources and Waste Strategy. 	<ul style="list-style-type: none"> - There is potential for nitrogen and phosphorus cycles to be addressed substantively in the 25 Year Environment Plan (through development of the Government's proposals relating to fertilisers and agricultural practices), and in the forthcoming Resources and Waste Strategy. - These strategies and plans provide an important opportunity to address nitrogen and phosphorus cycles systemically, going beyond the current pollution control approach (which is derived from the Nitrate and Waste Frameworks Directives).

	<p>Regional P current value: 14 Tg/yr Global N PB: 62 Tg/yr Global N zone of uncertainty: 62–82 Tg/yr Global N current value: 150 Tg/yr</p>		<ul style="list-style-type: none"> - For the nitrogen cycle, considerations should include increasing nitrogen use efficiency in agriculture, reducing waste in the food chain, and promoting diets with less animal protein. - For phosphorus, account also needs to be taken of concerns about 'peak phosphorus'. The combination of resource challenge and ecosystem impacts could be addressed through development of a circular economy for phosphorus, including a focus on improved use, recovery and recycling.
--	--	--	--