Norwegian University
of Life Sciences

Master's Thesis 2022 30 ECTS
Noragric, LANDSAM

Defining a safe and just operating space for the Norwegian economy

Thomas Røkås

International Environmental Studies
Supervisors: Erik Gomez-Baggethun and Moren Jerven

Preface

This thesis was developed in collaboration with the project “Embedding planetary boundaries in science, policy and education” led by professor Erik Gomez-Baggethun, in the framework of the “NMBU Sustainability Arenas 2021-2024”. The project is a collaboration across three departments at the Norwegian University of Life Sciences; LANDSAM, MINA, and Handelshøyskolen.

Abstract

The Safe and Sust operating Space (SJS) sustainability framework represents an alternative development tool to abate social inequality and environmental degradation by applying the concepts of environmental limits and social boundaries for a “good life”. Downscaling such limits to sub-global levels increase their policy-relevance, but remains a challenge as natural limits vary across spatiotemporal scales, and the lived human experience differs across cultures. Using Norway as an example, this paper examines how regulatory environmental and social limits can be established through a bottom-up approach. It develops an analytical framework that explores the compatibility between top-down vs. bottom-up approaches, and relative vs. absolute human needs assessments in the SJS sustainability framework. Our results show that the Norwegian economy is close to meeting citizens needs and rights, but with significant disparity across demographic groups, and to a high ecological cost, transgressing all the assessed planetary boundaries. Further methodological development is suggested to increase the relevance of the SJS sustainability framework at national scale.

Keywords

Safe and just operating space, doughnut economics, environmental limits, social limits, downscaling, Norway

1. Introduction

The world economy has grown manyfold the last century and Earth system scientists claim that anthropogenic activity has already transgressed safe environmental limits (Rockström et al., 2009; Steffen et al., 2015). Ecological systems are deteriorating, and meanwhile social disparity remains a global issue for hundreds of millions of people worldwide that lacks access to clean drinking water, experience long term food insecurity or are denied access to education and basic health services (United Nations [UN], 2020). An alternative to the dominant economic growth and development nexus has received attention the last years, and is visible through the Safe and Just operating Space (SJS) framework for sustainability. The SJS describes sustainability as the situation where safe limits to human consumption of environmental resources are respected (a safe operating space) (Rockström et al., 2009; Steffen et al., 2015), while at the same time basic necessities that promote dignified lives for all are fulfilled (a just operating space) (Raworth, 2017).

Originally designed for the global scale, there has been growing interest to operationalize the framework at sub-global levels to be relevant for local policymakers (Downing et al., 2019). O`Neill et al. (2018) and Fanning et al. (2022) downscaled the SJS to national level and assessed over 140 countries, concluding that no nation is currently meeting citizens needs without using excessive amounts of resources, and that no country operating within safe planetary boundaries is fulfilling basic needs.

However, defining environmental and social limits across scales remains a major challenge due to the biophysical properties and spatial heterogeneity of earth system processes (Nykvist et al., 2013), and the different perceptions of what constitutes a “good life”. There is inconsistency in how previous studies relate to this, either allocating sub-global limits from global proxies (e.g., O`Neill et al., 2018), or asserting limits for place-specific ecological and social systems (e.g., Cole et al., 2014).

This study addresses these inconsistencies, outlining a downscaling framework that explicitly accounts for different earth system processes, while facilitating sound parameters for the lived human experience. To increase the policy relevance of the SJS for national stakeholders, this study asserts environmental and social limits within contemporary policy frameworks, using the case of Norway. We aim to define a safe and just operating space for the Norwegian economy, and ask i) how ecological limits, conceptualised as a “safe operating space”, can be defined, and ii) how social limits, conceptualised as a “just operating space”, can be defined. Further, we assess iii) the Norwegian economy’s ecological cost of meeting human needs.

In the following we first map out different understandings of environmental and social limits, and define key concepts (section 2), before describing the SJS sustainability framework and how it has been applied so far (section 3). Next, we present our methodological frameworks and the methods used (section 4), before presenting (section 5) and discussing (section 6) our results. Section 7 provides a brief conclusion.

2. Theoretical background

2.1 Notions of environmental limits

Environmental limits have been conceptualized differently (Table 1), but a key difference between natural and regulatory limits is made here (see e.g., Jax, 2014; Gomez-Baggethun, 2020). Natural limits are physical realties and can be observed in nature. The concept of carrying capacity e.g., describes a point where habitats can sustain populations` demands for biological resources indefinitely (Odum, E. P. & Barrett, 1971). This amount, or stock of natural capital (Costanza & Daly, 1992), is quantitatively less than the total amount of biological resources and waste a habitat can regenerate and assimilate (Wackernagel et al., 2002). An ecosystem's capacity to produce resources can however be reduced (Daly, 1990) when ecological thresholds are transgressed, which describes abrupt and non-linear changes to these system`s structure and functioning, transitioning from one state into a qualitatively less productive state (Holling, 1973; Scheffer et al., 2001).

Table 1. Different conceptualizations of environmental limits

Author(s)	**Environmental limit conceptualised as…**
Odum & Barrett, 1971	…carrying capacity, a point where an ecosystem or habitat can sustain a population indefinitely
Wackernagel et al., 2002	…bio capacity, the total amount of biological resources and waste an ecosystem or habitat can regenerate and assimilate
Scheffer et al., 2001	…an ecological threshold, the point where an ecological system change structure and functioning abruptly, non-linearly and sometimes irreversibly.
Bishop, 1978	…safe minimum standards, politically decided levels of anthropogenic activity to prevent irreversible losses
Rockström et al., 2009	…planetary boundaries, planetary scale safe limits to human activities, asserted to avoid a shift in the Earth system

While natural limits are descriptive, regulatory limits are defined normatively, based on human risk aversion in the tradeoff between socio-economic activities and environmental degradation (Johnson, 2013). Typical examples are public policies aiming to prevent irreversible environmental degradation from contemporary economic activity, or safe minimum standards (Bishop, 1978). Regulatory limits have also been conceptualized as planetary boundaries (Rockström et al., 2009), which are safe limits to anthropogenic activity, asserted on a precautionary principle (Raffensperger & Tickner, 1999), to avoid shifting the Earth system to a less human-friendly state.

2.2 Notions of social limits

Like environmental limits, social limits have been conceptualized differently (Table 2), but can be ascribed to basic human needs. The International Labour Organization (ILO) defined basic needs as a "[…] minimum standard of living which a society should set for the poorest groups of its people" (ILO, 1976, p. 7 in Chiappero-Martinetti, 2014, p. 331). Basic needs can be framed in either *absolute* or *relative* terms, the former referring to "[…] aspects that are considered to be necessary for mere survival of individuals and without which human life would be seriously impaired" (Chiappero-Martinetti, 2014, p. 330), while the latter represents a set of aspects which may differ in between cultures in the social process of defining and selecting basic necessities (p. 330-331). An absolute framing of basic needs is visible among scholars such as Doyal & Gough (1991) and Max-Neef (1991) which argued that humans have some finite, satiable and non-substitutable needs, which are universal across time and space, but can be fulfilled by different satisfiers. The universality of human needs is also visible in the UN Sustainable Development Goals (SDGs) and related minimum social thresholds (UN, 2015).

Table 2. Different conceptualizations of social limits

Author(s)	**Social limits conceptualised as …**
ILO (1976)	…a "minimum standard of living which a society should set for the poorest groups of its people" (p. 7)
Doyal & Gough (1991)	…a few satiable and non-substitutable basic needs, universal both across time and space and to the extend they can be fulfilled
Max Neef (1991)	…a few finite and classifiable basic needs, universal across time and space, and can be fulfilled by different cultural satisfiers
UN (2015)	…globally defined goals and minimum social standards to achieve a sustainable and better future for all
Townsend (1987)	… contemporary and contextual indicators of human deprivation, which differ across time and scale as societies evolves

Sen (1993)	…human capabilities to choose and fulfil valuable individual or social functions, which are differently defined across cultures.
Nussbaum (2003)	…ten fundamental human capabilities governments should provide their citizens to facilitate social functioning

A more relative framing of human needs is visible in the work of Townsend (1987), which argued that as societies evolve, human deprivation should be evaluated according to contemporary societal circumstances. Sen (1993) and Nussbaum (2003) argued that social well-being depends on individuals` and societies` capabilities to achieve valuable functions (read needs). The freedom (or capability) to choose a combination of different functions, which differs across cultures, is ultimately what constitutes a good life.

2.3 Limits across scales

To measure what constitutes a "good life" across spatial and temporal scales is a difficult task, whether framed in absolute or relative terms. Costanza et al. (2007) differentiate between "subjective" and "objective" indicators to measure quality of life, where the former focus on persons` identities and lived experiences at individual level, while the latter tries to capture such experiences at higher spatial scales (e.g., nation, globally) through aggregated data. The higher on the spatial scale one moves, the more heterogeneity within the assessed group is lost (Constanza et al., 2007, p. 274).

To assess and define environmental limits is also a difficult and complex matter, as ecosystems operate at multiple spatiotemporal scales (Levin 1992; Gunderson & Holling, 2002). Ecological thresholds have been identified for local and regional (Scheffer et al., 2001; Biggs et al., 2018) as well as for sub-continental systems (Lenton et al., 2008), whilst there is more ambiguity around global systems. Some argue that large scale systems inhibit ecological thresholds, and when transgressed leads to abrupt and irreversible changes (Barnosky et al., 2012; Hughes, Carpenter et al., 2013), whilst others argue that such systems change smoothly and over long time periods (Brook et al., 2013; Hughes, Linares et al., 2013). However, asserting regulatory limits to avoid regime shifts at local and regional scales is nevertheless crucial for the functioning of the earth system (Steffen et al., 2015). Scientific uncertainty remains around the effects of transgressing ecological thresholds across different scales (Wheatley & Johnson, 2009).

Assessing environmental limits within a defined territory is also illusioned by spatial appropriation of resources conditioned by international trade and technological advancement (Haberl et al., 2019). Populations at regional scales, such as cities, are likely to largely exceed the regenerative and absorptive capacities of local ecosystems (Kennedy et al., 2007; Elliot et al., 2022), but can sustain themselves by shifting socio-ecological costs of production across space and time (Kapp, 1950).

3. Analytical framework

3.1 Safe and just operating space (Doughnut economics)

The Safe and Just operating Space (SJS) sustainability framework combines nine planetary boundaries representing a safe operating space (SOS) (Rockström et al., 2009; Steffen et al., 2015), and twelve social dimensions (Raworth, 2017) representing a just operating space (JOS). They form an ecological ceiling and social foundation, demonstrated as an outer- and inner-circle of a doughnut shaped diagram (Fig. 1). Sustainability is described within these two circles as when all people fulfill their basic needs within the regenerative capacity of the earth system (Raworth, 2017).

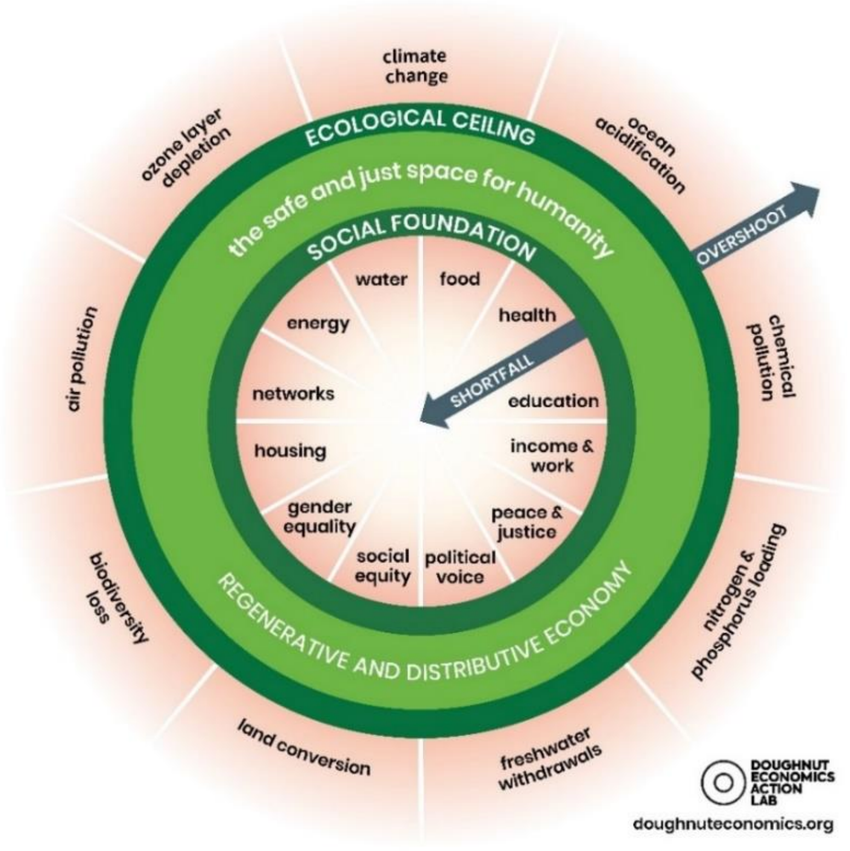

Fig. 1. The safe and just operating space depicted within an ecological ceiling and social foundation. Figure from Raworth (2017), sourced from https://doughnuteconomics.org/tools-and-stories/65

For planetary boundaries, Rockström et al (2009) made a distinction between i) globally systemic (or homogenous) processes inhabiting threshold behaviour at a planetary scale, and ii) spatial-heterogenous processes which inhibit threshold behaviour at local scales but with no apparent global threshold (Fig. 2). The boundaries for the spatial heterogenous processes were criticised for being insensitive to local-regional system behaviours (Carpenter & Bennett, 2011; Gerten et al., 2013; de Vries et at., 2013; Mace et al., 2014), for which Steffen et al. (2015) suggested regional control variables (Appendix A). To account for some of the sensitivity to place for local and regional systems, boundaries for such systems should be defined using a *bottom-up* approach. This implies assessing ecosystems at the scale at which they inhibit threshold behaviour, define a boundary that prevent transgressing such thresholds, and aggregate such boundaries to higher scales e.g., national scale. For processes that are homogenous, one can define sub-global boundaries through a *top-down* approach. This implies allocating a share of the environmental resource embedded in the globally defined boundary, to a sub-global entity, without considering sensibility across scales (Fig. 2).

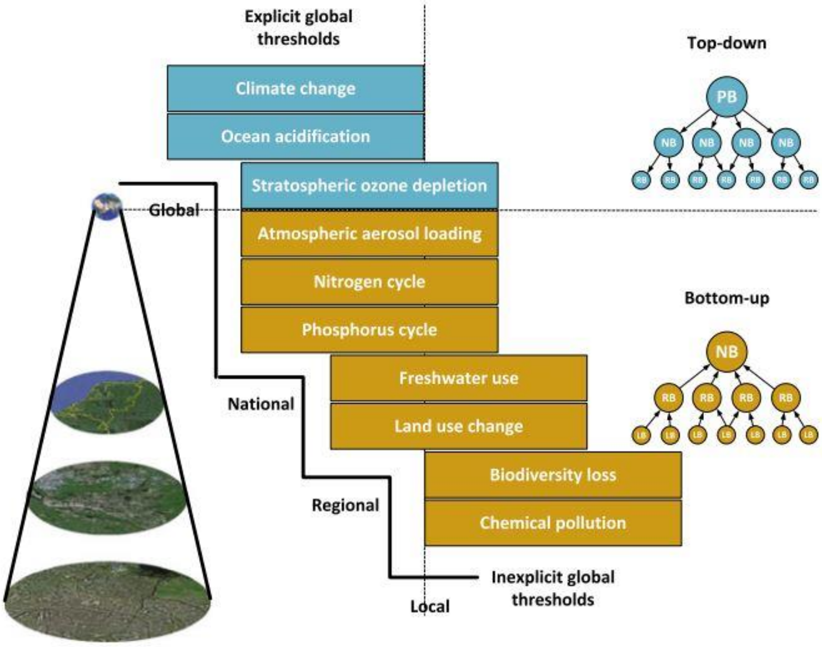

Fig. 2. Top-down and bottom-up approaches for downscaling homogenous and heterogenous planetary

boundaries, where NB = national boundary, RB = regional boundary, and LB = local boundary. Sourced from Fang (2021, p. 82), who adapted it from Rockström et al. (2009).

The social foundation was conceptualized through countries submissions to the UN Rio+20 Sustainable Development conference (Raworth, 2012). It was later updated to constitute twelve social dimensions linked with the SDGs, and twenty proposed indicators to measure and illustrate their progress (Appendix B). These indicators were selected as proxies for broader human concerns and to measure global deprivation, where boundaries were defined at zero percent, allowing no shortfall for each dimension (Raworth, 2017).

3.2 Previous downscaling operations

Previous studies have downscaled the SJS framework to sub-global scales using either *top-down* or *bottom-up* approaches for the ecological dimensions. For the social dimensions, previous studies have either applied Raworth`s (2017) global proxies (*absolute needs approach* from now), or defined indicators based on place-specific social norms (*relative needs approach* from now).

Top-down analyses have been done with a global focus (O`Neill et al., 2018; Hickel et al., 2020; Shaikh et al., 2021; Fanning et al., 2022), for big economies (Hoff et al., 2014; Häyhä et al., 2018; European Environment Agency [EEA], 2020; Lucas et al., 2020), for nations (Nykvist et al., 2013; Fanning & O`Neill, 2016; Dao et al., 2018; Lucas & Wilting, 2018; Huang et al., 2020; Allen et al., 2021) and with a local/sector focus (Hoornweg et al., 2016; Hachaichi & Baouni, 2020; Bowles et al., 2019). Bottom-up analyses have been done with a national focus (Cole et al., 2014), and local/regional focus (Dearing et al., 2014; Teah et al., 2016; McLaughlin, 2018). Kahiluoto et al. (2015) and Sayers et al. (2014) either combined top-down and bottom-up approaches for the same boundary, or applied them interchangeably. Six studies incorporated a JOS, using either an absolute needs approach (O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2021) or a relative needs approach (Cole et al., 2014; Dearing et al., 2014; Sayers et al., 2014).

A general trend across studies seems to be that high-income countries and regions (e.g., EU, UK, Switzerland) transgress more ecological boundaries than middle- and low-income countries (e.g., African states), and especially so when resources embedded in trade are considered (O`Neill et al., 2018). High-income countries also tend to fulfill more basic needs than that of low- and middle-income countries (ibid). However, a range of different indicators have been applied for the different dimensions (see Appendix C and D), and several alternative dimensions have been suggested (e.g., material footprint, household goods), which makes comparison across studies difficult.

3.3 Scalability

Previous studies relate either implicitly or explicitly to three aspects which should be considered in a downscaling operation (Häyhä et al., 2016). Firstly, as pointed out above, planetary boundaries behave different in regards to threshold behaviour. Some of their biophysical properties also lack policy-relevance, and causality needs to be established for alternative indicators, e.g., by shifting domain in the Driver-Pressure-State-Impact-Response (DPSIR) framework (Nykvist et al., 2013). Secondly, agreeing on nationally fair shares of environmental resources is politically contested, for example negotiating over countries responsibilities and rights to cut or emit greenhouse gases (GHGs). Different sharing principles can be applied to evaluate countries fair shares (see e.g., Lucas & Wilting, 2018; EEA, 2020). Lastly, populations` environmental impacts are usually measured through so-called production-based accounting (PBA), which only incorporates emissions and impacts occurring within the respective territory. Complementary methods such as environmental footprints (Wackernagel & Rees, 1996), or so-called consumption-based accounting (CBA), trace populations` environmental impacts embedded in goods and services demanded outside their respective territories. These three aspects, respectively the biophysical, ethical and socio-economic, should be considered in a downscaling operation (Häyhä et al., 2016).

4. Methods

4.1 Case study

Our chosen case Norway has been previously assessed with the SJS sustainability framework from a top-down perspective and through an absolute human needs approach (O’Neill et al., 2018; Fanning et al., 2021; Hickel et al., 2022). They found that the Norwegian economy has historically, and still is using excessive (i.e., exceeding fair shares) amounts of environmental resources to fulfill all needs of its population. However, some of the indicators they used seem inadequate to capture social trends in Norway, such as increasing inequalities (Norwegian Labour and Welfare Administration, 2017), or are poorly grounded in national policies (e.g., material and ecological footprint). Our motivation for a bottom-up and relative human needs assessment is to capture appropriate ecosystem behaviors and socio-economic trends within sound and policy relevant parameters. Norway houses many research institutes and agencies that monitor and assess ecological and social phenomena, facilitating high quality data, some which includes the Norwegian Institute of Bioeconomy Research (NIBIO), the Norwegian Institute for Nature Research (NINA), the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Environment Agency, and Statistics Norway.

4.2 Methodological framework

We developed two separate methodological frameworks to downscale the SJS to national scale, one relating to the SOS and one relating to the JOS. The nine planetary boundaries (Rockström et al., 2009; Steffen et al., 2015) served as the starting point for assessing the SOS (Appendix A). The homogenous processes were downscaled using a top-down approach (section Y, Fig. 3). For the heterogenous processes we used a bottom-up approach (section X, Fig. 3), aggregating local boundaries to national ones. These two separate approaches facilitate comparison between bottom-up analysis and previously assessed top-down analysis for *heterogenous* dimensions.

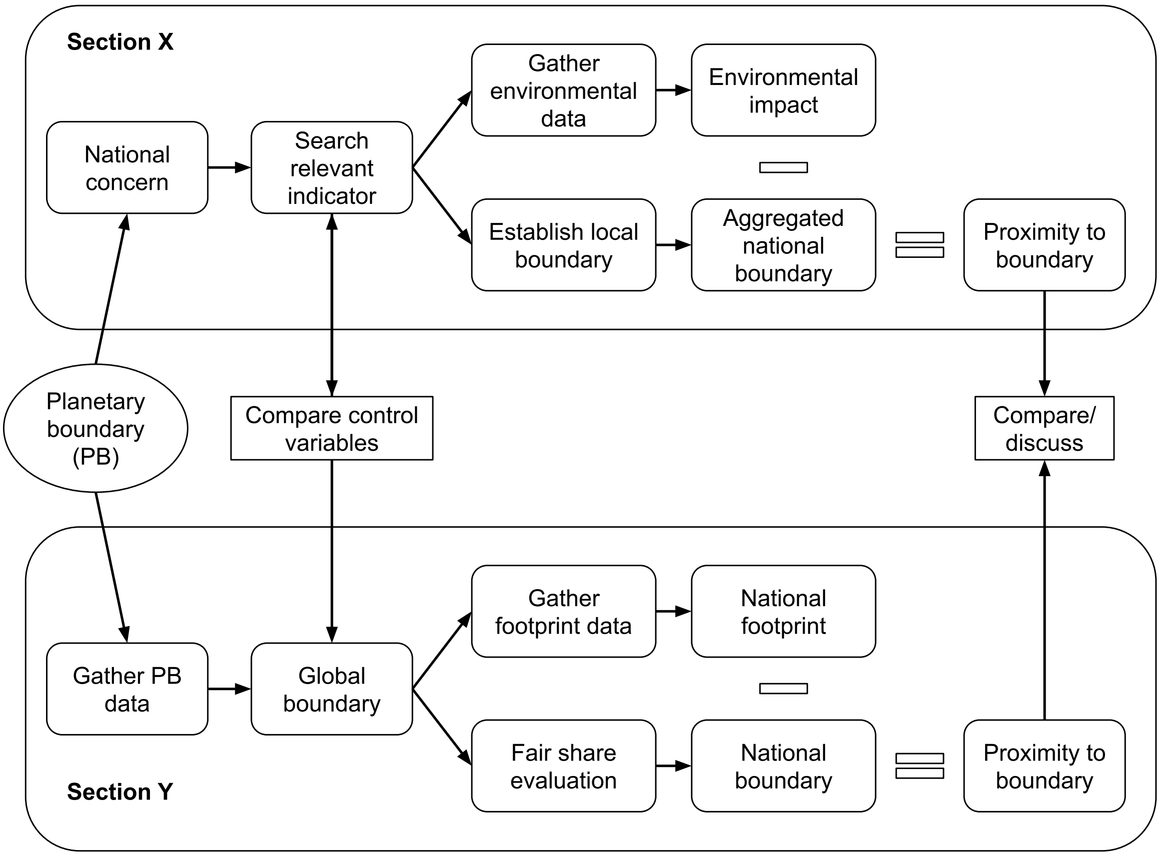

Fig. 3. Methodological framework to downscale the SOS. Section X depicts a bottom-up approach, where the environmental concern posed in each planetary boundary was analyzed towards national

environmental concerns related to territorial ecosystems, and appropriate indicators was sought and compared to previous studies (e.g., O`Neill et al., 2018; Fanning et al., 2022). Section Y depicts a top-down approach and is inspired by the Thriving Cities Initiative`s (2021, p. 22-27) methodological development for city scale. In this study, section Y is applied for the homogenous dimensions only, but the framework facilitates comparisons between studies where such an approach has been applied for heterogenous dimensions.

Fig. 4 illustrate the process for the JOS. The analysis departed from the twelve dimensions of basic needs and corresponding indicators suggested by Raworth (2017) (Appendix B). To assess each indicator`s relevance for national circumstances and concerns, we used the Voluntary National Review produced by the Norwegian government and civil society organizations (Ministry of Local Government and Modernization, 2021a) as a starting point. If original indicators were found irrelevant, alternative indicators were sought from the global SDG indicator framework (UN, 2021); a government assessment of alternative indicators to the SDGs suggested to be relevant for Norwegian circumstances (Meld. St. 40 (2020-2021)); and/or Statistics Norway`s (2020) review of potential human rights indicators. Selection criteria for each indicator was that it existed publicly available and reliable data with timeseries, and that public policy (or alternative targets if not present) addressed the indicator and could be operationalized quantitively to constitute a social boundary.

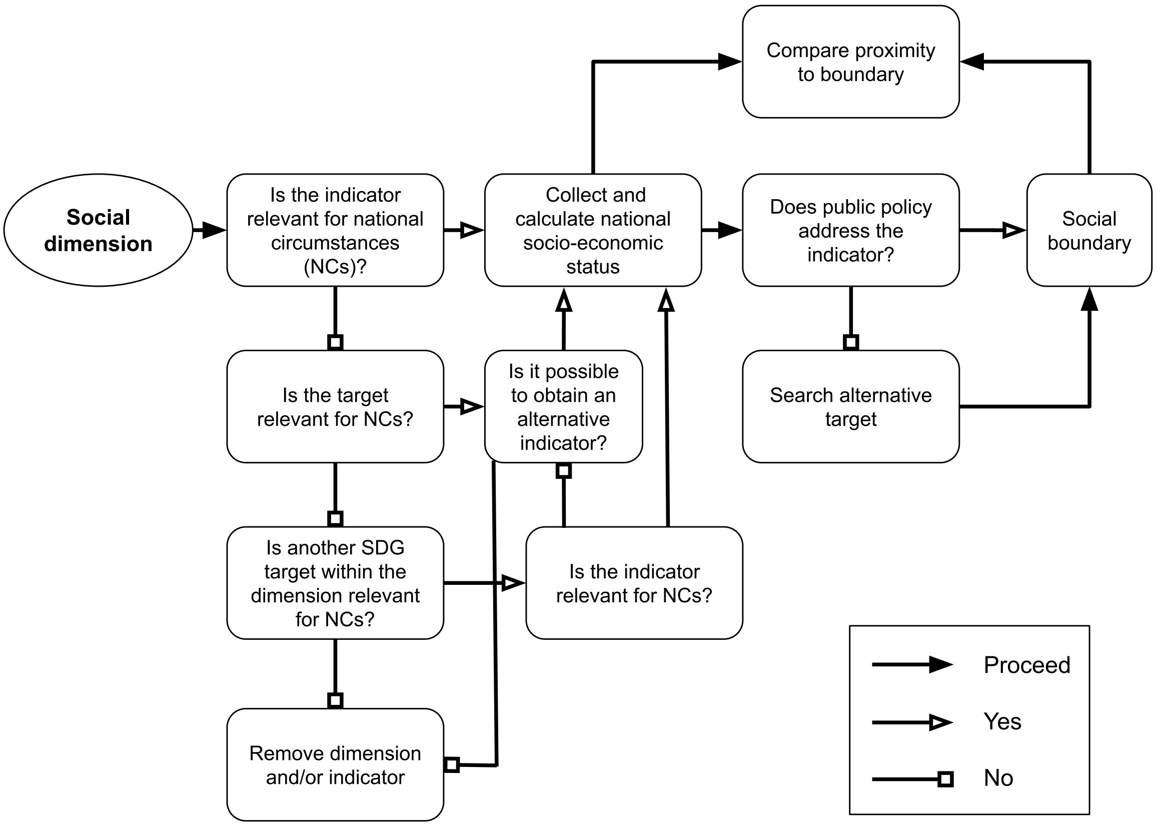

Fig. 4. Methodological framework to downscale the JOS. If the original indicator from Raworth (2017) or related SDG targets and indicators were found irrelevant to national circumstances, or alternative indicators could not be operationalized, the dimension and/or indicator was excluded.

In the following chapters 4.3 and 4.4 we summarize our method for each ecological and social dimension. An elaborated description of each dimension is available in Appendix F, whilst an overview of the sources used is provided in Appendix E.

4.3 Safe operating space (SOS)

4.3.1 Homogenous processes

In the following we assess the planetary boundaries *climate change* and *ocean acidification*. Although *stratospheric ozone depletion* is one of the planetary boundaries considered to be homogenous, it is excluded in this study as i) the ozone layer is recovering following the international efforts to reduce anthropogenic ozone-depleting substances following the Montreal protocol (World Meteorological Organization, 2018), and ii) because Norway has already phased out all CFC gasses within its territory.

4.3.1.1 Climate change

Rockström et al.`s (2009) original boundary for *climate change* (350 ppm) is already transgressed (414 ppm) (National Oceanic and Atmospheric Administration, 2021). A control variable with more policy relevance according to the DPSIR framework was selected, and expressed as the *remaining cumulative greenhouse gas emissions (excluding land cover changes) for a 50% chance to stay below a 1.5°C increase by 2055 compared with pre-industrial level*. We modified the methodology of Dao et al. (2018, p. 53) by dividing the total Norwegian population based on yearly average estimates from 1990 up to 2054 (CHP_{1990_2054}) with that of the world`s (WP_{1990_2054}). We also updated past world GHG emissions from 1990 up to 2019 (PE_W), and the remaining carbon budget from 2020 onwards (FE_W). Instead of using yearly budgets until the phase out year based on population projections (Dao et al., 2018), we demonstrate the results as cumulates following Fanning et al. (2022), where the boundary value signifies the national fair share of GHGs from the global budget. The current status for Norway (FE_{CH}) is calculated as follows:

$$FE_{CH} = CHP_{1990\_2054} / WP_{1990\_2054} * (PE_W + FE_W) - PE_{CH} \qquad (1)$$

where PE_{CH} signify emissions induced by the Norwegian economy from 1990 up to 2020. The selected phase out year of 2055 reflects the political ambition of reducing GHGs with 90-95% by 2050 from 1990 level (Meld. St. 13 (2020-2021), p. 34), assuming a complete phase out by 2055. Our selected reference year of 1990 reflects when climate change emerged on the political agenda and the first climate polices were made in Norway (St.meld. 46 (1988-89)).

4.3.1.2 Ocean acidification

Although Rockström et al. (2009) used aragonite ion concentration in the ocean surface as a control variable for *ocean acidification*, we applied a more policy friendly indicator according to the DPSIR framework, expressed as the *remaining cumulative emissions of carbon dioxide from human activities to maintain an acceptable calcium carbonate saturation state* **Ω**. We first used Dao et al.`s (2018, Appendix A, p. 20-21) methodology to find a global carbon dioxide (CO_2) budget (E_1):

$$E_1 = (ppm_l - ppm_c) \cdot C \qquad (2)$$

where C equal the quantity of emissions leading to an additional ppm of CO_2 in the atmosphere, ppm_c equal the current atmospheric CO_2 concentration, and ppm_1 signify our selected limit of atmospheric CO_2 concentration (445 ppm), based on the scientific confidence that extensive aragonite saturation in high latitudes with major ecological consequences is likely to occur between 450-500 ppm (Good et al., 2018). We further made some modifications to Dao et al.`s (2018, p. 53) approach, by using our updated global CO_2 budget from 2020 onwards (FE_W) from equation 2, and past world emissions of CO_2 from 2005 up to 2019 (PE_W). The current status for Norway (FE_{CH}) is calculated as follows:

$$FE_{CH} = CHP_{2005\_2054} / WP_{2005\_2054} * (PE_W + FE_W) - PE_{CH} \tag{3}$$

where CHP_{2005_2054} signify the total population based on yearly average estimates from 2005 up to 2054 for Norway, and WP_{2005_2054} that of the world, while PE_{CH} signify emission induced by the Norwegian economy from 2005 up to 2020. As for *climate change*, the results are displayed as cumulates. The reference year of 2005 reflects the global shift in awareness on ocean acidification as an environmental concern (Laffoley & Baxter, 2012), and national efforts to reduce the effects of acidification in the Norwegian Sea (St.meld. 37 (2008-2009). The same emission phase out year as for *climate change* is assumed for *ocean acidification*.

4.3.2 Heterogenous processes

In the following we assess the planetary boundaries *water*, *land-system change*, *changes in biosphere integrity* and *biochemical flows*, including both *nitrogen* and *phosphorus*. There has been scientific interest in finding chemical substances to constitute a boundary for *introduction of novel entities* (MacLeod et al., 2014), with a special interest for plastic (Arp et al., 2021). Although Persson et al. (2022) concluded that the safe operating space for this dimension is transgressed based on global in-capacity to monitor and assess the current amount of chemicals and engineered materials released to the environment, it remains a challenge to operationalize, and is excluded in this study. A boundary value for *atmospheric aerosol loading* has not yet been defined, and so this dimension is excluded here.

4.3.2.1 Water

Considering that water is abundant in Norway and that drinking water withdrawal is not an immediate environmental concern, we assessed the impact of hydropower production and its effect on hydro-morphological conditions in rivers and streams. A national boundary based on environmental water flow requirements for a representative set of rivers would be ideal to align with Steffen et al.`s (2015) indicator, but does not exist. Instead, we used the work to implement the European Unions` (EU) Water Framework Directive (WFD) in Norway (Direktoratsgruppen vanndirektivet, 2018) and the objective to achieve *good ecological condition* for all surface waters (Vannforskriften, 2006, § 4). To define local boundaries, we made a distinction between “natural” rivers and rivers which hydro-morphological conditions had been encroached due to hydropower production and classified as heavily modified water bodies (HMWB) (Departementsgruppen vanndirektivet, 2014). A potential transgression of the national boundary equates to the aggregated number of rivers classified as HMWB to that of “natural” rivers. The evaluation basis was all registered rivers and streams in the Vann-Nett database (www.vann-nett.no).

4.3.2.2 Land-system change and biosphere integrity

As Steffen et al. (2015) emphasised, *changes in biosphere integrity* and *land-system change* are highly connected. Considering also that the original indicators for these two dimensions have weak grounding in Norwegian policy, we developed an integrated dimension expressed as *ecosystem integrity*, based on a newly developed ecosystem evaluation system (Nybø & Evju, 2017). The selected indicator *forest ecosystem intactness compared to natural state* evaluates the current state of the forest ecosystem in Norway, compared to a reference state similar to that of ancient woodlands (Rolstad et al., 2002, p. 45). The evaluation system assesses seven overall ecosystem characteristics, including species functional- and genetic diversity, and ecological landscape patterns. We applied a national boundary at the index value 0.6 defined as *good ecological condition*, the government ambition for all ecosystems (Meld. St. 14 (2015-2016)), which signify a forest ecosystem not significantly affected by post-industrial and pervasive human influences (Framstad et al., 2021). The index scale ranges from 0 to 1, where 1 represents an intact ecosystem.

4.3.2.3 Biochemical flows

4.3.2.3.1 Nitrogen (N)

The selected indicator *total N levels in aquatic ecosystems* for *nitrogen* reflects the environmental concerns regarding N run-off from agriculture soils to freshwater lakes and coastal waters (aquatic ecosystems from now). As for the water dimension, we used a methodology developed to implement the EU WFD in Norway (Direktoratsgruppen vanndirektivet, 2018). In the assessment of ecological condition, the parameter *Total N* is a physio-chemical component, and we defined local boundaries as the limit between *good* and *moderate* condition, which differs between 250 to 775 µg N/l depending on the characteristics of different aquatic ecosystems in Norway (Direktoratsgruppen vanndirektivet, 2018, p. 111). A potential overshoot of the national boundary constitutes through the aggregated number of aquatic ecosystems in worse than *good* condition according to the classification system, which also includes the categories *very bad*, *bad* and *very good condition*, the latter indicating natural state. Our selection criteria were all aquatic ecosystems in the Vann-Nett database (www.vann-nett.no) where *Total N* had been assessed and the quality parameter was valid.

4.3.2.3.2 Phosphorous (P)

The selected *phosphorus* indicator *Agriculture soil P-fertilizer requirement (including manure and sewage sludge), corrected for mass of P in soil* is motivated by the fact that soil erosion is the greatest contributor to P-loss in arable production systems in Norway (Ulén et al., 2012). We used a balance fertilization principle to establish local boundaries, where the recommended level of plant available P (P-AL) in agriculture soils of 5-7 mg/100g (Krogstad et al., 2008) was used as a correction factor for P output (plant yields) at farm level to find fertilization requirement. The national boundary equals the aggregated P requirement of plants at farm level, and proximity to this boundary is expressed as surplus fertilization following Hanserud et al.`s (2016, p. 312) methodology, modified to include mineral fertilizer:

Surplus fertilization = Housed manure + manure from grazing animals + plant available P in total sewage sludge + mineral fertilizer – fertilizer requirement (4)

4.4 Just operating space (JOS)

After assessing all social dimensions, we found the indicators associated with *gender equality* and *social equity* insufficient to cover the broader policy concerns of national authorities towards women and vulnerable groups. Ideally, these aspects should be integrated into other social dimensions (Cole et al., 2014; Raworth, 2017). We have done so here where data exist. Migrants and people with disabilities are particular vulnerable groups focused on in Norwegian policies. As data is missing for the latter group, we have focused our analysis on gender (men and women) and different migrant groups, namely migrants and persons born in Norway with migrant parents.

4.4.1 Dimensions in which social equity and gender equality are incorporated

Raworth`s (2017) indicator for *education* is based on SDG target 4.1, and we used indicator 4.1.2 concerning completion rates for upper secondary school as our proxy for Norway. The threshold was defined at 90% based on the governments ambition of graduating nine out of ten students by 2030 (Meld. St. 21 (2020-2021), p. 7). Raworth’s (2017) indicator for *work* ascribes to SDG 8.6.1 and concerns youths not in education, employment or training (NEET), which we used as our indicator. The boundary was defined at 5% based on the government’s ambition of including all that are able and willing to work and participate in civil society (Meld. St. 32 (2020-2021), p. 7).

For *income, political voice,* and *housing,* we found Raworth's (2017) original and related SDG indicators unsuited for national circumstances. Instead, we applied the suggested indicator related to SDG 1.2, *share of children living in consistent low-income households* (Meld. St. 40 (2020-2021), p. 18) for *income*. A boundary established at zero percent reflects the political ambition to prevent child poverty (Ministry of Children, Equality and Social inclusion, 2017, p. 15).) and to prevent poverty from passing from parents to children (Ministry of Children and Families, 2020, p. 14). For *political voice* we used *women representation in municipal- and county councils* as the main indicator, but representation of non-Norwegian persons is also assessed. Although an indicator suggested to measure gender equality (Raworth, 2017; Meld. St. 40 (2020-2021), p. 60), it could arguably be used as a proxy for political voice through descriptive representation - a cornerstone in the Norwegian democracy. We assume full descriptive representation as the boundary for this dimension.

For *housing*, the *share of population living cramped*, an indicator proposed by Statistics Norway (2020), was selected. This indicator is also part of all seven definitions by Statistics Norway (2017) for the suggested indicator related to SDG 11.1; *share of disadvantaged people in the housing market* (Meld. St. 40 (2020-2021), p. 106). The political ambition to ensure that everyone has a safe and comfortable home (Ministry of Local Government and Modernisation, 2021b, p. 3) defines the boundary at zero percent.

4.4.2 Dimensions in which gender equality is incorporated

Raworth`s (2017) indicator, the *share of population without a confidential they can trust on for help if they have personal problems,* for *network* was found relevant for national circumstances, and we defined a boundary at zero percent based on government pledges to prevent loneliness and increase social support within the society (Meld. St. 19 (2018-2019), p. 49). For *health* we applied SDG indicator 3.4.2, *suicide mortality rate*, which is also emphasized by national authorities (Meld. St. 40 (2020-2021), p. 38). The governments` zero-suicide goal (Ministry of Health and Care Services, 2020, p. 4) defines the boundary.

The selected indicator for *food* is not concerned with undernutrition, but rather obesity and unhealthy diets as prominent national health concerns (Ministry of Local government and Modernisation, 2021a). The suggested alternative indicator related to SDG 2.2, *share of population overweight and obese* (Meld. St. 40 (2020-2021), p. 26), was applied. A boundary at zero percent reflects the government’s ambition to provide a healthy and varied diet for the entire population (Ministry of Health and Care Services, 2017, p. 5). For *peace & justice* we used the s*hare of the population which lately have been worried about violence or threats in place of residence* as an alternative indicator to SDG 16.1 (Meld. St. 40 (2020-2021), p. 165). The boundary is defined at zero percent reflecting the governments ambition to prevent violence in close relationships, and ensure that everyone feels safe and are free from violence, everywhere and always (Ministry of Justice and Public Security, 2021, p. 14).

4.4.3 Dimensions in which social equity and gender equality are not incorporated

Considering that access to reliable and safe energy, clean cooking facilities, drinking water and sanitation are universal in Norway, we applied SDG indicator 7.2.1 *renewable share of total energy consumption* for *energy*. Currently the Norwegian government has no concrete policy goal regarding this indicator. They are however obligated to draft EU`s renewable energy directive (Directive 2018/2001, 2018), where a renewable share of 88% by 2030 is a potential outcome for Norway (Mekki, 2019), for which we applied as our boundary. For *water & sanitation*, the alternative suggested indicator for SDG 6.4, *share of produced drinking water going to waste due to leakages in the main system* (Meld. St. 40 (2020-2021), p. 68) was chosen. A boundary was defined at 25% following the governments` commitment to the Protocol on Water and Health (Norwegian Food Safety Authority, 2014, p. 15).

5. Results

The SJS for the Norwegian economy is illustrated in Fig. 5. Selected indicators, boundary values and current status for the SOS and JOS are listed in Tables 3 and 4 respectively. Data associated with Fig. 7 and 8 is available in Supplementary Data.

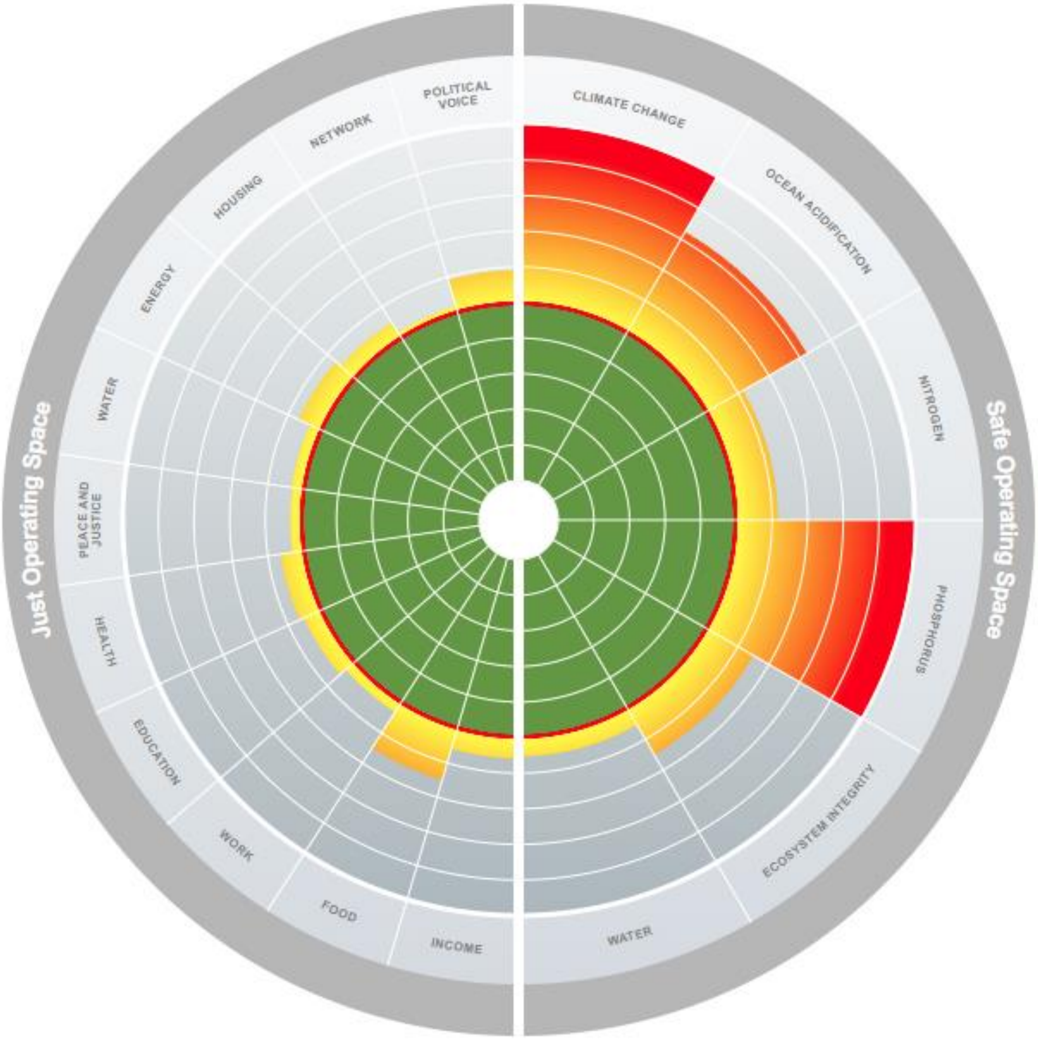

Fig. 5. The green area within the red circle represents the safe and just operating space for the Norwegian economy. Transgressions beyond the red circle either signify a shortfall of human needs (left side), or the excessive use of environmental resources (right side).

Note: Overshoots beyond 100% of the boundary value (red circle) is not captured in the diagram.

Despite excessive use of environmental resources, Norway falls short in providing needs for *all* their inhabitants (Fig. 5). All the assessed environmental limits are transgressed (Fig. 6), varying between a 3.4% overshoot for *ocean acidification* using PBA, to a 358% overshoot for *phosphorus*. Considering GHG emissions using CBA, Norway has already exhausted its fair share of the global budget for the period 1990 to 2055 with 1 284 Mt CO_2eq for *climate change*, and 443 Mt CO_2 for *ocean acidification*. In order for Norway to respect their SOSs for these two dimensions, yearly negative emissions of 37.8 Mt CO2eq and 13 Mt CO2 would be required until 2055, in addition to compensate for all pre-net-zero emissions.

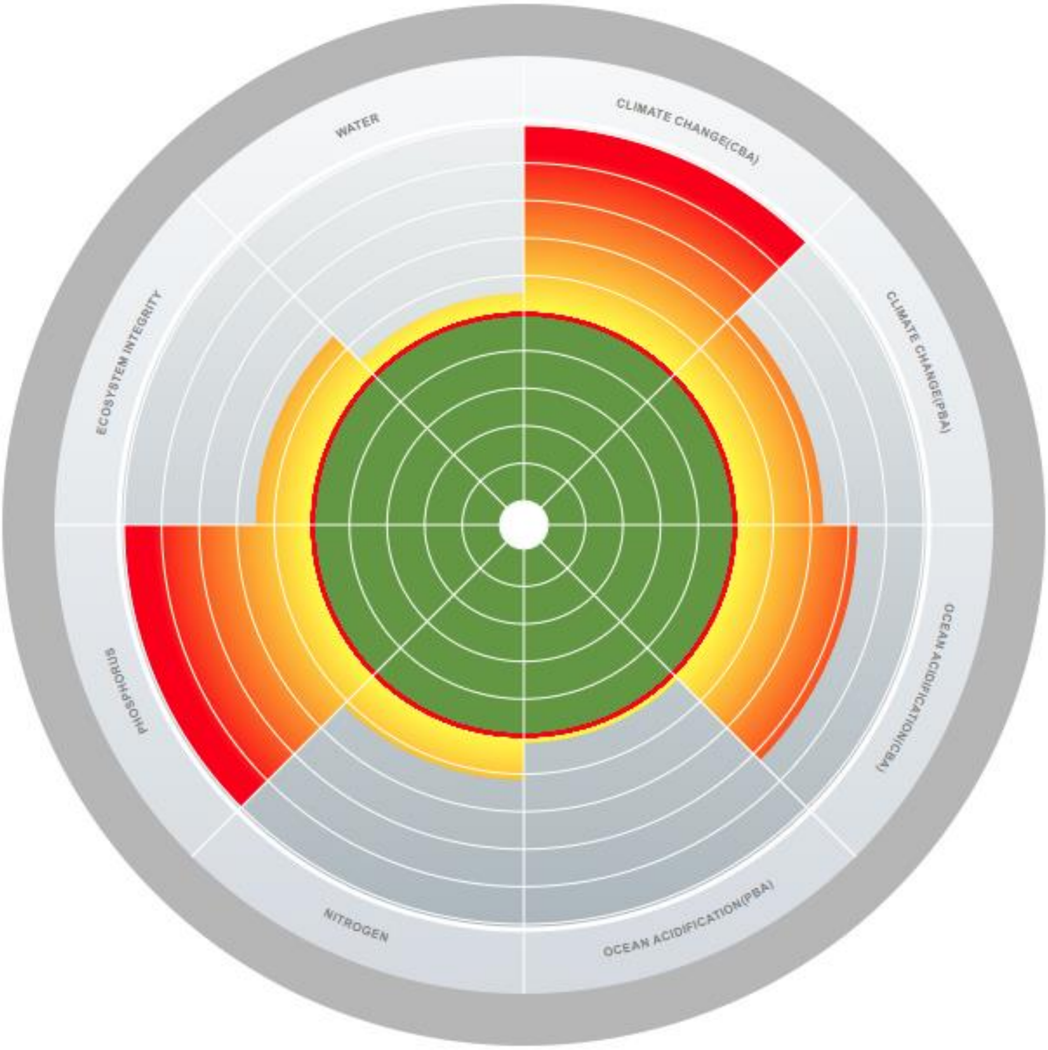

Fig. 6. The SOS for the Norwegian economy, including both production-based and consumption-based accounts for the two dimensions climate change and ocean acidification.

Note: Overshoots beyond 100% of the boundary value (red circle) is not captured in the diagram.

Table 3. Overview of the selected indicators for each ecological dimension, their units of measurement, boundary values and current statuses. The proximity to boundary describes the relationship between current status and boundary value, where deviations above 100% represents overshoots.

Ecological dimension	**Indicator**	**Unit**	**Boundary value**	**Status**	**Year(s)**	**Prox. to boundary**	**Source**
Climate change	The remaining cumulative greenhouse gas emissions (excluding land cover changes) for a 50% chance to stay below a 1.5°C increase by 2055 compared with pre-industrial level	Mt CO_2 eq.	1 129	2 413 (CBA)	1990-2020	213.8%	Eora MRIO
		Mt CO_2 eq.	1 129	1 655 (PBA)	1990-2020	146.6%	Statistics Norway
Ocean acidification	The remaining cumulative emissions of carbon dioxide from human activities to maintain an acceptable calcium carbonate saturation state **Ω**	Mt CO_2	685	1 128 (CBA)	2005-2020	164.7%	Eora MRIO
		Mt CO_2	685	708 (PBA)	2005-2020	103.4%	Statistics Norway
Nitrogen	Total N levels in aquatic ecosystems	%	100	76.7%	2021	123.3%	Vann-Nett.no
Phosphorus	Agriculture soil P-fertilizer requirement (including manure and sewage sludge), corrected for mass of P in soil	tonnes	5 462	19 560	2011	358.1%	Hanserud et al., 2016
Ecosystem integrity	Forest ecosystem intactness compared to natural state	Index 0-1	0.6	0.42 *	2020	130%	Framstad et al., 2021
Water	Hydro-morphological conditions of rivers and streams	%	100	89.4%	2021	110.6%	Vann-Nett.no

* From the scale 0-1, 1 signify best condition and 0 worst, meaning that 0.42 is an overshoot from the boundary value of 0.6.

Table 4. Overview of the selected indicators for each social dimension, their boundary values and the current statuses. The proximity to boundary describes the relationship between current status and boundary value, where deviations above 100% represents shortfalls.

Social dimension	**Indicator**	**Boundary value**	**Status**	**Year**	**Prox. to boundary**	**Source**
Income	Children (<18) living in persistent low-income households	0%	11.7 %	2020	111.7%	Statistics Norway
Food	Population (>15yr) overweight and obese (BMI >27)	0%	30%	2019	130%	Statistics Norway
Work	Youth population (15-29 years) not in education, employment or training (NEET)	5%	11.2 %	2020	106.2%	Statistics Norway
Education	Share of students completing upper secondary education within 5/6 years	90%	79.6%	2020	110.4%	Statistics Norway
Health	Suicide mortality rate	0%	11.9% *	2020	111.9 % *	Norwegian Institute of Public Health
Peace and justice	Share of population that lately have been worried about violence or threats in the place of residence	0%	6%	2018	106%	Statistics Norway
Water and sanitation	Share of produced drinking water going to waste due to leakages in the main system	25%	31.6%	2021	106.6%	Statistics Norway
Energy	Share of renewable energy in total energy consumption	88%	74.5%	2019	113.5%	Statistics Norway

Housing	Share of population living cramped	0%	9.8%	2021	109.8%	Statistics Norway
Network	Share of population without a confidential they can trust on for help if they have personal problems	0%	3%	2019	103%	Statistics Norway
Voice	Women representation in municipal- and county councils	100%	81.8%	2019	118.2%	Statistics Norway

* Figures are upscaled for visualization. The numbers of suicides equal 11.90 per 100 000 inhabitants, or equivalent to 0.0119% of the population (11.90 / 100 000 * 100).

Overall, the Norwegian economy is currently meeting many of its citizen’s needs and rights (Fig. 5), however falling notably short on *food* (30%) and *political voice* (18.2%). There exists as well substantial disparity across demographic groups (Table 5) not captured in Fig. 5. Migrant children and youths are falling particularly short on *work* (20.1%), *education* (27.4%) and *income* (48.4%), while non-Norwegians are poorly represented in local/regional political institutions (81.5%). When accounting for gender disparities, men fall shorter on *health*, *food* and *education*, while women do so for *political voice* and *peace & justice*.

Table 5. Social disparities across gender and demographics groups. For each group, the current status demonstrates shortfalls relative to the group`s population size. Figures are illustrated as the current status` proximity to the boundary value, where deviations above 100% represents shortfalls.

Social dimension	**Overall population**	**Female pop.**	**Male pop.**	**Migrant pop.**	**Norwegian born, migrant parents**	**Remaining population**
Income	111.7%	n/a	n/a	148.4%	133.2%	105.8%
Food	130%	126%	135%	n/a	n/a	n/a
Work	106.2%	106.1%	106.2%	120.1%	n/a	103.8%
Education	110.4%	106.5%	114.2%	127.4%	111.8%	108.4%
Health*	111.9%	106.5%	117.2%	n/a	n/a	n/a
Peace and justice	106%	109%	102.9%	n/a	n/a	n/a

Water and sanitation	106.6%	n/a	n/a	n/a	n/a	n/a
Energy	113.5%	n/a	n/a	n/a	n/a	n/a
Housing	109.8%	109.7%	110%	122.4%	n/a	107%
Network	103%	102%	103%	n/a	n/a	n/a
Political voice	n/a	118.2%	n/a	181.5% **		n/a

Note: Gender and demographic data for *water and sanitation* and *energy*, as well as the overall population for *political voice,* are not applicable. Otherwise, n/a signify that data is not available.

* See asterisk under Table 4. ** Statistics Norway don't separate between migrants and persons that are born in Norway with migrant parents in public records when accounting for municipal/county representatives and population eligible for voting, but uses the variables i) land background, ii) Norwegian citizens with migrant background, and iii) foreign citizens with voting right. The data material across the two former groups, compared to the three latter groups may deviate somewhat but not substantially (Ø. Kleven, personal communication, 28. April 2022). The combination of the three latter groups is expressed as non-Norwegian persons here.

The Norwegian economy has been successful in providing a greater overall share of the population with *education*, clean *energy* and *peace & justice* over a period of time (Fig. 7). However, it has not been able to "close the gap" for a share of the population, as the majority of social trends have remained stable over time, or even worsened as is the case for *food* and *income*. This is so despite the country`s high cumulative appropriation of environmental resources over a period of time (Fig. 8).

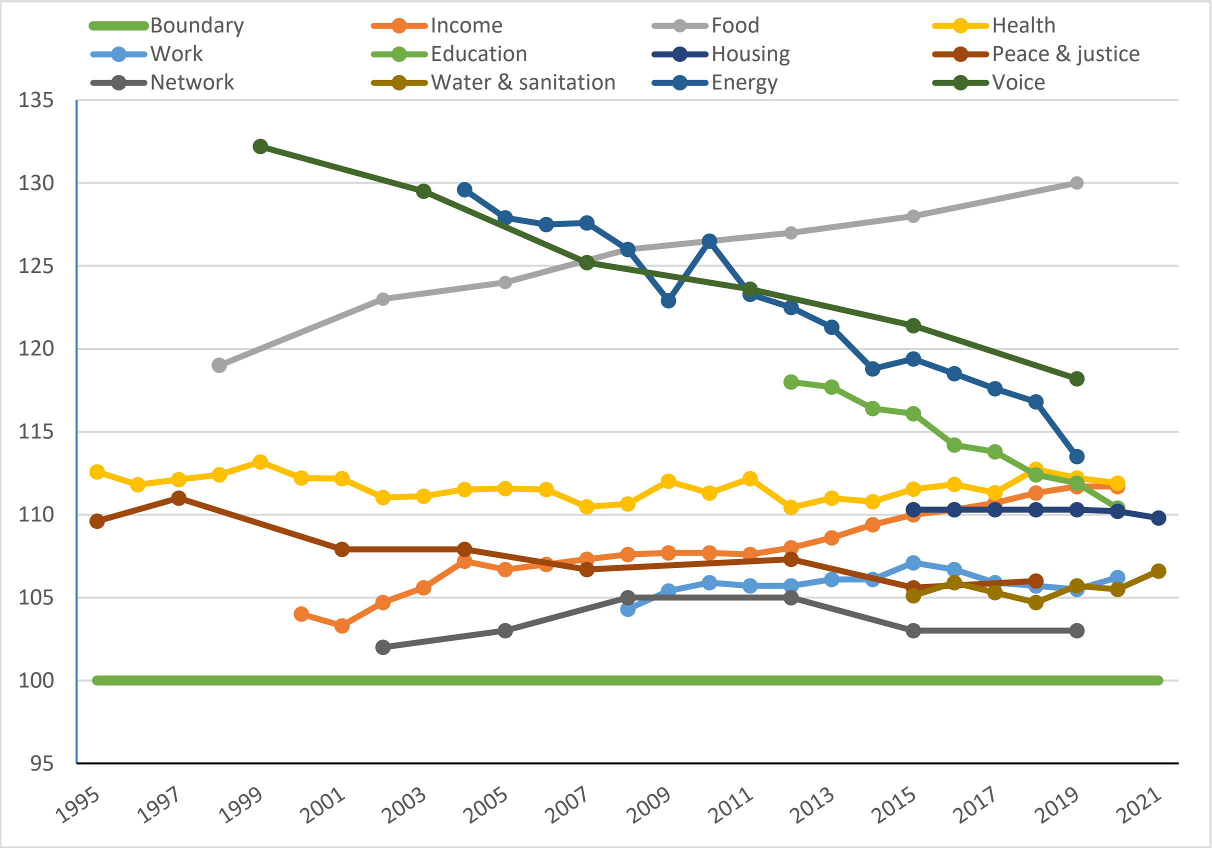

Fig. 7. Social trends compared to the JOS (below the green line) over the period 1995 to 2021. The Y axis describes percentage shortfall from the boundary value (100%) for the overall population. Social trends across genders and demographic groups are demonstrated in Figs. F.1-F.9 in Appendix F, while the data points for these figures are available in Supplementary Data.

Note: The health dimension is adjusted for visualisation as emphasised in Table 4.

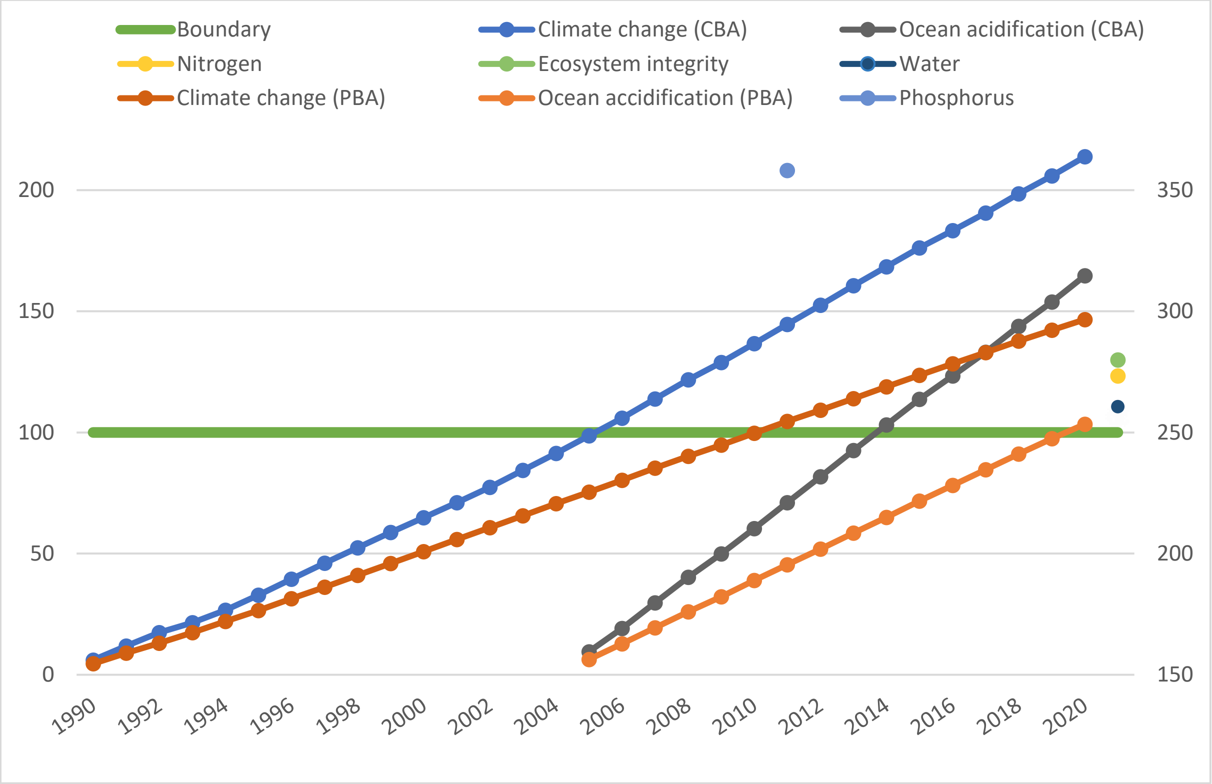

Fig. 8. Ecological trends compared to the SOS (below the green line) over the period 1990 to 2020. GHG emissions for climate change and ocean acidification are displayed as cumulates, whilst the remaining dimensions are displayed as yearly budgets.

Note: *Phosphorus* is the only dimension associated with the secondary Y axis.

---

6. Discussion

6.1 The issue of scales

This study answers the call for bottom-up perspectives where human needs and impacts are assessed place specifically within the context of global sustainability challenges (Downing et al., 2019). To downscale the ecological processes described in the SJS framework has proven to be a particular challenge. Regarding Häyhä et al.`s (2016) threefold requirement for sub-global analyses, we have focused particularly on the biophysical element for the heterogenous planetary boundaries, whilst remained less specific about the socio-economic and ethical considerations. Although we acknowledge the importance of the three, there seems to be some inherent tradeoffs between them.

While a bottom-up study like this asserts meaningful biophysical limits, it does not account for Norway`s demand for resources abroad, and automatically assumes a sovereign right over territorial resources. On the other hand, top-down analyses have been effective in accounting for environmental impacts outside territorial borders through footprint assessments, measured against fairs shares of global resource budgets (O`Neill et al., 2018; Fanning et al., 2022; Hickel et al., 2022), but shares that potentially constitutes as weak biophysical parameters for the respective territories. Future consensus on which indicators to apply across scales can reduce these tradeoffs, and spur cross-scale and comparative studies through e.g., hybrid downscaling approaches (Zhang et al., 2022).

However, universalizing indicators may also reduce the frameworks` relevance at sub-global scales, if these are incapable of describing place-specific challenges to environmental degradation. This seems to be evident in our study for *land-system change* and *biosphere integrity*, where we instead operationalized an integrated boundary which we evaluate as sound within the environmental concerns of the original boundaries, as well as being highly policy relevant. More spatial and scale specific indictors seems also preferable when considering the question of data availability, where lack of data was the main reason as for why we selected alternative indicators for *nitrogen* and *water*. Zipper et al.`s (2020) approach of integrating local and global boundaries for management and governance at sub-global scales can serve as an example of the complementary use of different indicators.

6.2 Applying polices to define limits

Using contemporary policy frameworks as tools to define environmental and social limits increases the relevance of the SJS framework for national stakeholders, but will most likely illusion environmental and social responsibilities. Our JOS for example accepts that one of ten upper secondary students do not graduate, and that a quarter of produced drinking water goes to waste. Applying baseline years for *climate change* (1990) and *ocean acidification* (2005) in line with climate policies, basically disregards previous emissions induced by the Norwegian economy. Compared to Hickel (2020) that operationalized the original boundary of 350 ppm CO_2 and accounted emissions from 1850 up to 2015, our boundaries are less strict and less fair. Both the environmental and social dimensions would need to be revised in future analyses to comply with aspirational goals and policies as society develops, which complicates the tracking of progress over time. Nevertheless, defining a SJS at sub-global scales through democratically agreed upon laws and pledges can arguably increase its legitimacy (Pasgaard & Dawson, 2019).

6.3 Limitations and future research

Our study takes a more holistic approach towards gender equality and social equity compared to previous studies (e.g., Cole et al., 2014; O`Neill et al., 2018), by integrating these aspects into several other social dimensions. We did not however find a satisfactory way to visualize our results beyond descriptive text, something the SJS sustainability framework (Raworth, 2017) seems incapable of. Besides finding sound ways of integrating gender equality and social equity more strongly into future SJSs, visualization strategies to communicate social disparities across demographic groups should be prioritized.

Our results showing a 420 Mt higher CO_2-emissions burden related to consumptive activities than of territorial activities could seem ambiguous considering that Norway is a major oil and gas producer. Alternatively, one can account CO_2 emissions embedded in exported fossil fuels to the extracting territory (Davis et al., 2011; Erickson & Lazarus, 2013), which would yield a considerably higher emission burden to the Norwegian economy (Andrew, 2021). To showcase the extra responsibilities of fossil fuel producing territories, future studies can incorporate such extraction-based accounts.

We were not able to produce timeseries for the heterogonous ecological boundaries. Data from the Vann-nett portal for *nitrogen* and *water* are snapshots of current conditions based on the latest registration, whilst previous registrations are not archived. The evaluation system for *ecosystem integrity* is newly established and has only been assess for the year 2020. For *phosphorus* it is possible to generate timeseries, as NIBIO collects P-AL data from farms on a regular basis, but we were not able to conduct such an analysis due to time constraints.

7. Conclusion

This study downscales the Safe and Just operating Space (SJS) sustainability framework to national scale through a bottom-up perspective, using Norway as a case. We develop an analytical framework which takes explicit account of the different biophysical properties of planetary boundaries, and expresses the place-specific lived human experience. To increase the policy relevance of the SJS framework to national stakeholders, we define environmental and social limits within contemporary policy frameworks. Our findings suggest that the Norwegian economy is providing many needs for its population overall, but to high ecological costs, exceeding all the assessed planetary boundaries. It has however failed to “close the gap” for some, despite high cumulative appropriation of environmental resources over a period of time. In addition, social inequities prevail when accounting for different demographic groups, migrants falling particularly short on income, work, education and political voice. While challenges in translating global sustainability criteria across scales remains, we make the case for a more context-specific and policy-relevant SJS for the national scale.

Acknowledgements

This research did not receive any funding. We want to express our deep appreciation to Nikolai Reed-Larsen, Gregor Gundersen and Trygve Grant, students associated with Noroff – School of technology and digital media in Bergen, for their effort and time spent developing the artwork in this study, and thank their supervisor Jon Fossheim for facilitating the collaboration. Many thanks to the working group part of the project “Embedding planetary boundaries in science, policy and education” within the framework of “NMBU Sustainability Arenas 2021-2024” for feedback and suggestions during a workshop held in Oslo, Norway, March 2022. Thanks also to Lisa Hernandez (Norwegian Environment Agency) for input on the WFD classification system, to Øyvin Kleven (Statistics Norway) for clarifications regarding population data, to Marianne Bechmann (Norwegian Institute of Bioeconomy Research) for literature suggestions, and to Lukas Gode (Norwegian University of Life Sciences) for input on emission-accounting methodologies.

I am grateful to Erik Gomez-Baggethun and Morten Jerven for supervision throughout this master thesis project, and thank you for the support and guidance which facilitated this paper.

References

Allen, C., Metternicht, G., Wiedmann, T., & Pedercini, M. (2021). Modelling national transformations to achieve the SDGs within planetary boundaries in small island developing states. *Global Sustainability, 4*. https://doi.org/10.1017/sus.2021.13

Andrew, R. (2021, September 1). Norway`s emissions exports. *Robbie Andrew*. https://folk.universitetetioslo.no/roberan/t/export_emissions.shtml

Arp, H. P. H., Kühnel, D., Rummel, C., MacLeod, M., Potthoff, A., Reichelt, S., Rojo-Nieto, E., Schmitt-Jansen, M., Sonnenberg, J., Toorman, E., & Jahnke, A. (2021). Weathering Plastics as a Planetary Boundary Threat: Exposure, Fate, and Hazards. *Environmental Science & Technology, 55*(11), 7246–7255. https://doi.org/10.1021/acs.est.1c01512

Barnosky, A., Hadly, E., Bascompte, Berlow, E. L., Brown, J. H., Fortelius, M., Getz, W. M., Harte, J., Hastings, A., Marquet, P. A., Martinez, N. D., Mooers, A., Roopnarine, P., Vermeij, G., Williams, J. W., Gillespie, R., Kitzes, J., Marshall, C., Matzke, N., … Smith, A. (2012). Approaching a state shift in Earth's biosphere. *Nature, 486*, 52–58. https://doi.org/10.1038/nature11018

Biggs, R., G. D. Peterson, & J. C. Rocha. (2018). The Regime Shifts Database: a framework for analyzing regime shifts in social-ecological systems. *Ecology and Society 23*(3), Article e9. https://doi.org/10.5751/ES-10264-230309

Bishop, R. C. (1978). Endangered species and uncertainty: the economics of a safe minimum standard. *American journal of agricultural economics*, *60*(1), 10-18. https://doi.org/10.2307/1240156

Bowles, N., Alexander, S., & Hadjikakou, M. (2019). The livestock sector and planetary boundaries: A 'limits to growth' perspective with dietary implications. *Ecological Economics*, *160,* 128-136. https://doi.org/10.1016/j.ecolecon.2019.01.033

Brook, B. W., Ellis, E. C., Perring, M. P., Mackay, A. W., & Blomqvist, L. (2013). Does the terrestrial biosphere have planetary tipping points? *Trends in Ecology & Evolution, 28*(7), 396-401. https://doi.org/10.1016/j.tree.2013.01.016

Carpenter, S. R., & Bennett, E. M. (2011). Reconsideration of the planetary boundary for phosphorus. *Environmental Research Letters, 6*(1), Article e014009. https://doi.org/10.1088/1748-9326/6/1/014009

Chiappero-Martinetti E. (2014) Basic Needs. In: Michalos A.C. (eds) Encyclopedia of Quality of Life and Well-Being Research. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0753-5_150

Cole, M.J., Bailey, R.M. & New, M.G. (2014). Tracking sustainable development with a national barometer for South Africa using a downscaled "safe and just space" framework. *Proceedings of the National Academy of Sciences, 111*(42), e4399-e4408. https://doi.org/10.1073/pnas.1400985111

Costanza, R., & Daly, H. (1992). Natural Capital and Sustainable Development. *Conservation Biology*, *6* (1), 37-46. https://doi.org/10.1046/j.1523-1739.1992.610037.x

Costanza, R., Fisher, B., Ali, S., Beer, C., Bond, L., Boumans, R., ... & Snapp, R. (2007). Quality of life: An approach integrating opportunities, human needs, and subjective well-being. *Ecological economics*, *61*(2-3), 267-276. https://doi.org/10.1016/j.ecolecon.2006.02.023

Daly, H. E. (1990). Towards some operational principles of sustainable development. *Ecological Economics*, *2*, 1-6. https://doi.org/10.1016/0921-8009(90)90010-R

Dao, H., Peduzzi, P., & Friot, D. (2018). National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland. *Global Environmental Change*, *52*, 49-57. https://doi.org/10.1016/j.gloenvcha.2018.06.005

Davis, S. J., Peters, G. P., & Caldeira, K. (2011). The supply chain of CO2 emissions. *Proceedings of the National Academy of Sciences, 108*(45), 18554-18559. https://doi.org/10.1073/pnas.1107409108

de Vries, W., Kros, J., Kroeze, C., & Seitzinger, S. P. (2013). Assessing planetary and regional nitrogen boundaries related to food security and adverse environmental impacts. *Current Opinion in Environmental Sustainability, 5*(3-4), 392-402. https://doi.org/10.1016/j.cosust.2013.07.004

Dearing, J.A., Wang, R., Zhang, K., Dyke, J.G., Haberl, H., Hossain, M.S., Langdon, P.G., Lenton, T.M., Raworth, K., Brown, S. and Carstensen, J. (2014). Safe and just operating spaces for regional social-ecological systems. *Global Environmental Change*, *28*, 227-238. https://doi.org/10.1016/j.gloenvcha.2014.06.012

Departementsgruppen vanndirektivet. (2014). *Veileder 01:2014 Sterkt modifiserte vannforekomster*. Retrieved from https://www.vannportalen.no/veiledere/veileder-012014-sterkt-modifiserte-vannforekomster/

Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (Text with EEA relevance.). (2018). Document 32018L2001. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001

Direktoratsgruppen vanndirektivet. (2018). *Veileder 02:2018 Klassifisering av miljøtilstand i vann.* Retrieved from https://www.vannportalen.no/veiledere/klassifiseringsveileder/

Downing, A. S., Bhowmik, A., Collste, D., Cornell, S. E., Donges, J., Fetzer, I., Häyhä, T., Hinton, J., Lade, S., & Mooij, W. M. (2019). Matching scope, purpose and uses of planetary boundaries science. *Environmental Research Letters, 14*(7), Article e073005. https://doi.org/10.1088/1748-9326/ab22c9

Doyal, L., & Gough, I. (1991). *A theory of Human Need*. https://link.springer.com/book/10.1007/978-1-349-21500-3

European Environment Agency. (2020). *Is Europe living within the limits of our planet? An assessment of Europe's environmental footprints in relation to planetary boundaries*. (EEA report number 1/2020). European Environment Agency & Swizz Federal Office for the Environment. Retrieved from https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

Elliot, T., Torres-Matallana, J. A., Goldstein, B., Almenar, J. B., Gómez-Baggethun, E., Proença, V., & Rugani, B. (2022). An expanded framing of ecosystem services is needed for a sustainable urban future. *Renewable and Sustainable Energy Reviews, 162*, Article e112418. https://doi.org/10.1016/j.rser.2022.112418

Erickson, P., & Lazarus, M. (2013). *Accounting for greenhouse gas emissions associated with the supply of fossil fuels* (Discussion Brief). Seattle: Stockholm Environment Institute. Retrieved from: https://www.jstor.org/stable/resrep00382?seq=1

Fang, K. (2021). *Environmental Footprints: Assessing Anthropogenic Effects*. https://link.springer.com/content/pdf/10.1007/978-3-030-61018-0.pdf

Fanning, A. L., & O`Neill, A. W. (2016). Tracking resource use relative to planetary boundaries in a steady-state framework: A case study of Canada and Spain. *Ecological Indicators, 69*, 836-849. https://doi.org/10.1016/j.ecolind.2016.04.034

Fanning, A. L., O'Neill, D. W., Hickel, J., & Roux, N. (2022). The social shortfall and ecological overshoot of nations. *Nature Sustainability*, *5*(1), 26-36. https://doi.org/10.1038/s41893-021-00799-z

Framstad, E., Berglund, H., Jacobsen, R. M., Jacokbsson, S., Ohlson, M., Sverdrup-Thygeson, A., & Töpper, J. (2021). *Vurdering av økologisk tilstand for skog i Norge i 2020*. (NINA rapport 2000). Retrieved from https://brage.nina.no/nina-xmlui/handle/11250/2739886

Gerten, D., Hoff, H., Rockström, J., Jägermyr, J., Kummu, M., & Pastor, A. V. (2013). Towards a revised planetary boundary for consumptive freshwater use: role of environmental flow requirements. *Current Opinion in Environmental Sustainability, 5*(6), 551-558. https://doi.org/10.1016/j.cosust.2013.11.001

Gómez-Baggethun, E. (2020). More is more: Scaling political ecology within limits to growth. *Political Geography*, *76*(2020), Article e102095. https://doi.org/10.1016/j.polgeo.2019.102095

Good, P., Bamber, J., Halladay, K., Harper, A. B., Jackson, L. C., Kay, G., Kruijt, B., Lowe, J. A., Phillips, O. L., Ridley, J., Srokosz, M., Turley, C., & Williamson, P. (2018). Recent progress in understanding climate thresholds: Ice sheets, the Atlantic meridional overturning circulation, tropical forests and responses to ocean acidification. *Progress in Physical Geography: Earth and Environment*, *42*(1), 24-60. https://doi.org/10.1177%2F0309133317751843

Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: understanding transformations in human and natural systems*. Washington DC: Island press,

Haberl, H., Wiedenhofer, D., Pauliuk, S., Krausmann, F., Müller, D. B., & Fischer-Kowalski, M. (2019). Contributions of sociometabolic research to sustainability science. *Nature Sustainability 2*, 173–184. https://doi.org/10.1038/s41893-019-0225-2

Hachaichi, M., & Baouni, T. (2020). Downscaling the planetary boundaries (Pbs) framework to city scale-level: De-risking MENA region's environment future. *Environmental and Sustainability Indicators*, *5*, Article e100023. https://doi.org/10.1016/j.indic.2020.100023

Hanserud, O. S., Brod, E., Øgaard, A. F., Müller, D. B., & Brattebø, H. (2016). A multi-regional soil phosphorus balance for exploring secondary fertilizer potential: the case of Norway. *Nutrient Cycling in Agroecosystems*, *104*(3), 307-320. https://doi.org/10.1007/s10705-015-9721-6

Hickel, J. (2020). Quantifying national responsibility for climate breakdown: an equality-based attribution approach for carbon dioxide emissions in excess of the planetary boundary. *The Lancet Planetary Health, 4*(9), e399-e404. https://doi.org/10.1016/S2542-5196(20)30196-0

Hickel, J., O'Neill, D. W., Fanning, A. L., & Zoomkawala, H. (2022). National responsibility for ecological breakdown: a fair-shares assessment of resource use, 1970–2017. *The Lancet Planetary Health*, *6*(4), e342-e349. https://doi.org/10.1016/S2542-5196(22)00044-4

Hoff, H., Nykvist, B., & Carson, M. (2014). *Living Well, Within the Limits of Our Planet? Measuring Europe's Growing External Footprint*. Stockholm Environment Institute. Retrieved from https://www.researchgate.net/profile/Marcus-Carson/publication/272488205_Living_well_within_the_limits_of_our_planet_Measuring_Europe%27s_growing_external_footprint/links/54eefe800cf2e55866f3d01a/Living-well-within-the-limits-of-our-planet-Measuring-Europes-growing-external-footprint.pdf

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, *4*, 1-23. https://doi.org/10.1146/annurev.es.04.110173.000245

Hoornweg, D., Hosseini, M., Kennedy, C. & Behdadi, A. (2016). An urban approach to planetary boundaries. *Ambio*, *45*(5), 567-580. https://doi.org/10.1007/s13280-016-0764-y

Huang, L. H., Hu, A. H., & Kuo, C-H. (2020). Planetary boundary downscaling for absolute environmental sustainability assessment — Case study of Taiwan. *Ecological Indicators*, *14*, Article e106339. https://doi.org/10.1016/j.ecolind.2020.106339

Hughes, T. P., Carpenter, S., Rockström, J., Scheffer, M., & Walker, B. (2013). Multiscale regime shifts and planetary boundaries. *Trends in Ecology & Evolution*, *28*(7), 389-395. https://doi.org/10.1016/j.tree.2013.05.019

Hughes, T. P., Linares, C., Dakos, V., Van De Leemput, I. A., & Van Nes, E. H. (2013). Living dangerously on borrowed time during slow, unrecognized regime shifts. *Trends in Ecology & Evolution*, *28*(3), 149-155. https://doi.org/10.1016/j.tree.2012.08.022

Häyhä, T., Lucas, P. L., van Vuuren, D. P., Cornell, S. E., & Hoff, H. (2016). From Planetary Boundaries to national fair shares of the global safe operating space—How can the scales be bridged? *Global Environmental Change*, *40*, 60-72. https://doi.org/10.1016/j.gloenvcha.2016.06.008

Häyhä, T., Cornell, S.E., Hoff, H., Lucas, P., & van Vuuren, D. (2018). Operationalizing the concept of a safe operating space at the EU level – first steps and explorations. Stockholm Resilience Centre Technical Report, prepared in collaboration with Stockholm Environment Institute (SEI) and PBL Netherlands Environmental Assessment Agency. Stockholm Resilience Centre, Stockholm University, Sweden. Retrieved from https://stockholmuniversity.app.box.com/s/hajg8ru0ihvxj8d5topjqp87285c4rj6

IPCC. (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O.

Yelekçi, R. Yu, & B. Zhou (eds.)]. In Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Jax, K. (2014). Thresholds, tipping points and limits. Open-NESS Reference Book. EC FP7 Grant Agreement, (308428). www.opennessproject.eu/library/reference-book

Johnson, C. J. (2013). Identifying ecological thresholds for regulating human activity: Effective conservation or wishful thinking? *Biological Conservation*, *168*, 57-65. https://doi.org/10.1016/j.biocon.2013.09.012

Kahiluoto, H., Kuisma, M., Kuokkanen, A., Mikkilä, M., & Linnanen, L. (2015). Local and social facets of planetary boundaries: right to nutrients. *Environmental Research Letters, 10*(10), Article e104013. https://doi.org/10.1088/1748-9326/10/10/104013

Kapp, W. (1950). *The social costs of private enterprise*. http://www.kwilliam-kapp.de/documents/SCOPE.pdf

Kennedy, C., Cuddihy, J., & Engel-Yan, J. (2007). The Changing Metabolism of Cities. *Industrial Ecology, 11*(2), 43-59. https://doi.org/10.1162/jie.2007.1107

Krogstad, T., Øgaard, A. F. & Kristoffersen, A. Ø. (2008). New P recommendations for grass and cereals in Norwegian agriculture. Nordic Association of Agricultural Scientists (NJF) *Report, 4* (4): 42-46.

Laffoley, D. d'A., & Baxter, J.M. (eds). (2012). Ocean Acidification: The knowledge base 2012. Updating what we know about ocean acidification and key global challenges. European Project on Ocean Acidification (EPOCA), UK Ocean Acidification Research Programme, (UKOA), Biological Impacts of Ocean Acidification (BIOACID) and Mediterranean Sea Acidification in a Changing Climate (MedSeA). 8pp. Retrieved from https://www.oceanacidification.org.uk/pdf/IOA_KnowledgeBase-pdf.pdf

Lenton, T. M, Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., & Schellnhuber, H. J. (2008). Tipping elements in the Earth`s climate system. *Proceedings of the National Academy of Sciences, 105*(6), 1786-1793. https://doi.org/10.1073/pnas.0705414105

Levin, S. A. (1992). The problem of Pattern and Scale in Ecology: The Robert H. MacArthur Award Lecture. *Ecology, 73*(6), 1943-1967. https://doi.org/10.2307/1941447

Lucas, P., & Wilting, H. (2018). *Using planetary boundaries to support national implementation of environment-related sustainable development goals.* PBL Netherlands Environmental Assessment Agency, The Hague. (Publication number 2748). Retrieved from: https://www.pbl.nl/sites/default/files/downloads/Using_planetary_boundaries_to_support_national_implementation_of_environment-related_Sustainable_Development_Goals_-_2748.pdf

Lucas, P. L., Wilting, H. C., Hof, A. F., & van Vuuren, D. P. (2020). Allocating planetary boundaries to large economies: Distributional consequences of alternative perspectives on distributive fairness. *Global Environmental Change*, *60*, Article e102017. https://doi.org/10.1016/j.gloenvcha.2019.102017

Mace, G. M., Reyers, B., Alkemade, R., Biggs, R., Chapin III, F. S., Cornell, S. E., Días, S., Jennings, S., Leadley, P., Mumby, P. J., Purvis, A., Scholes, R. J., Seddon, A. W.R., Solan, M., Steffen, W., & Woodward, G. (2014). Approaches to defining a planetary boundary for biodiversity. *Global Environmental Change, 28,* 289-297. https://doi.org/10.1016/j.gloenvcha.2014.07.009

MacLeod, M., Breitholtz, M., Cousins, I. T., Wit, C. A. D., Persson, L. M., Rudén, C., & McLachlan, M. S. (2014). Identifying chemicals that are planetary boundary threats. *Environmental science & technology, 48*(19), 11057-11063. https://doi.org/10.1021/es501893m

Max-Neef, M. (with Elizalde, A., & Hopenhayn, M.) (1991). *Human-Scale Development – Conception, Application and Further Reflection*. New York: Apex Press. Retrieved from: http://www.wtf.tw/ref/max-neef.pdf

McLaughlin, J. F. (2018). Safe operating space for humanity at a regional scale. *Ecology and Society, 23*(2), Article e43. https://doi.org/10.5751/ES-10171-230243

Mekki, A. (2019). *Hva kan vinterpakken bety for norsk småkraft?* [PowerPoint slides]. Wordpress, Småkraftforeninga. Retrieved from: https://www.smakraftforeninga.no/wp-content/uploads/2019/03/Mulige-implikasjoner-av-Vinterpakken-for-norsk-sm%C3%A5kraft.pdf

Meld. St. 13 (2020-2021). *Klimaplan for 2021-2030.* Ministry of Climate and Environment. https://www.regjeringen.no/contentassets/a78ecf5ad2344fa5ae4a394412ef8975/nn-no/pdfs/stm202020210013000dddpdfs.pdf

Meld. St. 14 (2015-2016). *Nature for life – Norway`s national biodiversity action plan.* Ministry of Climate and Environment. https://www.regjeringen.no/contentassets/902deab2906342dd823906d06ed05db2/en-gb/pdfs/stm201520160014000engpdfs.pdf

Meld. St. 19 (2018-2019). *Saman mot einsemd – regjeringa sin strategi for å førebyggje einsemd (2019 – 2023),* in *Folkehelsemeldinga – Gode liv i eit trygt samfunn*. Ministry of Health and Care Services. https://www.regjeringen.no/no/dokumenter/meld.-st.-19-20182019/id2639770/?ch=2#kap3

Meld. St. 21 (2020-2021). *Fullføringsreform – med åpne dører til verden og fremtiden*. Ministry of Education and Research. https://www.regjeringen.no/no/dokumenter/meld.-st.-21-20202021/id2840771/?ch=1

Meld. St. 32 (2020-2021). *Ingen utenfor – En helhetlig politikk for å inkludere flere i arbeids- og samfunnsliv.* Ministry of Labour and Social Inclusion. https://www.regjeringen.no/no/dokumenter/meld.-st.-32-20202021/id2856870/?ch=2#fn15

Meld. St. 40 (2020-2021). *Mål med mening – Norges handlingsplan for å nå bærekraftsmålene innen 2030*. Ministry of Local Government and Modernisation. https://www.regjeringen.no/no/dokumenter/meld.-st.-40-20202021/id2862554/?ch=4#kap4-2-3

Ministry of Children, Equality and Social inclusion. (2017). *Children Living in Poverty - The Government`s Strategy (2015-2017).* Retrieved from: https://www.regjeringen.no/contentassets/ff601d1ab03d4f2dad1e86e706dc4fd3/children-living-in-poverty_q-1230-e.pdf

Ministry of Children and Families. (2020). *Like muligheter i oppveksten. Regjeringens samarbeidsstrategi for barn og ungdom i lavinntektsfamilier (2020-2023)*. Retrieved from: https://www.regjeringen.no/contentassets/bb45eed3479549719fb14c78eba35bd4/strategi-mot-barnefattigdom_web.pdf

Ministry of Health and Care Services. (2017). *Norwegian National Action Plan for a Healthier Diet – an outline*. Retrieved from: https://www.regjeringen.no/contentassets/fab53cd681b247bfa8c03a3767c75e66/norwegian_national_action_plan_for_a_healthier_diet_an_outline.pdf

Ministry of Health and Care Services. (2020). *Handlingsplan for forebygging av selvmord (2020-2025). Ingen å miste*. Retrieved from: https://www.regjeringen.no/contentassets/ef9cc6bd2e0842bf9ac722459503f44c/regjeringens-handlingsplan-for-forebygging-av-selvmord-2020-2025.pdf

Ministry of Justice and Public Security. (2021). *Frihet fra vold. Regjeringens handlingsplan for å forebygge og bekjempe vold i nære relasjoner 2021-2024*. Retrieved from: https://www.regjeringen.no/contentassets/2dda3b36640d4dfbbbac11598a1dc792/209755-jd-frihetfravold-web.pdf

Ministry of Local government and Modernisation. (2021a). *Voluntary National Review 2021 Norway: Report on the Implementation of the 2030 Agenda for Sustainable Development*. Retrieved from: https://sustainabledevelopment.un.org/content/documents/28233Voluntary_National_Review_2021_Norway.pdf

Ministry of Local Government and Modernisation. (2021b). *We all ned a safe place to call home. National strategy for social housing policies (2021-2024)*. Retrieved from: https://www.regjeringen.no/contentassets/c2d6de6c12d5484495d4ddeb7d103ad5/we-all-need-a-safe-place-to-call-home-national-strategy-for-social-housing-policies-2021-2024.pdf

National Oceanic and Atmospheric Administration. (2021). Dr. Pieter Tans, NOAA/GML (gml.noaa.gov/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/). https://gml.noaa.gov/ccgg/trends/data.html

Norwegian Food Safety Authority. (2014). *Protocol on Water and Health. Nasjonale mål – vann og helse*. Retrieved from: https://www.mattilsynet.no/mat_og_vann/drikkevann/nasjonale_maal_vann_og_helse/norges_maal_for_vann_og_helse.36772/binary/Norges%20m%C3%A5l%20for%20vann%20og%20helse

Norwegian Labour and Welfare Administration. (2017). *Fattigdom og levekår i Norge*. (NAV Rapport 2017:4). Retrieved from https://www.nav.no/_/attachment/download/b7651a81-4fbe-49f4-a8b9-c47bcc3720bf:1f5afa5df4d7f7e7f76159ac75ce680f2740ec74/fattigdomsrapporten-2017.pdf

Nussbaum, M. (2003). Capabilities as fundamental entitlements: Sen and social justice. *Feminist Economics*, *9*(2-3), 33-59. https://doi.org/10.1080/1354570022000077926

Nybø, S. & Evju, M. (red). (2017). *Fagsystem for fastsetting av god økologisk tilstand. Forslag fra et ekspertråd.* Ekspertrådet for økologisk tilstand. Retrieved from https://www.regjeringen.no/no/dokumenter/fagsystem-for-fastsetting-av-godokologisk-tilstand/id2558481

Nykvist, B., Persson, Å., Moberg, F., Persson, L., Cornell, S., & Rockström, J. (2013). *National Environmental Performance on Planetary Boundaries: A study for the Swedish Environmental Protection Agency*. Stockholm Environment Institute, Stockholm. Retrieved from https://mediamanager.sei.org/documents/Publications/SEI-Report-Naturvardsverket-NationalEnvironmentalPerformance-2013.pdf

Odum, E. P., & Barrett, G. W. (1971). *Fundamentals of ecology* (3rd ed.). Saunders.

O'Neill, D.W., Fanning, A.L., Lamb, W.F., & Steinberger, J.K. (2018). A good life for all within planetary boundaries. *Nature sustainability*, *1*(2), 88-95. https://doi.org/10.1038/s41893-018-0021-4

Pasgaard, M., & Dawson, N. (2019). Looking beyond justice as universal basic needs is essential to progress towards 'safe and just operating spaces'. *Earth System Governance, 2,* Article e100030. https://doi.org/10.1016/j.esg.2019.100030

Persson, L., Carney Almroth, B. M., Collins, C. D., Cornell, S., de Wit, C. A., Diamond, M. L., Fantke, P., Hassellöv, M., MacLeod, M., Ryberg, M. W., Jørgensen, P. S., Villarrubia-Goméz, P., Wang, Z., & Hauschild, M. Z. (2022). Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environmental Science & Technology*, *56*(3), 1510–1521. https://doi.org/10.1021/acs.est.1c04158

Raffensperger, C., & Tickner, J. (eds). (1999). *Protecting public health and the environment: Implementing the precautionary principle*. Washington, DC: Island Press.

Raworth, K. (2012). *A safe and just space for humanity: can we live within the doughnut?* Oxfam. Retrieved from https://www-cdn.oxfam.org/s3fs-public/file_attachments/dp-a-safe-and-just-space-for-humanity-130212-en_5.pdf

Raworth, K. (2017). *Doughnut Economics. Seven Ways to Think Like a 21st-Century Economist*. Penguin Random House.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. C., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., … & Foley, J. A. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*, *14*(2), Article e32. http://www.ecologyandsociety.org/vol14/iss2/art32/

Rolstad, J., Framstad, E., Gundersen, V. & Storaunet, K. O. (2002). *Naturskog i Norge. Definisjoner, økologi og bruk i norsk skog- og miljøforvaltning*. (Aktuelt fra skogforskningen rapport 1/02). Retrieved from https://nmbu.brage.unit.no/nmbu-xmlui/bitstream/handle/11250/2567761/Skogforsk-Aktuelt-2002-01.pdf?sequence=1&isAllowed=y

Sayers, M., Trebeck, K., & Stuart, F. (2014). *The Scottish Doughnut: A safe and just operating space for Scotland.* Oxfam GB. Retrieved from: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/323371/rr-scottish-doughnut-safe-just-space-scotland-250714-en.pdf?sequence=7&isAllowed=y

Scheffer, M., Carpenter, S., Foley, J. A., Folke, C., & Walker, B. (2001). Catastrophic shifts in ecosystems. *Nature, 413*, 591-596. https://doi.org/10.1038/35098000

Sen, A. (1993). Capability and well-being. In M. Nussbaum & A. Sen (Eds.), *The quality of life* (pp. 270-293). Oxford. https://books.google.no/books?hl=en&lr=&id=mOHnCwAAQBAJ&oi=fnd&pg=PA30&dq=amartya+sen+capability&ots=HKHTP_icQz&sig=B_6WNg34fBZfSDWifvwAHtsN3Qs&redir_esc=y#v=onepage&q=amartya%20sen%20capability&f=false

Shaikh, A. M., Hadjikakou, M., & Bryan, B. A. (2021). National-level consumption-based and production-based utilisation of the land-system change planetary boundary: patterns and trends. *Ecological Indicators*, *121*, Article e106981. https://doi.org/10.1016/j.ecolind.2020.106981

St.meld. 37 (2008-2009). *Report No. 37 to the Storting (2008-2009). Integrated Management of the Marine Environment of the Norwegian Sea. Chapter 6: Climate change and ocean acidification.* Ministry of the Environment. https://www.regjeringen.no/no/dokumenter/stmeld-nr-37-2008-2009-/id560159/?ch=6

St.meld. 46 (1988-89). *Miljø og Utvikling: Oppfølging av Verdenskommisjonens rapport.* Ministry of the Environment. https://www.stortinget.no/no/Saker-og-publikasjoner/Stortingsforhandlinger/Lesevisning/?p=1988-89&paid=3&wid=d&psid=DIVL401&pgid=d_0412

Statistics Norway. (2017). *Vanskeligstilte på boligmarkedet. Hvordan måle og hvem er usatt på boligmarkedet?* (Rapport 2017/9). Retrieved from https://www.ssb.no/bygg-bolig-og-eiendom/artikler-og-publikasjoner/_attachment/302752?_ts=15b3883f218

Statistics Norway. (2020). *Forprosjekt om indikatorer for menneskerettigheter. Innspill fra SSBs arbeidsgruppe*. (Notater 2020/32). Retrieved from https://www.ssb.no/sosiale-forhold-og-kriminalitet/artikler-og-publikasjoner/_attachment/433620?_ts=17501d31888

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/science.1259855

Thriving Cities Initiative. (2021). *Creating City Portraits: A methodological guide from The Thriving Cities Initiative.* Retrieved from https://doughnuteconomics.org/tools-and-stories/14

Teah, H. Y., Akiyama, T., San Carlos, R., Rayo, O. V., Khew, Y. T. J., Zhao, S., Zheng, S., & Onuki, M. (2016). Assessment of downscaling planetary boundaries to semi-arid ecosystems with a local perception: a case study in the middle reaches of Heihe River. *Sustainability*, *8*(12), Article e1233. https://doi.org/10.3390/su8121233

Townsend, P. (1987). Deprivation. *Journal of social policy*, *16*(2), 125-146. https://doi.org/10.1017/S0047279400020341

Ulén, B., Bechmann, M., Øygarden, L., & Kyllmar, K. (2012). Soil erosion in Nordic countries–future challenges and research needs. *Acta Agriculturae Scandinavica, Section B–Soil & Plant Science*, *62*(sup2), 176-184. https://doi.org/10.1080/09064710.2012.712862

United Nations. (2015). *Resolution adopted by the General Assembly on 25 September 2015. Transforming our world: the 2030 Agenda for Sustainable Development*. General

Assembly. Retrieved from https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

United Nations. (2020). *The Sustainable Development Goals Report 2020*. Retrieved from https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf

United Nations. (2021). *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development*. Retrieved from: https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%2020021%20refinement_Eng.pdf

Vannforskriften. (2006). *Forskrift om rammer for vannforvaltningen* (FOR-2006-12-15-1446). Lovdata. https://lovdata.no/dokument/SF/forskrift/2006-12-15-14462

Wackernagel, M., & Rees, W.E. (1996*). Our Ecological Footprint— Reducing Human Impact on the Earth.* New Society, Gabriola Island, B.C., Canada.

Wackernagel, M., Schulz, N. B., Deumling, D., Linares, A. C., Jenkins, M., Kapos, V., Monfreda, C., Loh, J., Myers, N., Norgaard, R., & Randers, J. (2002). Tracking the ecological overshoot of the human economy. *Proceedings of the national Academy of Sciences, 99*(14), 9266-9271. https://doi.org/10.1073/pnas.142033699

Wheatley, M., & Johnson, C. (2009). Factors limiting our understanding of ecological scale. *Ecological Complexity*, *6*(2), 150-159. https://doi.org/10.1016/j.ecocom.2008.10.011

World Meteorological Organization. (2018). *Scientific Assessment of Ozone Depletion: 2018 – Executive Summary*. Global Ozone Research and Monitoring Project. (Report 58). Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/26858/SAOD-2018.pdf?sequence=1&isAllowed=y

Zhang, Q., Wiedmann, T., Fang, K., Song, J., He, J., & Chen, X. (2022). Bridging planetary boundaries and spatial heterogeneity in a hybrid approach: A focus on Chinese provinces and industries. *Science of The Total Environment, 804,* Article e150179. https://doi.org/10.1016/j.scitotenv.2021.150179

Zipper, S. C., Jaramillo, F., Wang-Erlandsson, L., Cornell, S. E., Gleeson, T., Porkka, M., Häyhä, T., Crépin, A-S., Fetzer, I., Gerten, D., Hoff, H., Matthews, N., Ricaurte-Villota, C., Kummu, M., Wada, Y., & Gordon, L. (2020). Integrating the water planetary boundary with water management from local to global scales. *Earth's future*, *8*(2), Article e2019EF001377. https://doi.org/10.1029/2019EF001377

Appendix A. Planetary boundaries

The information in the table below was sourced from Steffen et al. (2015).

Earth system process	**Control variable (indicator)**	**Unit**	**Boundary value**
Climate change	Atmospheric carbon dioxide concentration	Parts per million	350
	Energy imbalance at top of biosphere	Watt per square meter	+1.0
Ocean acidification	Average saturation of aragonite (calcium carbonate) at the ocean surface	As a % of pre-industrial levels	At most 80
Introduction of novel entities	No control variable yet defined	-	-
Biogeochemical flows	*Global*: Phosphorous leak from freshwater to ocean	Teragram a year	11
	Regional: Phosphorus applied to land as fertilizer	Teragram a year	6.2
	Industrial and intentional Nitrogen fixation	Teragram a year	62
Freshwater withdrawals	*Global*: Blue water consumption	Cubic kilometres per year	At most 4000
	Basin: Blue water withdrawal; low-, intermediate-, high-flow months	% of mean monthly river flow	25, 30, 55
Land system change	*Global:* Area of forested land	% of forested land as of original cover	75
	Biome: Area of forested land; tropical, temperate, boreal	% of potential forest	85, 50, 85
Biosphere integrity	*Genetic diversity*: extinction rate	Per million species a year	At most 10

	Functional diversity: Biodiversity Intactness Index (BII)	%	90
Atmospheric aerosol loading	*Global*: Aerosol Optical Depth (AOD)	-	-
	Regional: AOD as a seasonal average over a region	Case study South Asian region only	---
Stratospheric ozone depletion	Concentration of ozone in the stratosphere	% reduction of Dobson Unit	<5% reduction of 290

Appendix B. Social foundation

The information in the table below was sourced from Raworth (2017).

Social dimension	**Illustrative indicators (% of global population unless otherwise stated)**
Food	Population undernourished
Health	Population living in countries with under-five mortality rate exceeding 25 per 1,000 live births
	Population living in countries with life expectancy at birth of less than 70 years
Education	Adult population (aged 15+) who are illiterate
	Children aged 12-15 out of school
Income & work	Population living on less than the international poverty line of 3.10$ a day
	Proportion of young people (aged15-24) seeking but not able to find work
Water & sanitation	Population without access to improved drinking water
	Population without access to improved sanitation
Energy	Population lacking access to electricity
	Population lacking access to clean cooking facilities
Networks	Population stating that they are without someone to count on for help in times of trouble

	Population without access to the Internet
Housing	Proportion of global urban population living in slum housing in developing countries
Gender equality	Worldwide earnings gap between women and men
	Representation gap between woman and men in national parliaments
Social equity	Population living in countries with a Palma ratio of 2 or more (the ratio of the income share of the top 10% of people to that of the bottom 40%)
Political voice	Population living in countries scoring 0.5 or less out of 1.0 in the Voice and Accountability Index
Peace & justice	Population living in countries scoring 50 or less out of 100 in the Corruption Perception Index
	Population living in countries with a homicide rate of 10 or more per 10,000

Appendix C. Previous downscaling of planetary boundaries

Dimension	**Control variable**	**Study**
Climate change	Annual direct CO_2 emissions compared to government commitment	Cole et al., 2014
	Remaining CO_2 < 2°C by 2050	Fang et al., 2015
	Remaining CO_2 < 2°C by 2100	Nykvist et al., 2013; Hoff et al., 2014; Sayers et al., 2014
	Remaining cumulative CO_2 (2010 benchmark), < 1.5°C by 2100	Lucas et al., 2020
	Remaining cumulative CO_2 (2015 benchmark) 50% < 1.5°C by 2100	Lucas & Wilting, 2018
	Remaining cumulative CO_2 (1850 benchmark), to reach 350 ppm by 2100.	Fanning & O`Neill et al., 2016
	Remaining cumulative CO_2 (2011 benchmark), 66% < 2°C by 2100	O`Neill et al., 2018
	Remaining cumulative CO_2 (2015 benchmark), 66% < 2°C by 2100	Allen et al., 2021

	Remaining cumulative GHGs (1990 benchmark), including land cover changes, 50% < 2°C by 2100	Dao et al., 2018
	CO_2 (1850-1990) until 350 ppm reached, divided on average populations (1850-2015)	Hickel, 2020; Fanning et al., 2022
	Remaining cumulative and annual GHGs (2016 benchmark) < 1.5 °C and < 2 °C (lower and upper boundary) by 2100	Huang et al., 2020
Ocean acidification	Annual and cumulative CO_2 (2016 benchmark)	Huang et al., 2020
	Remaining cumulative CO_2 budgets to maintain an acceptable calcium carbonate saturation state Ω	Dao et al., 2018
Stratospheric ozone depletion	Annual HCFC compared to government commitment	Cole et al., 2014
	Consumptive use of Ozone depleting substances	Sayers et al., 2014
Biosphere integrity	Number of species threatened	Nykvist et al., 2013
	Mean species abundance loss	Lucas & Wilting, 2018; Lucas et al., 2020
	Endangered and critically endangered ecosystems	Cole et al., 2014
	UK Farmland Birds Index	Sayers et al., 2014
	Area available for regeneration of biological resources (biocapacity)	Fanning & O`Neill et al., 2016
	Potential damage to biodiversity per land cover type accounting for the level of biodiversity per biome	Dao et al., 2018
Land-system change	Percentage of land converted to cropland	Nykvist et al., 2013; Hoff et al., 2014; Lucas & Wilting, 2018; Lucas et al., 2020; Allen et al., 2021; Shaikh et al., 2021;
	Rain-fed arable land converted to cropland	Cole et al., 2014
	Potential available cropland	Shaikh et al., 2021
	Territorial biocapacity	Fang et al., 2015
	Anthropized land as percentage of ice-free land	Sayers et al., 2014; Dao et al., 2018; EEA, 2020

	Anthropized land compared to original forest cover	Huang et al., 2020
	eHANPP	O`Neill et al., 2018; Fanning et al., 2022
	Total coverage area of grassland, forest, and wetland	Teah et al., 2016
	i) Riparian forest cover, ii) Forest area, iii) Impervious surface area	McLaughlin, 2018
Nitrogen	Net territorial use of N fertilizer	Nykvist et al., 2013; Huang et al., 2020
	N from industrial and intentional biological fixation (N flow from fertilizer to arable land)	Fanning & O’Neill, 2016; Lucas & Wilting, 2018; O’Neill et al., 2018; Lucas et al., 2020; Allen et al., 2021; Fanning et al., 2022
	Loss of N from agriculture	EEA, 2020;
	Loss of reactive N into the environment (soil, water air)	Dao et al., 2018
	N application rate for maize production	Cole et al., 2014
	Imports of manufactured N	Sayers et al., 2014
	Accumulated N flows to water systems	Kahiluoto et al, 2015
	Total N concentrations in river	Teah et al., 2016
	Groundwater nitrate concentration	McLaughlin, 2018
Phosphorus	P mined and applied to agricultural land	Fanning & O’Neill, 2016; O’Neill et al., 2018; Lucas & Wilting, 2018; Lucas et al., 2020; Huang et al., 2020; Allen et al., 2021; Fanning et al., 2022;
	P loss from agriculture	Dao et al., 2018
	P loss from agriculture and wastewater	EEA, 2020;
	P flow from rivers to ocean	Huang et al., 2020
	Total P concentration in dams	Cole et al., 2014
	P load in rivers	Sayers et al., 2014
	Accumulated P flows to water systems	Kahiluoto et al, 2015
	Total P concentrations in river	Teah et al., 2016

	P influx to water supply	McLaughlin, 2018
Freshwater use	Maximum amount of consumptive blue water (global proxy)	Nykvist et al., 2013; Hoff et al., 2014; O’Neill et al., 2018; EEA, 2020; Allen et al., 2021
	Maximum amount of consumptive blue water specific to territories available water resources	Cole et al., 2014; Fang et al., 2015; Teah et al., 2016
	Maximum blue water withdrawal as % of mean monthly river flow	Fanning & O`Neill, 2016; Huang et al., 2020
	Dry season in-stream flow	McLaughlin, 2018
Atmospheric aerosol loading	Particulate concentration (PM10)	Cole et al., 2014; Sayers et al., 2014; Teah et al., 2016
Alternative dimensions		
Material footprint	Per capita footprint, tonnes of extracted raw materials	O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2022
Ecological footprint	Per capita footprint, global hectares of productive land and sea area	O`Neill et al., 2018; Fanning et al., 2022
Marine harvesting	Depleted marine fisheries stocks	Cole et al., 2014
	Sustainable rate of fish stock harvesting, according to scientific advice	Sayers et al., 2014
→	i) Air quality, ii) Water quality, iii) Soil stability, iiii) Sediment regulation, v) Water Regulation, vi) Sediment quality	Dearing et al., 2014

Appendix D. Previous downscaling of social foundation

Dimension	**Indicator**	**Study**
Food	Nutrition (2.700 kilocalories per person per day)	O`Neill et al., 2018; Fanning et al., 2022
	Population without malnutrition	Allen et al., 2021;
	Children undernourished (0-5 years)	Dearing et al., 2014
	Households without adequate food	Cole et al., 2014
	Adequate diet	Sayers et al., 2014
Health	Healthy life expectancy 65 years	O`Neill et al., 2018; Allen et al., 2021

	Healthy life expectancy 74 years	Fanning et al., 2022
	Children (0-5 years) mortality	Dearing et al., 2014
	Infant (<1 y) immunization coverage	Cole et al., 2014
	Years of average healthy life expectancy	Sayers et al., 2014
	Anxiety or depression	Sayers et al., 2014
Education	95% enrolment in secondary school	O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2022
	Illiteracy rate	Dearing et al., 2014
	Adults (≥20 y old) without more than 7 years of schooling	Cole et al., 2014
	Adults lacking any formal qualifications	Sayers et al., 2014
Income	95% of pop. above 1.90 $ a day	O`Neill et al., 2018; Allen et al., 2021
	95% of pop. above 5.50 $ (2011 PPP) a day	Fanning et al., 2022
	Population living below $1.25 (PPP) / day	Dearing et al., 2014
	Population living below the national poverty line	Cole et al., 2014
	Households below 60% average income – after housing costs	Sayers et al., 2014
Work	94% of labour force employed	O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2022
	Urban unemployment rate	Dearing et al., 2014
	Broad unofficial unemployment rate (adults aged 15–64 available to work)	Cole et al., 2014
	People lacking satisfying work	Sayers et al., 2014
Water	Households with piped water	Dearing et al., 2014
	Households without access to piped water within 200m	Cole et al., 2014
Sanitation	95% of population with access	O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2022
	Households with lavatories	Dearing et al., 2014
	Households without a toilet or ventilated pit latrines	Cole et al., 2014
Energy	95% of population with access	O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2022
	Households without access to electricity	Cole et al., 2014

	Households with clean energy	Dearing et al., 2014
	10% or more of income required to be spent on all energy	Sayers et al., 2014
Networks	90% of population have friends or family to depend on	O`Neill et al., 2018; Fanning et al., 2022
	Support from family, friends and others	Sayers et al., 2014
	People without internet due to barriers such as affordability and complexity	Sayers et al., 2014
Housing	Households without formal dwellings	Cole et al., 2014
	Overcrowding	Sayers et al., 2014
Social equity	70 (0-100) on Gini index scale	O`Neill et al., 2018; Allen et al., 2021; Fanning et al., 2022
Political voice	Sense of personal political efficacy	Sayers et al., 2014
Peace & justice	Average governance index 0.8 (scale -2.5 to 2,5, approximate UK\US values)	O`Neill et al., 2018; Allen et al., 2021
	7 (scale 0 to 10) = transformed scale from O’Neil et al 2018	Fanning et al., 2022
	Households feel unsafe walking alone in their area at night	Cole et al., 2014
	Risk of victimization	Sayers et al., 2014
Alternative dimensions		
Life satisfaction	6,5 Cantril ladder scale (0-10)	O`Neill et al., 2018; Allen et al., 2021
Household goods	Household does not own a refrigerator	Cole et al., 2014
Local environment	Access the natural environment once per week	Sayers et al., 2014

Appendix E. Source overview

Dimension	**Data description**	**Source**
Climate change	National population estimates, 1990 to 2054	Statistics Norway (2020h)
	World population estimates, 1990 to 2054	United Nations (2019)

	Carbon budget from 2020 onwards	Intergovernmental Panel on Climate Change (2021)
	World GHG emissions from 1990 to 2019	Gütschow, J. et al. (2021)
	National GHG emissions (consumption-based accounting), 1990 to 2020, from Eora MRIO database	Lenzen et al. (2012, 2013)
	National GHG emissions (production-based accounting), 1990 to 2020	Statistics Norway (2021c)
Ocean acidification	National population estimates, 1990 to 2054	Statistics Norway (2020h)
	World population estimates, 1990 to 2054	United Nations (2019)
	World CO_2 emissions, 1990 to 2019	Gütschow, J. et al. (2021)
	National CO_2 emissions (consumption-based accounting), 2005 to 2020, from Eora MRIO database	Lenzen et al. (2012, 2013)
	National CO_2 emissions (production-based accounting), 2005 to 2020	Statistics Norway (2021c)
Water	The total number of registered rivers in Norway, sourced from the Vannstatistikk portal	https://vann-nett.no/innsyn-klient/ (07.02.2022)
	The numbers of rivers evaluated as HMWB where hydropower is the main driver of hydro morphological deterioration, sourced from Vann-nett portal	https://vann-nett.no/portal/ (07.02.2022)
Ecosystem integrity	Data was duplicated from a NINA-report which evaluates the forest ecosystem in Norway	Framstad et al. (2021)
Nitrogen	The number of freshwater lakes and coastal waters in which the quality parameter Total nitrogen has been assessed, sourced from Vann-Nett portal	https://vann-nett.no/portal/ (04.05.2022)
Phosphorus	Data was duplicated from a study which assess P balances and P recycling potential in Norwegian agricultural soils	Hanserud et al. (2016)
Education	Statistikkbanken 12969:	Statistics Norway (2021g)

	Upper secondary school completion rates of the overall population and demographic groups, 2012-2020	
Work	Statistikkbanken 12424: Employment register facilitating NEET calculations for the overall population and demographic groups, 2008-2020	Statistics Norway (2021f)
Income	Article with datasets reporting on children living in low-income households, overall population (2000-2020) and demographic groups (2006-2020)	Statistics Norway (2021h)
Food	Statistikkbanken 06181: Computed BMI figures from survey based on self-reported weight and height, 1998-2019	Statistics Norway (2020e)
Health	Registered suicides in the cause-of-death register, all ages, 1995-2020	https://www.norgeshelsa.no/norgeshelsa/
	National population estimates, 1995-2020	Statistics Norway (2020h)
Political voice	Statistikkbanken 05453: Population eligible to vote with country background, 2003-2019	Statistics Norway (2021a)
	Statistikkbanken 08295: Population eligible to vote with gender, 1999-2015	Statistics Norway (2018)
	Statistikkbanken 12758: Population eligible to vote with gender, 2019	Statistics Norway (2019b)
	Statistikkbanken 04996: County members with country background, 1999-2019	Statistics Norway (2020d)
	Statistikkbanken 04980: Municipal members with country background, 1999-2019	Statistics Norway (2020c)
	Statistikkbanken 12872: Municipal members with gender, 1999-2019	Statistics Norway (2020f)

	Statistikkbanken 01183: County members with gender, 1999-2019	Statistics Norway (2020a)
Network	Statistikkbanken 04306: Population (with gender) answering they are without a confidential in living condition survey, 2002-2019	Statistics Norway (2020b)
Housing	Statistikkbanken 11042: Data on cramped living for the overall population and genders from residence register, 2015-2021	Statistics Norway (2022b)
	Statistikkbanken 11045: Data on cramped living for the migrant population from residence register, 2015-2021	Statistics Norway (2022c)
Peace & justice	Statistikkbanken 04621: Population (with gender) answering they have recently been worried or threatened at home, 1995-2018	Statistics Norway (2019a)
Energy	Statistikkbanken 11564: Calculated shares of renewables in total energy consumption, 2004-2019	Statistics Norway (2021d)
Water & sanitation	Statistikkbanken 13143: Calculated shares of produced drinking water going to waste, 2015-2021.	Statistics Norway (2021e)

Appendix F. Supplementary information

Ecological dimensions

Climate change

The control variable for *climate change* was defined by Rockström et al. (2009) as carbon dioxide (CO_2) concentration in the atmosphere measured as parts per million (ppm), with a safe limit set at 350 ppm. This boundary has already been transgressed, measured at 414 ppm as the annual mean in 2020 (National Oceanic and Atmospheric Administration [NOAA], 2021). To increase the policy relevance of this control variable, one can shift domains in the

Driver-Pressure-State-Impact-Response (DPSIR) framework (European Environment Agency [EEA], 1999), from carbon concentration in the atmosphere to greenhouse gasses (GHGs).

Hickel (2020) tracked previous world emissions from 1850 up to 2015, and used the equivalent of GHGs to the limit of 350 ppm as a benchmark. Fanning et al (2022) also used this approach for over 140 countries, and distributed previous emissions from 1850 up to 1988 (when the 350-ppm limit was reached) using an equal, yearly per capita sharing principle based on population estimates. For Norway, the boundary equalled 800 Mt CO_2 (Fanning et al., 2022), which could have been adopted in this study, with updated emissions data from 2015 onwards. However, considering that there is no explicit consensus on allocating past emissions (burden sharing) in the global climate policy regime, and that returning to the original 350 ppm limit in a short- to medium-term is highly unlikely (Meinshausen et al., 2020), we sought an alternative indicator.

Instead, we applied the international consensus on limiting global warming to 1.5 degrees relative to pre-industrial baseline (United Nations Framework Convention on Climate Change [UNFCCC], 2016), and used remaining emissions estimates to stay within this target (Intergovernmental Panel on Climate Change [IPCC], 2021) as the basis for a global boundary. Such carbon budgets vary depending on the probability assumed to stay within different temperature increases (Table F.1). Here, a 50% probability of limiting global warming to 1.5 degrees relative to pre-industrial time is selected, which yields 500 Giga tonnes (Gt) CO_2 from 2020 onwards.

Table F.1. Estimated remaining carbon budgets ($GtCO_2$). Figures vary depending on the likelihoods of staying within different human-induced global surface temperature increases, relative to pre-industrial time. Modified from IPCC (2021, p. 29)

	17%	**33%**	**50%**	**67%**	**83%**
1.5°C	900	650	500	400	300
1.7°C	1450	1050	850	700	550
2.0°C	2300	1700	1350	1150	900

To evaluate Norway’s fair share of this budget we wanted to apply a sharing principle in line with public policy to have relevance for national stakeholders. Although a range of different sharing principles can be applied to distribute such a budget (see e.g., Lucas & Wilting, 2018; EEA, 2020), an equal per capita share was chosen based on the government's emissions pledges in their nationally determined contribution (UNFCCC, 2020). Here, Norway aligns their emissions reductions to the global emissions cuts needed to stay within 1.5 degree warming (p. 14-15). We adopted Dao et al.`s (2018) approach of accounting for previous and future emissions. The year 1990 was selected as the benchmark as this is the same base year applied for Norwegian emissions cuts (UNFCCC, 2020), and around the same period climate change was recognised and prioritised in public policy (St.meld. 46 (1988-89). The phase out year of emissions was selected based on national pledges of cutting 90-95% of GHGs by 2050 from 1990 levels (Meld. St. 13 (2020-2021), where we assume a complete phase out by 2055, which is in line with the net-zero emission pathway supported by the Norwegian government (UNFCCC, 2020, p. 14-15).

Based on these premisses for a national fair share budget, we modified Dao et al.`s (2018, p. 53) approach slightly; instead of using 1990 as base year to establish the national share relative to the global population, we extracted and added yearly average population estimates from 1990 up to 2055 for Norway (Statistics Norway, 2020h, Fig. 1), and compared it to the world`s for the same time period (United Nations [UN], 2019), using the main alternative and standardised, medium-variant projections respectively. A national share based on this method is a strength in that it captures population fluctuations between 1990 and 2055. We also updated world past emissions of GHGs between 1990 2019 using the PRIMAP dataset (Gütschow et al., 2021). Instead of calculating and demonstrating the remaining emissions as yearly budgets until the phase out year based on population estimates as Dao et al. (2018) did, we followed Hickel (2020) and Fanning et al. (2022) demonstrating the national boundary (=national share multiplied by previous and remaining emissions between 1990 and 2055) and current status (emissions between 1990 and 2020) as cumulative totals. Such a boundary constitutes as 1 129 Mt CO_2eq for *climate change* following equation 1 in the main article.

The current status for Norway compared to the derived boundary was calculated using both production-based accounting (PBA) and consumption-based accounting (CBA) for the period 1990 to 2020. While PBA is the standardised method to calculate and ascribe GHGs accounts, and for which Statistics Norway (2021c) registers official figures, CBA has received attention the last years, and several political parties in Norway wants to apply it to make visible the emissions associated with Norwegians consumption of goods and services abroad (Lydersen, 2021). We sourced CBA emission data from the Eora MRIO database (Lenzen et al., 2012;

2013) which is based on the same PRIMAP dataset (Gütschow et al., 2021) used for global emission data. Both the Eora MRIO and PRIMAP dataset includes Kyoto Greenhouse Gasses (AR4), but excludes emissions from land use, land use change and forestry (LULUCF).

Ocean acidification

For *ocean acidification*, Rockström et al. (2009) used the average global saturation state of aragonite at the ocean surface as the control variable, with a safe limit at >80% of pre-industrial levels. As with *climate change*, this control variable has little policy relevance, but can be converted to CO_2 emissions using the DPSIR framework. For such a control variable, a global boundary constitutes at a safe level of ppm CO_2 in the atmosphere to avoid extensive undersaturation in ocean ecosystems. To find such a boundary we used Good et al.`s (2018) review on acidification thresholds in the world’s ocean.

A safe limit for coral reefs has been suggested at 350 ppm (Veron et al., 2009) where coral productivity has been found to be reduced (thresholds) at $\Omega > 3.0$ (Steinacher et al., 2013). Evidence from other ocean ecosystems suggest that increased occurrence of surface undersaturation will take place at 500-650 ppm in the Antarctica and Southern America, at ~900 ppm in the Barent and Norwegian Seas, and that this is already occurring in some parts of the Artic Ocean at ~400 ppm (Hauri et al., 2016). Good et al. (2018) concludes that there is greater confidence that extensive undersaturation of aragonite in surface waters, which will have huge negative ecological consequences, will occur in high latitude waters when exceeding atmospheric carbon dioxide of 450-500 ppm. Based on this we selected our safe limit at 445 ppm, the same boundary value as in Dao et al. (2018).

To convert this limit from ppm CO_2 in the atmosphere to CO_2 emissions, and find the remaining carbon budget to stay within this safe limit, we used Dao et al.`s (2018) approach, explained in equation 2 in the main article. The quantity of CO_2 leading to an additional CO_2 ppm was found by first calculating the increase of ppm in the atmosphere from 1990 (354.1 ppm) and up to 2019 (410.1 ppm), which equalled 56 ppm based on global yearly abundance (NOAA, 2021). We further divided previous world CO_2 emissions from the same time period using the PRIMAP data set (Gütschow et al, 2021) on this figure which equated 15.45 Gt. This figure was multiplied by the difference in CO_2 ppm between 2019-level (410 ppm) and the selected safe level (445 ppm), which equated 541 Gt. 541 Gt CO_2 thus represent the remaining global budget and equals the global boundary for ocean acidification in this study.

To find Norway`s fair share of this budget we used the same equal per capita sharing principle as for *climate change*, in line with the Norwegian governments reasoning for GHG reductions (UNFCCC, 2020). But we used the methodology suggested by Dao et al. (2018) that includes past and future emission (see equation 3 in the main article). A reference year of 2005 was selected, which represent a shift in the global awareness concerning ocean acidification (Laffoley & Baxter, 2012), as well as for Norwegian authorities concerning the effects of acidification in the Norwegian Sea (St.meld. 37 (2008-2009). The same emission phase out year of CO_2 was assumed in 2055 as in *climate change*, following Norwegian national pledges (Meld. St. 13 (2020-2021).

To calculate Norway`s share of the world population between 2005 and 2055 we used yearly average estimates nationally (Statistics Norway, 2020h, Fig. 1) and globally (UN, 2019), using the main alternative and standardised, medium-variant projections respectively. As for *climate change*, this is a slight modification to Dao et al.`s (2018) approach deriving the national population ratio from the year of 1990. To evaluate the current status for Norway concerning this dimension, we extracted CO_2 emission data from both PBA and CBA for comparison, sourced from Statistics Norway (2021c) and the Eora MRIO database (Lenzen et al, 2012; 2013) respectively, between 1990 and 2020. As for *climate change*, we adopted Fanning et al.`s (2022) approach of demonstrating both the boundary value and current status as cumulative, instead of calculating and demonstrating yearly budgets until the phase out year based on population estimates (Dao et al., 2018). As such, a potential overshoot signifies excess emissions of the total fair share budget until 2055.

Water

Rockström et al. (2009) defined the global water boundary as the amount of freshwater consumed by humans, and proposed a safe limit of 4000 cubic kilometres per year. Gerten et al. (2013) argued that the proposed limit did not take into account ecological requirements for river flows in different regions. To this critic, Steffen et al, (2015) defined regional blue water withdrawal boundaries as a percentage of river basins environmental water flow (EWF) requirements, equalling 25%, 40% and 55% in low, intermediate and high flow regimes respectively. A recent study suggested a complimentary water boundary concerning evaporation, soil moisture and terrestrial precipitation (green water) (Wang-Erlandsson et al., 2022), but due to time constraint we were not able to evaluate its criteria towards our case.

Establishing an ecologically sound and policy relevant national boundary for Norway based on Rockström et al.`s (2009) indicator, which could be compared to O`Neill et al.`s (2018) results, seems irrelevant as freshwater is abundant in Norway, with water usage assessed to less than one percent of available renewable freshwater resources within the territory (EEA, 2021). Thus, withdrawal of drinking water is not an immediate environmental concern, however the impacts of hydropower on water bodies is, and it is estimated that activities related to hydropower production have affected 70% of all watersheds to some degree, where 17% of all rivers and 30% of all freshwater lakes may have altered their ecological condition considerably (Norwegian Environment Agency [NEA], 2020). To apply Steffen et al.`s (2015) indicator thus seems relevant to national concerns, though measured through the effects of hydropower production on EWF instead of freshwater withdrawal.

In Norway, the current practice of regulating river basins in regards to energy production is based on minimum water flow regimes, to reduce the negative effects of interventions on the environment (Vannressursloven, 2000, § 10). Alternative regulation practices have been suggested to better sustain the biological integrity of watersheds, and mimic water flows in unregulated and natural river systems, such as through the R&D program “Environmentally based water flows” (Eide, 2013). Here, different EWF regimes specifically adjusted for Norwegian river conditions was developed for some rivers (e.g., Alfredsen et al., 2011; Bakken et al., 2012). However, such analysis is scarce and are not available for a representative set of rivers, as well as not being prioritized in public policies.

We sought an alternative indicator based on the work to implement the European Unions`(EU) Water Framework Directive (WFD) (Directive 2000/60/EC, 2000) in Norway, where the government has committed to ensure *good ecological condition* for all ground- and surface waters through national legislation (Vannforskriften, 2006, § 4). The proposed evaluation system facilitates ecological assessments of waterbodies, which are classified according to their *very bad*, *bad, moderate, good* or *very good* condition (Direktoratsgruppen vanndirektivet, 2018a). A range of different biological elements, in addition to supporting physio-chemical and hydro morphological elements, are evaluated towards their natural states equal *very good condition*, meaning that it has not been, or has been insignificantly affected by human activities (p.18). A waterbody in *good ecological condition* inhabits acceptable deviations from the natural condition (p. 12).

The evaluation system distinguishes between “natural” and heavily modified water bodies (HMWB), where only the former can achieve any one of the five classification categories mentioned above. HMWBs represent water bodies where significant hydro-morphological changes have been made to serve socio-economically beneficial activities, and which cannot achieve *good ecological condition* without compromising such activities or degrading the environment (Departementsgruppen vanndirektivet, 2014). These changes however affect the composition of water bodies negatively, either morphologically (changes in structures and physical conditions) and/or hydrologically (significant changes in water flows and water levels) (p. 4). To evaluate the effect of socio-economic activities (e.g., agriculture, hydropower production) on different ecological quality elements of waterbodies, three different impact classifications are used; *small*, *medium*, and *strong*, where the two latter can impair waterbody conditions on their own (Direktoratsgruppen vanndirektivet, 2018b, p. 29). Where impacts related to hydropower production are the main driver of hydro morphological encroachment, rivers are classified as HMWBs (L. Hernandez, personal communication, January 2021).

Here we use the distinction between rivers classified as *natural* and HMWB as our local boundary. The national boundary constitutes as the aggregated number of rivers classified as "natural", while a potential overshoot equates to the aggregated numbers of rivers which are classified as HMWB where hydropower is the main driver of encroachment. We note that although a river may be classified as *natural*, hydropower can still have a *medium* or *strong* negative impact on its hydro morphological condition, but not significantly so that *good ecological condition* cannot be obtained. Our results showing the negative effects of hydropower production on water flows in Norway are thus potentially underestimates.

To calculate the current status, we used the Vann-Nett portal (www.vann-nett.no) developed and operated by the Norwegian Water Resources and Energy Directorate, and the NEA. The portal registers all waterbodies which have been evaluated by the classification system, either through data collection, modelling methods, or based on local and expert knowledge. To find the total number of registered rivers in Norway (N = 23 308) we used the Water Statistics database (https://vann-nett.no/innsyn-klient/chart/waterbodyCountForRiverBasinDistrict?regionid=all). To find the numbers of rivers registered as HMWB with hydropower as the main driver of hydro morphological encroachment (N = 2 461), we applied the report describing impacts, named "Vannforekomster med påvirkninger, påvirkningsgrad, påvirkningsgruppe, driver, effect", and used the searching criteria displayed in Table F.2.

Table F.2. Selection criteria to find rivers classified as HMWB due to hydropower production, in the report; "Vannforekomster med påvirkninger, påvirkningsgrad, påvirkningsgruppe, driver, effect", in the Vann-nett portal.

Category name	**Applied subcategory**
Water category (Vannkategori)	River (elv)
Natural or HMBW (naturlig eller SMVF)	Heavily modified (sterkt modifisert)
Impact driver (påvirkningsdriver)	Hydropower (vannkraft)

The result from the search included duplicates, as some waterbodies have several impact types registered, but these were removed. The search was done the 7th of February 2022, which is relevant as the results are just a snapshot of current water conditions based on the most recent registration.

Phosphorus (P)

Rockström et al. (2009) used the flow of P from freshwater systems into the ocean as the control variable for *phosphorus*, and proposed a safe global limit of 11 Tg P per year to avoid a large-scale anoxic event in the ocean. This indicator was criticised by Carpenter and Bennett (2011) for not taking into account freshwater systems, where they proposed three alternative indicators; i) the mass of P in erodible soil, ii) the flow of P from terrestrial ecosystems to freshwater, and iii) the flow of P to erodible soil. The latter was adopted by Steffen et al. (2015) as a proxy to evaluate regional boundaries. The main concern is the disruption of the P cycle, where P fertilizers generates disproportional concentrations of P in soils which is causing eutrophication through erosion and run-off (ibid).

In Norway, aquaculture is the largest emitter of P to coastal ecosystems (Norwegian Institute for Water Research, 2021). The main source of P is however found in agriculture systems from manure and imported mineral fertilizers (NEA, 2015). Norway has been identified as a P surplus region, partly because of high concentrations of secondary fertilizers compared to the country's agriculture production requirements (Hanserud et al., 2016; Hamilton et al., 2017). Surplus fertilization over many years, and particularly in some regions, has led to high stocks of plant available P in agricultural soils (NEA, 2015), which increases the risk of P loss from run-off and soil erosion, the latter being the main source of P loss from arable production systems in Norway (Ulén et al., 2012).

Considering this we chose a *driver* indicator following the DPSIR framework regarding P fertilizers, in line with both Steffen et al. (2015) and O`Neill et al. (2018). However, we chose to assess beyond fertilizer flows to erodible/arable soils, by taking into account plant fertilization requirement adjusted for accumulated P in soils. This indicator, expressed as *agriculture soil P-fertilizer requirement (including manure and sewage sludge), corrected for mass of P in soil,* is also policy relevant as farmers in Norway are obliged by law (Forskrift om gjødslingsplanlegging, 1999, § 3) to follow a fertilizer planning regime and crop specific fertilization norms (Norwegian Institute of Bioeconomy Research [NIBIO], n.d.a). Fertilization norms are based on plant available soil P (P-AL), measured as mg per 100 g soil in Norway, where farmers are obliged to report P-AL levels every four to eight years.

A maintenance norm equal P-AL 5-7 was enforced in 2007 based on a balance fertilization principle aimed to reduce the negative environmental effects of P on aquatic ecosystems through erosions and run off, while still optimizing plant yields (NIBIO, n.d.b). The local boundaries for *phosphorus* is established at farm level as the recommended level of P fertilization, corrected for P-AL 5-7. The national boundary constitutes as the aggregated P fertilizer requirement (tonnes) for plants in Norway.

To calculate the current status, we used Hanserud et al.`s (2016) method to measure surplus secondary P adjusted for P-AL 5-7 (p. 312), but we modified it to include mineral fertilizer (equation 4 in main article). We replicated the results from Hanserud et al. (2016) which includes data on P in yields, P in house manure, P in manure from grazing animals, total plant-available P in sewage sludge, data on mineral fertilizer, as well as the corrected P fertilizer requirements at aggregated county level, for which we computed results for the national level. Their analysis accounts for permanent pasture used for fodder, and yields deriving from wheat, oat, barley, rye and triticale, oilseeds, potato, green fodder and silage, peas, and grass.

Table F.3. Recommended correction factor of P fertilization adjusted to P-AL levels (classes) for grass, cereals and oil seeds. Sourced from Hanserud et al. (2016, Supplementary Information), based on Krogstad et al. (2008).

Class	P-AL value (mg per 100 g soil)	Name of class	Mean P-AL class value	Regression equation for percentage correction (Y) of P requirement	Mean percentage correction (Y) of P requirement
A	1–5	Low	3	Y = −25 * P-AL + 125	50
B	5–7	Medium/optimal	6	Y = 0	0
C1	7–10	Moderate high	8.5	Y = −14.28 * P-AL + 100	−21.38
C2	10–14	High	12	Y = −14.28 * P-AL + 100	−71.36
D	>14	Very high	–	Y = −100	−100

Hanserud et al. (2016) used P-AL data from 2001 to 2011 and applied the recommended P-AL correction factors developed by Krogstad (2008) demonstrated in Table F.3. P-AL data is available up until 2016 in NIBIO`s database, and they are currently working to get access to data up until present time (M. Bechman, personal communication, October, 2021).

Nitrogen (N)

Rockström et al. (2009) used industrial and intentional biological fixation of N as the global indicator for *nitrogen*, and suggested a safe limit at 35 Tg N per year to avoid eutrophication of aquatic ecosystems. de Vries (2013) criticised the boundary for being insufficient to meet the food demand of a growing population and rather suggested a yearly boundary value at 62 Tg N per year, which Steffen et al. (2015) applied. They emphasised the importance of regional impacts and that some regions are responsible for transgressing the global boundary due to excessive N fertilization. In Norway, agriculture is a large contributor of N-losses to coastal ecosystems, while aquaculture is the largest (Norwegian Institute for Water Research, 2021). N contamination of surface waters and the issue of eutrophication due to over- or mal-fertilization practices have been a national concern for decades, and Norway has made international commitments to reduce the negative environmental impact of such activities (e.g., Declaration to protect the North Sea, Nitrate Directive).

There are several potential indicators that can cover such concerns, including Rockström et al.`s (2009) original indicator, which has already been applied for Norway using a top-down approach (O`Neil et all., 2018). To generate a national boundary for this indicator from a bottom-up perspective proved however more difficult. A possibility is to establish local boundaries based on nationally recommended N fertilization norms for different crops, vegetables and grass varieties (NIBIO, n.d.a), and multiply such norms with land utilization (hectare) for a national aggregate (kg/N). Proximity to such a boundary could then be assessed through N fertilizer usage. However, we could not obtain satisfying data on land utilization accounting for seasons and the number of harvests per season, that could be assessed through different N norms. There exist many empirical analyses on N balances and N use efficiencies in Norwegian agriculture (see e.g., Øgaard, 2014; Riley, 2016; Øgaard & Bechmann, 2018), but we weren't able to operationalise a boundary that cover the whole territory using an indicator on fertilizer consumption.

Instead of using a *driver* indicator regarding fertilizers, we selected a *state* indicator regarding N levels in aquatic ecosystems following the DPSIR framework. Although this makes comparison across studies difficult, it covers national concerns of N contamination and eutrophication in freshwater lakes and coastal waters (aquatic ecosystem from now). This indicator is also policy relevant regarding the implementation of the WFD in Norway, and the goal of achieving *good ecological condition* in all surface waters (Vannforskriften, 2006, § 4). *Total N* is a supporting physio-chemical parameter part of the assessment of aquatic ecosystems in the WDF classification system (Direktoratsgruppen vanndirektivet, 2018a). We applied this indicator and established local boundaries on the limit between *good* and *moderate* condition. For freshwater lakes such limits vary between 250 to 775 µg N/l due to the different characteristics of such water bodies across the country depending on geological, climatic and morphological conditions (Table F.4) (Direktoratsgruppen vanndirektivet, 2018a, p. 20-25). For the surface layers of coastal waters, such limits vary between 330-398 µg N/l depending on the season and water salinity (Table F.5) (Direktoratsgruppen vanndirektivet, 2018a, p. 172)

Table. F.4. Demonstrates the overarching freshwater lakes types in Norway, their natural reference state with regards to Total N concentrations (µg/L), and the different limits between *very good*, *good* and *moderate* condition. The table is modified from Direktoratsgruppen vanndirektivet, 2018a, p. 111.

Lake type	**Total N in freshwater lakes (µg/L)**			
	Reference state	Very good	Good	Moderate
L-N2a	200	1-325	325-475	475-775
L-N2b	175	1-200	200-400	400-650
L-N3a	275	1-475	475-650	650-1075
L-N1	275	1-425	425-675	675-950
L-N8a	325	1-550	550-775	775-1325
L-N5a	150	1-250	250-425	425-675
L-N6a	250	1-400	400-550	550-900
L-N7	125	1-175	175-250	250-475

Note: The classifications *bad* and *very bad* are excluded from this table

Table. F.5. Demonstrates the limits between *very good*, *good* and *moderate* condition measured in Total N concentration (µg/L), depending on the season and salinity of the water. The table is modified from Direktoratsgruppen vanndirektivet, 2018a, p. 173-174.

Season	**Salinity**	**Total N in coastal waters (µg/L)**		
		Very good	Good	Moderate
Summer (June to August)	5	<250	250-383	383-538
	18	<250	250-337	337-505
	>18	>250	250-330	330-500
Winter (December to February)	5	<261	261-385	385-553
	18	<291	291-398	398-559
	>18	<291	291-380	380-560

Note: The classifications *bad* and *very bad* are excluded from this table

The national boundary constitutes as the aggregated number of aquatic ecosystems in which the parameter *Total N* has been assessed, equalling 100% in *good condition* or better. A potential overshoot constitutes through the aggregated number of aquatic ecosystems in worse than *good condition* for this parameter. The current status was calculated using data from the Vann-Nett portal (www.vann-nett.no). To find the total number of aquatic ecosystems where

Total N had been assessed, and which had a valid quality and parameter element (N = 1 723), we applied the report describing quality elements, named “Vannforekomster med GYLDIGE økologiske kvalitetselement - har grenseverdier for KE og vanntype”, and used the searching criteria displayed in Table F.6.

Table F.6. Selection criteria to find aquatic ecosystems for which Total N has been assessed, in the report “Vannforekomster med GYLDIGE økologiske kvalitetselement - har grenseverdier for KE og vanntype”, in the Vann-Nett portal.

Search	**Category name**	**Applied subcategory**
First	Water category (Vannkategori)	Freshwater lake (innsjø)
	Ecological quality element parameter (økologisk kvalitetselementparameter)	Totalnitrogen
Second	Water category (Vannkategori)	Coastal waters (kystvann)
	Ecological quality element parameter (økologisk kvalitetselementparameter)	Totalnitrogen

Ecosystem integrity

In the original framework, Rockström et al. (2009) defined *land-system change* through crop land conversion at a safe limit of 15% globally, and *change in biosphere integrity* through species extinction rate at ten per million species a year as the safe limit. Mace et al. (2014) criticised the latter for being a weak threshold indicator at global scale, disregarding the complexities and interconnectedness across and between species and biomes that sustain functional ecosystems. They proposed alternative metrics; i) genetic diversity through phylogenetic species variability, ii) functional diversity among organism which affect key ecosystem processes, and iii) the integrity of biomes. Steffen et al. (2015) retained the species extinction rate as an indicator for genetic diversity, but based a second indicator on functional diversity, defined through the biodiversity intactness index (BII) (Scholes & Biggs, 2005), and a safe limit at 90% or above. For *land-system change*, Steffen et al. (2015) changed the global indicator to forest cover with a safe limit at 75% of original cover. This boundary is a weighted average of the three individual biomes tropical, temperate and boreal, for which should be assessed at the biome scale with safe limits at 85%, 50% and 85% of potential forest cover respectively (ibid).

In Norway, the forest cover has increased the last century (Svensson & Dalen, 2021). However, forestry development in Norway and practices of e.g., clear-cutting, forest road construction and afforestation have had detrimental impacts on biodiversity, and land-use changes pose the greatest threat to endangered species (NOU 2009: 16, 2009, p. 42). 112 species have gone regionally extinct since 1800, while 1308 species are endangered or critically endangered in Norway today (Artsdatabanken, 2021). The Nature index (https://www.naturindeks.no/), a proxy to the BII, measures biological diversity within different ecosystems in Norway compared to background levels, including the state of keystone species.

Such indicators based on species extinction and biodiversity indexes could serve as national proxies resembling the originally defined indicators (Rockström et al., 2009; Steffen et al., 2015). However, considering that these proxies have weak grounding in public policy, and that an indicator based on forest cover seem environmentally contradictive for the Norwegian case, we sought an alternative indicator.

The government has a goal of *good ecological condition* for all ecosystems in Norway (Meld. St. 14 (2015-2016)). Work has been done to define and operationalise this goal, which has resulted in an ecosystem evaluation system (Nybø & Evju, 2017). Framstad et al. (2021) evaluated the forest ecosystem for the first time using several indicators that represent its structure, function and productivity, including the Nature index. These indicators are grouped into seven overarching ecosystem characteristics which among others describe genetic and functional diversity of species, primary production, and ecological landscape patterns compatible with species survival over time (see Table F.7) (Framstad et al. (2021). We evaluate this indicator to cover the environmental concerns related to both the *land-system change* and *change in biosphere integrity* boundaries, and as such incorporated them into a single boundary which we named *ecosystem integrity*.

Table. F.7. The seven overall ecosystem characteristics and the different indicators evaluated for each, as part of assessing ecological condition of the forest ecosystem in Norway. Some of the indicators are used for several characteristics. Modified from Framstad et al., 2021, p. 36.

Ecosystem characteristics	**Indicators**
Primary production	NDVI - high thr.
	NDVI - low thr.
	Ellenberg N - high thr.
	Ellenberg N - low thr.
Abiotic conditions	Ellenberg N - high thr.
	Ellenberg N - low thr.
	Ellenberg F - high thr.
	Ellenberg F - low thr.
Functionally important species and structures	Absence of invasive species
	Blueberry cover
	Rogn-osp-selje
	Total dead wood
	Dead rough wood
	Biological old forest
Landscape ecological patterns	Biological old forest
	Area without technical intervention
Biomass distribution in-between tropich levels	Deer
	Predators
Biological diversity	Naturindeks for forest
Functional groups in-between tropich levels	N/A

To establish a boundary for this indicator, we used the index scale applied by the evaluation system, which ranges from 0 to1, where 1 equals an intact ecosystem (Nybø & Evju, 2017). For the Norwegian forest ecosystem, 1 represents a similar ecosystem to that of ancient woodlands (Rolstad et al., 2002, p. 45). *Good ecological condition* is defined as when the ecosystems` structure, function and productivity do not deviate substantially from the reference condition, defined as intact ecosystems (Nybø & Evju, 2017, p. 34). This definition was operationalised as 0.6 at the index scale for forests (Framstad et al., 2021), which we applied as our boundary value for this dimension. In the assessment, each of the indicators in Table G.7 was evaluated, weighted and scaled towards the main index value. The current status was duplicated from Framstad et al. (2021).

Social dimensions

Education

Raworth (2017) used children (12-15 years) out of school as an indicator for *education*, which relates to SDG indicator 4.1.2, ascribing to completion rates in secondary school compared to the issues of access which Raworth was concerned about. The issue of access is not relevant to the Norwegian case as the government provides universal and free schooling for primary up to upper secondary school students. Completion rates within upper secondary education is however a concern (Ministry of Local government and Modernisation, 2021a) as 21.9% of students fail to graduate within either five or six years depending on the study program (study competence vs. vocational competence) (Statistic Norway, 2021g). An indicator expressed as *share of students completing upper secondary education within 5/6 years* was selected, for which Statistics Norway (2020g) provide data, including on gender and migrant groupings.

The government launched a strategy in 2021 to reform parts of the educational system with an overall goal that nine out of ten students complete and passes upper secondary school by 2030 (Meld. St. 21 (2020-2021)), for which constitutes the boundary for this dimension. Statistics Norway (2014) separates between i) migrants, which are persons living in Norway, but born abroad by two foreign-born parents, having four foreign-born grandparents, and ii) persons that are born in Norway by two foreign-born parents, and which have four foreign-born grandparents (p.10). We use this distinction throughout the study if not otherwise stated. To find the current status for the overall population and for each demographic group we added the number of students that “completed the program within standard time” and “completed the program beyond standard time but within 5/6 years” in table 12969, and divided it on the total registered first year students (Statistics Norway, 2021g). The female and male population represents genders among the entire population, which also applies to the remaining dimensions below. Fig. F.1 displays the trend for *education* between 2012 and 2020.

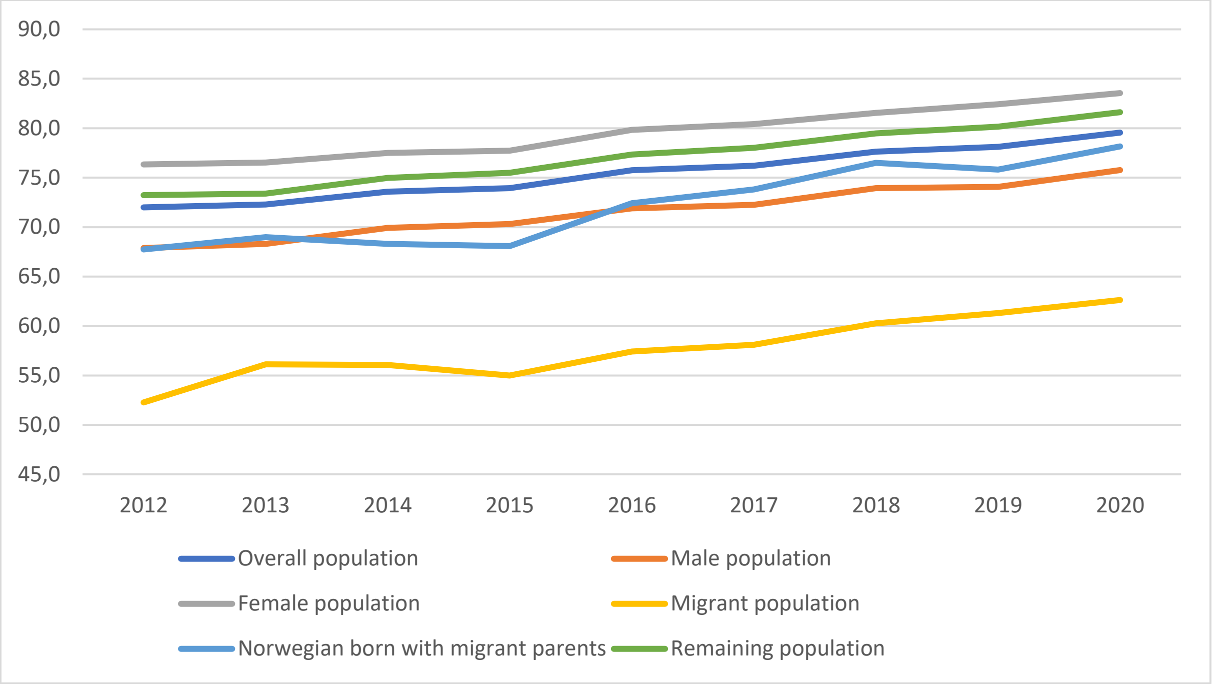

Fig. F.1. The share (%) of students completing upper secondary education within 5/6 years by different demographic groups, between 2012 and 2020.

Work

Raworth (2017) combined *income* and *work* as one dimension, but these were separated in this study. Her indicator *proportion of young people (aged 15–24) seeking but not able to find work* derives from SDG target 8.6 and indicator 8.6.1, which is a priority for the Norwegian government. Government policies target high employment rates for young people aged 15-29 which are not in education, employment or training (NEET). We applied the NEET indicator for this dimension, a heterogenous group in Norway, which size vary depending on the data set sought. Statistics Norway (2021f) register employment status, of which 11.2 % were categorised as NEETs in Norway in 2020, a number which is higher than the 6.6% registered NEETs from their working-life survey (Statistics Norway, 2022a). This is so because the working-life survey absorbs informal employment situations (Fyhn et al., 2021). We chose the prior data set as it contains reliant timeseries and because it includes gender and migrant groupings. It would be interesting to also include persons with impaired functioning and health related issues as this is a government priority, and because of the group`s most likely overrepresentation among NEETs in Norway (Fyhn et al, 2021). However, this is not possible due to lack of data.

To define a boundary for this indicator, we used the government`s ambition to include everyone in civil society and employ all persons that wishes to work (Meld. St. 32 (2020-2021)). We defined a threshold at 5% considering the issue of informal employment described above, and also considering that some young people take time of in-between education and employment. We found the number of NEETs by adding the number of persons "registered unemployed", "recipients of work clearance allowance", "recipients of disability benefits", "other schemes, not on measures" and "unknown status" in table 12424, and dividing it on the total number of registered persons aged 15-29 as the overall population, as well as for each demographic group (Statistics Norway, 2021f). Fig. F.2. shows the trend for *work* between 2008 and 2020.

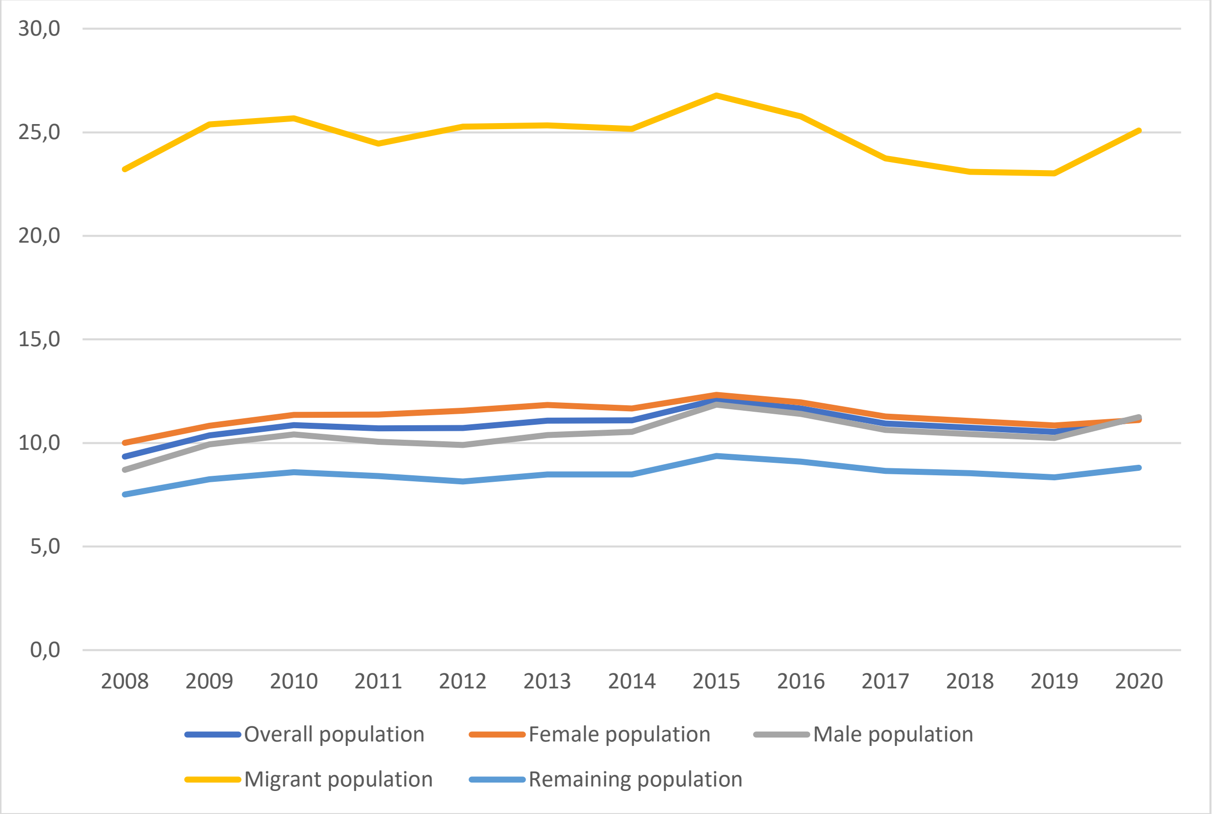

Fig. F.2. The share (%) of youths aged 15 to 29 that are not in education, employment or training (NEET) by different demographic groups, between 2008 and 2020.

Income

Raworth (2017) used an international poverty line of $3.10 a day as the indicator for *income*. This is a higher boundary level than SDG indicator 1.1 set at $1.25 a day, but lower than the World Bank`s (n.d.) boundaries for lower-middle and upper-middle income countries set at

$3.20 and $5.50 a day respectively. Neither of these indicators are relevant to Norway, which currently experience average monthly salaries of NOK 50 790, the equivalent of around $5500 (currency rate as of April, 2022) (Statistics Norway, 2022e). Poverty according to national circumstances and definitions, the ambition of SDG target 1.2, is however relevant as social inequalities and income disparity has been rising in recent years (Norwegian Labour and Welfare Administration, 2017; Statistics Norway, 2020i). The Norwegian government has not defined a national poverty line, but an alternative indicator was suggested as the *share of children in households with persistence low-income* (Meld. St. 40. (2020-2021), p. 18), for which we applied for this dimension. Persistent low-income is the most commonly applied parameter to poverty in Norway, and is usually understood according to the EU as below 60% of the median net income per household during a three years period (Hyggen et al., 2018).

The Norwegian government launched a strategy in 2015 to prevent child poverty (Ministry of Children, Equality and Social inclusion, 2015), which was followed up in 2020 with an inter-departmental strategy for children and youths in low-income families (Ministry of Children and Families, 2020). It had an overall goal of reducing the disadvantages of low-income households and prevent poverty from passing from generation to generation. Based on this we defined our *income* boundary at zero percent. Statistic Norway (2021h, Fig. 1 & 3) report on children below 18 years living in households with persistent low-income according to EUs definition, including on migrant groups. Fig. F.3 demonstrate the trend for *income* between 2000 and 2020.

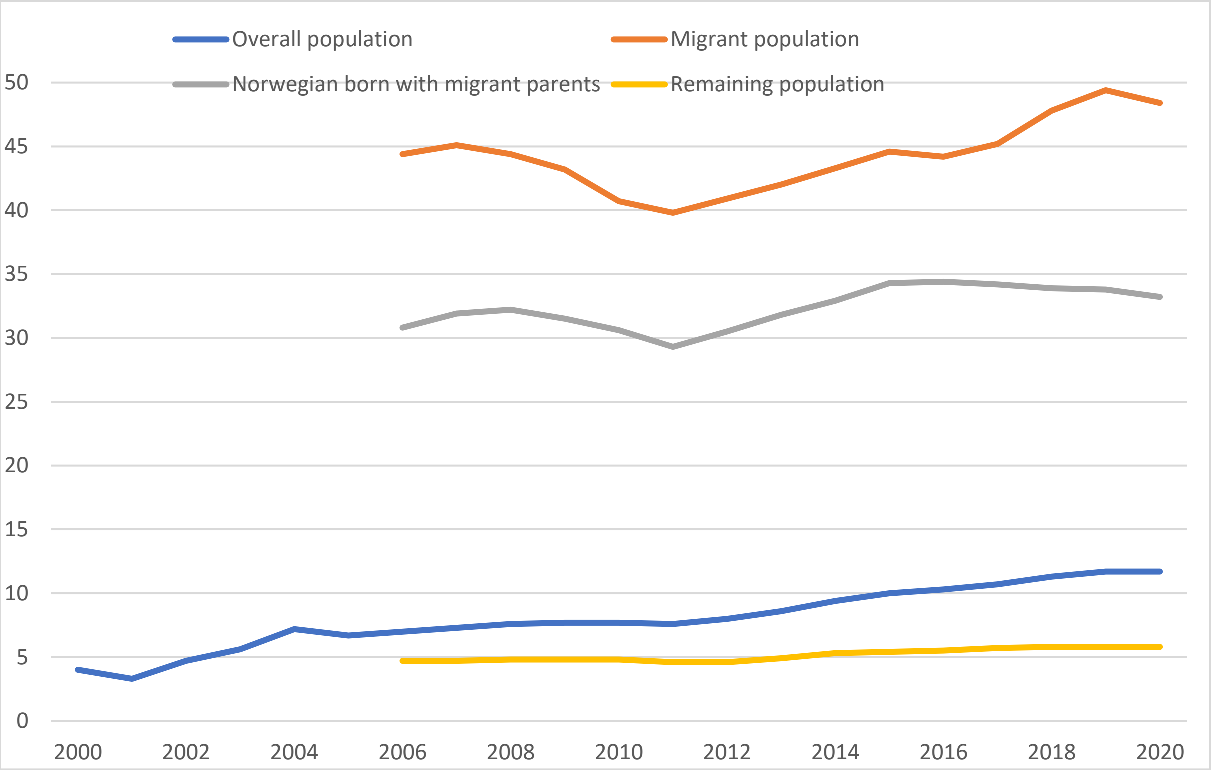

Fig. F.3. The share (%) of children below 18 of age living in persistent low-income households by demographic groups, between 2000 and 2020. Timeseries for migrant groupings between 2000 and 2006 are not available.

Food

Raworth (2017) used the share of people undernourished as the indicator for *food*, which is based on SDG target 2.1 and indicator 2.1.1. Food security is considered high in Norway where people have access to varied foods all year round, and undernourishment is not a national concern (Ministry of Local government and Modernisation, 2021a). However, malnutrition in the form of overnutrition due to unhealthy diets and lack of physical exercise is a prominent health concern in Norway (ibid). This reflects the global malnutrition trend where overnutrition has become more prevalent than undernourishment (World Health Organization [WHO], 2021). SDG target 2.2 is concerned with ending any form of malnutrition, where indicator 2.2.2 threats malnutrition either as under- or over-nourishment through the WHO Child growth Standard among children under five years of age (UN, 2021, p, 2). This indicator does not however cover the broader concern of overweigh and obesity among the overall population, so we sought and selected an alternative indicator related to

SDG 2.2, namely the *share of people overweight and obese* (Meld. St. 40. (2020-2021), p. 26). The most applied method to evaluate weight ratios in the Norwegian population is the body mass index (BMI), for which we applied.

To address the nutritional challenges in the country, the government launched a strategy in 2017 to improve the national diet (Ministry of Health and Care Services, 2017a). It contains concrete targets to increase the consumption of specific healthy foods, enforce the knowledge on the connection between healthy diets and physical and mental health, halt child obesity, and set out an overarching goal to provide the entire population with a healthy and varied diet. We used this target and defined the threshold at zero percent, considering the connections between healthy diets and weight ratios.

Statistics Norway (2020e) has since 1998 carried out a living condition survey that assess Norwegians` physical and mental health symptoms, functioning and living habits. The survey includes self-reported weight and height measurements, enabling computed BMI figures. While the nationally defined threshold between normal weight and overweight is 25 BMI, there are many factors to be considered beyond classification of BMI for each individual, where e.g., someone who have been classified as slightly overweight could still be healthy, and eat well and varied (Norwegian Directorate of Health, 2010). To account for some of these complexities we defined the boundary at 27 BMI as a national proxy. The current status was calculated by adding the two variables "overweight BMI 27-30" and "obesity BMI <=30" from table 06181 (Statistics Norway, 2020e). Differentiated data on gender is available, but not for migrant groupings. Fig. F.4 shows the trend for food between 1998 and 2019.

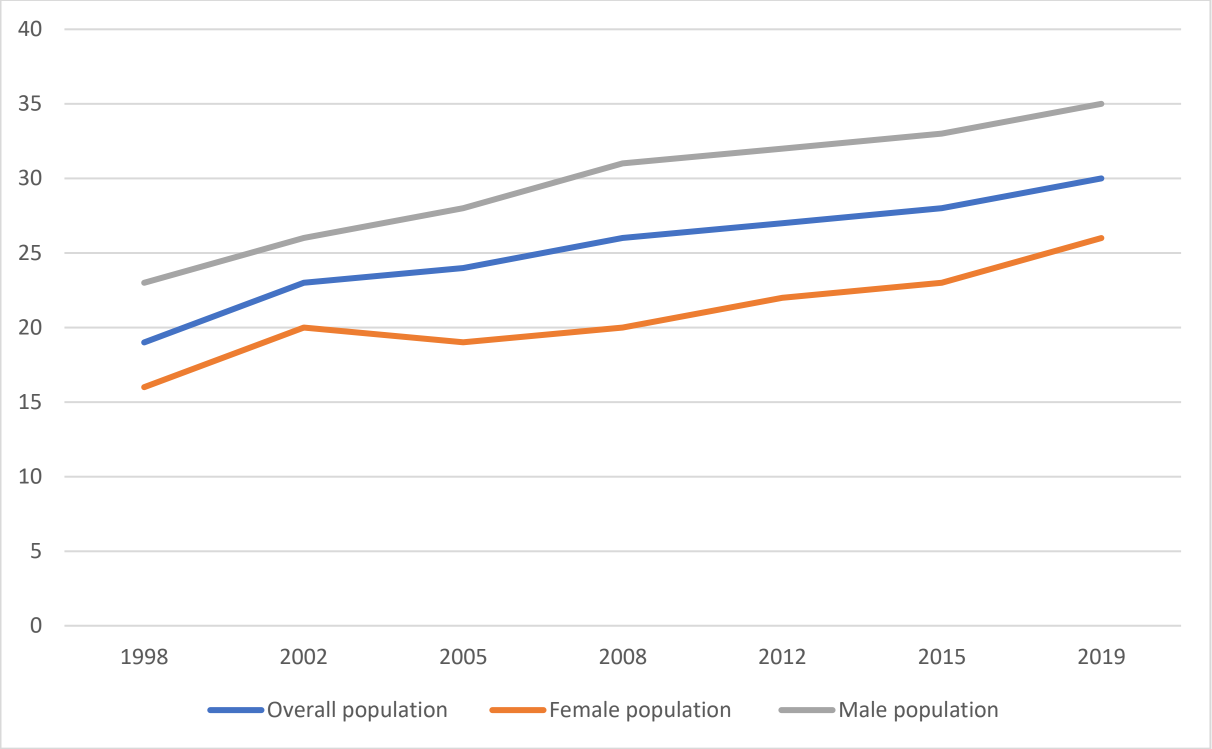

Fig. F.4. The share (%) of persons aged 16 and above with a BMI of 27 and above by gender, between 1998 and 2019.

Health

For *health*, Raworth (2017) used SDG target 3.2 and indicator 3.2.1 *under-five mortality rate*, and defined a boundary at 25 deaths per 1,000 live births. She also used life expectancy rate with a threshold at 70 years as a second indicator. Norway experience among the highest life expectancy rates in the world (84,7 years for women and 81,6 years for men) (Statistics Norway, 2022d), and some of the lowest under-five mortality rates (3,04 for girls and 2,75 for boys per 1,000) (Statistics Norway, s.a.). The government has however flagged non-communicable diseases as the biggest health issue (Ministry of Local government and Modernisation, 2021a), which represented 87% of the health burden in Norway in 2016, the main risk factors for fatalities and health loss being unhealthy diets, smoking and high blood pressure (Øverland et al, 2018). As there exist correlation between these concerns and our applied indicator for *food*, we have focused on another health concern in Norway, that of the increasing trend of mental health issues (Ministry of Local government and Modernisation, 2021a). To cover this, we applied the *suicide mortality rate* as our indicator, an SDG indicator (3.4.2) as well as a national priority (Meld. St. 40 (2020-2021)). The Norwegian government launched a zero-vision for suicide in 2020 (Ministry of Health and Care Services, 2020), for which we applied as our boundary for this dimension.

Statistics Norway (s.a.) compute suicide rates for the female and male population as suicides per 100 000 inhabitants. Their data is sourced from the Norgeshelsa database (www.norgeshelsa.no), operated by the Norwegian Institute of Public Health. To find the suicide rate for the overall population, we sourced the total number of registered suicides for all genders and age groups from the-cause-of-death register (https://www.norgeshelsa.no/norgeshelsa/) between 1995 and 2020. We divided the yearly number of suicides on the average population estimate to the corresponding year (Statistics Norway, 2020h, Fig. 1) and multiplied this figure with 100 000[a] to find the number of suicides per 100 000 inhabitants.

For the female and male population, we sourced the suicide rates directly from the Norgeshelsa database, figures derived from using the same method we applied for the overall population.[b] As expressed in the main article, we treat the derived figures of suicides per 100 000 inhabitants as whole percentages, which are highly overestimated figures, but done with the purpose of visualization within the diagrams in the main article. Data on migrant groupings are not available. Fig. F.5 demonstrates the trend for *health* between 1995 and 2020.

---

[a] This is the unstandardized method, also used by Statistics Norway. In public reports, the Norwegian Institute of Public Health apply a standardized method common across Europe to adjust for age compositions.

[b] Both standardized and unstandardised figures are illustrated in the database. The unstandardised figures were sourced.

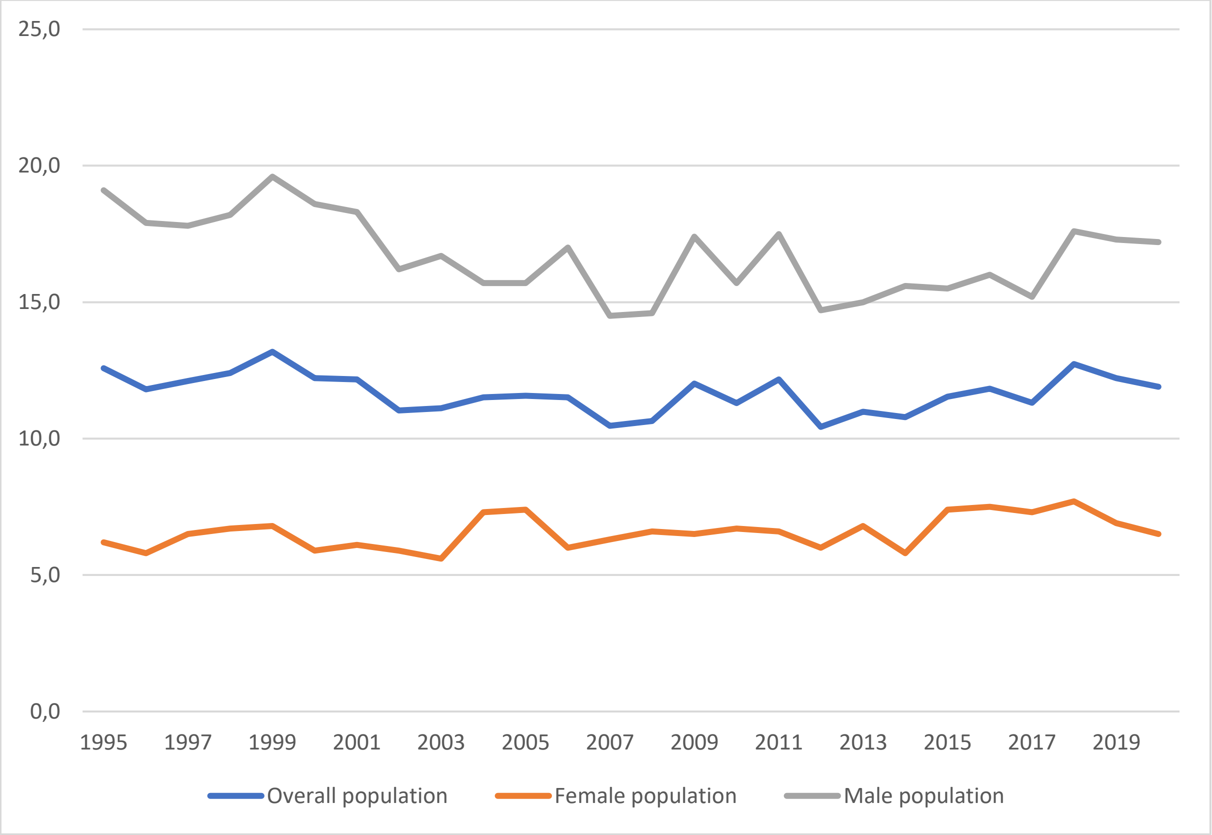

Fig. F.5 The number of suicides per 100 000 inhabitants by gender, between 1995 and 2020.

Political voice

Raworth (2017) used the Voice and Accountability Index (VAI) as an indicator for *political voice*. Norway has topped the VAI the last decades (http://info.worldbank.org/governance/wgi/), however it is not a relevant target indicator for public policy. The VAI is neither an SDG target but aspires to 16.7 of ensuring "responsive, inclusive, participatory and representative decision-making at all levels" (UN, 2021, p. 19). The government suggested different indicators related to this target, regarding citizens experiences of being respected and listened to, citizen inclusion to shape public services, and contact between citizens and politicians (Meld. St. 40. (2020-2021), p. 167). However, consistent and reliable data lacks for these indicators. SDG indicator 16.7.1 regarding representativity in national and local institutions can however serve as a proxy. The indicator includes representation by sex, population groups, age and persons with disabilities, among legislators, the public service and the judiciary (UN, 2021, p. 19). Here, we apply the variables sex and population groups, for municipal and county council seats only, as there exist reliable and available data for these variables (Statistics Norway, 2018, 2019b, 2020a, 2020c, 2020d, 2020f, 2021a).

This indicator has been suggested by Statistics Norway (2020g) to describe an individual's right to participate in the public and to free elections (p. 34). Although the indicator has been suggested as a proxy for *gender equality* (Raworth, 2017; Meld. St. 40. (2020-2021), p. 60), it could arguably be used to measure political influence through descriptive representation, a corner stone in the Norwegian democracy. Here, we assume complete descriptive representation as our boundary for *political voice*, where the current status is demonstrated as percentage deviations, calculated by dividing different demographic groups` shares of seats in municipal and county councils, by the same groups' respective shares in the total population (persons eligible to vote). As such, 100% signify full representation, whilst 0% signify no representation, meaning that none of the examined groups members hold seat in municipal/country councils.

Potential deviations were calculated using data on eligible person to vote in municipal and county elections for the female population (Statistics Norway, 2018, 2019b) and for non-Norwegian persons (Statistics Norway, 2021a), and data on members of municipal and county councils for the female population (Statistics Norway, 2020a, 2020f) and non-Norwegian persons (Statistics Norway, 2020c, 2020d). As data on members in municipal and county councils are archived separately, we added the numbers of seats held by the different demographic groups, and divided it on the total numbers of seats across both councils. Non-Norwegian persons represents here the combination of the two groups *migrants* and *Norwegian born with migrant parents* used in other dimensions, as Statistics Norway don't separate between these groups in public records for this indicator (see explanation under Table 5 in the main article). Fig. F.6 demonstrate the trend for *political voice* between 1999 and 2019.

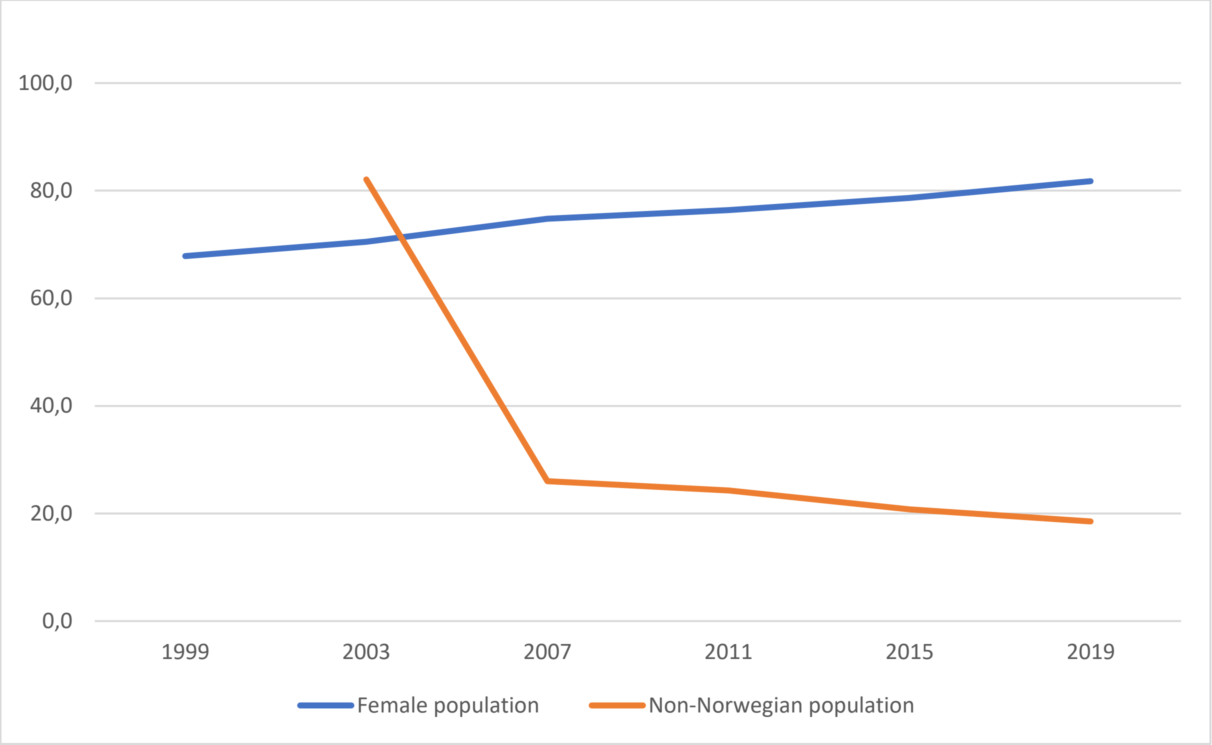

Fig. F.6. The degree (%) of representation of females and non-Norwegians in municipal and county councils between 1999 and 2019, where 100% signify full representation while 0% signify no representation.

Network

Raworth (2017) used people without access to the internet as one indicator for *network*, an indicator we evaluate as irrelevant for Norway as internet is widespread and of high-speed quality across the country. A second indicator Raworth (2017) used was the *share of the population that state they are without someone to count on when in trouble*. This is not specifically linked to an SDG target or indicator, but is relevant as loneliness has been emphasised as an important public health problem by national authorities (Meld. St. 19 (2018-2019)), being especially present among certain socio-economic groups (Statistics Norway, 2021i). We applied Raworth`s (2017) indicator, for which Statistics Norway (2020b) provide data through their living condition survey.

In a strategy from 2019, the government proposed different policies to increase social participation and social support, with an overall goal to prevent loneliness in the population (Meld. St. 19 (2018-2019)). An indicator measuring the presence of loneliness within the population would have corresponded better with the policy goals above, however, the data which Statistics Norway provide for such an indicator is not comparable over time (Statistics

Norway, 2021i). We nevertheless used the same policy goals to define the boundary at zero percent for the selected indicator, meaning that everyone should at least have a confidential to thrust on for help when having personal problems. The current status was sourced from Statistics Norway, and includes the overall population aged 16 and above stating they are without a confidential, including data on gender (2020b). Data on migrant groupings are not available. Fig. F.7 shows the trend for *network* between 2002 and 2019.

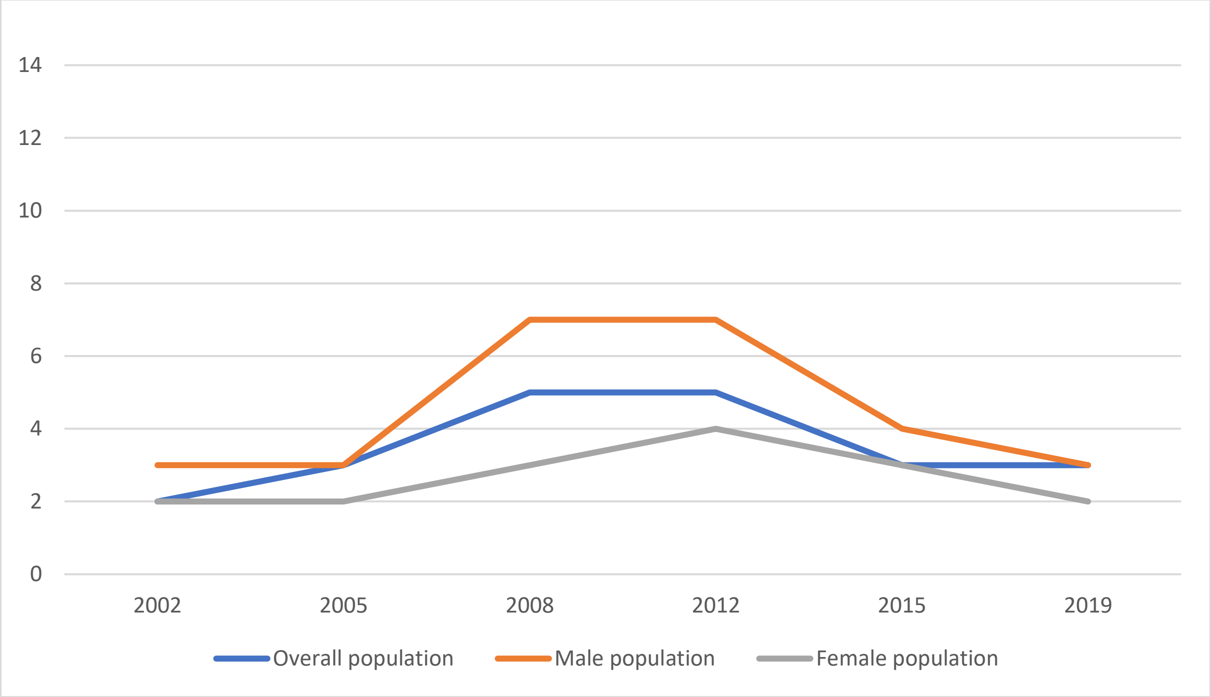

Fig. F.7. The share (%) of persons aged 16 and above stating they are without a confidential by gender, between 2002 and 2019.

Housing

For *housing*, Raworth (2017) used the share of urban population living in slums in developing countries as the indicator, which relates to SDG target 11.1. Slums or other informal settlements is practically non-existing in Norway. The government suggested several alternatives to this indicator, one being the share of disadvantaged people in the housing market (Meld. St. 40. (2020-2021), p. 106). Providing suitable and safe housing for this group is a national priority (Ministry of Local Government and Modernisation, 2021b).

To quantify this group is however not straightforward; from the seven different definitions Statistics Norway (2017) suggested, the group size differed between 17 5000 and 259 000 persons. The definition chosen by the government to constitute disadvantaged people in the housing market includes *households with low income, and which has a high debt burden and/or lives cramped*, which would have constituted 179 000 persons or 3.5% of the population in 2019 (Ministry of Local Government and Modernisation, 2021b, appendix 1, p. 2). The data they used in their report is however exclusive and not publicly available. Considering that low-income households is covered in the *income* dimension, we defined our indicator using the cramped living variable solely, a variable present in all seven definitions described above, as well as being a suggested human right indicator regarding housing (Statistics Norway, 2020g, p. 38).

The boundary for the selected indicator is established at zero percent based on national authorities' ambition of providing everyone with a safe and comfortable home (Ministry of Local Government and Modernisation, 2021b, p. 3). Statistics Norway report on the share of the overall population living cramped, as well as for different genders (2022b). Statistics Norway (2022c) also provide data on migrants living cramped, but differentiated on migrants' origins. We calculated the total share of migrants living cramped by adding both migrant origin categories in table 11045, and divided this on the total number of migrants from the same table (Statistics Norway, 2022c). The collected data represents the share of persons living in cramped households, which is defined as when i) the number of rooms is lower than the number of residents or one resident lives in one room, and ii) the number of square metres (P-area) is below 25 sq.m. (Statistics Norway, 2022b). Fig. F.8 shows the trend for *housing* between 2015 and 2021.

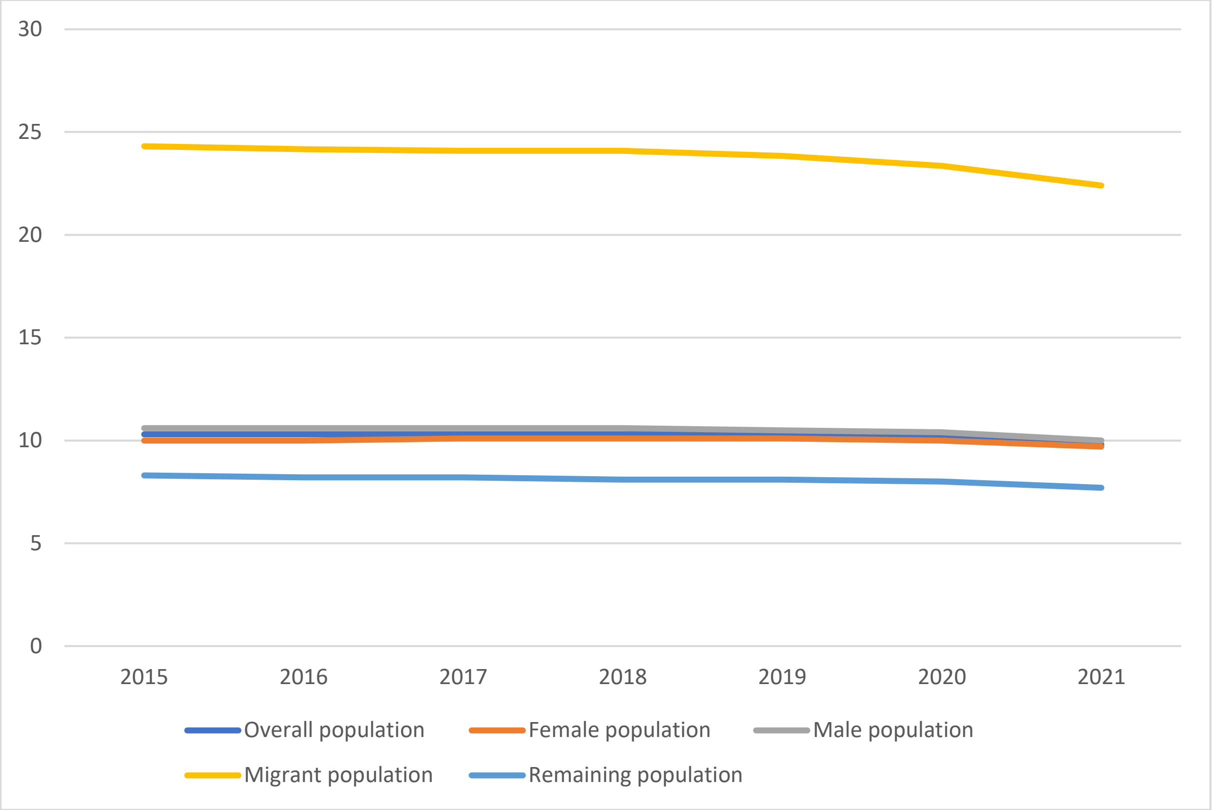

Fig. F.8. The share (%) of persons living in cramped households by demographic groups, between 2015 and 2021.

Peace and justice

Raworth (2017) used two indicators for *peace and justice*, one being the Corruption Perception Index (https://www.transparency.org) which Norway scores high on, however it is a difficult indicator to operationalise besides not being used by national policymakers. The SDGs neither applies this indicator, but it aspires to target 16.5. Considering that the SDG indicators for this target related to briberies are virtually impossible to measure, and that the governments suggested alternative indicators concerning perceived corruption (Meld. St. 40. (2020-2021), p. 166) lack reliant and consistent data, we excluded this indicator.

The second indicator Raworth (2017) used, the *share of population living in countries with a homicide rate of >10 per 10,000*, is related to SDG indicator 16.1.1. In 2020, 31 persons were killed in Norway (Statistics Norway, 2021b), equal a homicide rate of 0.6 per 100 000. Although this is among the lowest in the world, the prevalence of domestic violence and intimate partner homicides where women are most exposed is a national concern (Ministry of Local government and Modernisation, 2021a). The government suggested an alternative indicator expressed as the *share of the population which lately have been worried about* *violence or threats in place of residence* (Meld. St. 40. (2020-2021), p. 165), which we selected as the indicator for this dimension, and for which Statistics Norway (2019a) provides data on through their living condition survey.

The boundary was defined at zero percent, meaning that no one should be worried about violence or threats at home. This is based on a government strategy from 2021, that aims to prevent and combat violence in close relationships, with an overall goal that everyone should feel safe and be free from violence, everywhere and always (Ministry of Justice and Public Security, 2021). The current status was sourced from Statistics Norway, and includes the overall population aged 16 and above which stated that they recently have been worried about violence or treats in the place of residence, including differentiated data on genders (2019a). Data on migrant groupings are not available. Fig. F.9 display the trend *for peace and justice* between 1995 and 2018.

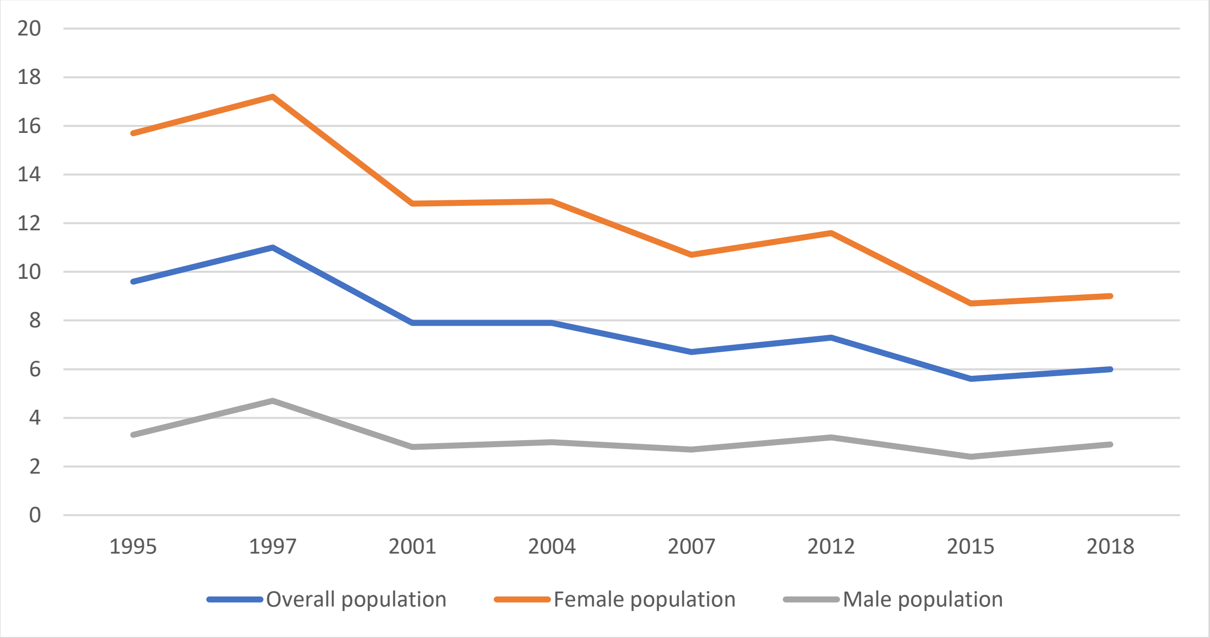

Fig. F.9. The share (%) of persons aged 16 and above which lately have been worried about violence or threats in place of residence by gender, between 1995 and 2018.

Energy

Raworth (2017) used the population without access to electricity and clean cooking facilities as two indicators for *energy*, which relates to the indicators of SDG target 7.1. Practically all have access to safe and sufficient electricity in Norway, as well as having access to clean cooking facilities. An alternative indicator was sought from SDG 7.2 concerning the share of renewable energy at end consumption, for which the government found relevant as the renewable share of total energy consumption (Meld. St. 40 (2020-2021), p. 73). We applied this indicator for *energy*, for which Statistic Norway (2021d) provide data. Although Norway produces more renewable energy than their total yearly consumption, they export substantial quantities as they are integrated in the European energy market.

There is currently no policy goal regarding the share of renewables in the energy mix that can be quantified to constitute the boundary for this dimension. Instead, we sought an alternative target following Norway's obligation (through the European Economic Area agreement) to draft EU`s renewable energy directive which entered into force for all member states in 2018 (Directive 2018/2001, 2018). The directive targets a European renewable share of 32% by 2030, based on national voluntary commitments. If these commitments do not correspond to 32%, a benchmark approach is enforced to ensure a fair contribution across countries based on their wealth (GDP), renewable potential and energy exchange capacity, in addition to a mutually increased target share for all countries (Directive 2018/2001, 2018). Mekki (2019) assessed what this would imply for Norway, and calculated an 88% renewable share by 2030, for which we applied as the boundary for *energy*. The current status was sourced from Statistics Norway, and represent the overall share of total energy consumption excluding the transport sector (2021d), for which the EU directive proposed a separate target for (Directive 2018/2001, 2018). Fig. F.10 shows the trend for energy between 2004 and 2019.

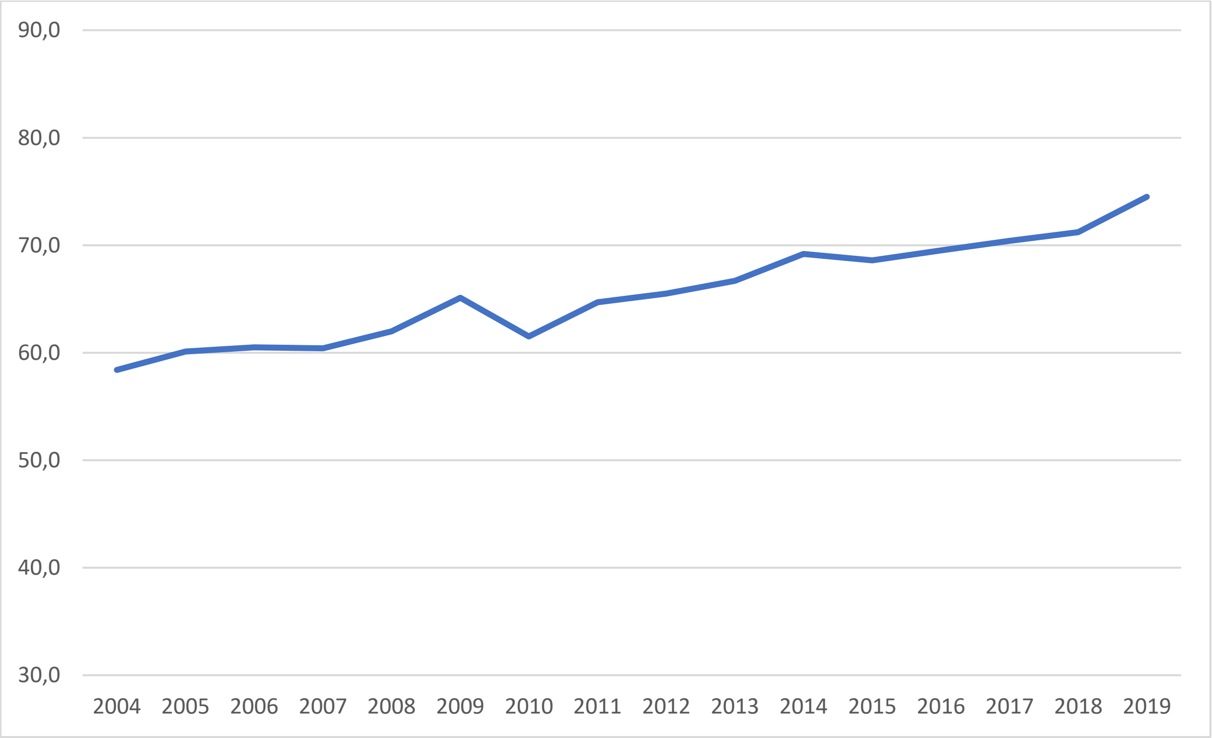

Fig. F.10. The share (%) of renewables in total energy consumption in Norway, between 2004 and 2019.

Water & Sanitation

The indicators for *water and sanitation* were defined by Raworth (2017) as the share of population without access to improved drinking water and sanitation, which is based on SDG targets 6.1 and 6.2. Practically all has access to clean drinking water in Norway, while sanitation is not considered an issue. However, concerns have been raised regarding aging infrastructure and lack of replacements in the public main system for drinking water (Norwegian Food Safety Authority, 2019). Besides being a risk factor for future water contamination, these conditions result in major spillages of produced drinking water, a share which equalled 31.6% in 2019, or the equivalent of 219 million cubic meters (Statistics Norway, 2021e). Considering this, we sought an alternative indicator suggested by the government related to SDG 6.4 regarding water use efficiency, namely the s*hare of produced drinking water going to waste due to leakages in the main system* (Meld. St. 40 (2020-2021), p. 68).

To find a boundary for this indicator, we operationalised a government pledge from the Protocol on Water and Health (Norwegian Food Safety Authority, 2014) to reduce water leakages to 25%. This target was due in 2020, but was not reached. There have not been any revised targets, although this can materialise in the aftermath of the government-ordered report that evaluates improvement potentials in the water and waste water sector (Oslo Economics, 2022). For now, we apply the old target of 25%. Statistics Norway (2021e) provides national estimates on leakages (m3) of produced drinking water based on self-reported estimates from the municipalities. These estimates are most likely conservative as they are based on a high average household consumption proxy (Oslo Economics, 2022), but is nevertheless used here as the data is publicly available and provide timeseries. Fig. F.11 shows the trend for *water and sanitation* between 2015 and 2021.

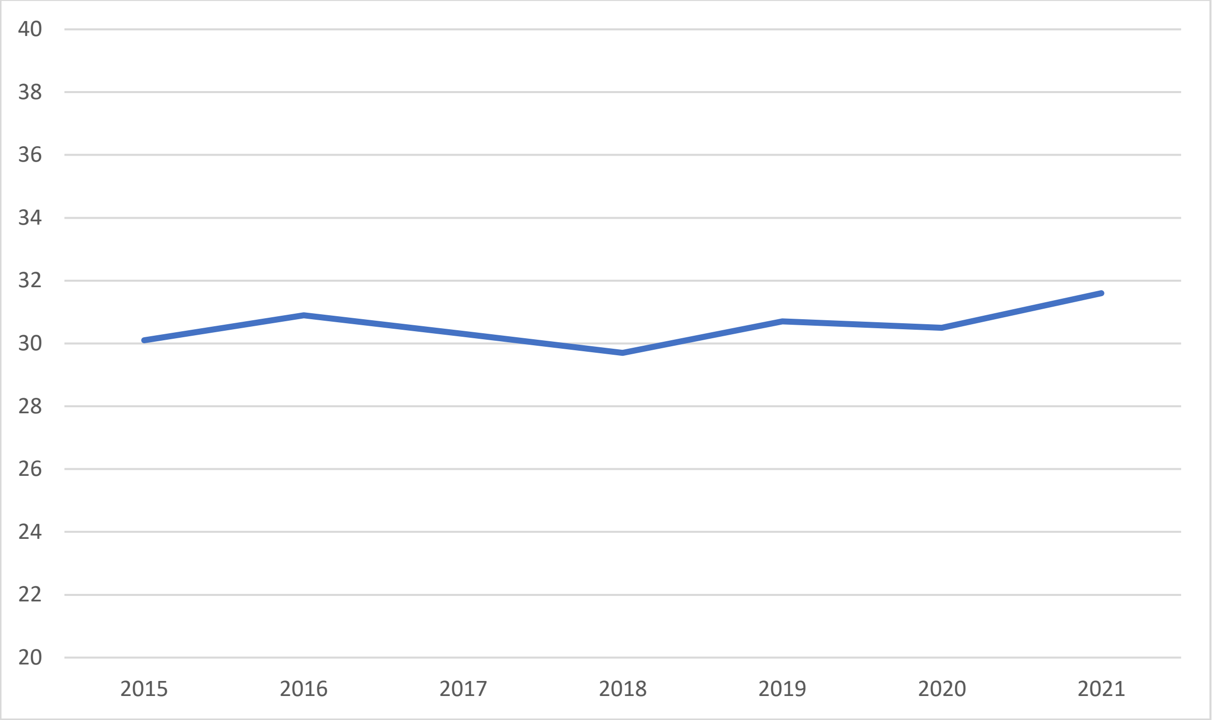

Fig. F.11. The share (%) of produced drinking water going to waste due to leakages in the main system, between 2015 and 2021.

References

Alfredsen, K., Harby, A., Linnansaari, T., & Ugedal, O. (2012). Development of an inflow-controlled environmental flow regime for a Norwegian river. *River Research and Applications*, *28*(6), 731-739. https://doi.org/10.1002/rra.1550

Allen, C., Metternicht, G., Wiedmann, T., & Pedercini, M. (2021). Modelling national transformations to achieve the SDGs within planetary boundaries in small island developing states. *Global Sustainability, 4*. https://doi.org/10.1017/sus.2021.13

Artsdatabanken. (2021, November 24). *Norsk rødliste for arter 2021*. Retrieved from https://www.artsdatabanken.no/lister/rodlisteforarter/2021

Bakken, T. H., Zinke, P., Melcher, A., Sundt, H., Vehanen, T., Jorde, K., & Acreman, M. (2012). *Setting environmental flows in regulated rivers*. (SINTEF report TRA, 4276). http://dx.doi.org/10.13140/RG.2.2.36830.28484

Carpenter, S. R., & Bennett, E. M. (2011). Reconsideration of the planetary boundary for phosphorus. *Environmental Research Letters*, *6*(1), Article e014009. https://doi.org/10.1088/1748-9326/6/1/014009

Cole, M.J., Bailey, R.M. & New, M.G. (2014). Tracking sustainable development with a national barometer for South Africa using a downscaled “safe and just space” framework. *Proceedings of the National Academy of Sciences, 111*(42), e4399-e4408. https://doi.org/10.1073/pnas.1400985111

Dao, H., Peduzzi, P., & Friot, D. (2018). National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland. *Global Environmental Change*, *52*, 49-57. https://doi.org/10.1016/j.gloenvcha.2018.06.005

de Vries, W., Kros, J., Kroeze, C., & Seitzinger, S. P. (2013). Assessing planetary and regional nitrogen boundaries related to food security and adverse environmental impacts. *Current Opinion in Environmental Sustainability, 5*(3-4), 392-402. https://doi.org/10.1016/j.cosust.2013.07.004

Dearing, J.A., Wang, R., Zhang, K., Dyke, J.G., Haberl, H., Hossain, M.S., Langdon, P.G., Lenton, T.M., Raworth, K., Brown, S. and Carstensen, J. (2014). Safe and just operating spaces for regional social-ecological systems. *Global Environmental Change*, *28*, 227-238. https://doi.org/10.1016/j.gloenvcha.2014.06.012

Departementsgruppen vanndirektivet. (2014). *Veileder 01:2014 Sterkt modifiserte vannforekomster*. Retrieved from https://www.vannportalen.no/veiledere/veileder-012014-sterkt-modifiserte-vannforekomster/

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. (2000). 32000L0060. Document 32000L0060. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (Text with EEA relevance). (2018). Document 32018L2001. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001

Direktoratsgruppen vanndirektivet. (2018a). *Veileder 02:2018 Klassifisering av miljøtilstand i vann.* Retrieved from https://www.vannportalen.no/veiledere/klassifiseringsveileder/

Direktoratsgruppen vanndirektivet. (2018b). *Veileder 1:2018 Karakterisering*. Retrieved from https://www.vannportalen.no/veiledere/veileder-12018-karakterisering-metodikk-fora-karakterisere-og-vurdere-miljooppnaelse-etter-vannforskriften--15/

Eide, J. A. (2013). *Vannkraft og miljø. Resultater fra FoU-programmet Miljøbasert vannføring.* Norwegian Water Resources and Energy Directorate. Retrieved from https://nve.brage.unit.no/nve-xmlui/bitstream/handle/11250/2500847/rapport2013_73.pdf?sequence=1&isAllowed=y

European Environment Agency. (1999). *Environmental indicators: Typology and overview*. (Technical report No 25/1999). Retrieved from https://www.eea.europa.eu/publications/TEC25

European Environment Agency. (2020). *Is Europe living within the limits of our planet? An assessment of Europe's environmental footprints in relation to planetary boundaries*. (EEA report number 1/2020). European Environment Agency & Swizz Federal Office for the Environment. Retrieved from https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

European Environment Agency. (2021). *Use of freshwater resources in Europe. Fig. 3: Development of the water exploitation index plus (WEI+)*. Retrieved from https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-3/assessment-4

Fanning, A. L., & O`Neill, A. W. (2016). Tracking resource use relative to planetary boundaries in a steady-state framework: A case study of Canada and Spain. *Ecological Indicators*, *69*, 836-849. https://doi.org/10.1016/j.ecolind.2016.04.034

Fanning, A. L., O'Neill, D. W., Hickel, J., & Roux, N. (2022). The social shortfall and ecological overshoot of nations. *Nature Sustainability*, *5*(1), 26-36. https://doi.org/10.1038/s41893-021-00799-z

Forskrift om gjødslingsplanlegging. (1999). *Forskrift om gjødslingsplanlegging*. (FOR-1999-07-01-791). Lovdata. https://lovdata.no/dokument/SF/forskrift/1999-07-01-791

Framstad, E., Berglund, H., Jacobsen, R. M., Jacokbsson, S., Ohlson, M., Sverdrup-Thygeson, A., & Töpper, J. (2021). *Vurdering av økologisk tilstand for skog i Norge i 2020*. (NINA rapport 2000). Retrieved from https://brage.nina.no/nina-xmlui/handle/11250/2739886

Fyhn, T., Radlick, R.L., & Sveinsdottir, V. (2021). *Unge som står utenfor arbeid, opplæring og utdanning. En analyse av unge i NEET-kategorien*. (Rapport 2-2021, NORCE Helse). Retrieved from https://www.ks.no/contentassets/25072fbf9d4d4577899c335e431117d7/Unge-utenfor-arbeid-opplering-og-utdanning.pdf

Gerten, D., Hoff, H., Rockström, J., Jägermyr, J., Kummu, M., & Pastor, A. V. (2013). Towards a revised planetary boundary for consumptive freshwater use: role of environmental flow requirements. *Current Opinion in Environmental Sustainability*, *5*(6), 551-558. https://doi.org/10.1016/j.cosust.2013.11.001

Good, P., Bamber, J., Halladay, K., Harper, A. B., Jackson, L. C., Kay, G., Kruijt, B., Lowe, J. A., Phillips, O. L., Ridley, J., Srokosz, M., Turley, C., & Williamson, P. (2018). Recent progress in understanding climate thresholds: Ice sheets, the Atlantic meridional overturning circulation, tropical forests and responses to ocean acidification. *Progress in Physical Geography: Earth and Environment*, *42*(1), 24-60. https://doi.org/10.1177%2F0309133317751843

Gütschow, J., Günther, A., & Pflüger, M. (2021). The PRIMAP-hist national historical emissions time series (1750-2019). v2.3.1. zenodo. https://doi.org/10.5281/zenodo.5494497

Hamilton, H. A., Brod, E., Hanserud, O., Müller, D. B., Brattebø, H., & Haraldsen, T. K. (2017). Recycling potential of secondary phosphorus resources as assessed by integrating substance flow analysis and plant-availability. *Science of the total Environment*, *575*, 1546-1555. https://doi.org/10.1016/j.scitotenv.2016.10.056

Hanserud, O. S., Brod, E., Øgaard, A. F., Müller, D. B., & Brattebø, H. (2016). A multi-regional soil phosphorus balance for exploring secondary fertilizer potential: the case of Norway. *Nutrient Cycling in Agroecosystems*, *104*(3), 307-320. https://doi.org/10.1007/s10705-015-9721-6

Hauri, C., Friedrich, T. & Timmermann, A. (2016). Abrupt onset and prolongation of aragonite undersaturation events in the Southern Ocean. *Nature Climate Change*, *6*, 172–176. https://doi.org/10.1038/nclimate2844

Hickel, J. (2020). Quantifying national responsibility for climate breakdown: an equality-based attribution approach for carbon dioxide emissions in excess of the planetary boundary. *The Lancet Planetary Health*, *4*(9), e399-e404. https://doi.org/10.1016/S2542-5196(20)30196-0

Hoff, H., Nykvist, B., & Carson, M. (2014). *Living Well, Within the Limits of Our Planet? Measuring Europe's Growing External Footprint*. Stockholm Environment Institute. Retrieved from https://www.researchgate.net/profile/Marcus-Carson/publication/272488205_Living_well_within_the_limits_of_our_planet_Measuring_Europe%27s_growing_external_footprint/links/54eefe800cf2e55866f3d01a/Living-well-within-the-limits-of-our-planet-Measuring-Europes-growing-external-footprint.pdf

Huang, L. H., Hu, A. H., & Kuo, C-H. (2020). Planetary boundary downscaling for absolute environmental sustainability assessment — Case study of Taiwan. *Ecological Indicators*, *14*, Article e106339. https://doi.org/10.1016/j.ecolind.2020.106339

Hyggen, C., Brattbakk, I. & Borgeraas, E. (2018). *Muligheter og hindringer for barn i lavinntektsfamilier: en kunnskapsoppsummering* (NOVA Rapport 11/2018). Retrieved from https://oda.oslomet.no/oda-xmlui/bitstream/handle/20.500.12199/5129/Nettutgave-NOVA-Rapport-11-2018-Muligheter-og-hindringer-.pdf?sequence=1

Intergovernmental Panel on Climate Change. (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K.

Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (eds.)]. In Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Jacobsson, S., & Pedersen, B. (red). (2020). *Naturindeks for Norge 2020. Tilstand og utvikling for biologisk mangfold*. (NINA Rapport 1886). Retrieved from https://www.miljodirektoratet.no/globalassets/publikasjoner/m1800/naturindeksfornorge2020_m1800.pdf

Kahiluoto, H., Kuisma, M., Kuokkanen, A., Mikkilä, M., & Linnanen, L. (2015). Local and social facets of planetary boundaries: right to nutrients. *Environmental Research Letters*, *10*(10), Article e104013. https://doi.org/10.1088/1748-9326/10/10/104013

Krogstad, T., Øgaard, A. F. & Kristoffersen, A. Ø. (2008). New P recommendations for grass and cereals in Norwegian agriculture. Nordic Association of Agricultural Scientists (NJF) *Report*, *4* (4): 42-46.

Laffoley, D. d'A., & Baxter, J.M. (eds). (2012). Ocean Acidification: The knowledge base 2012. Updating what we know about ocean acidification and key global challenges. European Project on Ocean Acidification (EPOCA), UK Ocean Acidification Research Programme, (UKOA), Biological Impacts of Ocean Acidification (BIOACID) and Mediterranean Sea Acidification in a Changing Climate (MedSeA). Retrieved from https://www.oceanacidification.org.uk/pdf/IOA_KnowledgeBase-pdf.pdf

Lenzen M, Kanemoto K; Moran D, & Geschke A (2012). Mapping the structure of the world economy. *Environmental Science & Technology 46*(15), 8374–8381. https://doi.org/10.1021/es300171x

Lenzen, M., Moran, D., Kanemoto, K., & Geschke, A. (2013). Building Eora: A Global Multi-regional Input-Output Database at High Country and Sector Resolution. *Economic Systems Research*, *25*(1), 20-49. https://doi.org/10.1080/09535314.2013.769938

Lucas, P., & Wilting, H. (2018). *Using planetary boundaries to support national implementation of environment-related sustainable development goals.* PBL Netherlands Environmental Assessment Agency, The Hague. (Publication number 2748). Retrieved from: https://www.pbl.nl/sites/default/files/downloads/Using_planetary_boundaries_to_support_national_implementation_of_environment-related_Sustainable_Development_Goals_-_2748.pdf

Lucas, P. L., Wilting, H. C., Hof, A. F., & van Vuuren, D. P. (2020). Allocating planetary boundaries to large economies: Distributional consequences of alternative perspectives on distributive fairness. *Global Environmental Change*, *60*, Article e102017. https://doi.org/10.1016/j.gloenvcha.2019.102017

Lydersen, T. (2021, April 6). Rødgrønt ønske om klimaregnskap på forbruk. *NRK*. https://www.nrk.no/norge/rodgront-onske-om-klimaregnskap-pa-forbruk-1.15418143

Mace, G. M., Reyers, B., Alkemade, R., Biggs, R., Chapin III, F. S., Cornell, S. E., ... & Woodward, G. (2014). Approaches to defining a planetary boundary for biodiversity. *Global Environmental Change*, *28*, 289-297. https://doi.org/10.1016/j.gloenvcha.2014.07.009

McLaughlin, J. F. (2018). Safe operating space for humanity at a regional scale. *Ecology and Society*, *23*(2), Article e43. https://doi.org/10.5751/ES-10171-230243

Meinshausen, M., Nicholls, Z. R., Lewis, J., Gidden, M. J., Vogel, E., Freund, M., ... & Wang, R. H. (2020). The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500. *Geoscientific Model Development*, *13*(8), 3571-3605. https://doi.org/10.5194/gmd-13-3571-2020

Mekki, A. (2019). *Hva kan vinterpakken bety for norsk småkraft?* [PowerPoint slides]. Wordpress, Småkraftforeninga. Retrieved from https://www.smakraftforeninga.no/wp-content/uploads/2019/03/Mulige-implikasjoner-av-Vinterpakken-for-norsk-sm%C3%A5kraft.pdf

Meld. St. 13 (2020-2021). *Klimaplan for 2021-2030*. Ministry of Climate and Environment. https://www.regjeringen.no/contentassets/a78ecf5ad2344fa5ae4a394412ef8975/nn-no/pdfs/stm202020210013000dddpdfs.pdf

Meld. St. 14 (2015-2016)). *Nature for life – Norway`s national biodiversity action plan*. Ministry of Climate and Environment. Retrieved from https://www.regjeringen.no/contentassets/902deab2906342dd823906d06ed05db2/en-gb/pdfs/stm201520160014000engpdfs.pdf

Meld. St. 19 (2018-2019). *Saman mot einsemd – regjeringa sin strategi for å førebyggje einsemd (2019 – 2023)*, in *Folkehelsemeldinga – Gode liv i eit trygt samfunn*. Ministry of Health and Care Services. https://www.regjeringen.no/no/dokumenter/meld.-st.-19-20182019/id2639770/?ch=2#kap3

Meld. St. 21 (2020-2021). *Fullføringsreform – med åpne dører til verden og fremtiden*. Ministry of Education and Research. https://www.regjeringen.no/no/dokumenter/meld.-st.-21-20202021/id2840771/?ch=1

Meld. St. 32 (2020-2021). *Ingen utenfor – En helhetlig politikk for å inkludere flere i arbeids- og samfunnsliv*. Ministry of Labour and Social Inclusion. https://www.regjeringen.no/no/dokumenter/meld.-st.-32-20202021/id2856870/?ch=2#fn15

Meld. St. 40 (2020-2021). *Mål med mening – Norges handlingsplan for å nå bærekraftsmålene innen 2030*. Ministry of Local Government and Modernisation. https://www.regjeringen.no/no/dokumenter/meld.-st.-40-20202021/id2862554/?ch=4#kap4-2-3

Ministry of Children, Equality and Social inclusion. (2015). *Children Living in Poverty. The Government`s Strategy (2015-2017)*. Retrieved from https://www.regjeringen.no/contentassets/ff601d1ab03d4f2dad1e86e706dc4fd3/children-living-in-poverty_q-1230-e.pdf

Ministry of Children and Families. (2020). *Like muligheter for alle. Regjeringens sammarbeidsstrategi for barn og ungdom i lavinntekstfamilier (2020-2023)*. Retrieved from https://www.regjeringen.no/contentassets/bb45eed3479549719fb14c78eba35bd4/strategi-mot-barnefattigdom_web.pdf

Ministry of Health and Care Services. (2017a). *Norwegian National Action Plan for a Healthier Diet – an outline. Healthy diet, meal enjoyment and good health for everyone!* Retrieved from https://www.regjeringen.no/contentassets/fab53cd681b247bfa8c03a3767c75e66/norwegian_national_action_plan_for_a_healthier_diet_an_outline.pdf

Ministry of Health and Care Services. (2020). *Handlingsplan for forebygging av selvmord. 2020-2025. Ingen å miste*. Retrieved from https://www.regjeringen.no/contentassets/ef9cc6bd2e0842bf9ac722459503f44c/regjeringens-handlingsplan-for-forebygging-av-selvmord-2020-2025.pdf

Ministry of Justice and Public Security. (2021). *Frihet fra vold. Regjeringens handlingsplan for å forebygge og bekjempe vold i nære relasjoner 2021-2024*. Retrieved from: https://www.regjeringen.no/contentassets/2dda3b36640d4dfbbbac11598a1dc792/209755-jd-frihetfravold-web.pdf

Ministry of Local government and Modernisation. (2021a). *Voluntary National Review 2021 Norway: Report on the Implementation of the 2030 Agenda for Sustainable* Development. Retrieved from: https://sustainabledevelopment.un.org/content/documents/28233Voluntary_National_Review_2021_Norway.pdf

Ministry of Local Government and Modernisation. (2021b). *We all ned a safe place to call home. National strategy for social housing policies (2021-2024).* Retrieved from https://www.regjeringen.no/contentassets/c2d6de6c12d5484495d4ddeb7d103ad5/we-all-need-a-safe-place-to-call-home-national-strategy-for-social-housing-policies-2021-2024.pdf

National Oceanic and Atmospheric Administration. (2021). Dr. Pieter Tans, NOAA/GML (gml.noaa.gov/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/). https://gml.noaa.gov/ccgg/trends/data.html

Norwegian Directorate of Health. (2010). *Forebygging, utredning og behandling av overvekt og fedme hos voksne. Nasjonale retningslinjer for primærhelsetjenesten.* (IS-1735). Retrieved from https://www.helsedirektoratet.no/retningslinjer/overvekt-og-fedme-hos-voksne/Overvekt%20og%20fedme%20hos%20voksne%20%E2%80%93%20Nasjonal%20faglig%20retningslinje%20for%20forebygging,%20utredning%20og%20behandling.pdf/_/attachment/inline/24ec824b-646d-4248-951f-db6b867ce6cb:4e0740b933ffd5bc03c8f0fdcab00b4135fe4ae9/Overvekt%20og%20fedme%20hos%20voksne%20%E2%80%93%20Nasjonal%20faglig%20retningslinje%20for%20forebygging,%20utredning%20og%20behandling.pdf

Norwegian Environment Agency. (2015). *Bedre utnyttelse av fosfor i Norge. Muligheter og anbefalinger*. (Rapport M-351: 2015). Retrieved from https://www.miljodirektoratet.no/globalassets/publikasjoner/m351/m351.pdf

Norwegian Environment Agency. (2020, September 25). *Vassdragsregulering*. Miljøstatus. https://miljostatus.miljodirektoratet.no/tema/ferskvann/vassdragsutbygging/

Norwegian Food Safety Authority. (2014). *Protocol on Water and Health. Nasjonale mål – vann og helse*. Retrieved from https://www.mattilsynet.no/mat_og_vann/drikkevann/nasjonale_maal_vann_og_helse/norges_maal_for_vann_og_helse.36772/binary/Norges%20m%C3%A5l%20for%20vann%20og%20helse

Norwegian Food Safety Authority. (2019). *Status for drikkevannsområdet i landets kommuner*. Retrieved from https://www.mattilsynet.no/mat_og_vann/drikkevann/opplysninger_om_vannforsyningssystemer/status_for_drikkevannsomraadet_i_landets_kommuner.36692/binary/Status%20for%20drikkevannsomr%C3%A5det%20i%20landets%20kommuner

Norwegian Institute for Water Research. (2021). *Kildefordelte tilførsler av nitrogen og fosfor til norske kystområder i 2019.* (NIVA Rapport L.NR. 7599-2021). Retrieved from https://www.miljodirektoratet.no/publikasjoner/2021/mars-2021/kildefordelte-tilforsler-av-nitrogen-og-fosfor-til-norske-kystomrader-i-2019---tabeller-figurer-og-kart/

Norwegian Institute of Bioeconomy Research. (n.d.a). Fertilization hanbook. Retrieved from https://www.nibio.no/tema/jord/gjodslingshandbok

Norwegian Institute of Bioeconomy Research. (n.d.b). *Redusert gjødslingsnorm for fosfor til korn. Fosfornormen endret november 2007*. Bioforsk. Retrieved from https://www.nibio.no/tema/jord/gjodslingshandbok/korreksjonstabeller/fosforbehov--korreksjon-etter-jordanalyser/_/attachment/inline/19fb5213-2b39-4dde-bea3-6025b00b9857:3b760ae9ebc344a7115b86955e0f629bcb1d288a/GH,%20Notat%201%20Ny%20gj%C3%B8dslingsnorm%20for%20fosfor%20til%20korn.pdf

Norwegian Labour and Welfare Administration. (2017). *Fattigdom og levekår i Norge*. (NAV Rapport 2017:4). Retrieved from https://www.nav.no/_/attachment/download/b7651a81-4fbe-49f4-a8b9-c47bcc3720bf:1f5afa5df4d7f7e7f76159ac75ce680f2740ec74/fattigdomsrapporten-2017.pdf

NOU 2009: 16. (2009). *Globale miljøutfordringer – norsk politikk— Hvordan bærekraftig utvikling og klima bedre kan ivaretas i offentlige beslutningsprosesser*. Ministry of Finance. https://www.regjeringen.no/no/dokumenter/nou-2009-16/id568044/?ch=1

Nybø, S. & Evju, M. (red). (2017). *Fagsystem for fastsetting av god økologisk tilstand. Forslag fra et ekspertråd.* Ekspertrådet for økologisk tilstand. Retrieved from https://www.regjeringen.no/no/dokumenter/fagsystem-for-fastsetting-av-godokologisk-tilstand/id2558481

Nykvist, B., Persson, Å., Moberg, F., Persson, L., Cornell, S., & Rockström, J. (2013). *National Environmental Performance on Planetary Boundaries: A study for the Swedish Environmental Protection Agency*. Stockholm Environment Institute, Stockholm. Retrieved from https://mediamanager.sei.org/documents/Publications/SEI-Report-Naturvardsverket-NationalEnvironmentalPerformance-2013.pdf

O'Neill, D.W., Fanning, A.L., Lamb, W.F. & Steinberger, J.K. (2018). A good life for all within planetary boundaries. *Nature sustainability*, *1*(2), 88-95. https://doi.org/10.1038/s41893-018-0021-4

Oslo Economics. (2022). *Mulighetsstudie for VA-sektoren med samfunnsøkonomiske analyser*. (OE-rapport 2022-2). Retrieved from https://www.regjeringen.no/contentassets/aa137c6a37ff4bdd936660ed6668d0f8/mulighetsstudie-for-va-sektoren-rapport-oslo-economics.pdf

Raworth, K. (2017). Doughnut Economics. Seven Ways to Think Like a 21st-Century Economist. London: Penguin Random House

Riley, H. (2016). N-gjødslingsnormen og N-balansen i korn [PowerPoint slides]. Docplayer. Retrieved from: https://docplayer.me/36092328-N-gjodslingsnormen-og-n-balanse-i-korn-hugh-riley-apelsvoll-korn-2016-skjetten.html

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. C., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen P., & Foley, J. A. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society, 14*(2), Article e32. http://www.ecologyandsociety.org/vol14/iss2/art32/

Rolstad, J., Framstad, E., Gundersen, V. & Storaunet, K. O. (2002). *Naturskog i Norge. Definisjoner, økologi og bruk i norsk skog- og miljøforvaltning*. (Aktuelt fra skogforskningen rapport 1/02). Retrieved from: https://nmbu.brage.unit.no/nmbu-xmlui/bitstream/handle/11250/2567761/Skogforsk-Aktuelt-2002-01.pdf?sequence=1&isAllowed=y

Sayers, M., Trebeck, K., & Stuart, F. (2014). *The Scottish Doughnut: A safe and just operating space for Scotland.* Oxfam GB. Retrieved from: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/323371/rr-scottish-doughnut-safe-just-space-scotland-250714-en.pdf?sequence=7&isAllowed=y

Scholes, R. J., & Biggs, R. (2005). A biodiversity intactness index. *Nature, 434*(7029), 45-49. https://doi.org/10.1038/nature03289

Shaikh, A. M., Hadjikakou, M., & Bryan, B. A. (2021). National-level consumption-based and production-based utilisation of the land-system change planetary boundary: patterns and trends. *Ecological Indicators*, *121*, Article e106981. https://doi.org/10.1016/j.ecolind.2020.106981

St.meld. 37 (2008-2009). *Report No. 37 to the Storting (2008-2009). Integrated Management of the Marine Environment of the Norwegian Sea. Chapter 6: Climate change and ocean acidification.* Ministry of the Environment. https://www.regjeringen.no/no/dokumenter/stmeld-nr-37-2008-2009-/id560159/?ch=6

St.meld. 46 (1988-89). *Miljø og Utvikling: Oppfølging av Verdenskommisjonens rapport.* Ministry of the Environment. https://www.stortinget.no/no/Saker-og-publikasjoner/Stortingsforhandlinger/Lesevisning/?p=1988-89&paid=3&wid=d&psid=DIVL401&pgid=d_0412

Statistics Norway (s.a.). *Bærekraftsmål 3: God helse og livskvalitet. Delmål 3.4: Redusere dødeligheten fra ikke-smittsomme sykdommer og fremme mental helse*. Retrieved from: https://www.ssb.no/sdg/god-helse-og-livskvalitet

Statistics Norway. (2014). *Oversikt over personer med ulik grad av innvandringsbakgrunn.* (Rapport 2014/16). Retrieved from: https://www.ssb.no/en/befolkning/artikler-og-publikasjoner/_attachment/175380?_ts=145cbac2a08

Statistics Norway. (2017). *Vanskeligstilte på boligmarkedet. Hvordan måle og hvem er usatt på boligmarkedet?* (Rapport 2017/9). Retrieved from: https://www.ssb.no/bygg-bolig-og-eiendom/artikler-og-publikasjoner/_attachment/302752?_ts=15b3883f218

Statistics Norway. (2018). *08295: Kommunestyre- og fylkestingsvalget. Stemmeberettigede, etter kjønn, statistikkvariabel og fireårlig* [Statistikk]. https://www.ssb.no/statbank/table/08295/tableViewLayout1/

Statistics Norway. (2019a). *04621: Utsatthet og uro for lovbrudd, etter type lovbrudd, kjønn og alder (prosent) 1983-2018* [Statistikk]. https://www.ssb.no/statbank/table/04621/

Statistics Norway. (2019b). *12758: Kommunestyre- og fylkestingsvalget. Stemmeberettigede, etter gruppe av stemmeberettigede, statistikkvariabel, fireårlig og kjønn* [Statistikk]. https://www.ssb.no/statbank/table/12758/tableViewLayout1/

Statistics Norway. (2020a). *01183: Fylkestingsvalget. Representanter, etter kjønn, statistikkvariabel og fireårlig* [Statistikk]. https://www.ssb.no/statbank/table/01183/tableViewLayout1/

Statistics Norway. (2020b). *04306: Sosial kontakt, etter kjønn og alder (prosent) 1998-2019* [Statistikk]. https://www.ssb.no/statbank/table/04306/

Statistics Norway. (2020c). *04980: Kommunestyremedlemmer, etter landbakgrunn, statistikkvariabel og fireårlig* [Statistikk]. https://www.ssb.no/statbank/table/04980/tableViewLayout1/

Statistics Norway. (2020d). *04996: Fylkestingsmedlemmer, etter landbakgrunn, statistikkvariabel og fireårlig* [Statistikk]. https://www.ssb.no/statbank/table/04996/tableViewLayout1/

Statistics Norway. (2020e). *06181: Levevaner, etter kjønn og alder (prosent) 1998 – 2019* [Statistikk]. https://www.ssb.no/statbank/table/06181/

Statistics Norway. (2020f). *12872: Medlemmer og gjenvalgte medlemmer til kommunestyret, etter kjønn, statistikkvariabel og fireårlig* [Statistikk]. https://www.ssb.no/statbank/table/12872/tableViewLayout1/

Statistics Norway. (2020g). *Forprosjekt om indikatorer for menneskerettigheter. Innspill fra SSBs arbeidsgruppe.* (Notater 2020/32). Retrieved from: https://www.ssb.no/sosiale-forhold-og-kriminalitet/artikler-og-publikasjoner/_attachment/433620?_ts=17501d31888

Statistics Norway. (2020h). *Nasjonale befolkningsframskrivinger* [Statistikk]. https://www.ssb.no/befolkning/befolkningsframskrivinger/statistikk/nasjonale-befolkningsframskrivinger

Statistics Norway. (2020i, September 24). *Ulikheten – betydelig større enn statistikken viser*. (Analyse 2020/13). Retrieved from https://www.ssb.no/inntekt-og-forbruk/artikler-og-publikasjoner/ulikheten-betydelig-storre-enn-statistikken-viser

Statistics Norway. (2021a). *05453: Kommunestyre- og fylkestingsvalget. Stemmeberettigede. Foreløpige tall, etter gruppe av stemmeberettigede, statistikkvariabel og fireårlig* [Statistikk]. https://www.ssb.no/statbank/table/05453/tableViewLayout1/

Statistics Norway. (2021b). *08638: Personoffer for anmeldte lovbrudd, etter år, lovbruddstype, statistikkvariabel og kjønn* [Statistikk]. https://www.ssb.no/statbank/table/08638/tableViewLayout1/?loadedQueryId=10043955&timeType=from&timeValue=2004

Statistics Norway. (2021c). *08940: Klimagasser, etter utslippskilde, energiprodukt og komponent 1990 – 2020* [Statistikk]. https://www.ssb.no/statbank/table/08940/tableViewLayout1/

Statistics Norway. (2021d). *11564: Andelen fornybar energi for Norge totalt og transportmålet 2004 – 2019* [Statistikk]. https://www.ssb.no/statbank/table/11564/

Statistics Norway. (2021e). *11787: Vannforsyning og beredskap. Kommunalt drikkevann, etter statistikkvariabel, region og år* [Statistikk]. https://www.ssb.no/statbank/table/11787/tableViewLayout1/

Statistics Norway. (2021f). *12424: Arbeidsstyrkestatus for personer 15-29 år 2008 - 2020.* [Statistikk]. https://www.ssb.no/statbank/table/12424/tableViewLayout1/

Statistics Norway. (2021g). *12969: Gjennomføring i videregående opplæring, etter statistikkvariabel, fullføringsgrad, todelt utdanningsprogram, kjønn, innvandringskategori og intervall (år)* [Statistikk]. https://www.ssb.no/statbank/table/12969/tableViewLayout1/

Statistics Norway. (2021h, March 29*). 115 000 barn i husholdninger med vedvarende lavinntekt.* Retrieved from: https://www.ssb.no/inntekt-og-forbruk/inntekt-og-formue/artikler/115-000-barn-i-husholdninger-med-vedvarende-lavinntekt

Statistics Norway. (2021i, May 7). *Blir vi stadig mer ensomme?* (Analyse 2021/08). Retrieved from: https://www.ssb.no/sosiale-forhold-og-kriminalitet/artikler-og-publikasjoner/blir-vi-stadig-mer-ensomme

Statistics Norway. (2022a). *09858: Personer i alderen 15-29 år som verken er sysselsatt eller under utdanning, etter alder, kjønn, statistikkvariabel og år* [Statistikk]. https://www.ssb.no/statbank/table/09858/tableViewLayout1/

Statistics Norway. (2022b). *11042: Personer, etter statistikkvariabel, alder, kjønn, trangboddhet og år* [Statistikk]. https://www.ssb.no/statbank/table/11042/tableViewLayout1/

Statistics Norway. (2022c). *11045: Personer, etter statistikkvariabel, innvandringskategori, trangboddhet og år* [Statistikk]. https://www.ssb.no/statbank/table/11045/tableViewLayout1/

Statistics Norway. (2022d). *Døde.* Retrieved from: https://www.ssb.no/befolkning/fodte-og-dode/statistikk/dode

Statistics Norway. (2022e). *Lønn*. Retrieved from: https://www.ssb.no/arbeid-og-lonn/lonn-og-arbeidskraftkostnader/statistikk/lonn

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223). https://doi.org/10.1126/science.1259855

Steinacher, M., Joos, F. & Stocker, T. (2013). Allowable carbon emissions lowered by multiple climate targets. *Nature 499*, 197–201. https://doi.org/10.1038/nature12269

Svensson, A., & Dalen, L. S. (Red.) 2021. *Bærekraftig skogbruk i Norge*. Norwegian Institute of Bioeconomy Research. Retrieved from https://www.skogbruk.nibio.no/skogareal

Teah, H. Y., Akiyama, T., San Carlos, R., Rayo, O. V., Khew, Y. T. J., Zhao, S., Zheng, S., & Onuki, M. (2016). Assessment of downscaling planetary boundaries to semi-arid ecosystems with a local perception: a case study in the middle reaches of Heihe River. *Sustainability*, *8*(12), Article e1233. https://doi.org/10.3390/su8121233

Ulén, B., Bechmann, M., Øygarden, L., & Kyllmar, K. (2012). Soil erosion in Nordic countries–future challenges and research needs. *Acta Agriculturae Scandinavica, Section B–Soil & Plant Science*, *62*(sup2), 176-184. https://doi.org/10.1080/09064710.2012.712862

United Nations. (2019). United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, Online Edition. Rev. 1: https://population.un.org/wpp/Download/Standard/Population/

United Nations. (2021). Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. United Nations. Retrieved from: https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202021%20refinement_Eng.pdf

United Nations Framework Convention on Climate Change. (2016). *The Paris Agreement*. Retrieved from: https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf

United Nations Framework Convention on Climate Change. (2020). *Update of Norway's nationally determined contributions.* Retrieved from https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Norway%20First/Norway_updatedNDC_2020%20(Updated%20submission).pdf

Vannforskriften. (2006). *Forskrift om rammer for vannforvaltningen* (FOR-2006-12-15-1446). Lovdata. https://lovdata.no/dokument/SF/forskrift/2006-12-15-14462

Vannressursloven. (2000). *Lov om vassdrag og grunnvann (vannressursloven)* (LOV-2000-11-24-82). Lovdata. https://lovdata.no/dokument/NL/lov/2000-11-24-82

Veron, J. E., Hoegh-Guldberg, O., Lenton, T. M., Lough, J. M., Obura, D. O., Pearce-Kelly, P. A. U. L., ... & Rogers, A. D. (2009). The coral reef crisis: The critical importance of< 350 ppm CO2. *Marine pollution bulletin, 58*(10), 1428-1436. https://doi.org/10.1016/j.marpolbul.2009.09.009

Wang-Erlandsson, L., Tobian, A., van der Ent, R. J., Fetzer, I., te Wierik, S., Porkka, M., ... & Rockström, J. (2022). A planetary boundary for green water. *Nature Reviews Earth & Environment*, 1-13. https://doi.org/10.1038/s43017-022-00287-8

World Bank. (n.d.). *Did you know?* Poverty and Inequality Platform. Retrieved from <2022, May 11> https://pip.worldbank.org/home

World Health Organization. (2021, June 9). *Obesity and overweight*. World Health Organization. Retrieved from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight#:~:text=Worldwide%20obesity%20has%20nearly%20tripled,%2C%20and%2013%25%20were%20obese.

Øgaard, A. F. (2014). Nitrogen balance and nitrogen use efficiency in cereal production in Norway. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *63*(sup2), 146-155. https://doi.org/10.1080/09064710.2013.843718

Øgaard, A. F., & Bechmann, M. (2018). Nitrogen Balances and Nitrogen Use Efficiency in the Nordic Countries. In *Soil Nitrogen Uses and Environmental Impacts* (pp. 141-150). CRC Press.

Øverland, S., Knudsen, A. K., Vollset, S. E., Kinge, J.M., Skirbekk, V., & Tollånes, M.C. (2018). *Sykdomsbyrden i Norge 2016 Resultater fra Global Burden of Diseases, Injuries, and Risk Factors Study 2016 (GBD 2016).* (Rapport 2018). Norwegian Institute of Public Health. Retrieved from https://www.fhi.no/globalassets/dokumenterfiler/rapporter/2018/sykdomsbyrden-i-norge-i-2016.pdf

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway