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SWEDISH ENVIRONMENTAL PROTECTION AGENCY

Living within the limits of our planet – a Swedish perspective

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by Lisa Eriksson at the Knowledge Coordination Unit

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Preface

The 2019 in-depth evaluation of the Swedish environmental objectives states that knowledge about planetary boundaries is a cornerstone in planning and developing policy instruments to allow society to develop sustainably.

The operational plan of the Swedish Environmental Protection Agency for the years 2022–2024[2] notes that implementing the European Green Deal requires a new focus on developing knowledge and increased cooperation with experience from the EU and the European Environmental Agency. The Swedish EPA participates in the Eionet working group on planetary boundaries coordinated by the EEA.

The purpose of this report is to look further into planetary boundaries from a Swedish perspective to improve our understanding ahead of the in-depth evaluation of the Swedish environmental objectives in 2023. Better understanding of the impact of our consumption on Earth's resources may help inspire priorities in policy development. The aim has been to point to footprints in the Swedish share of planetary boundaries, compare with earlier or adjacent results, and discuss prerequisites and indicators for Sweden.

This report has been written by Lisa Eriksson at the Knowledge Coordination Unit.

Stockholm, December 2022

Maria Ohlman
Head of Sustainable Development Department

[1] Naturvårdsverket (2022). Verksamhetsplan 2022-2024. NV-06356-21

Contents

Summary

For society to develop sustainably, understanding planetary boundaries is a cornerstone in planning and developing policy instruments. There are also large synergies between environmental objectives and other societal goals. The Swedish generational goal states that "The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside of Sweden's borders."

The planetary boundary framework was introduced in 2009 and consists of proposed boundaries within which humanity can continue to develop and thrive, known as a "safe operating space". This report looks deeper into planetary boundaries from a Swedish perspective to point to footprints in the Swedish share of planetary boundaries, to compare with earlier and adjacent results, and to introduce a discussion on prerequisites and indicators for Sweden.

Different principles can show the way when analysing the Swedish safe operating space in relation to the planetary boundaries. Depending on the starting point – equality, needs, right to development, sovereignty, or ability – we come to a variety of answers. This can broaden the perspectives of what a safe operating space might be. This report uses a mix of these principles to come to a median value while also illustrating the zone of uncertainty. With the aim to point to footprints in the Swedish share, this report then uses European footprint results and estimates rough values for Sweden. When these different perspectives are taken into account, in the final results only freshwater use is within the estimated Swedish share of safe operating space.

The four planetary boundaries in focus for these analyses – biogeochemical flows (both nitrogen cycle and phosphorus cycle), land system change, and freshwater use – are strongly driven by the food system. The European Green Deal mentions transformation of production and consumption systems like energy, food, mobility and the built environment. These systems rely on the same natural resources, which means that policy interventions may generate both synergies and trade-offs across natural resources.

Transforming a system is preferably guided by a systemic approach. This means policy development needs to address different levels and to follow up on progress with indicators that can capture the complexity of the issue. The framework for monitoring the environmental impacts linked to Swedish consumption, both inside and outside of Sweden's borders, developed by the PRINCE project is one important approach, as well as looking further into footprints in relation to planetary boundaries.

Results indicate that from a social perspective Sweden has a strong platform from which to intensify sustainable transformation. The generational goal encourage us to not increase environmental and health problems outside of Sweden's borders. The PRINCE project lets us see where our footprints are geographically situated. Social indicators then allow us to find whether these areas are within their social boundaries. This creates an opportunity to look deeper into how our society should be organised for a sustainable and just transition.

Informed decisions need knowledge that can tell us more about the direct and indirect interconnections between different natural resources, their management, use and governance, and synergies and trade-offs. Findings can highlight knowledge gaps and imbalances in policy focus, increasing the systemic understanding of sustainability challenges and responses. This report shows examples of analyses from a systems perspective, with a focus on consumption footprints and analyses from the viewpoint of planetary boundaries.

The Swedish Riksdag has decided to work for sustainable development in all three dimensions and to integrate that work in existing processes. Further understanding of what impact our consumption has on Earth's resources can serve to inspire priorities in policy development. Discussions on "what is a good life" and what a possible sustainable life could look like are important steps along the way.

Sammanfattning

För att samhället ska utvecklas på ett långsiktigt hållbart sätt är kunskapen om planetens gränser en grundsten när vi planerar samhället och utvecklar styrmedel. Det finns också stora synergier mellan miljömål och andra samhällsmål. Det svenska generationsmålet säger att *”Det övergripande målet för miljöpolitiken är att till nästa generation lämna över ett samhälle där de stora miljöproblemen är lösta, utan att orsaka ökade miljö- och hälsoproblem utanför Sveriges gränser.”*

Planetära gränser som ramverk introducerades 2009 och är föreslagna gränser inom vilka mänskligheten kan fortsätta att utvecklas och blomstra, som ett tryggt utrymme att agera inom. Denna rapport tittar närmare på planetära gränser utifrån ett svenskt perspektiv med syftet att visa fotavtryck i relation till Sveriges andel av de planetära gränserna, att göra jämförelser med tidigare och närliggande resultat och att introducera en diskussion om förutsättningar och indikatorer för Sverige.

Det finns olika principer som kan visa vägen vid analys av Sveriges andel av de planetära gränserna. Beroende på utgångspunkt – jämlikhet, behov, rätt till utveckling, suveränitet, eller förmåga – så får vi en variation av svar. Detta kan bidra till att bredda perspektiven på vad vårt utrymme kan vara. I denna rapport används en mix av dessa principer för att få fram ett medianvärde samtidigt som osäkerheten för utrymmet illustreras. I syfte att visa fotavtryck inom Sveriges andel av utrymmet, har rapporten använt approximerade värden för Sverige utifrån europeiska fotavtryck. När hänsyn tas till dessa olika perspektiv, så är det bara resultatet för färskvattenanvändning som håller sig inom Sveriges andel av utrymmet.

För de fyra planetära gränserna i fokus för rapportens analyser – biogeokemiska flöden (både fosforcykeln och kvävecykeln), förändrad markanvändning och färskvattenanvändning – är livsmedelssystemet en särskilt stark bakomliggande drivkraft. Den europeiska gröna given nämner omställning av system för produktion och konsumtion inom energi, livsmedel, mobilitet och byggd miljö. Dessa system förlitar sig på samma naturresurser, vilket betyder att styrmedel kan ge upphov till både synergier och målkonflikter i användningen av naturresurser.

En omställning av olika system kan med fördel vägledas av ett systemtänkande. Detta betyder att inte bara behöver styrmedelsutvecklingen adressera de olika nivåer som ingår, utan uppföljningen av framsteg behöver också ske med indikatorer som kan fånga frågans komplexitet. Ramverket för uppföljning av miljöeffekter kopplade till svensk konsumtion, både inom och utanför Sveriges gränser, som har utvecklats av projektet PRINCE är en viktig metod, liksom att närmare undersöka fotavtryck i relation till de planetära gränserna.

Från ett samhällsperspektiv har Sverige en stark plattform för att intensifiera en hållbar samhällsomställning. Enligt generationsmålet så ska vi inte öka miljö- och hälsoproblemen utanför Sveriges gränser. Med hjälp av projektet PRINCE är det möjligt att få en bild av var våra fotavtryck sker geografiskt sett. Därtill kan sociala indikatorer möjliggöra för oss att se om dessa områden befinner sig inom sina sociala gränsvärden. Detta skapar en möjlighet att närmare undersöka hur vårt samhälle behöver organiseras för en hållbar och rättvis omställning.

Informerade beslut behöver kunskapsunderlag som kan berätta mer om direkta och indirekta samband mellan olika naturresurser, deras hantering,

användning och styrning, liksom synergier och målkonflikter. Resultaten kan belysa kunskapsluckor och obalanser i styrmedelsfokus vilket på så sätt kan öka förståelsen för hållbarhetsutmaningarna och återkopplingarna sett i ett systemperspektiv. Denna rapport visar exempel på analyser som utgår från ett systemperspektiv, med fokus på fotavtryck från konsumtion och analyser utifrån planetära gränser.

Sveriges riksdag har beslutat att verka för hållbar utveckling i de tre dimensionerna och inom ordinarie processer. Ytterligare förståelse av vilken påverkan vår konsumtion har på jordens resurser kan fungera som inspiration för prioriteringar i styrmedelsutvecklingen. Diskussioner om vad ett gott liv är och hur ett möjligt hållbart liv kan se ut är viktiga steg längs vägen.

1. Introduction

We face urgent environmental challenges in the coming years. It continues to be important to have the appropriate knowledge to support our priorities and decisions. One of the key messages of the 2019 in-depth evaluation of the Swedish environmental objectives is the need to decrease the environmental impact from our consumption: *"Swedish consumption of flights, food, palm oil, electronics, textiles etcetera have a large impact on environment and health, of which a very large part is found in other countries. Sweden has a responsibility for the environmental problems caused by our consumption, wherever in the world they appear. To develop effective policy instruments for decreasing environmental impact is important for achieving the environmental objectives"*[2]

The 2019 in-depth evaluation also states that knowledge about planetary boundaries is a cornerstone in planning and developing policy instruments for society to develop sustainably and that there are large synergies between the environmental objectives and other societal goals. The Swedish generational goal says that *"The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside of Sweden's borders."*

The environmental objectives together with the Agenda 2030 and the Global Goals for Sustainable Development are important beacons, as is the EU 2050 vision of living well within the planetary boundaries[3].

The planetary boundary framework was introduced in 2009[4] and revised in 2015[5] by Stockholm Resilience Center. Efforts to further define boundaries are ongoing. The planetary boundaries are proposed boundaries within which humanity can continue to develop and thrive, as a "safe operating space". Crossing these borders may increase the risk of generating large-scale abrupt or irreversible environmental changes that could turn the Earth system into states damaging or catastrophic for our development. The framework is based on nine planetary boundaries: (1) climate change; (2) change in biosphere integrity; (3) stratospheric ozone depletion; (4) ocean acidification; (5) biogeochemical flows — interference with phosphorus (P) and nitrogen (N) cycle; 6) land system change; (7) freshwater use; (8) atmospheric aerosol loading; and (9) introduction of novel entities such as new substances or modified life forms.

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[2] Naturvårdsverket (2019). Fördjupad utvärdering av miljömålen 2019: Med förslag till regeringen från myndigheter i samverkan. Naturvårdsverket, Rapport 6865.

[3] Council of the EU, Press release, 29 March 2022. https://www.consilium.europa.eu/en/press/press-releases/2022/03/29/council-adopts-8th-environmental-action-programme/ 5 May 2022.

[4] Rockström et al. (2009). Planetary boundaries: exploring the safe operating space for humanity, *Ecology and Society* 14(2) (DOI: 10.5751/ES-03180-140232).

[5] Steffen et al. (2015). Planetary boundaries: guiding human development on a changing planet. Science 347(6223), p. 1259855 (DOI:10.1126/science.1259855).

The last state of the environment report from the European Environmental Agency[6] uses the planetary boundary framework to illustrate the degree to which Europe lives within the limits of our planet. The underlying report "Is Europe living within the limits of our planet?"[7] contains analyses and discussions of the European results for some of the planetary boundaries.

That report is also the starting point for the analyses in this report, with a Swedish perspective on living within the limits of our planet, and an ambition to investigate the issue based on existing data. This may also improve the ability to compare and exchange experience with the European level.

1.1 Aim with the Swedish perspective

The purpose of this report is to look further into planetary boundaries from a Swedish perspective to improve our knowledge in time for the next in-depth evaluation of the Swedish environmental objectives. Further understanding of what impact our consumption has on Earth's resources can help inspire priorities in policy development. The aim has been to point to footprints in the Swedish share of planetary boundaries, compare with earlier or adjacent results, and discuss prerequisites and indicators for Sweden.

1.2 The approach

With the aim of looking more closely at planetary boundaries from a Swedish perspective and to introduce a discussion on prerequisites for Sweden, the approach of this report is to combine new findings, comparisons of shares/limits and footprints and to relate these to Swedish conditions. This means both showing research in related areas and telling how planetary boundary analyses are connected to other initiatives and discussions.

Analysing whether Sweden lives within the limits of our planet is done in four steps: 1) selecting control variables for the planetary boundaries we intend to study; 2) determining how to allocate the Swedish share of the planetary boundaries and define our safe operating space; and 3) calculating the footprints from Swedish consumption using the same variables as above (a simplified approach is used in this report); and 4) analysing whether these footprints are within limits.

As noted earlier, the EEA/FOEN report "Is Europe living within the limits of our planet?"[8] is a starting point for the methodological approach of this report. Their analyses focused on four planetary boundaries: biogeochemical flows (both nitrogen cycle and phosphorus cycle), land system change, and freshwater use. This report follows the same approach and uses the same control variables.

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[6] EEA (2019b). The European environment – state and outlook 2020. SOER 2020. Luxemburg: Publications Office of the European Union.

[7] EEA/FOEN (2020). Is Europe living within the limits of our planet? Joint EEA/FOEN Report. EEA Report No 1/2020: https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

[8] EEA/FOEN (2020). Is Europe living within the limits of our planet? Joint EEA/FOEN Report. EEA report No 1/2020: https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

EEA/FOEN analysed allocation of the European shares using five allocation principles: equality, needs, right to development, sovereignty, and capability[9]. This report uses the same calculation methods to define Swedish limits and to compare and discuss the results for Sweden and Europe. The European results are taken directly from their report, which covered the combined territory of the 33 member countries of the EEA in 2019 (28 EU Member States – United Kingdom included – plus Iceland, Liechtenstein, Norway, Switzerland and Turkey). EEA/FOEN chose 2011 as the reference year because of the availability of corresponding footprint data. Accordingly, Swedish calculations are based on the same reference year. Finally, EEA/FOEN analysed footprints for the chosen planetary boundaries. This report uses their European footprint results and estimates rough values for Sweden. Further details are given later in this report.

In addition to this, results for social boundaries provide a complementary picture of whether we are living a good life within the limits. This is inspired by the doughnut concept[10], with data from Leeds University.[11] The report also illustrates footprints in relation to planetary boundaries for a Swedish diet, with data from the Swedish University of Agricultural Science[12].

The reference years for the report's analyses vary. Availability of data differs between countries, and the analyses including or comparing many countries date back to 2011[13]. Adding results from different references is an attempt to provide additional perspectives for the results. Additional footprint results from the PRINCE project show the development from 2005–2017 and 2008–2019, respectively[14] (see section 4.2), while the study on the Swedish diet has used an average of data from 2011–2015[15] (see section 5.2).

Three boxes in the chapters show examples from a recent internal project at the Swedish EPA called "Sweden 2050". The project consisted of discussions and underlying material for the discussions. The following three areas from the project are presented in the boxes: 1) discussions on "what is a good life"; 2) an analysis on transportation, energy sector and the connection to biomass; and 3) discussions about how a sustainable life could look like in Sweden in 2050 with a focus on food.

The following chapters introduce the steps and results one after the other, with more detailed descriptions on assumptions and references used along the way. Results are to be interpreted based on the assumptions chosen.

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[9] EEA/FOEN (2020), Annex 1, 'Computation methods used for each allocation principle'.

[10] Raworth (2012). A safe and just space for humanity — can we live within the doughnut? Oxfam Discussion Papers, Oxford, UK; Raworth (2017). A Doughnut for the Anthropocene. Humanity's compass in the 21st century. The Lancet Planetary Health 1(2), e48-e49.

[11] Leeds University (2021). A good life for all within planetary boundaries, Country Comparisons - A Good Life For All Within Planetary Boundaries, https://goodlife.leeds.ac.uk/national-snapshots/countries/, 23 August 2021.

[12] Moberg et al. (2020). "Benchmarking the Swedish Diet Relative to Global and National Environmental Targets—Identification of Indicator Limitations and Data Gaps." Sustainability 12(4): 1407. https://www.mdpi.com/2071-1050/12/4/1407

[13] This is the case in Stephen et al. (2015), EEA/FOEN (2020) and Leeds University (2021).

[14] Brown et al. (2022). New methods and environmental indicators supporting policies for sustainable consumption in Sweden. Swedish Environmental Protection Agency, Report 7032.

[15] Moberg et al. (2020). "Benchmarking the Swedish Diet Relative to Global and National Environmental Targets—Identification of Indicator Limitations and Data Gaps." Sustainability 12(4): 1407. https://www.mdpi.com/2071-1050/12/4/1407

2. Planetary boundaries

The planetary boundaries are proposed boundaries within which humanity can continue to develop and thrive, as a "safe operating space" [16]. All nine planetary boundaries are not defined, but efforts to do so are ongoing. Figure 2.1 illustrates the framework and the global situation for the defined boundaries. Exceeding the boundaries may increase the risk of generating large-scale abrupt or irreversible environmental changes that could turn the Earth system into states damaging or catastrophic for our development.

Two boundaries, climate change and biosphere integrity, are identified as core indicators and have the potential on their own to drive the Earth system into a new state if one of them should be substantially and persistently overshot[17]. The other boundaries influence these core indicators.

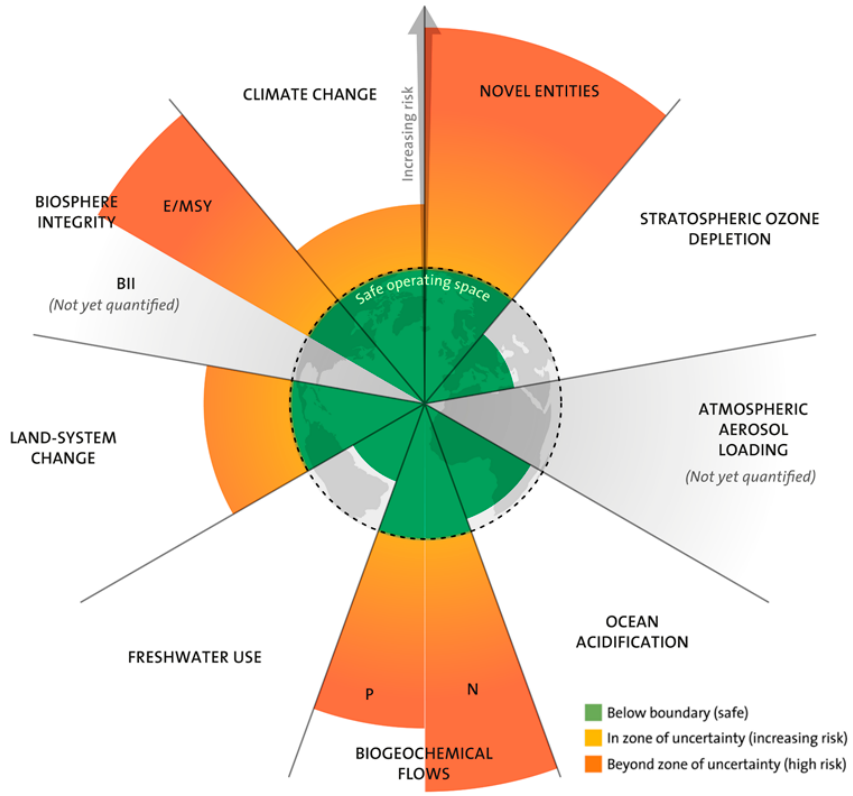


Figure 2.1. The nine planetary boundaries. The green, orange and red zones are explained in the legend. Source: Designed by Azote for Stockholm Resilience Centre, based on analysis in Persson et al. (2022) and Steffen et al. (2015).

[16] Steffen et al. (2015). Planetary boundaries: guiding human development on a changing planet. *Science* 347(6223), p. 1259855 (DOI:10.1126/science.1259855).

[17] Steffen et al. (2015). Planetary boundaries: guiding human development on a changing planet. *Science* 347(6223), p. 1259855 (DOI:10.1126/science.1259855).

According to Figure 2.1, humanity has already exceeded the safe operating space for the five planetary boundaries biosphere integrity, climate change, novel entities, biogeochemical flows, and land system change. The global situation for biosphere integrity, novel entities, and biogeochemical flows are at high risk level, and there is an increasing risk when it comes to climate change and land system change.

2.1 Planetary boundaries and the Swedish Environmental objectives

In 2013, a study on National Environmental Performance on Planetary Boundaries was commissioned by the Swedish EPA and conducted by the Stockholm Resilience Centre and the Stockholm Environment Institute[18]. The aim was to support work on the Swedish environmental objectives by drawing on new research on planetary boundaries to provide new perspectives on and new indicators for the international dimension of Swedish environmental policy. The report involved identifying appropriate data series that consider both territorial and consumptive performance.

The study examined the connections between planetary boundaries and Swedish environmental objectives, which are illustrated in Figure 2.2.

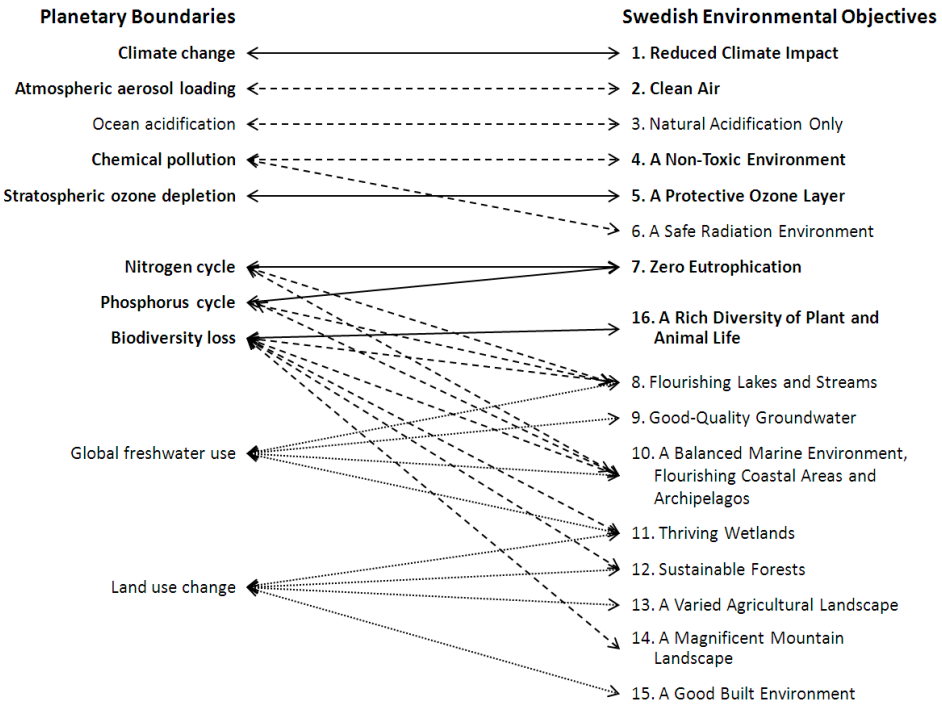


Figure 2.2. Connections between planetary boundaries and Swedish environmental objectives. Source: Nykvist et al. (2013).

[18] Nykvist et al. (2013). National Environmental Performance on Planetary Boundaries. A Study for the Swedish Environmental Protection Agency. Swedish Environmental Protection Agency, Report 6576.

2.2 Global limits and control variables

The report "Is Europe living within the limits of our planet?"[19] analysed European performance against four planetary boundaries: biogeochemical flows (both nitrogen cycle and phosphorus cycle), land system change, and freshwater use. The framework has proposed biophysical control variables[20], but in the report these variables were amended to make them compatible with European footprint data. Studies on planetary boundaries may differ in boundary definitions, which is important to have in mind when comparing studies. Table 2.1 shows examples of differently defined boundaries, and Table 2.2 shows control variables used in this study.

Table 2.1. A comparison between some control variables (summarily). Source: EEA/FOEN (2020) for discussions on Steffen et al. (2015) and Dao et al. (2015, 2018). See also Moberg (2020) for EAT-Lancet variables (Willett et al. 2018), and O'Neill et al. (2018).

		Control variable	Global limit	Unit
Nitrogen cycle	Steffen	N fixation	62–82	Tg N/year
	Dao	N losses		
	Moberg	N application	90 (65–130)	Tg N/year
Phosphorus cycle	Steffen	P flows	11–100	Tg P/year
	Dao	P release		
	Moberg	P application	8 (6–16)	Tg P/year
Land system change	Steffen	Forested land/original forest cover		
	Dao	Anthropised land area	19.4	million km^2
	Moberg	Cropland use	13 (11–15)	million km^2
Freshwater use	Steffen	Maximum amount of consumptive blue water use	4000	km^3/year
	Moberg	Consumptive water use	2500 (1000–4000)	km^3/year
Biodiversity loss	Moberg	Extinction rate	10 (1–80)	E/MSY*
	Steffen	Extinction rate	10	E/MSY*
Climate change	Moberg	GHG emissions	5 (4.7–5.4)	Gton CO_2e/year
	O'Neill	Atmospheric CO_2 concentration/capita	1.6	tonnes CO_2/year

*E/MSY=yearly extinctions per million species-years

[19] EEA/FOEN (2020). Is Europe living within the limits of our planet? Joint EEA/FOEN Report. EEA report No 1/2020: https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

[20] Steffen et al. (2015). Planetary boundaries: guiding human development on a changing planet. Science 347(6223), p. 1259855 (DOI:10.1126/science.1259855), and Rockström et al. (2009).

Table 2.2. Control variables and global limits used in this study. Source: EEA/FOEN (2020).

Planetary boundary	EEA/FOEN control variable (compatible with European footprint data)	Global limit	Unit
Nitrogen cycle	Loss of nitrogen from agriculture per year	28.5	Tg N/year
Phosphorus cycle	Loss of phosphorus from agriculture and wastewater per year	0.92	Tg P/year
Land system change	Anthropised area	19 400 000	km^2
Fresh water use	Maximum amount of consumptive blue water use per year	4 000	km^3/year

3. A safe operating space

The planetary boundaries are established on a global scale. To estimate a safe operating space on a regional scale, a choice of allocation principles is required. The easiest way is to use an equality approach and an equal share per capita calculation, based on the population for a fixed year, without considering the needs of future populations. However, the negotiations on climate change and the United Nations Framework Convention on Climate Change (UNFCCC) include many ways to discuss equity and fairness.

There are normative questions to be asked: An equal and fair way, for whom? How do we define equality and fairness? What is a good life? As a comparison, the Swedish generational goal states *"…without increasing environmental and health problems outside of Sweden's borders"*.

3.1 Allocation of shares

"Is Europe living within the limits of our planet?" discusses six principles of allocation and five of them are used: equality, needs, rights to development, sovereignty, capability, and responsibility[21]. These principles are grouped by their focus on people or countries as the allocation recipients, see Table 3.1.

Table 3.1. Overview of allocation principles. Source: EEA/FOEN (2020).

People	Countries
Equality	Soveregnity
Needs	Capability (ability to pay)
Rights to development	Responsibility

Table 3.2 describes the principles. In the allocation process, the next step is then to operationalise the principles. For each of these allocation principles, calculation methods have been applied to ensure a broad range of perspectives of shares that also represents different normative choices. For a full description of the methodology, see "Is Europe living within the limits of our planet?" [22]. More information on allocation principles, calculation methods and allocation keys is also available in the Appendix.

[21] EEA/FOEN (2020). Is Europe living within the limits of our planet? Joint EEA/FOEN Report. EEA Report No. 1/2020: https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

[22] EEA/FOEN (2020). Is Europe living within the limits of our planet? Joint EEA/FOEN Report. EEA Report No. 1/2020: https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

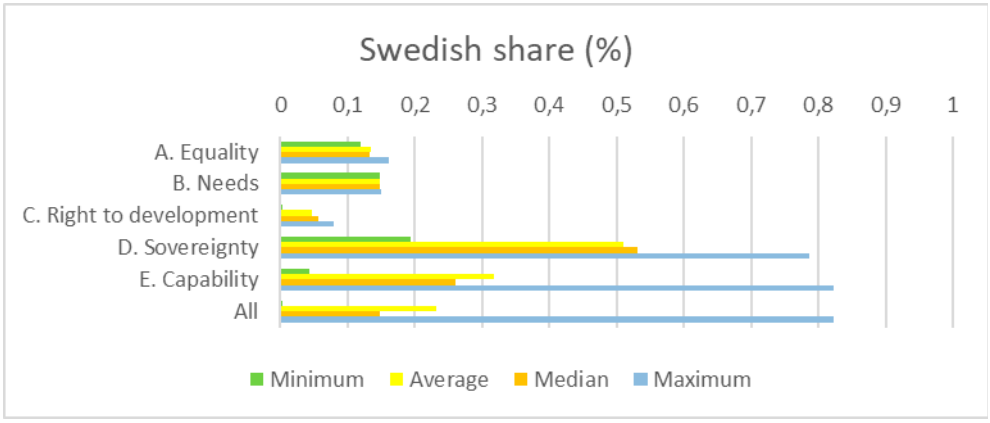
Table 3.2. Short description of allocation principles applied in "Is Europe living within the limits of our planet?" and in this report. Source: EEA/FOEN (2020).

Allocation principle	Description
A. Equality	People have equal rights to use resources, resulting in an equal share per capita. Equality can be envisaged among people living in a particular year or among people over time.
B. Needs	People have different resource needs. This could be because of their age, the size of the household they live in or their location. As a result, their right to resources could also be different.
C. Right to development	People have the right to have a decent life (e.g. the right to cover basic needs). In the long term, a convergence of welfare among people could be envisaged. People in countries with lower development levels could thus be allocated more resources or contribute less to mitigation efforts to enable development objectives to be met.
D. Sovereignty	Other than in relation to engagements in international treaties, countries are managed based on internal policy rules. Countries have a legal right to use their own territory as they choose. In addition, countries have different levels of economic wealth and environmental impacts (generated domestically and in foreign economies). This situation is accepted as a starting point for allocating the global budget on national scales (e.g. by grandfathering).
E. Capability	Countries have different levels of economic wealth. Countries with higher financial capabilities could contribute proportionally more to mitigation efforts or use less than their allocated share of resource, since their ability to pay is higher.
F. Responsibility (not applied in this report)	Countries have used resources in the past. It is thus possible to consider a date in the past to compute the remaining current rights. This principle can be applied for only two planetary boundaries, 'climate change' and 'ocean acidification', for which budgets can be calculated over time. Thus, this principle has not been applied in this study.

3.2 The Swedish share – a comparison

Swedish shares have been calculated as percentage levels that later will be used to establish the safe operating space for Sweden in relation to the global limits analysed in this report. A comparison with the European levels gives perspectives to the results. Figure 3.1 a-b shows Swedish and European allocation results.

One hypothesis, based on the calculation methods, is that equality could be considered as a kind of reference point for the comparisons and scales showing the equality bars in the same size in the figures would then be more helpful for the comparison. That would also mean that when looking at the two diagrams, all other Swedish results should be interpreted as higher in relation to the European. Differences between allocation results would still remain. With this in mind, some results can be examined more closely.



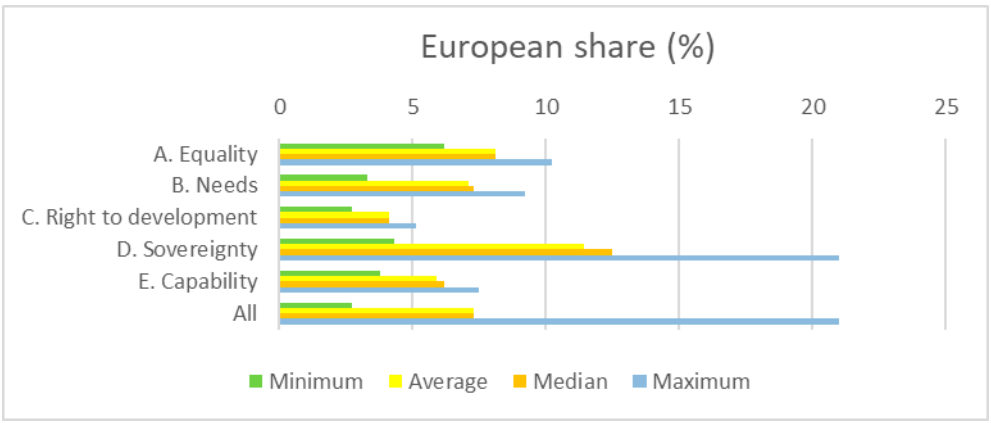


Figure 3.1 a-b. Swedish and European allocation results. The diagrams are placed in a way that makes comparisons easier. However, the scale is not the same. European values from EEA/FOEN (2020).

Equality means equal rights to use resources based on equal share per capita and within a particular year or over time. Needs, on the other hand, means different resource needs due to age and size of household. An allocation based on equality gives Sweden about the same results as an allocation based on needs, with a slightly higher median value for needs. The results within these principles (minimum, average, median, maximum) are also fairly close. For Europe, the median values for equality and needs are also close, with a slightly lower value for needs. The results within the principles are spread out.

Right to development means right to a decent life that meets basic needs, and a lower development level could be allocated more resources and contribute less. This allocation principles gives both Sweden and Europe a smaller share compared to the equality principle, with about half the equality median value and even less for the Swedish case.

Sovereignty means that countries are managed based on internal policy and have a legal right to use their own territory and have different economic wealth and impacts. This gives both Sweden and Europe a higher share compared to equality, and for Sweden the median value for sovereignty is four times higher than for the equality principle.

Capability means that countries have different levels of economic wealth and having a higher financial capability could mean contributing more or using less. For Sweden, the capability principle gives a higher share than equality, but for Europe the median value is slightly lower than for the equality principle. What can we learn from the overall results? For Sweden, there is a larger difference between the lowest and highest median values for the different allocation principles. This means that the results for the different allocation principles vary considerably. For Europe, the results are less wide ranging between the allocation principles. European results are also the sum of results for many countries, and therefore it is natural to find this pattern. However, for both regions, the overall median value is quite close to the median value for the equality principle[23].

For Sweden, the differences in allocation results are interesting to bear in mind in further discussions about living within the limits of our planet. The allocation process also relates to ideas about conditions for a good life presented in Box 1.

3.3 What is the limit?

The safe operating space for Sweden is found when the control variables have been multiplied by the allocation results. Table 3.3 shows Swedish limits for the four planetary boundaries in focus for this analysis.

Table 3.3. Swedish limits for the planetary boundaries in focus based on five allocation principles (absolute values).

Planetary boundary	Control variable	Minimum limit	Average limit	Median limit	Maximum limit
Nitrogen cycle	Loss of nitrogen from agriculture per year (Gg N/year)	0.81	66	42	230
Phosphorus cycle	Loss of phosforus from agriculture and wastewater per year (Gg P/year)	0.026	2.1	1.4	7.6
Land system change	Anthropised land (km^2)	550	45 000	29 000	160 000
Fresh water use	Maximum amount of consumptive blue water use per year (km^3)	0.11	5.9	5.9	31

A comparison with the European level is made by using per capita values, see Table 3.4. The Swedish shares per capita are higher due to the allocation results (see section 3.1 and section 3.2).

[23] For more details, see Appendix.

Table 3.4. Swedish limits for the planetary boundaries in focus based on five allocation principles, and a comparison with European values (per capita values). European values from EEA/FOEN (2020).

Planetary boundary	Control variable	Swedish limit	European limit
Nitrogen cycle	Loss of nitrogen from agriculture per year (kg N/year)	4.5	3.5
Phosphorus cycle	Loss of phosforus from agriculture and wastewater per year (kg P/year)	0.14	0.11
Land system change	Anthropised land (m^2)	3 040	2 360
Fresh water use	Maximum amount of consumptive blue water use per year (m^3)	627	488

BOX 1 – Conditions for a good life

This box discusses ideas from an internal project called "Sweden 2050". The project consisted of discussions and underlying material for the discussions. The following example comes from 1) discussions on "what is a good life".

The discussions were held in project working groups at the Swedish EPA in 2019, aimed at defining conditions for a good life in Sweden 2050.

Definition: Conditions created by or related to humans to consider when discussing visions for the future (2050).

Related to systems*	Related to individuals	Societal goals
Democracy	Participation in society (and democracy)	Human rights
Justice (rule of law)	Safe and just existence	Human rights, UN
Prerequisites for health (an equal and health supporting health care, physical activity, mental stimulus, social networks)	Health – help at illness, accidents, imposition, physical and mental well-being, social network	Human rights, UN, SDG
Prerequisites for education throughout life	Education/development – knowledge on ecological sustainability, labour capability, personal development	Human rights, SDG
Prerequisites for housing (a sound, safe and comfortable living environment)	Right to housing	Human rights, Public health agency of Sweden
Work opportunities that lead to equal health in society	Right to income	Human rights

*System in this context means the Swedish society

Other aspect to consider for a good life both at societal and individual levels include prerequisites for: social networks, identity, and a meaningful existence; citizens to have access to natural environments and different types of social services (mail, fire brigade, bank, etc.) to a reasonable degree; a balanced distribution of societal resources (equality) aiming at keeping differences between groups (gender, age, background, etc.) at a level that does not create conflicts and other disturbances in society; and reasonable prerequisites for all individuals to use their human rights (according to the convention).

Source: Swedish EPA (2019), internal material.

4. Footprints in a Swedish perspective

Environmental footprint indicators relate environmental pressures or resource use to the final demand for goods and services. This means that the total environmental pressures from the consumption of a country and its inhabitants are estimated regardless of where on Earth the production takes place. Another name for footprint indicators is consumption-based indicators. Figure 4.1 shows how a footprint perspective differs from a territorial perspective.

As the generational goal states that we should solve the major environmental problems in Sweden *"...without increasing environmental and health problems outside of Sweden's borders"*, these indicators are most relevant to follow our progress.

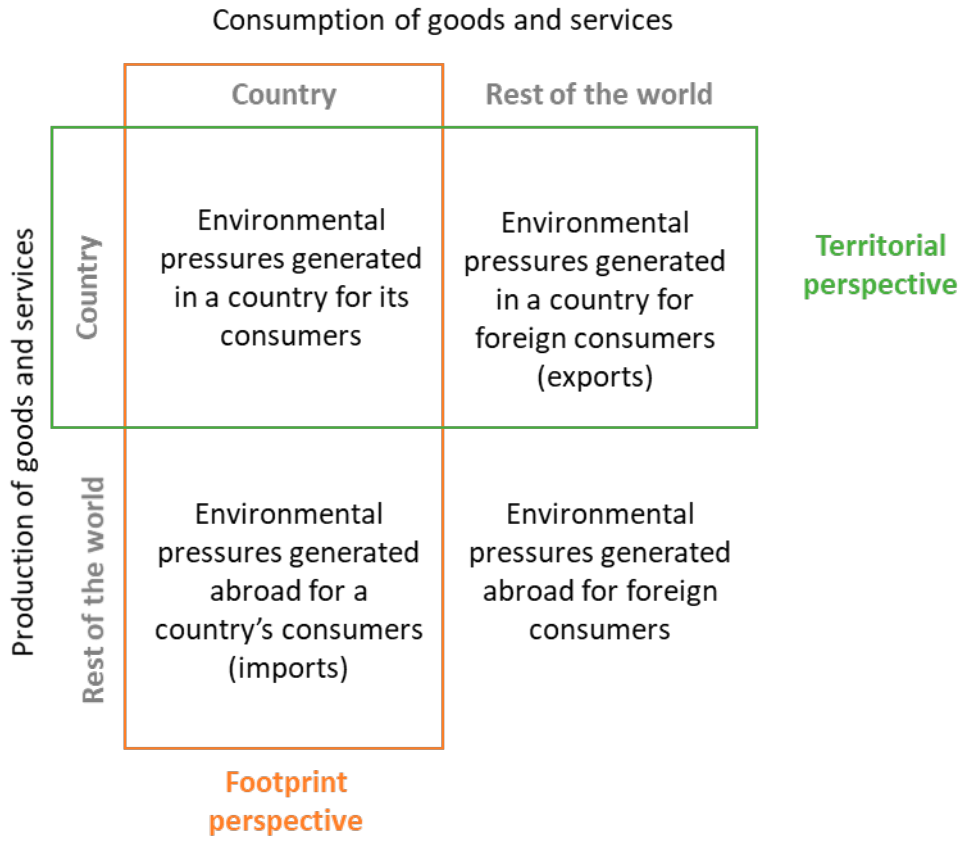


Figure 4.1. Differences in footprint and territorial perspectives. Source: EEA/FOEN (2020).

4.1 Footprint analyses

Footprint indicators are estimated by using economic-environmental models that provide economic and environmental information at country, industry and generic product levels. They combine economic information from national accounts with environmental information per industry. These models can be extended to a global level, which are called environmentally extended multiregional input-output (MRIO) models. Using an MRIO model allows the footprint to link: all economic activities required for producing a particular good in a specific country including international trade, all associated emissions and resource uses wherever they occur, and the consumer country with the producing country.

The footprint analyses in this report use footprint results from "Is Europe living within the limits of our planet?"[24] to calculate rough values for the Swedish perspective. The aim is to gain an indication of corresponding results for Sweden.

For the approximation, existing results for ecological footprints have been used as a starting point. The per capita ecological footprint for Sweden was divided by the mean per capita ecological footprint for the countries included in the EEA/FOEN report[25]. That value (1.22) was then multiplied with the footprints per capita from the report and with the population for Sweden[26]. Results for two assumptions are shown in Table 4.1 and Table 4.2.

Table 4.1. Footprints in absolute values for Sweden based on two assumptions. Swedish 1 is calculated from the European values and Swedish 2 by using an approximation factor of 1.22.

Footprint	Swedish limit (absolute value)	Swedish 1	Swedish 2
Loss of nitrogen from agriculture per year (Tg N/year)	0.042	0.110	0.130
Loss of phosforus from agriculture and wastewater per year (Tg P/year)	0.0014	0.0022	0.0027
Anthropised area (km^2)	29 000	39 000	48 000
Maximum amount of consumptive blue water use per year (km^3)	5.9	1.6	1.9

[24] EEA/FOEN (2020). Is Europe living within the limits of our planet? Joint EEA/FOEN Report. EEA report No 1/2020: https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits

[25] Inspired by Fig. 1.8 on page 51 in EEA (2019b). Values from 2013 were used for consistency with corresponding allocation year, http://data.footprintnetwork.org in Annex in EEA/FOEN (2020).

[26] The population for Sweden in 2011, which is the reference year in their report.

Table 4.2. Footprints in per capita values for Sweden based on two assumptions. Swedish 1 is equal to the European values and Swedish 2 is using an approximation factor of 1.22.

Footprint	Swedish limit (per capita)	Swedish 1	Swedish 2
Loss of nitrogen from agriculture per year (kg N/year)	4.5	11	14
Loss of phosforus from agriculture and wastewater per year (kg P/year)	0.14	0.23	0.28
Anthropised (m^2)	3 040	4 150	5 060
Maximum amount of consumptive blue water use per year (m^3)	627	167	203

Footprint approximation and footprints set equal to the European footprints give quite close results between Swedish and European footprints. As a comparison, an earlier study[27] presented a Swedish footprint for blue water consumption at about 200 m^3 per capita. Footprint values will be further used in chapter 5.

4.2 Other footprints

This report examines footprints in relation to chosen planetary boundaries to discuss if we are living within the limits. As noted earlier, research is ongoing to further define planetary boundaries, but also to estimate footprints. Examples on websites providing footprints for different countries are the European platform on life cycle assessment by the European Commission[28] and the Global Footprint Network[29].

The PRINCE research programme (Policy Relevant Indicators for Consumption and Environment)[30] has developed a new framework for monitoring the environmental impacts linked to Swedish consumption, both inside and outside of Sweden's borders, using the latest modelling and statistical techniques. In the last phase of the project, additional research was conducted on developing data and indicators in the areas of fisheries, tropical deforestation, biodiversity and chemicals[31].

There are interesting footprint results from this project, for example those related to areas of biosphere integrity and novel entities. Figure 4.2 shows Sweden's consumption footprint measured as land area, species losses and species hectares.

This relates to the planetary boundary biosphere integrity although not corresponding to a specific, safe operating space.

[27] Kulionis et al. (2021). Multiscale orientation values for biodiversity, climate and water: A scientific input for science-based targets. Swiss Federal Institute of Technology Zurich.

[28] European Commission (2022). https://eplca.jrc.ec.europa.eu/index, 2022-06-22.

[29] Global Footprint Network (2022). https://www.footprintnetwork.org/, 2022-06-22.

[30] The PRINCE project. The project was financed by the Swedish Environmental Protection Agency's environmental fund, see also https://www.prince-project.se, 2022-05-30.

[31] Brown et al. (2022). New methods and environmental indicators supporting policies for sustainable consumption in Sweden. Swedish Environmental Protection Agency, Report 7032.

Figure 4.3 shows consumption-based veterinary antibiotic use for Sweden in tonnes of active substance, and Sweden's consumption-based use of hazardous chemical products by consumed product. This relates to the planetary boundary novel entities although not corresponding to specific boundaries.

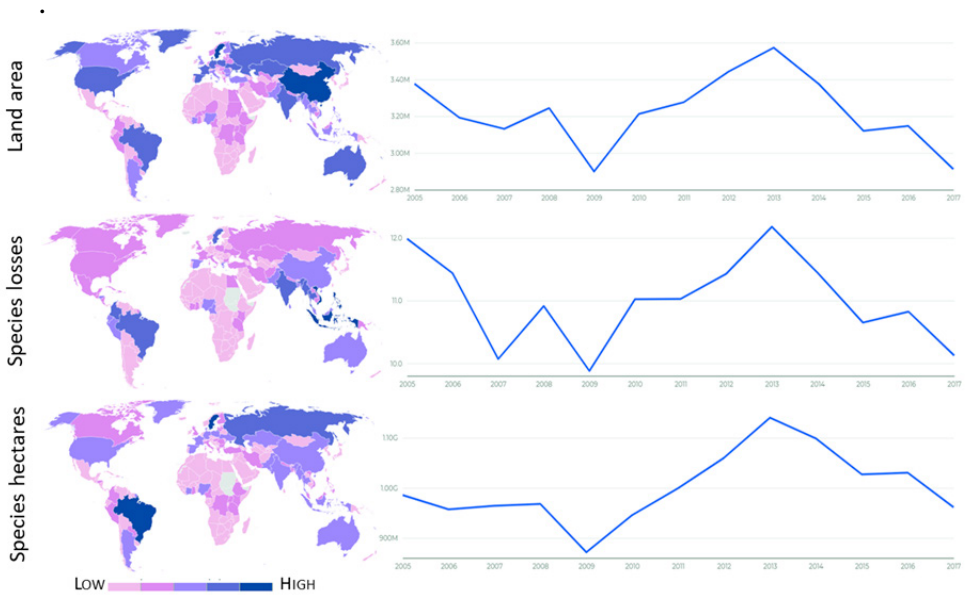


Figure 4.2. An example comparison of Sweden's consumption footprint, measured as land area, species losses and species hectares. In the maps, different colours reflect the severity of potential risk from low to high (Croft et al., 2021), commodityfootprints.earth. Source: Brown et al (2022).

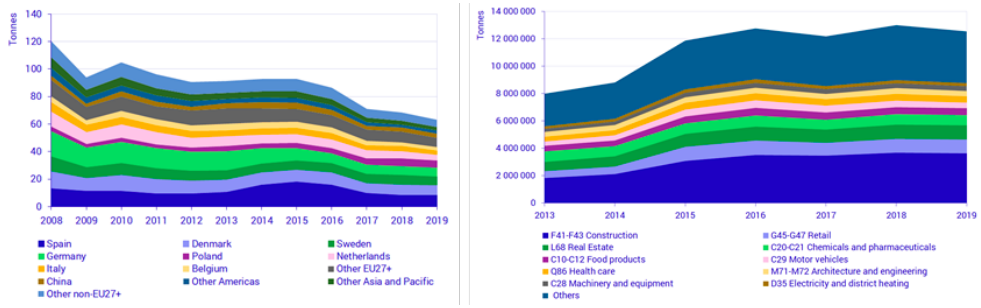


Figure 4.3. Consumption-based veterinary antibiotic use for Sweden in tonnes of active substance. Sweden's consumption-based use of hazardous chemical products by consumed product. Source: Brown et al (2022).

4.3 Footprints and available resources

Another way of analysing interconnections between resources and consumption is resource nexus assessments. These assessments analyse the direct and indirect interconnections between different natural resources, their management, use and governance, as well as the synergies and trade-offs that can be generated through policy interventions[32]. Resource nexus assessments focus on a link between resource systems, which can tell more about synergies and trade-offs across resource-related goals. The findings highlight knowledge gaps and imbalances in policy focus and may increase the systemic understanding of sustainability challenges and responses.

The Food and Agriculture Organization of the United Nations defines the resource nexus as a 'conceptual approach to better understand and systematically analyse the interactions between the natural environment and human activities, and to work towards a more coordinated management and use of natural resources across sectors and scales'[33].

An analysis on transportation, energy sector and the connection to biomass is presented in Box 2. The assessment examines the links between transportation, the energy sector and the connection to biomass from a Swedish perspective. The results show what an increased use of bioenergy could mean for Sweden in the light of not increasing environmental burdens outside of Sweden's borders.

[32] EEA (2021). Resource nexus and the European Green Deal, Briefing no. 24/2021. https://www.eea.europa.eu/publications/resource-nexus-challenges-and-opportunities/resource-nexus-and-the-european/, 25 May 2022.

[33] FAO (2014). The water-energy-food nexus. A new approach in support of food security and sustainable agriculture, Food and Agriculture Organization of the United Nations, Rome, Italy.

BOX 2 – Sustainable conditions for Climate

This box raises ideas from an internal project called "Sweden 2050". The project consisted of discussions and underlying material for the discussions. The following example comes from 2) an analysis on transportation, energy sector and the connection to biomass.

Action point – Checking the Feasibility, Viability and Desirability of the following hypotheses:

1. a reduction of emissions in the transport sector (FV) and implications on social practices (D);
2. a dramatic reduction of the use of fossil energy in Sweden - e.g. 50% and 80% - (FV) and implications on social practices (D);
3. a massive increase in the use of biomass (forest and biofuels) in the economy to check the internal (V) and external limits (F) of this option;
4. a reduction of imports (and exports) and its effect on the requirement of end uses (V) and environmental pressure (F).

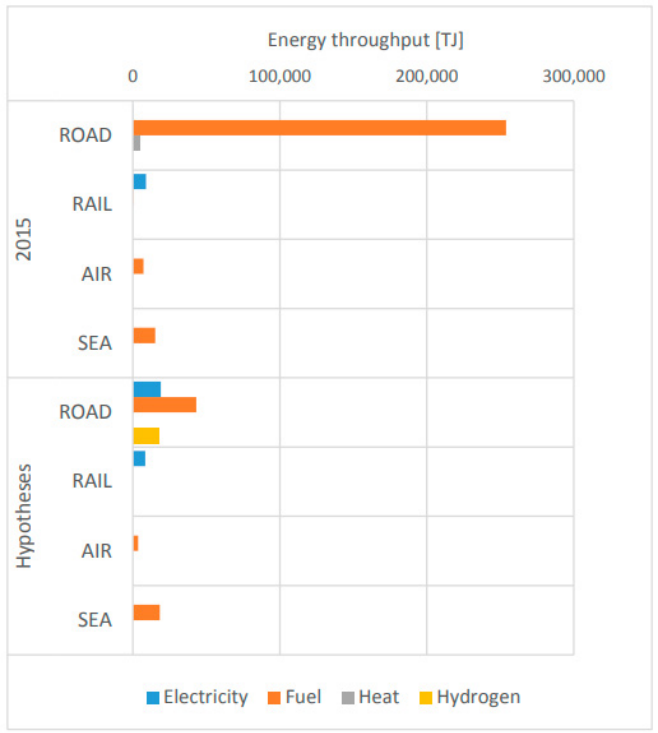


Figure 1: Comparison of energy throughput by type of transport (2015 vs explorative analysis).

One example: *"The biofuels required in Transport in this scenario sum up a 92% of the total biofuels in Sweden. The area required (domestic and embodied) to produce those biofuels sums up a 64% of the current arable land (36% in 2015). Only about a 4% is nowadays devoted to biofuel crops (Ahlgren et al., 2017)."*

Source: Pérez-Sánchez and Giampietro (2020). Transport and mobility – Sweden 2020, ICTA-UAB, June 2020. Swedish EPA: NV-06309-20.

5. A good life within the limits?

In earlier chapters we described the steps of choosing control variables for the planetary boundaries we intend to study, allocating the Swedish share of the planetary boundaries to define our safe operating space, and calculating rough values for footprints from a Swedish perspective. The last step is to analyse whether footprints are within the limits and to discuss if we are living a good life within the limits.

5.1 Limits versus footprints

This section shows results for footprints in a Swedish perspective in relation to the safe operating space. More information on the safe operating space for Sweden is given in section 3.3. The footprint values shown are mean values from Swedish 1 and Swedish 2 (from Table 4.1) with the aim to gain an indication of results for Sweden. First, separate results are presented for each of the studied planetary boundaries, and then an overview of a possible Swedish performance is shown together with a discussion on exceeding limits. Each figure shows and explains different zones. The zone of uncertainty represents the range between the minimum and the maximum Swedish shares for each allocation principle.

Figure 5.1 shows a Swedish perspective on performance for nitrogen losses. The performance exceeds the estimated share of safe operating space for three of five allocation principles but within the zone of uncertainty for two of five principles (sovereignty and capability). As a comparison, the European performance exceeds the shares according to all five principles.

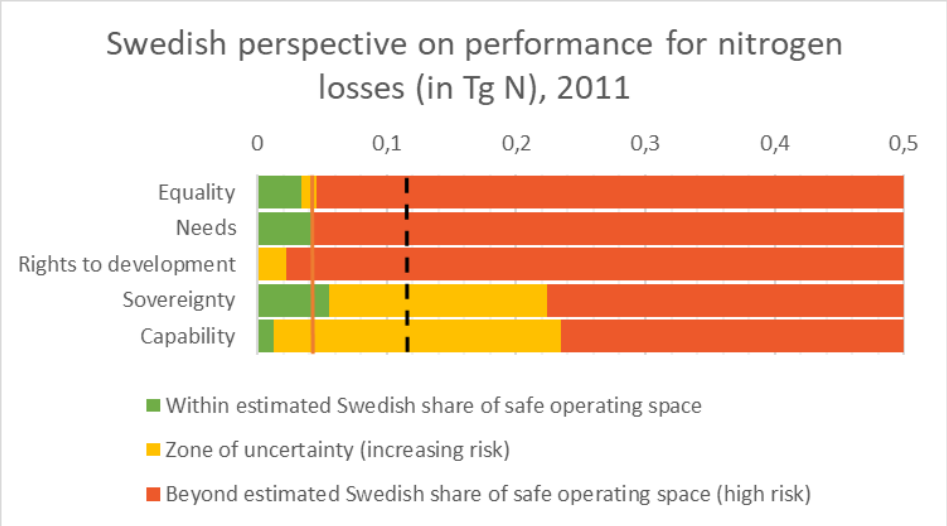


Figure 5.1. Swedish perspective on performance for nitrogen losses. The orange line shows median limit and the dashed line shows the Swedish footprint.

Figure 5.2 shows a Swedish perspective on performance for phosphorus losses. The performance exceeds the estimated share of safe operating space for three of five allocation principles but is within the zone of uncertainty for two of five principles (sovereignty and capability). The European performance exceeds the shares according to four principles but is within the limit for one principle (sovereignty).

A Swedish perspective on performance for land cover anthropisation is shown in Figure 5.3. Swedish results exceed the estimated share of safe operating space for three of five allocation principles but are within the zone of uncertainty for two of five principles (sovereignty and capability). European performance exceeds the shares according to four principles but is within according to one principle (sovereignty).

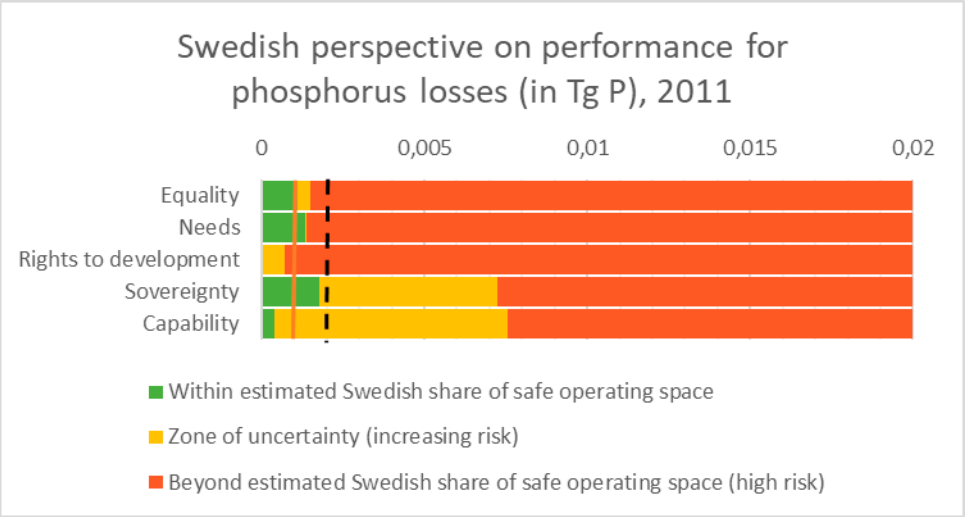


Figure 5.2. Swedish perspective on performance for phoshorus losses. The orange line shows median limit and the dashed line shows the Swedish footprint.

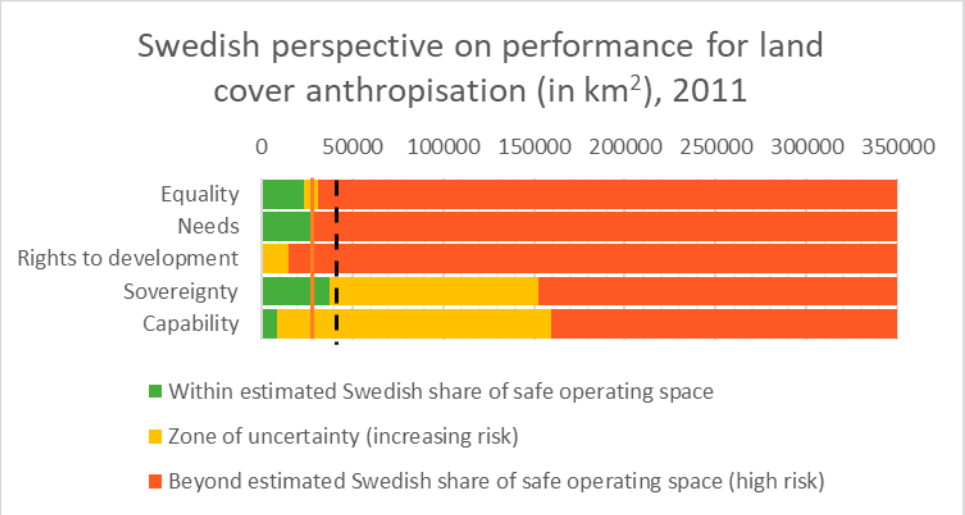


Figure 5.3. Swedish perspective on performance for land cover anthropisation. The orange line shows median limit and the dashed line shows the Swedish footprint.

A Swedish perspective on performance for freshwater use is shown in Figure 5.4. The results are within the estimated share of safe operating space for four of five allocation principles but are in the zone of uncertainty for one principle (rights to development). European performance is within the shares according to all five principles.

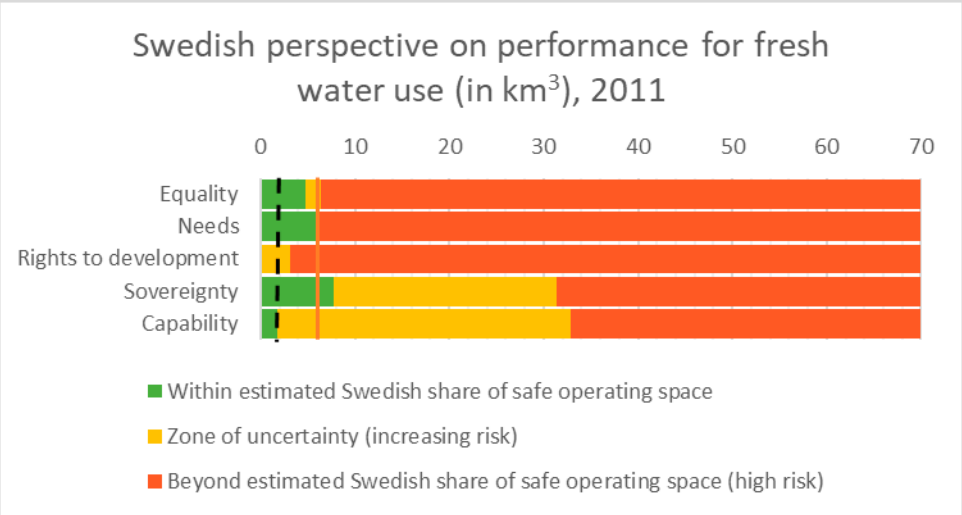


Figure 5.4. Swedish perspective on performance for freshwater use. The orange line shows median limit and the dashed line shows the Swedish footprint.

Figure 5.5 shows an overview of the results and results for all studied planetary boundaries in the same diagram, with different scales for different boundaries.

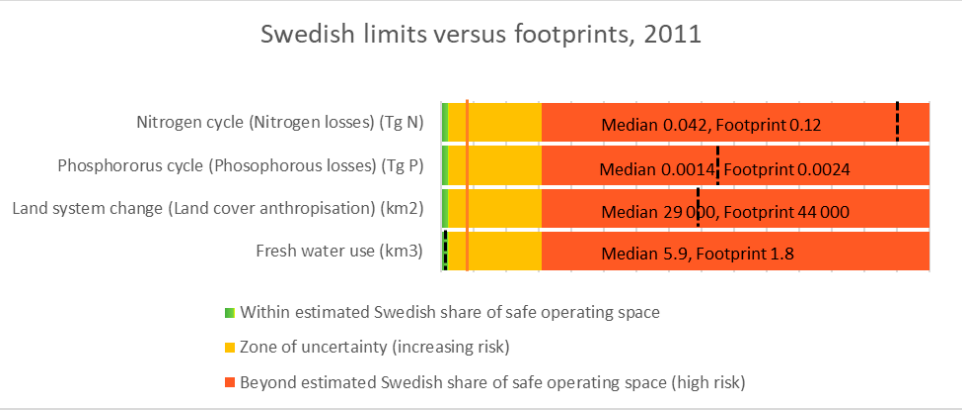


Figure 5.5. Swedish limits versus footprints. The orange line shows median limit and dashed lines show the Swedish footprints.

Table 5.1 compares performance in relation to operating space between global, European and Swedish levels. The Swedish results point to the possibility that the limits are overshot by almost three times for the nitrogen cycle, by almost two times for the phosphorus cycle, and by one and a half times for land cover anthropisation. Freshwater use is within the limit.

Table 5.1. Factors of over-/undershot for three different levels based on global planetary boundaries, and the allocation of European and Swedish limits. For details behind the Swedish values, see table 9.3 in the Appendix. Global and European values from EEA/FOEN (2020).

Planetary boundary	Global	European	Swedish
Loss of nitrogen	+1.7	+3.3	+2.8
Loss of phosphorus	+2	+2	+1.8
Anthropised land	Not overshoot	+1.8	+1.5
Freshwater use	-3.3	-0.3	-0.3

The main factors behind these results are the differences in the European and Swedish allocation results together with the footprint values used. Allocation results for Sweden and Europe show differences in share of the planetary boundaries due to how the allocation principles are defined. As seen in Chapter 3, footprint approximation and footprints set equal to the European footprints give quite close results between Swedish and European footprints. To sum up, this means that even though the footprint values used are higher from a Swedish perspective, the factors of overshot can still be lower.

5.2 The food system in focus

Environmental impacts of the average Swedish diet relative to boundaries in the EAT-Lancet framework[34] have been studied by the Swedish University of Agricultural Science[35]. Their results show per capita footprints in relation to per capita boundaries[36].

Performance from a Swedish diet in relation to these partly different planetary boundaries is shown in Figure 5.6. The analysis shows that the Swedish limits have been overshot by 3 to 6 times for GHG emissions, N application, P application and extinction rate, while water use is within its limit.

[34] Willett, et al. (2019). Food in the Anthropocene: The EAT-Lancet Commission on healthy diets from sustainable food systems. The Lancet 393(10170), pp. 447-492 (DOI: 10.1016/S0140-6736(18)31788-4).

[35] The research was funded by the Swedish Environmental Protection Agency.

[36] Moberg et al. (2020). Benchmarking the Swedish Diet Relative to Global and National Environmental Targets—Identification of Indicator Limitations and Data Gaps. Sustainability 2020, 12, 1407; doi:10.3390/su12041407

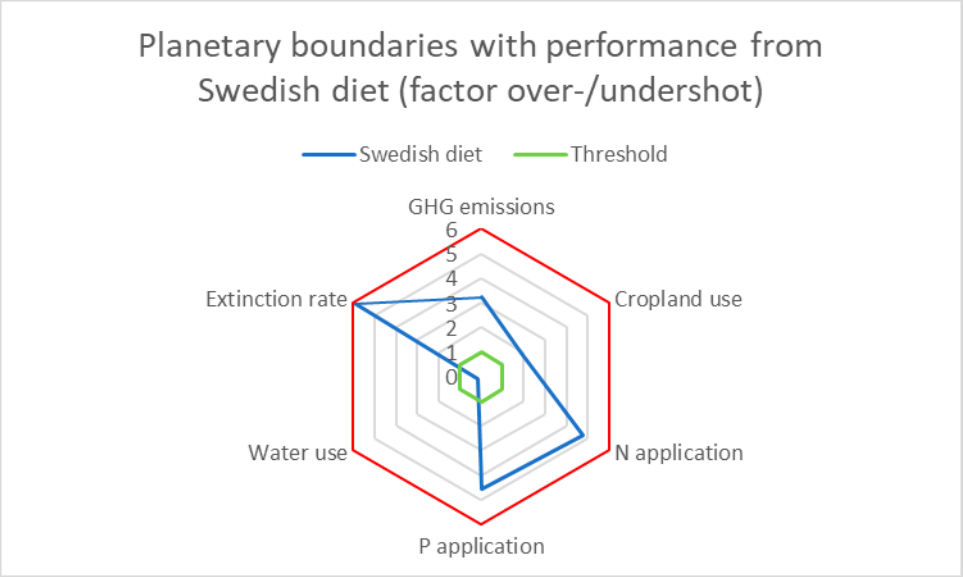


Figure 5.6. Planetary boundaries, in the form of EAT-Lancet framework boundaries, with performance from a Swedish diet. Only water use is undershooting the green threshold, which is shown by a result below zero. Source: Moberg et al. (2020).

Variables for global limits used in this study are listed in Table 2.1 and are consistent with the absolute boundaries proposed by the EAT-Lancet commission for six Earth system processes, within which the global food system should operate to be environmentally sustainable[37]. By doing so, healthy diets for about 10 billion people would be possible within biophysical limits of the Earth system[38].

5.3 To live within the limits

It is time to look further into whether we are living a good life within the limits. Figure 5.7 shows planetary boundaries with European and a possible Swedish performance for climate change, land system change, nitrogen cycle, phosphorus cycle, and freshwater use. Figure 5.8 shows corresponding results for social boundaries[39]. Together, the figures provide perspectives on whether we are living a good life within the limits of our planet.

[37] Moberg et al. (2020). Benchmarking the Swedish Diet Relative to Global and National Environmental Targets—Identification of Indicator Limitations and Data Gaps. Sustainability 2020, 12, 1407; doi:10.3390/su12041407

[38] Willett, et al. (2019). Food in the Anthropocene: The EAT-Lancet Commission on healthy diets from sustainable food systems. The Lancet 393(10170), pp. 447-492 (DOI: 10.1016/S0140-6736(18)31788-4).

[39] For corresponding SDGs, see Table 9.4 in Appendix.

The figures indicate that Sweden is overshooting four of five planetary boundaries viewed in the diagram. The situation is the same for the European performance. According to results on CO_2 emissions from Leeds University, there is an overshot by a factor of 6.4. The result would be in the same range if using figures from the website for the Swedish environmental objectives[40].

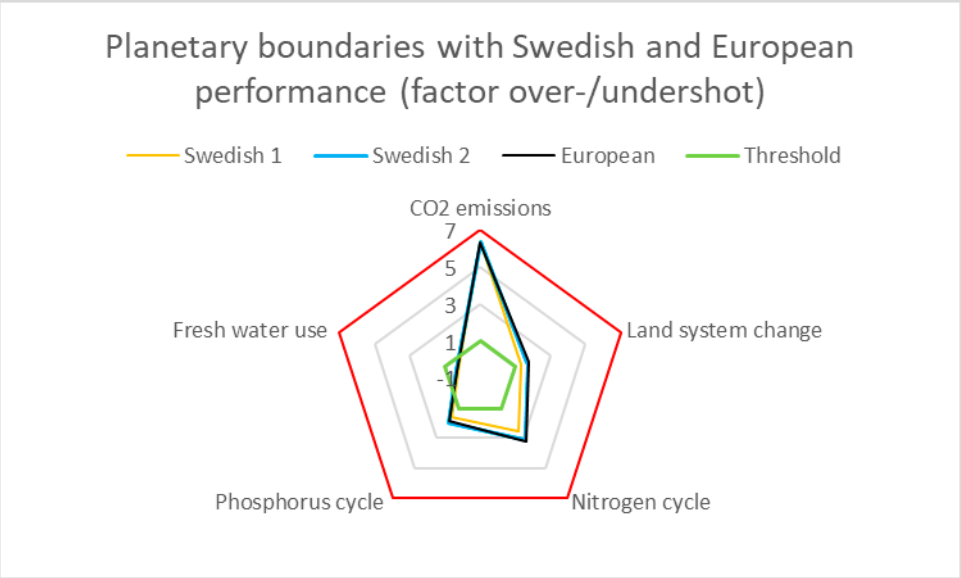


Figure 5.7. Planetary boundaries with European and a possible Swedish performance. Only freshwater use is undershooting the green threshold for all alternatives, which is shown by a result below zero. Source: Own calculations, for European values see EEA/FOEN (2020), and for CO_2 emissions see Leeds University (2021).

[40] 10.2 tonnes CO2 per capita is used by Leeds University (2021). The website for the Swedish environmental objectives shows 109 million tonnes, to be divided by a Swedish population in year 2011 of 9.47 million people, resulting in an overshot by around 7 with a boundary of 1.6, but the emissions are decreasing. See also http://sverigesmiljomal.se/miljomalen/begransad-klimatpaverkan/konsumtionsbaserade-utslapp-i-sverige-och-i-andra-lander/, 22 June 2022.

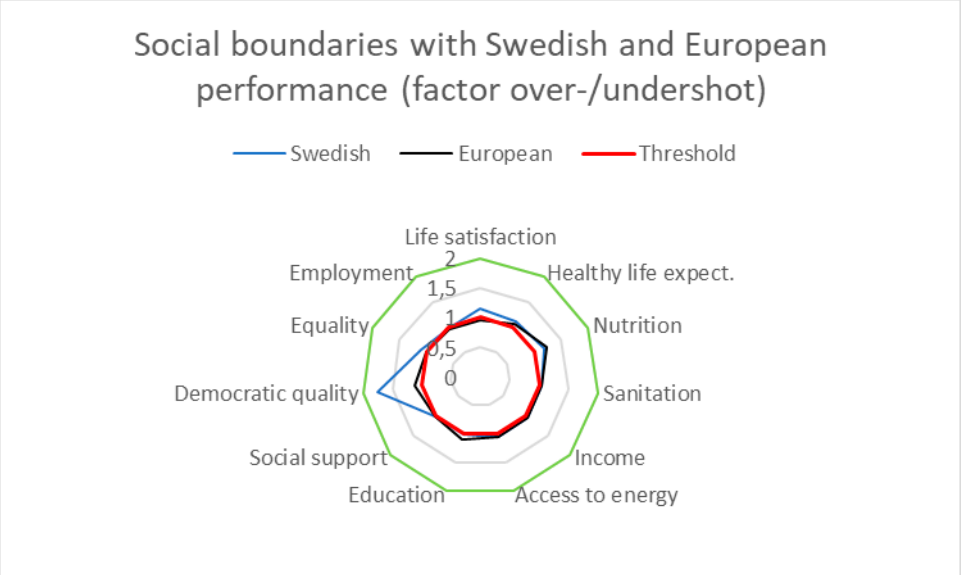


Figure 5.8. Social boundaries with Swedish and European performance. The Swedish performance stays in the green zone for all social boundaries except for Employment where it slightly crosses the red threshold. Source: Leeds University (2021).

On the other hand, our social performance in almost all cases does not overshoot the threshold, but a minor exception is employment. For many factors we are doing better than the threshold, especially regarding democratic quality, where the Swedish performance is very good.

These results indicate that from a social perspective Sweden has a strong platform from which to intensify its sustainable transformation, and efforts need to be focused on policies that lead us to a life within the limits of our planet.

Box 3 gives some ideas on required prerequisites with a focus on the food system. The box also includes questions to ask and reflect on for other areas. These could point the way for a sustainable life and necessary policy developments.

One interesting aspect to track is the performance of hotspot countries for environmental burden from Swedish consumption. According to Figure 4.2, India and parts of South America are two examples with large footprints from Swedish consumption. These regions undershoot several social boundaries[41]. This indicates that the process of transition needs to be systemic to assure its sustainability: how should our society be organised?

[41] See https://goodlife.leeds.ac.uk/national-snapshots/countries/, 2022-05-31.

BOX 3 – A sustainable life in Sweden 2050

This box discusses ideas from an internal project called "Sweden 2050". The project consisted of discussions and underlying material for the discussions. The following example comes from 3) discussions on what a sustainable life would look like in Sweden in 2050 with a focus on food.

All employees at the Swedish EPA were invited to the group discussions, which took place in December 2020, aiming at expanding ideas on how we can live a sustainable life in 2050.

Group discussion – What will we eat in Sweden in the future?

Statement: "In 2050 I can eat what I need for a good and healthy life."

What do you think about this statement?

- Is it possible to achieve?
- What prerequisites must be in place to make this possible?

Examples of prerequisites:

- Land and water are sustainably used
- Food distribution is efficient in every direction
- The food is primarily plant based and has a low environmental impact
- Healthy and sustainable food is the most available
- Health and togetherness are also important values with the meal

Group discussions in other areas:

1. Do we need a positive view of the future?
2. Living and housing all over Sweden in 2050
3. What will we eat in Sweden in the future?
4. How will we travel and meet in 2050?
5. How will we use goods and services in 2050?
6. A sustainable society without increasing the use of resources
7. Changed values and behaviour
8. What is a good sustainable life?
9. Prices that include impact on humans and environment
10. A global perspective
11. Goal conflict – are there enough forests and land for our needs and desires?
12. Metals for batteries and a functional ecosystem – can we have both?

Source: Swedish EPA (2020), internal material.

6. Implications for the future

Knowledge of planetary boundaries is a cornerstone in planning and developing policy instruments to allow society to develop sustainably. There are large synergies between environmental objectives and other societal goals.

The Swedish generational goal says that "The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside of Sweden's borders."

There are different principles that can show the way forward when analysing the Swedish safe operating space in relation to the planetary boundaries. Depending on the starting point – equality, needs, right to development, sovereignty, or ability – we come to a variety of answers. This might broaden the perspectives of what a safe operating space might be. In this report, a mix of these principles is used to calculate a median value while also illustrating the zone of uncertainty. With the aim to point to footprints in the Swedish share, this report has used European footprint results and estimated rough values for Sweden. When these different perspectives are taken into account, in the final results only freshwater use is within the estimated Swedish share of safe operating space.

The four planetary boundaries focused on in the analyses – biogeochemical flows (both nitrogen cycle and phosphorus cycle), land system change, and freshwater use – are strongly driven by the food system. An additional perspective on this issue is illustrated by the environmental impacts of the average Swedish diet relative to boundaries in the EAT-Lancet framework, which also shows results that relate to climate change and biosphere integrity. For their studied boundaries, the Swedish diet overshoots Swedish limits by 3 to 6 times, with extinction rate receiving the worst result. Climate change and biodiversity loss and their effects on Earth processes are raised by both IPCC[42] and IPBES[43] as the two most important challenges for our society.

Conclusively, one key player in the overall system is the food system. The food system involves elements of environment, people, inputs, processes, infrastructures, and institutions as well as activities that relate to the production, processing, distribution, preparation, and consumption of food[44]. As shown in this report, the food system is a global system, meaning all levels of the system need to be addressed.

[42] IPCC (2021). Climate Change 2021: The Physical Science Basis. Working Group I Contribution to the IPCC Sixth Assessment Report.

[43] IPBES (2021). IPBES-IPCC co-sponsored workshop report on biodiversity and climate change.

[44] See UN-HLTF (2010) in Willett et al. (2019).

As a part of the governmental management of the National Food Strategy, the Swedish Board of Agriculture did a study on sustainable food systems[45]. The report was conducted in close collaboration with the National Food Administration, the Swedish Veterinary Institute, the Swedish University of Agricultural Sciences, and the Swedish Agency for Economic and Regional Growth. Their report includes proposals for the definition of sustainable food systems in a Swedish context, mapping of ongoing initiatives and proposals for measures in four areas: innovation and united action; a clearer government responsibility; development of goals, data collection and analysis methods; and further work with the EU strategy From farm to fork. Their report states that ongoing initiatives are not enough and that all parts of the food system need to be involved and take action to achieve significant improvements.

Transforming a system is preferably guided by a systemic approach. This means policy development needs to address different levels and to follow up on progress with indicators that can capture the complexity of the issue. The framework for monitoring the environmental impacts linked to Swedish consumption, both inside and outside of Sweden's borders, which was developed by the PRINCE project, is one important approach and looking further into footprints in relation to planetary boundaries is another.

The European Green Deal mentions transformation of production and consumption systems such as energy, food, mobility and the built environment[46]. These systems rely on the same natural resources, which means that policy interventions may generate both synergies and trade-offs across natural resources. Figure 6.1 shows production and consumption systems and their interconnections delineated by planetary boundaries, with resources going into the society and leaving footprints as a result. Social boundaries are viewed in the centre.

Informed decisions need knowledge that can tell us more about the direct and indirect interconnections between different natural resources, their management, use and governance, and synergies and trade-offs. This means approaches combining multiple ways if framing the questions, perspectives, tools and forms of knowledge, such as resource nexus analyses, integrated modelling, foresight studies, and transition governance[47].

[45] Jordbruksverket (2021). Hållbara livsmedelssystem – Definition, pågående initiativ och förslag på åtgärder, Jordbruksverket, Report 2021:3.

[46] European Commission (2019). The European Green Deal. COM(2019) 640 final.

[47] EEA (2021). Resource nexus and the European Green Deal, Briefing no. 24/2021, https://www.eea.europa.eu/publications/resource-nexus-challenges-and-opportunities/resource-nexus-and-the-european/, 25 May 2022.

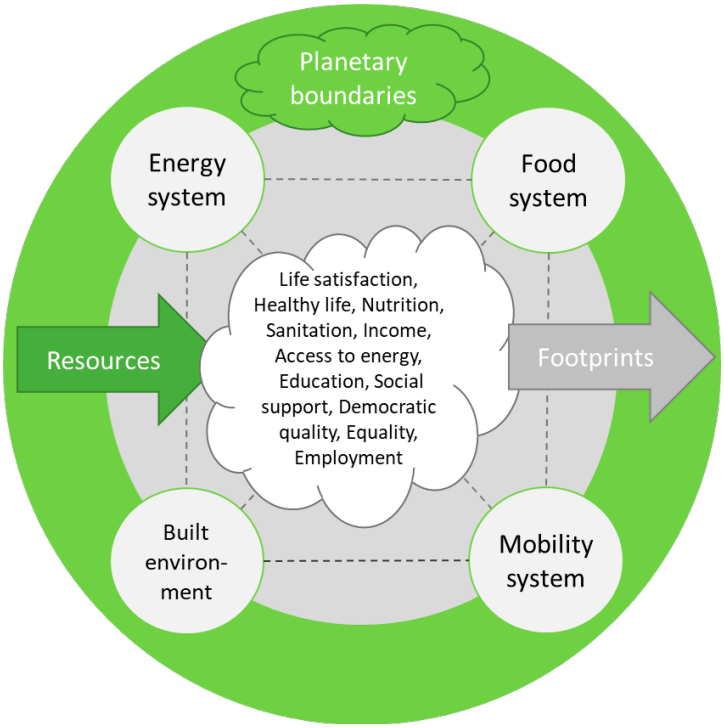


Figure 6.1. Production and consumption systems and their interconnections delineated by planetary boundaries, with resources going into the society and leaving footprints as a result. Social boundaries in the center.

Systemic questions also involve the time aspect. For example, the percentage change in farmland values[48] projected for the period 2071–2100 compared with 1961–1990 estimate an increase of 60% for Swedish farmland, which is higher compared to almost any other part of Europe[49].

From a social perspective Sweden has a strong platform to intensify a sustainable transformation. The generational goal stipulates that we should not increase environmental and health problems outside of Sweden's borders. The PRINCE project allows us to see where our footprints are geographically situated. Social indicators allow us to find whether these areas are within their social boundaries. This knowledge allows us to look deeper to see how our society should be organised for a sustainable and just transition.

The Swedish Riksdag has decided to work for sustainable development in all three dimensions and to integrate that work in existing processes[50]. Connections between the Swedish environmental objectives and the planetary boundaries shown in Chapter 4 indicate that the systemic nature of the planetary boundary framework could help in the transformation to a sustainable society. Further discussions on "what is a good life" and what a possible sustainable life would look like are important steps along the way.

[48] Value of arable land.

[49] EEA (2019a). Climate change adaptation in the agriculture sector in Europe, EEA report No 04/2019, https://www.eea.europa.eu/publications/cc-adaptation-agriculture.

[50] Regeringskansliet (2021). Sveriges genomförande av Agenda 2030 för hållbar utveckling. Sveriges genomförande av Agenda 2030 för hållbar utveckling 2021 (regeringen.se), 3 June 2022.

Further understanding of what impact our consumption has on Earth's resources can serve to inspire priorities in policy development. The findings may highlight knowledge gaps and imbalances in policy focus, increasing the systemic understanding of sustainability challenges and responses.

This report has looked deeper into planetary boundaries from a Swedish perspective to point to footprints in the Swedish share of planetary boundaries, to compare with earlier and adjacent results, and to introduce a discussion on prerequisites and indicators for Sweden. The report shows examples of analyses from a systems perspective, with a focus on consumption footprints and analyses from the viewpoint of planetary boundaries.

7. Acknowledgements

The EEA/FOEN report “Is Europe living within the limits of our planet?” is the inspiration and starting point for the methodological approach of this report. Their analyses on biogeochemical flows, land system change, and freshwater use, and the description of methodology for allocation of shares have been the basis for the corresponding calculations in this report. Special thanks also to colleagues for feedback on draft versions.

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9. Appendix

Table 9.1. Allocation principles and allocation keys (for computation methods, see source). Source: EEA/FOEN (2020), Table 3.2.

Allocation principles and computation methods	Allocation key
A. Equality	
1. Equal share per capita	Population
2. Equal share per capita over time	Cumulative population
B. Needs	
3. Equivalence between adults and children	Population weighted by age
4. Accessibility	Travel time to major cities
5. Nutrition	Food nutrient adequacy
C. Right to development	
6. Poverty line	Poverty headcount ratio
7. Development level	Population weighted by HDI
D. Sovereignty	
8. Land	Territorial land surface
9. Biocapacity	Territorial biocapacity
10. Economic throughput	GDP
11. Grandfathering	Consumption-based environmental inpacts
E. Capability	
12. Income	Inverse GDP
13. Cumulative income	Inverse cumulative GDP

Table 9.2 Allocation results for Sweden based on methodology from the Appendix in "Is Europe living within the limits of our planet?" (EEA/FOEN 2020).

Allocation principles and computation methods	Number of calcula-tions	Minimum Swedish share	Average	Median	Maximum Swedish share
A. Equality	**9**	**0.119%**	**0.135%**	**0.132%**	**0.161%**
1. Equal share per capita	3	0.134%	0.145%	0.145%	0.161%
2. Equal share per capita over time	6	0.119%	0.124%	0.123%	0.130%
B. Needs	**4**	**0.147%**	**0.148%**	**0.148%**	**0.150%**
3. Equivalence between adults and children	1	n/a	n/a	0.147%	n/a
4. Accessibility*	2	-	-	-	-
5. Nutrition	1	n/a	n/a	0.150%	n/a
C. Right to development	**3**	**0.003%**	**0.046%**	**0.057%**	**0.079%**
6. Poverty line	1	n/a	n/a	0.003%	n/a
7. Development level	2	0.035%	0.057%	0.057%	0.079%
D. Sovereignty	**5**	**0.193%**	**0.510%**	**0.531%**	**0.786%**
8. Land	1	n/a	n/a	0.315%	n/a
9. Biocapacity	1	n/a	n/a	0.786%	n/a
10. Economic throughput**	2	-	-	0.748%	-
11. Grandfathering	1	n/a	n/a	0.193%	n/a
E. Capability	**6**	**0.043%**	**0.317%**	**0.260%**	**0.823%**
12. Income	3	0.043%	0.281%	0.167%	0.633%
13. Cumulative income	3	0.066%	0.354%	0.174%	0.823%
All	**27**	**0.003%**	**0.253%**	**0.148%**	**0.823%**

* Allocation principle was left out because of expected estimation bias when applied on one country only.

** Only the first calculation was performed (bias considered to be small)

Table 9.3. Planetary boundaries with Swedish limits, footprint values for Sweden based on two assumptions, and factor over-/undershot. Swedish 1 is calculated from the European per capita footprint and Swedish 2 by using an approximation factor of 1.22. Factor over-/undershot (mean value) is based the mean value of Swedish 1 and Swedish 2.

Planetary boundary	Control variable	Swedish limit, median	Swe 1 footprint	Swe 2 footprint	Swe 1 factor over-/ undershot	Swe 2 factor over-/ undershot	Factor over-/ undershot (mean value)
Nitrogen cycle	Loss of nitrogen from agriculture per year (Tg N/year)	0.04232	0.10792	0.13166	2.6	3.1	2.8
Phosphorus cycle	Loss of phosforus from agriculture and wastewater per year (Tg P/year)	0.00137	0.00218	0.00266	1.6	1.9	1.8
Land system change	Anthropised area (m^2)	28 807	39 287	47 930	1.4	1.7	1.5
Fresh water use	Maximum amount of consumptive blue water use per year (m^3)	5.93963	1.57715	1.92413	0.27	0.32	0.29

Table 9.4. Social indicators from Leeds (2021) versus Sustainable development goals in Agenda 2030 (own interpretation).

SDG number	SDG	Social indicator
-	-	Life satisfaction
3	Good health and well-being	Healthy life expect.
2	Zero hunger	Nutrition
6	Clean water and sanitation	Sanitation
1	No poverty	Income
7	Affordable and clean energy	Access to energy
4	Quality education	Education
-	-	Social support
16	Peace, justice and strong institutions	Democratic quality
5, 10	Gender equality, Reduced inequalities	Equality
8	Decent work and economic growth	Employment

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Living within the limits of our planet – a Swedish perspective

The purpose of this report is to look further into planetary boundaries from a Swedish perspective. Better understanding of the impact of our consumption on Earth's resources may help inspire priorities in policy development. The aim has been to point to footprints in the Swedish share of planetary boundaries, compare with earlier or adjacent results, and discuss prerequisites and indicators for Sweden.

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