



Nordic Council
of Ministers

IS ECONOMIC GROWTH COMPATIBLE WITH A SUSTAINABLE NORDIC FUTURE?

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Preface

In the document "Our Vision 2030", the Nordic prime ministers emphasize that a sustainable development is possible: "We can change our lifestyles, production methods and patterns of consumption, balance out the use and protection of natural resources on land and at sea, and achieve sustainable development for the future." An underlying and often unspoken requirement is that a substantial decoupling of economic growth from environmental pressures is possible on the macro level. This means that sustained GDP growth will have to be compatible with reduced and eventually zero net greenhouse gas emissions, a halt in the loss of biodiversity, etc.

This is a formidable task. The purpose of this project has been to review existing literature, to find out to which extent radical decoupling has been achieved in the past. The point is not to presuppose that the future will be a copy of the past, but to put the task ahead in perspective and thus contribute to the policy debate. To get a broad picture we asked the consultants to include studies with both an optimistic, a pessimistic and an agnostic approach to the core questions. We also asked for the review only to include studies relevant to the Nordic countries.

The report has been prepared by consultants in PlanMiljø. Members of the Nordic working group for Environment and Economy (NME) have provided comments on draft reports during the project. In addition to a literature review, the report contains a number of policy messages. The authors of the report are responsible for the content, and any views and recommendations presented in the report do not necessarily reflect the views and the positions of the governments in the Nordic countries.

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Executive Summary

Objectives

Green growth forms the core of sustainable development strategies in the Nordic countries, the rest of Europe and indeed in the rest of the world. The central assumption is that economic growth can be continued while reducing resource use, environmental pressures and impacts. In other words that resource use and environmental pressures can be absolutely decoupled from economic growth such that climate change and biodiversity loss can be halted.

However, it is not clear whether absolute decoupling is possible in the long-term or whether it is simply a pipe-dream that those who see economic growth as a societal priority can hang on to. The objective of this report is to assess, evaluate and question the arguments and evidence for and against decoupling as a realistic long-term solution to rapidly approaching environmental crises, and to raise awareness amongst Nordic policymakers and others, as to the key issues and uncertainties in the green growth concept.

Method

The core of this research has been a systematic and in-depth literature review on the evidence and arguments for historical decoupling of environmental impacts and resource use from economic growth, and the potential for decoupling in the future, with a Nordic focus. 48 papers, reports and books presenting pro-growth, de-growth and agnostic viewpoints were assessed against an analytical framework.

Some important concepts and definitions

Decoupling in the context of environmental economics is the antithesis of what is often considered the norm for an economy under development; economic growth leads to, or is caused by, an increase in the throughput of materials and energy through the economy, which itself leads to increases in environmental pressures. Decoupling can be *relative* or *absolute*. Under *relative* decoupling environmental pressures continue to grow but at a slower rate than economic growth. Under *absolute* decoupling, environmental pressures reduce despite economic growth.

When investigating decoupling, the geographical boundaries used can be very different. National governments tend to only take responsibility for greenhouse gas (GHG) emissions and other pressures occurring in their borders, but the value chains of products consumed within the country can cause pressures across the globe. Decoupling analysis often takes either a *territorial-based perspective* (where trends in direct emissions/pressures within national boundaries are compared to trends in national GDP) or a *footprint-based perspective* (where trends in global pressures caused along the value chains of all consumed products and services are compared to trends in national consumption expenditure).

The framework of *planetary boundaries* defines a safe operating space for humanity that respects ecological and geophysical systems. It provides a set of thresholds which can be used to assess the degree to which growth in pressures needs to be slowed down, or reversed, if the boundaries are not to be exceeded. Several planetary boundaries are at high risk of being crossed in the near future including climate change, biodiversity, land-use change and nitrogen and phosphorus flows. A safe operating space may often be defined in terms of the remaining *budget* of resource use or emissions that there is space for, without overstretching the boundary. It is common to discuss the *fair share* of this budget as being the remaining budget per global citizen, although there are varying views on this issue.

Absolute reductions in pressures needed to respect planetary boundaries

Most authors agree that absolute reductions of environmental pressures are needed in the richer countries of the world, including the Nordics, if planetary boundaries are to be respected globally whilst freeing up resources for developing countries to increase the welfare of their citizens. If further growth in welfare is something that the Nordics and other rich countries aspire to, then this entails an absolute decoupling of environmental pressures from growth. Relative decoupling will not be sufficient. Several authors argue that rich developed countries (including the Nordics) have already long overshot their fair share of available resource and emissions budgets.

Nordic countries should engage actively in quantifying the safe operating spaces for various planetary boundaries, what the Nordic fair share of remaining budgets within this space is, and investigate how green growth policy targets can be developed to respect these.

Limited evidence of absolute decoupling to date

The reviewed articles find limited evidence for absolute decoupling having been achieved to date. Where absolutely decoupling has been achieved it has not been rapid enough to respect planetary boundaries by mid-century. Evidence for absolute decoupling seems to be strongest for GHG and other emissions to air when considered from a *territorial perspective*. There is strong evidence that much of this has been a result of carbon leakage e.g. the outsourcing of heavy industrial production to other regions of the world, without corresponding changes in consumption.

However, both Denmark and Sweden have had periods where they have achieved absolute decoupling of *footprint-based* GHG emissions from growth in GDP. Sweden has in recent years also decoupled other air emissions, and global water and land use footprints from its consumption in recent years. These reductions may have resulted from the implementation of the Sweden's overarching environmental objective to decrease environmental pressures from Swedish consumption and production both within and outside its borders. However, in neither Denmark nor Sweden have the

rates of absolute decoupling in footprint-based GHG emissions been rapid enough as that needed globally to respect a 2 ° C global warming threshold.

For material resource use, the picture is even gloomier. A few cases of absolute decoupling of material resource use were identified but mostly for material indicators that do not include the full material rucksack of imported goods. At global level, only relative decoupling has been achieved. This is of concern since material resource extraction is estimated to have been responsible for half of greenhouse gas emissions and 90% of biodiversity loss to date.

Nordic governments should consider the adoption of targets for clear reductions in a range of environmental pressures including material resource use, and in environmental footprints abroad related to domestic consumption. They could develop systems to allow regular monitoring of environmental pressures abroad caused by national consumption, similar to those developed in Sweden.

Potential for sufficient absolute decoupling is limited – new measures of progress needed

Many authors argue, either based on the historical evidence or from a theoretical point of view, that absolute decoupling will not be possible at the rate needed to respect planetary boundaries, if we continue to use GDP as a measure of progress. Some theorists argue that GDP is strongly linked to material resource use, such that any reductions in material resource use will necessarily lead to reductions in GDP. This is due to the strong coupling of GDP to capital growth which itself is strongly linked to material use through the construction of infrastructure, machinery and building stock.

Many argue for new, or supplementary measures of progress and prosperity. It is argued that beyond a certain level of GDP, further increases in GDP do not guarantee increases in well-being and therefore more direct measures of progress in well-being are needed. It is also argued that absolute decoupling of environmental pressures can be more readily achieved from progress measured according to indicators that include human well-being at their core. A large number of candidates for alternative measures have been proposed but there appears to be no consensus, as yet, on which of these is most promising. Many governments are caught in ambiguous notions such as 'beyond GDP' and 'beyond growth' without having a true understanding of what these notions entail.

Nordic countries could work within EU and international monitoring fora towards alternative measures of progress to GDP, that focus on human prosperity and well-being and move towards achieving consensus on these at international level.

Reconsidering the 'growth at any cost' economic model

Several authors argue that adopting alternative measures of progress can open the door to economic models that do not rely on growth as the main route towards ecological sustainability and human well-being. Being neutral about economic growth can facilitate the acceptance of ambitious climate policy such as engendering significant reductions in material consumption and redirecting technology towards functional value and durability of goods.

Several authors argue that if economic growth is to continue to be a policy imperative, debate is needed on appropriate targets for this growth. The slower the growth and the earlier transition to a steady state economy are, the more effective the efforts toward absolute decarbonization are likely to be. While de-growth risks depressing investments, increases in unemployment and social unrest, there is historical evidence that modest economic growth rates of 1% or less allow absolute decoupling of pressures while reducing risk of widespread unemployment. Modest growth rates also appear to be more realistic for post-industrial countries such as the Nordics. Employment can potentially be ensured in a low-growth economy, through replacing labour taxes with environmental taxes, promotion of circular businesses such as repair, maintenance and refurbishment and the support and encouragement of reduced working hours.

Nordic governments should consider modest growth targets and investigate how this can be achieved without increased unemployment. They could also stimulate debate on which mechanisms lie behind the growth imperative and how these mechanisms might be tackled without causing social instability.

Green technologies, eco-efficiency and the rebound effect

There is general recognition in the literature that green technologies, improved resource efficiency and the circular economy are essential elements of the effort to decouple pressures from economic growth.

However, many argue that such technical transitions will only allow relative decoupling of environmental pressures, particularly at higher levels of economic growth, due to rebound effects. The *rebound effect* describes cases where efficiency improvements result in an increase in consumption that partially or wholly offsets the expected reductions in energy/resource use. Considerable evidence for the rebound effect was found in the literature, placing a question-mark against the potential of technological improvements to deliver absolute decoupling.

Despite these findings, rebound effects are seldom considered in energy efficiency policy. Authors argue that policy-makers need to be better informed on the various types of rebound mechanisms, in order to reduce the negatives associated with them while maximizing the merits. Sociological and anthropological studies of changes in behaviour in response to energy and material efficiency improvements can significantly improve this understanding.

Many authors argue for a shift in taxes from labour towards carbon-intensive and resource-intensive production, products and consumption in order to encourage and

fund green technologies. This can also potentially counter direct and indirect rebound effects that result from price elasticities. Such taxes should be implemented carefully to ensure that the poor aren't disproportionately affected and also to mitigate resource-intensive industries from relocating elsewhere.

The Nordic countries have large public sectors and the tax regimes needed for funding such green investments. Moreover, the Nordic countries can profit from being frontrunners in the green transition through increased competitiveness and export of green technologies.

Nordic governments should consider a green tax reform, how it could best be implemented and the resulting benefits and impacts. They should also investigate how to further invest in and subsidise green technologies and material productivity in order to increase competitiveness and export markets for green technologies.

The circular economy and the fourth industrial revolution

Most authors view the circular economy as a possible means to achieve decoupling of environmental impacts by looping resources in the economy while generating growth. By avoiding extraction of resources and further production, a circular economy can also reduce carbon emissions compared to a non-circular economy and lead to more areas set aside for nature.

However, circular economy strategies need to move away from a focus on recycling, which allows a continuation of a linear business model. Many argue that policy needs to focus on the inner circles of circularity through encouraging long product lifetimes, reuse, repair and refurbishment. It is also argued that promoting circularity in an individual company or industrial sector does not guarantee reductions in resource use across the whole economy due to cross-sectoral rebound effects.

Some authors argue that the Fourth Industrial Revolution in terms of nano-technology, the internet of things and machine learning have considerable potential to decarbonize and dematerialize the economy. However, more study is needed on this potential as the evidence seems rather weak.

Nordic governments should identify and implement policies to promote the inner circles of circularity through encouraging long product lifetimes, repair and refurbishment, while at the same time developing a better understanding of rebound effects and how they can be countered.

Decoupling of material resource use from capital investments

Many argue that the key reason why the use of material resources has only seen relative decoupling from economic growth is the continued expansion of building stock and infrastructure. They also argue that absolute reductions in material use and GHG emissions can only be achieved through a radical change to the design of, demand for and use of buildings and other infrastructure. Under current trends, investment in infrastructure will on its own overshoot available GHG emissions

budgets for all societal activities.

Material footprints can potentially be reduced through improved building standards and policy that encourage more efficient and more shared use of buildings such that growth in floor space per capita is halted and even reversed. This can be combined with carbon-neutral or carbon-positive buildings and infrastructure.

With respect to decoupling, one paper argues that since capital investment is the driving force of GDP growth, absolute decoupling of resource use from economic growth can only be achieved if material use is decoupled from capital investment e.g. capital investment is dematerialised. There is no evidence of this having been achieved in the past.

Nordic governments should identify policies that encourage efficient, more shared use of buildings to halt growth in floor space per capita. They should also develop policy measures for channelling private and public capital investments into low-energy using infrastructure, and from bricks and mortar into non-material investments such as ICT. Economic stimulation following a recession should be fully integrated with dematerialization and decarbonization policies.

Need for lifestyle change and greener public spending

Consumption behaviour is increasingly seen as a key factor in reducing environmental pressures. It is argued that to reduce resource use and meet climate targets, significant changes in lifestyles are needed. Policies for lifestyle changes require citizen engagement and approval to succeed. A green transition requires a combination of behavioural change and supportive framework conditions. According to several authors, policy should aim to change the frameworks within which consumers operate. They should reduce lock-ins and spill-over effects such that *all* consumers reduce their environmental footprint and not just those that are the environmentally-engaged.

According to a number of authors, the social logic can be addressed through reduced working hours, addressing inequality, strengthening social capital, and dismantling the culture of consumerism. Ownership norms can be challenged through promotion of sharing and leasing models.

Public spending has significant carbon and material footprints particularly in welfare states such as the Nordics. Adjusting public spending to be less impact-intensive can have significant benefits.

Nordic governments should identify lifestyles that are both environmentally less impacting and socially acceptable, and develop positive win-win language for use when promoting these. They should also consider encouraging a transition from ownership to sharing, leasing and product service systems, and adopt regulation that ensures a fair allocation of risks and responsibilities in such models.

Resumé

Mål og metode

Grøn vækst udgør kernen i de nordiske landes strategier for bæredygtig udvikling. Grøn vækst bygger på en antagelse om, at absolut afkobling mellem økonomisk vækst og miljøbelastning er mulig. Med andre ord at ressourceforbruget kan reduceres, og miljøbelastningen kan mindskes, samtidig med at den økonomiske vækst fastholdes. Absolut afkobling gennemsyrrer de nordiske landes politiske programmer, der på den ene side indeholder ambitioner om CO₂-neutralitet og halvering af biodiversitetstab, og på den anden side indeholder stimuli af økonomisk vækst. Det er imidlertid ikke dokumenteret, om absolut afkobling er mulig på lang sigt.

Denne rapport præsenterer, vurderer og diskuterer beviserne for og imod afkobling med henblik på at give beslutningstagere og interessenter en forståelse for sammenhængen mellem miljøbelastningen og økonomisk vækst.

Dokumentation og argumentation for om absolut afkobling er mulig er blevet indsamlet gennem et systematisk og dybdegående litteraturstudie. 48 artikler, rapporter og bøger, der repræsenterer både pragmatikere, fortalere og kritikere af grøn vækst, er blevet læst og holdt op imod en analyseramme.

Nøglebegreber og definitioner

Økonomisk vækst fører ifølge klassisk økonomisk teori til, og skabes af, materiale- og energiforbrug, hvis udvinding- eller produktionsapparat udgør en miljøbelastning i sig selv. Afkobling kan være *relativ* eller *absolut*. Relativ afkobling forekommer, når miljøbelastningen stiger mindre end den økonomiske vækst, mens absolut afkobling betyder, at dens samlede miljøbelastning falder, selvom den økonomiske vækst stiger.

De geografiske rammer for undersøgelse af afkobling kan variere. Nationale regeringer anvender ofte mål, der alene metager den CO₂ -udledning og det ressourceforbrug, der finder sted indenfor landets grænser. En sådan national afgrænsning medtager dermed ikke de globale miljøeffekter, der eksempelvis forekommer, når et produkt produceres i udlandet. Afkoblingsanalyse kan enten tage afsæt i et *produktionsbaseret perspektiv* (hvor miljøeffekterne fra den nationale produktion sammenlignes med BNP) eller et *forbrugsbaseret perspektiv* (hvor miljøeffekter fra det nationale forbrug, og dermed miljøeffekter fra hele værdikæden, sammenlignes med trends i nationale forbrugsudgifter).

Forskere har udpeget ni *planetariske grænser*, der udstikker grænser for miljøbelastningen, og som dermed definerer et sikkert handlerum for menneskelig adfærd. Disse planetariske grænser indbefatter blandt andre mængden af drivhusgasser, nitrogen- og fosforudledning, biodiversitetstab og arealforbrug, der alle er overskredet eller er under høj risiko for at blive overskredet. For udledningen af drivhusgasser er der med de planetariske grænser blevet defineret et *budget*, der kan fordeles på borgere via en retfærdig fordelingsmekanisme, der muliggør, at

CO₂-kvoter kan fordeles ud på aktører – værende lande, virksomheder eller borgere. Globale og nationale budgetter kan også defineres for andre miljøeffekter.

Absolut reduktion i miljøbelastningen er afgørende for at respektere de planetariske grænser

De fleste forfattere er enige om at, i industrialiserede lande er absolut afkobling mellem miljøbelastning og økonomiske vækst nødvendig for at respektere planetens grænser. Flere forfattere hævder desuden, at de industrialiserede lande (herunder Norden) har overskredet deres retfærdige andel af tilgængelige ressourcer og CO₂-kvote.

Nordiske lande bør aktivt engagere sig i at oversætte de planetariske grænser til en nordisk kontekst, der tager højde for global retfærdighed, og endvidere undersøge hvorvidt de nordiske vækstmål overholder disse grænser.

Begrænset bevis for absolut afkobling

Der er fundet begrænset bevis for historisk absolut afkobling. I de perioder, hvor der er opnået absolut afkobling, er denne afkobling ikke være signifikant nok til at holde sig indenfor de planetariske grænser. Beviser for absolut afkobling synes desuden at være stærkest for drivhusgasser og andre luftemissioner, når de betragtes fra et produktionsbaseret perspektiv. Dette skyldes outsourcing af tung industriproduktion til andre regioner i verden uden tilsvarende ændringer i forbruget.

I de nordiske lande har både Danmark og Sverige haft perioder, hvor de har opnået absolut afkobling mellem forbrugsbaserede drivhusgasemissioner og vækst i BNP. Sverige har i de senere år også afkoblet andre luftemissioner samt globale vand- og arealanvendelsesaftryk fra deres forbrug. Disse reduktioner kan have været resultatet af implementeringen af Sveriges overordnede miljømål om at reducere miljøbelastningen fra svensk forbrug og produktion både inden for og uden for dets grænser. I hverken Danmark eller Sverige har hastighederne for absolut afkobling i forbrugsbaserede drivhusgasemissioner imidlertid været hurtig nok til at overholde en 2 ° C tærskel for global opvarmning.

Absolut afkobling mellem produktionsbaseret materialeforbrug og BNP er blevet identificeret i få tilfælde, og primært ved brug af for produktionsbaserede ressourceindikatorer, der ikke inkluderer det fulde materialeforbrug af importerede varer. Dette er bekymrende, da udvinding af materielle ressourcer anslås at stå for halvdelen af drivhusgasemissionerne og 90% af tabet af biodiversitet til dato.

De nordiske regeringer bør overveje vedtagelsen af mål for klare reduktioner i en række miljøbelastninger, der medtager den globale miljøbelastning. De nordiske lande kan med fordel udvikle systemer, der muliggør regelmæssig overvågning af miljøbelastningen i udlandet forårsaget af nationalt forbrug, svarende til dem, der blev udviklet i Sverige.

Potentialet for tilstrækkelig absolut afkobling er begrænset - yderligere tiltag er nødvendige

Mange forfattere argumenterer for, at absolut afkobling ikke kan opnås, hvis vi fortsat bruger BNP som et mål for fremskridt. BNP er stærkt knyttet til anvendelse af materielle ressourcer, således at fald i ressourceforbruget fører til fald i BNP. Dette skyldes den stærke kobling mellem BNP og kapitalvækst, der afhænger af materialeanvendelse i form af opførelse af infrastruktur, maskiner og bygningsmasse.

Mange argumenterer desuden for nye eller supplerende udviklingsmål, der skal sikre trivsel. De hævder, at, ud over et vist BNP-niveau, garanterer yderligere stigninger i BNP ikke højere trivsel. Det hævdes også, at absolut afkobling mellem miljøbelastning og samfundsudvikling, lettere kan opnås når udvikling er målt i forhold til trivsel fremfor økonomisk vækst. Et stort antal kandidater til trivselsindikatorer er blevet foreslået, men der synes endnu ikke at være enighed om hvilke af disse, der er mest lovende. Mange regeringer anvender tvetydige mål som 'hinsides vækst' uden at give en egentlig definition af, hvad disse mål indebærer.

Nordiske lande kan med fordel arbejde på at fremme globale og konsensusbaserede udviklingsmål, der fokuserer på menneskelig trivsel.

Genovervej den økonomiske model om 'vækst for enhver pris'

Flere forfattere hævder, at vedtagelsen af alternative udviklingsmål kan åbne døren for økonomiske modeller, der ikke er afhængige af økonomisk vækst, og som leverer miljømæssig bæredygtighed og menneskelig trivsel. At forholde sig neutralt til økonomisk vækst bidrager til en øget accept af ambitiøse klimapolitikker som f.eks. en bremsning af efterspørgslen efter ressourceforbrug såvel som produktholdbarhed og fokus på en høj funktionel værdi af produkter.

Nulvækst risikerer at undertrykke investeringer, stigninger i arbejdsløshed og social uro. Omvendt er der historisk bevis for, at beskedne økonomiske vækstrater på 1% eller derunder tillader absolut afkobling og samtidig reducerer risikoen for øget arbejdsløshed. Beskedne vækstrater synes også at være mere realistiske for postindustrielle lande som Norden. Beskæftigelse kan potentielt sikres i en lavvækstøkonomi ved at fremme af cirkulære virksomheder baseret på reparation, vedligeholdelse og renovering, og gennem reduceret arbejdstid.

Nordiske regeringer bør overveje beskedne vækstmål og undersøge, hvordan dette kan opnås uden at øge arbejdsløsheden. De nordiske lande kan endvidere starte en debat om de antagelser, der ligger bag vækstdoktrinen, og om økonomisk vækst kan bremses uden at forårsage social uro.

Grønne teknologier, miljøeffektivitet og rebound-effekten

Der er generel anerkendelse i litteraturen om, at grønne teknologier, forbedret ressourceeffektivitet og cirkulær økonomi kan bidrage til at afkoble miljøbelastning fra økonomisk vækst. Rebound-effekter, hvor f.eks. effektivitetsforbedringer resulterer i en stigning i forbruget, risikerer helt eller delvist at opveje forventede reduktioner i energi- og/eller ressourceforbruget. Rebound-effekter giver derfor anledning til at stille spørgsmålstejn ved potentialet for at teknologiske forbedringer leverer absolut afkobling. På trods af disse fund tages der sjældent højde for rebound-effekter i energieffektivitetspolitikker.

Mange forfattere argumenterer for at en skattereform, der beskatter CO₂-tung og ressourceintensiv produktion, produkter og forbrug fremfor arbejdskraft, kan bidrage til absolut afkobling, og samtidig modvirke rebound-effekter. Sådanne skatter bør implementeres omhyggeligt for at sikre, at lavindkomstgrupper ikke påvirkes uforholdsmæssigt meget og for at afbøde ressourceintensive industrier fra at flytte udenlands. De nordiske lande har store offentlige sektorer og skatteforvaltninger, der muliggør grønne skattereformer. Ligesom de nordiske lande har kapacitet til at mobilisere grønne investeringer. De nordiske lande kan øge deres grønne konkurrenceevne og eksport af grønne teknologier ved at være frontløbere i den grønne omstilling.

De nordiske regeringer bør overveje, hvordan en grøn skattereform kan designes og implementeres, og de deraf følgende fordele og ulemper. De nordiske lande bør desuden undersøge, hvordan de kan investere i og subsidiere grønne teknologier og materialeproduktivitet for at øge konkurrenceevnen og eksportmarkederne for grønne teknologier.

Den cirkulære økonomi og den fjerde industrielle revolution

De fleste forfattere ser den cirkulære økonomi som et muligt middel til at opnå afkobling mellem økonomisk vækst og miljøpåvirkning ved at recirkulere ressourcer i økonomien og dermed undgå udvinding af ressourcer og yderligere produktion, hvorved der udledes mindre CO₂, og der teoretisk set frigives flere områder til natur.

Handlingsplaner for cirkulær økonomi har indtil nu fokuseret på genanvendelse, som muliggør en forsættelse af den lineære 'køb forbrug-smid ud' kultur. Mange hævder, at cirkulære initiativer i stedet bør fokusere og fremme de indre cirkler herunder længere produkt levetid, genbrug, reparation og renovering. Det hævdes også, at øget cirkularitet i en enkelt virksomhed eller i en enkelt industri ikke garanterer reduktioner i ressourceanvendelsen total set på grund af tværsektorielle rebound-effekter.

Nogle forfattere hævder, at den fjerde industrielle revolution og de tilknyttede intelligente digitale teknologier som 'internet of things' og kunstig intelligens kan bidrage til at dematerialisere økonomien. Der er dog behov for yderligere undersøgelser, da argumentet har et teoretisk udspring.

De nordiske regeringer bør identificere og gennemføre politikker for at fremme de indre cirkler af den cirkulære økonomi herunder forlænge produktlevetid, reparation og renovering, samtidig med at de udvikler en bedre forståelse af rebound-effekter, og hvordan de kan modvirkes.

Afkobling af materiel ressourceanvendelse fra kapitalinvesteringer

Mange hævder, at nøgleårsagen til, at der kun er forekommet relativ afkobling mellem økonomisk vækst og ressourceforbrug, skyldes udvidelsen af det byggede miljø og særligt anlæg af infrastruktur. De mener, at absolutte reduktioner i ressourceforbrug og drivhusgasemissioner kun kan opnås gennem radikale ændringer af, hvordan vi designer, bruger og efterspørger bygninger og anden infrastruktur. Hvis det nuværende niveau af nybyggeri og opbygning af infrastruktur fastholdes, vil disse alene overskride nordens CO₂-budgetter.

Det materielle fodaftryk kan potentielt reduceres gennem forbedrede bygningsstandarder og politiske tiltag, der fremmer en mere effektivt og fælles brug af bygninger, således at væksten i gulvplads pr. indbygger reduceres. Dette kan kombineres med CO₂-neutrale og sågar CO₂-positive bygninger og infrastruktur.

Med hensyn til afkobling hævder en artikel, at da kapitalinvesteringer er drivkraften i BNP-væksten, kan absolut afkobling mellem ressourceanvendelse og økonomisk vækst kun opnås, hvis ressourceanvendelse afkobles væsentlig fra kapitalinvesteringer, dvs. ved at dematerialisere kapitalinvesteringer. Der er ingen tegn på, at dette er opnået tidligere.

Nordiske regeringer bør gennemføre initiativer, der fremmer en effektiv og fælles brug af bygninger og dermed reducerer gulvplads pr. indbygger. De bør også udvikle incitamenter, der fremmer offentlige og private kapitalinvesteringer i lavenergi og materialeeffektivt byggeri og anlæg, samt i teknologiske investeringer frem for fysiske strukturer.

Behov for ændret forbrugeradfærd og grønnere offentlige udgifter

Ændret forbrugeradfærd ses i stigende grad som en nøgelfaktor for at reducere ressourceanvendelsen og opfylde klimamålene. Ændret forbrugeradfærd kræver imidlertid borgernes støtte for at lykkes og bør både være målrettet de forbrugere, der allerede er klimabevidste, og de, der er det i mindre grad. Tiltag, der stimulerer adfærdsmæssige ændringer, bør desuden suppleres af initiativer, der sikrer de rette rammebetingelser, og som undgår såkaldte afsmittende virkninger, hvor forbruget flyttes hen på andre produktgrupper.

For at undgå social modstand, foreslår en række forfattere, at arbejdstiden nedsættes, samtidig med at der sættes initiativer, der reducerer uligheden, styrker den sociale kapital og adresserer den nuværende forbrugskultur. Øget udbredelse af

deling- og leasingmodeller kan desuden bidrage til at udfordre gældende ejerskabsnormer.

Offentlige indkøb har ligeledes et betydeligt klima- og ressourceaftryk, og der er store miljøeffekter at hente ved at efterspørge produkter og services med lavere miljøbelastning.

De nordiske regeringer bør identificere klimavenlig adfærd, der støttes af befolkningen. De bør ligeledes fremme dele-, leje- og leasing-modeller, og vedtage regulering, der sikrer en retfærdig fordeling af risiko og ansvar i disse modeller.

1 Background and objectives

1.1 Background

The key challenge for government in the 2st century is finding out how to maintain healthy economies that guarantee employment and quality of life while at the same time living within the limits of the earth's resources and environmental services and not undermining the web of life on which human society is dependent. This challenge is just as relevant to the Nordic countries as it is to the rest of the world.

In "Vision 2030" the Nordic prime ministers stressed that sustainable development is possible: *"We can change our lifestyles, production methods and patterns of consumption, balance out the use and protection of natural resources on land and at sea, and achieve sustainable development for the future"*.

Similarly, the European Commission says of its new Green Deal: *"It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use"*.

The basic concept being defined by these strategies is 'green growth'. The OECD, defines green growth as being *"about fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. It is also about fostering investment and innovation, which will underpin sustained growth and give rise to new economic opportunities"* (OECD, 2011:18).

The World Bank writes: *"Green growth is growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards"* (Fay, 2012:2). According to the European Commission, *"the aim is to create more value while using fewer resources, and substituting them with more environmentally favourable choices wherever possible"* (European Commission, 2016).

The underlying core assumption of green growth is that economic growth can be continued while reducing material use and associated environmental pressures and impacts associated with it. In other words that resource use and environmental impacts can be absolutely decoupled from economic growth such that climate impacts and biodiversity loss can be halted (see Box 1).

Box 1: Absolute and relative decoupling

Economic growth and environmental pressures (e.g. CO₂-emissions and resource use) and impacts (e.g. biodiversity loss and climate change) are coupled when these two variables move in the same direction at the same rate and a higher economic growth leads to a greater environmental impact. Decoupling refers to breaking this correlation, either in a way where:

- Economic growth increases, while environmental pressures or impact reduces (**absolute decoupling**),
- Environmental pressures or impacts reduce per unit economic growth but environmental pressures or impact continue to increase (**relative decoupling**).

More detailed descriptions of decoupling are provided in Chapter 5.

The OECD has been promoting decoupling as an objective since 2002, and in 2011 decoupling was central in the OECD's strategy document "Towards Green Growth" (OECD, 2011). The EU's 6th Environmental Action Programme 2002-2012 likewise included a decoupling objective to "break the old link between economic growth and environmental damage". This was reiterated in the 7th Environmental Action Programme¹ in a goal to "strive towards an absolute decoupling of economic growth and environmental degradation". Decoupling is likewise a central target of the UN SDG's to attain economic growth and social well-being, while decreasing the ecological footprint (Parrique et al., 2019).

The arguments and evidence for decoupling need to be assessed, evaluated and questioned, since the decoupling concept is fundamental to sustainable development strategies and environmental policy in the Nordic and other OECD countries. If it is found to be wrong or at least questionable, then fundamentally new approaches would be needed to meet the challenges of this century and centuries to come.

A wealth of literature has developed over the past two decades that has both considered historical achievements in decoupling and based on this or on economic and ecological theory, considers the potential for decoupling in the future in the light of approaching planetary boundaries. Policymakers in the Nordic countries and elsewhere need to be made aware of the findings of such literature, and on what is certain and what is less certain such that they can make informed decisions on the future economic and social development of the region in a global context.

1. ECISION No 1386/2013/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

1.2 Objectives

The project addresses the theme of decoupling and the problems associated with it. It discusses the question of what type and level of economic growth is possible and desirable within the frameworks set by nature.

The objectives of the project are to carry out a literature review on the subject and provide an overview of the arguments and evidence for and against various kinds of decoupling in order to provide answers to some of the following questions in a Nordic context:

1. Growth in what? GDP is an aggregated indicator: can its composition be changed so markedly that there is room for continued growth in production and consumption?
2. How big is the potential for resource efficiency and the replacement of environmentally harmful technology in production?
3. What technical, economic and other constraints could potentially set limits for decoupling and are there special conditions in Nordic societies, that give advantages in achieving radical decoupling?
4. What is the relationship between material consumption and well-being, especially at higher levels of income?
5. Which of the basic conditions of nature present the greatest challenges to economic growth?

The analysis examines the range of approaches to reducing environmental pressures and impacts from "green growth" to "degrowth", in other words approaches that are optimistic about economic growth and others that are more agnostic or pessimistic.

The review is limited to literature relevant to the Nordic countries by restricting the publications to ones covering advanced market economies with preference for works that refer to one or more of the Nordic countries or have a global or European perspective that is in some way relevant to the Nordic countries.

2 Structure of this report

This report is structured in eight chapters. **Chapter 3** describes an overview of the methodology used for the analysis including the selection and filtering of articles and the analysis of these articles against a framework inspired by the research questions. **Chapter 4** briefly characterises the selected articles.

Chapter 5 defines what is meant by decoupling as a whole, ° of decoupling and the various kinds of decoupling that can lie within the general concept. It also examines geographical boundaries with respect to decoupling. **Chapter 6**, meanwhile, considers whether GDP and human welfare are closely coupled and whether GDP is a good indicator for human welfare.

Chapter 7 looks at the historical evidence of decoupling to date, the extent to which decoupling has been achieved and how this was achieved and within which geographical frameworks. It also considers evidence for rebound effects that undermine technical efficiency improvements.

Chapter 8 is forward-looking. It briefly describes the current understanding of planetary boundaries, what budgets they leave available, if any, for any further environmental pressures, and what decoupling rates might be needed to keep within these budgets. It also examines discussions on the geopolitical split between regions of the responsibility for decoupling. Chapter 8 then goes on to consider the arguments on whether or not the necessary decoupling can be achieved, and how and through what types of policy.

Finally, **Chapter 9** draws the findings together with focus on the Nordic region and makes recommendations for the Nordic countries.

3 Methodology and approach

The core of this research has been a systematic and in-depth literature review on the evidence and arguments for historical decoupling of environmental impacts and resource use from economic growth, and the potential for decoupling in the future, with a Nordic focus.

The literature study comprised three overall phases. First, a long list of relevant literature on decoupling with relevance to the Nordic countries was identified based on a systematic search strategy. The second phase comprised a first analysis and filtering of the long-list to provide a short-list of approximately 50 articles and books that were most relevant to the research questions included in the objectives, such that all themes would be addressed. The final phase comprised a systematic analysis of the selected literature guided by an analytical framework that was developed with starting point in the research questions. The methodology is described briefly below. The detailed methodology is given in Appendix A.

3.1 Collating a long-list of relevant literature

This project phase aimed at identifying a long-list of relevant literature published after 2005. 2005 was selected as a watershed, at which point decoupling was firmly cemented into EU environmental policy with the publication of the Thematic Strategy on the Sustainable Use of Natural Resources under the EU Commission's 6th Environmental Action Program.

The long-list was compiled making use of two, complementary databases and associated search engines:

- **Scopus**, which is Elsevier's own database of primarily peer-reviewed articles from more than 5000 publishers covering both science, technology, social science and humanities.
- **The Danish Royal Library's REX Database**, containing all materials of the Royal Library including books and popular articles, which are not covered by Scopus.

A number of key words (see Appendix A for a full list) were identified for use in literature searches that include commonly used concepts and theories within or related to the general concept of decoupling or otherwise related to the research questions posed earlier. Queries were trialled iteratively using these key words in various combinations with the goal of focussing the query and narrowing the results to a size that could be reasonably handled in subsequent steps.

It was quickly found that there are a very large number of publications that have some potential relevance to the field. Several filtering steps were developed to further focus the selection of publications to those directly relevant to the research questions and in particular to the Nordic countries. These steps are described in Appendix A. The result was 290 titles in total. This was viewed as the limit of any filtering that could be carried out based on title only and from here on abstracts would need to be read.

3.2 Selection of short-list for detailed analysis

The selection of the short list from the 290 titles in the long-list was made through a review of abstracts.

Using the abstract each publication was characterised in terms of its relevance to various elements that could be drawn from the objectives of the project (see Box 2 below). This led to the prioritisation of 48 publications. The short list was reviewed by the consortium including the two academic experts associated with the project. A full list of the reviewed publications is given in Appendix B.

Box 2: Categorisation of articles

1. Does the article focus on the Nordic region?
2. Is the article a review paper or original research?
3. Is the information in the article based on empirical evidence or theoretical arguments?
4. Does the article focus on dematerialisation, substitution or technological development?
5. Does the article compare production and consumption perspectives?
6. Does the article take the planetary boundaries into account?
7. Which type of decoupling - resource use and/or environmental impacts from GDP and/or well-being – does the article consider?
8. Is the article optimistic, agnostic or pessimistic?

3.3 Analytical framework

An analytical framework was developed to guide the review and analysis of each publication in the short list. The main aims of the analytical framework were to 1) to allow a characterization of papers, and 2) ensure that all elements of potential interest in answering the research questions given in the Objectives were covered. The analytical framework (Table 2) is divided into four main areas.

- **Characterisation** of the paper/document, who wrote it and in what context
- **Backward-looking elements** that consider historical evidence for decoupling, shifting of impacts and rebound effects
- **Forward-looking elements** concerned with planetary boundaries, potential for and constraints to further decoupling and the potential negative social consequences of decoupling
- **Conclusions and key messages** with particular importance for the Nordic countries, including relevant recommendations found in the articles

The full analytical framework is provided in Appendix A. Each publication was comprehensively reviewed against the framework and all the results were provided in a single large spreadsheet to enable comparisons of specific themes and positions to guide the analysis.

4 Characterisation of the selected articles

In this section, the 48 reviewed works are briefly characterised in terms of publication year, type of publication and evidence, type of decoupling covered and position represented in the works.

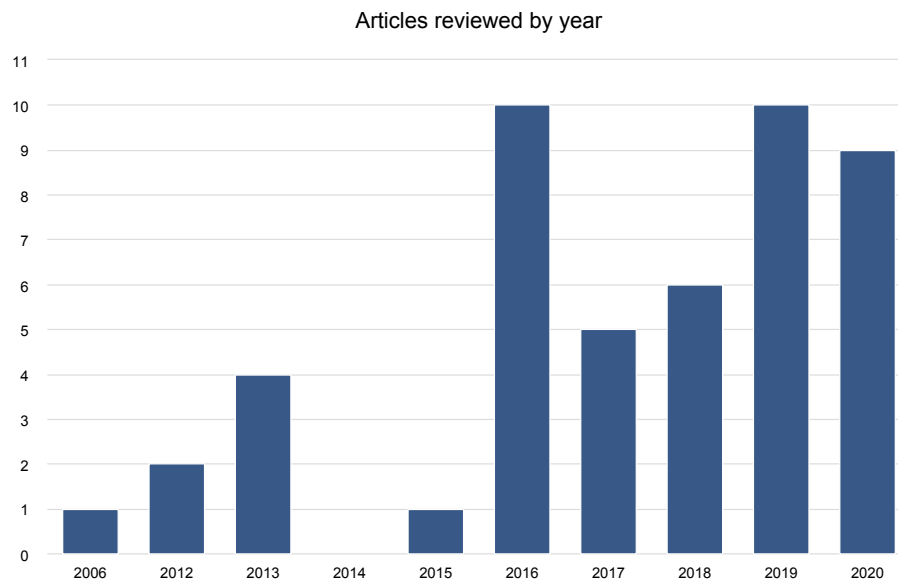


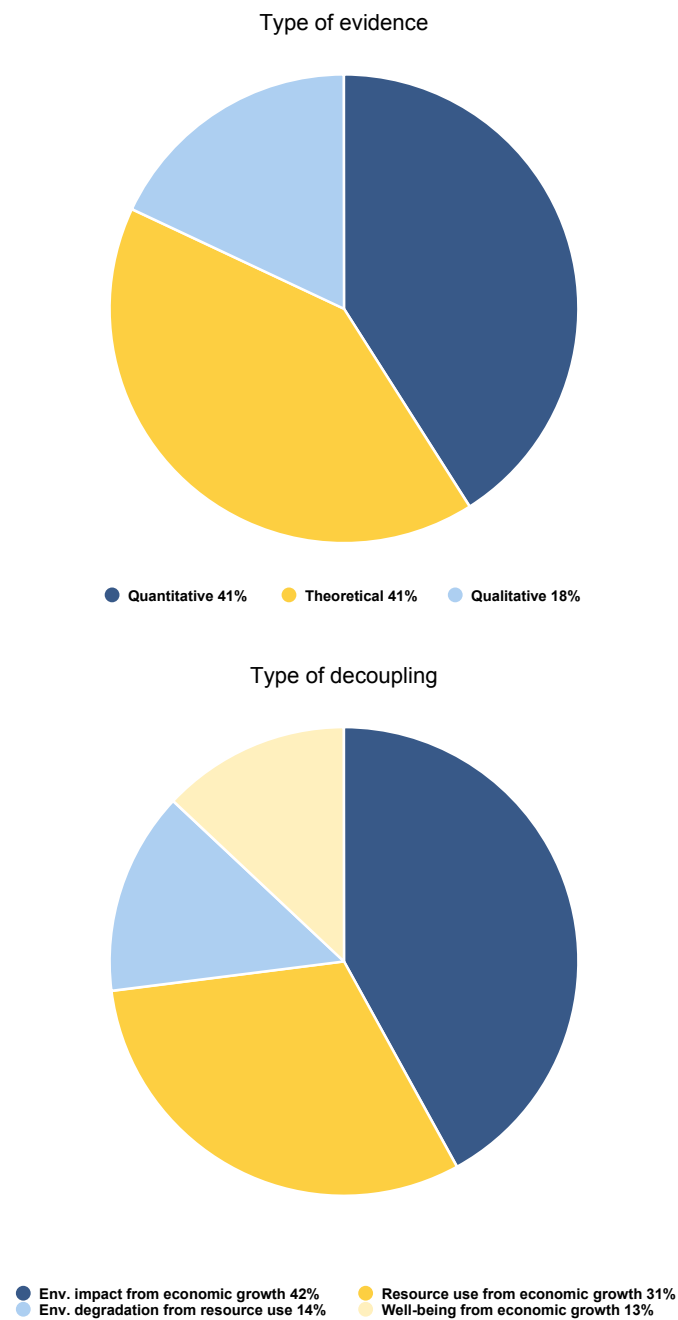
Figure 1: Number of articles per year.

The number of publications on decoupling has increased exponentially by year. This demonstrates the increase in interest in the subject as the ecological and climate crises become increasingly apparent and urgent and has also been demonstrated in other literature reviews. Wiedenhofer et al. (2020), for example, identified that the literature of decoupling has grown by 20% each year since 2005. The selected articles for deep analysis reflect this development over time, with most published since 2016 (see Figure 1).

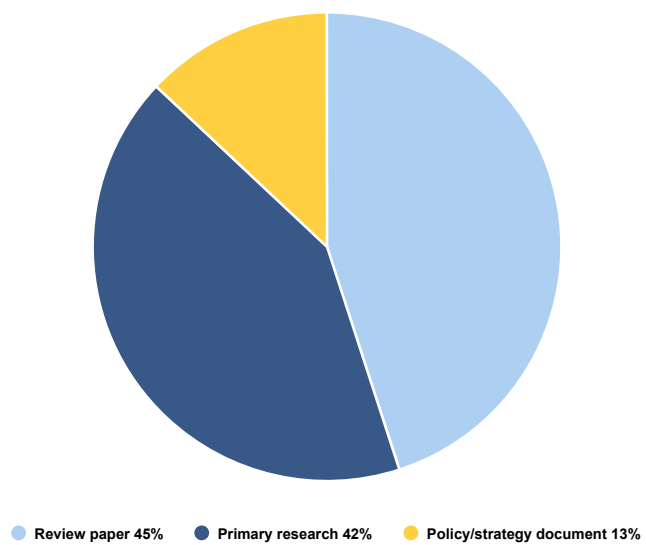
As can be seen in Figure 2, the articles/documents are relatively balanced with respect to the types of document, type of evidence considered and the decoupling addressed. With respect to the latter the majority of papers consider either decoupling of resource use or of impacts from economic growth while decoupling of welfare from economic growth has been less in focus (see Figure 3 and Chapter 5 for a detailed description of the theory behind types of decoupling).

Nearly two thirds of the articles/documents are assessed as taking a pragmatic/agnostic approach with roughly one quarter taking a de-growth position. Just 12% were written from a pro-growth perspective. This is discussed further in Chapter 8.2.

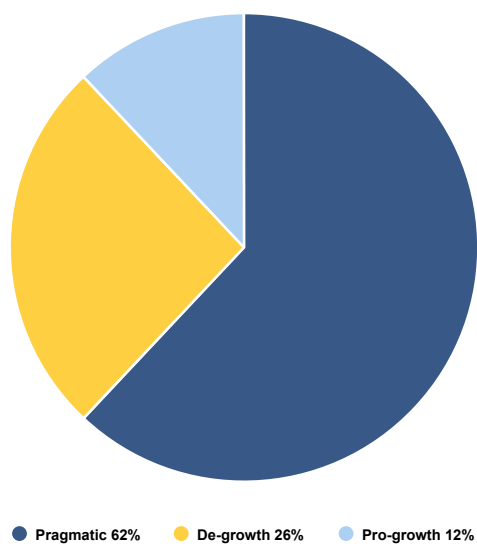
Figure 2: characterization of articles according to: types of evidence, types of decoupling considered, type of paper and position with respect to decoupling.



Type of document



Position



5 What is meant by decoupling?

Decoupling is the central element of the arguments for green growth as a means to reduce environmental impacts and respect the limits of the earth's planetary boundaries, while at the same time continuing with an economic growth paradigm. Whether it is feasible or not is the main subject of this report. It is, therefore, of importance to examine what we actually mean when we use the term decoupling.

Decoupling in the context of environmental economics has arisen as an important concept, namely as an antithesis of what is often (with the exception of proponents of the Environmental Kuznet curve theory – see Section 7.2 later) considered the *norm* for an economy under development. This norm is that economic growth leads to, or is caused by, an increase in the throughput of materials and energy through the economy, which in itself leads to increases in environmental pressures (such as carbon dioxide emissions and land utilisation) and from there to increasing environmental impacts (such as climate change or biodiversity loss).

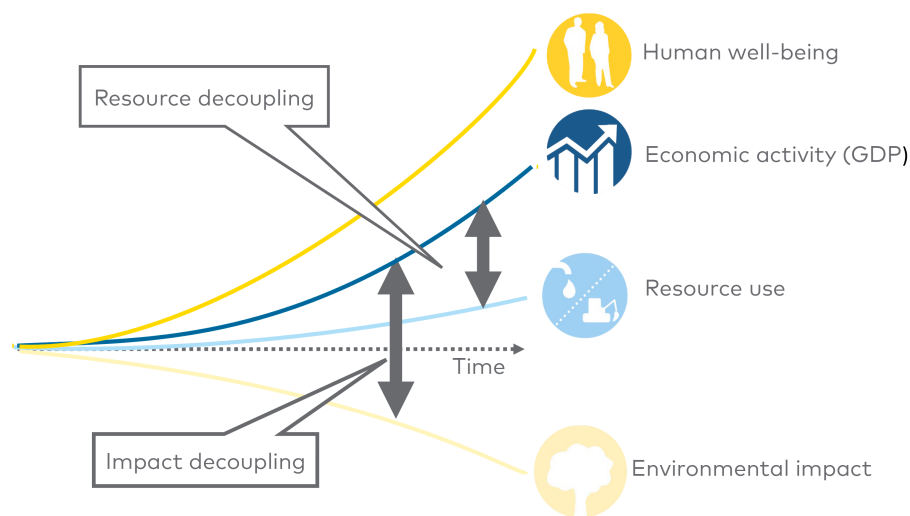


Figure 3: A theoretical and idealised overview of the various components of decoupling that together can decouple growth in human well-being from resulting environmental impact.

Source: Adapted from *International Resource Panel (2011)*

Breaking the strong link between economic growth and environmental impacts can be termed as 'decoupling'. Decoupling can occur at various places within the causal link between economic growth and environmental impacts. The International Resource Panel (2011) identified several types of decoupling which, in theory, can act in combination to reinforce one another (see Figure 3).

Resource use can be decoupled from economic growth (for example, by switching

from private cars to public transport) and in turn environmental pressures and impacts can be decoupled from resource use (for example, through replacing fossil fuel energy with renewable energy). In addition, economic growth can, in theory, also be decoupled from increasing human welfare which is, after all, the ultimate objective of human and economic development.

Decoupling between any pair of these dimensions can be *relative* or *absolute*. *Relative* decoupling refers to a situation where the second variable, for instance resource use, continues to grow but at a slower rate than the variable that it has been decoupled from, for instance economic growth. *Absolute* decoupling refers to a situation where the second variable is stable or reducing e.g. environmental pressures reduce despite continued economic growth (see Figure 4).

If economic growth or human welfare is to increase indefinitely, decoupling needs to be absolute, otherwise the capacity of the earth's environmental services will be exceeded at some point in the future, with potentially catastrophic consequences for nature, biodiversity and, ultimately, human beings (e.g. Krausmann et al, 2020; Jackson, 2017; Haberl et al, 2020; Akenji et al. 2016).

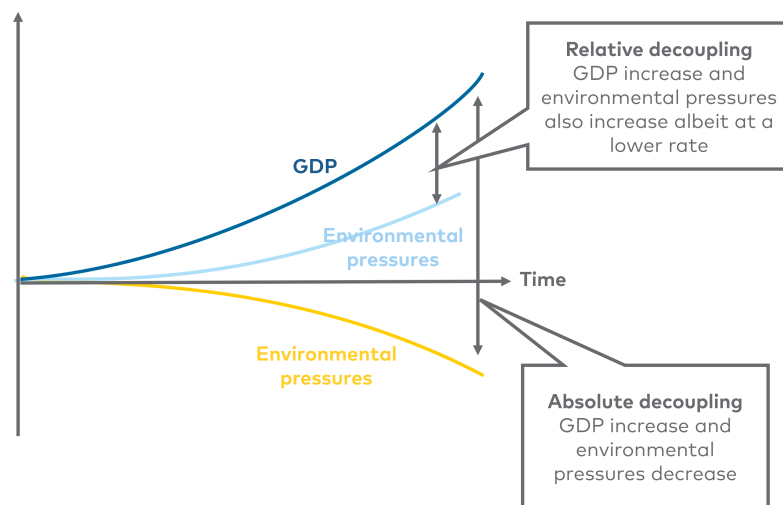


Figure 4: A comparison of relative and absolute decoupling that demonstrates that the rate of GDP growth is critical in whether absolute or only relative decoupling can be achieved.

Source: Adapted from EEA (2012)

When investigating decoupling, the geographical boundaries used can be highly relevant. Many empirical studies of decoupling have used national boundaries for both economic growth (e.g. a country's GDP) and for environmental pressures (e.g. direct national emissions of greenhouse gases). This appears to make sense since the boundary is consistent for each variable being considered.

However, global economies are intimately linked via trade in goods and services. The

purchase of a product in Sweden may indirectly have caused the release of environmental pressures in a string of other countries along the value chain of the consumed product.

Decoupling analysis often takes either a **territorial-based perspective** (where trends in direct emissions/pressures within national boundaries are compared to trends in national GDP) or a **footprint-based perspective** (where trends in global emissions/pressures caused along the value chains of all consumed products and services are compared to trends in national consumption expenditure).

Complex methods that make use of so-called *multi-regional input output tables* can be used to estimate the environmental footprint of a nation's consumption patterns (see, for example, Palm et al, 2019). These are not as accurate as inventories of direct emissions under a territorial perspective but have been argued to be 'fairer' in determining the decoupling progress of a nation.

When considering decoupling progress in the *global* economy, a territorial perspective and footprint perspective ought to give identical results. For individual economies, however, territorial and footprint-based perspectives of decoupling can significantly diverge from one another in post-industrial development trajectories which characterize the Nordic countries and much of the rest of Europe. Consumption-based greenhouse gas emissions are higher than territorial emissions in most developed countries (Witting and Vringer, 2009; Ahmad and Wyckoff, 2003).

The reason for this is that heavy industry and the extraction of resources is increasingly outsourced to other global regions, as national economies go through a transition to more service-based and knowledge-based sectors, but where private households and governments continue to consume the products of emissions-intensive industries (see, for example, Asafu-Adjaye et al., 2015; Bithas & Kalimeris 2017, Wiedmann et al., 2015). Peters and Hertwich (2008) showed that 21.5% of global CO₂ emissions in 2001 were embodied in international trade and that developed countries are typically net importers of emissions while developing countries are net exporters.

This outsourcing of heavy industries to other regions risks increasing global net environmental pressures due to the *race-to-the-bottom* hypothesis. This hypothesis asserts that countries tend to lower their environmental standards in order to attract more investment and that increasing integration of global value chains through trade, leads to an overall increase in pressures on the environment (Aşici, 2013; Borghesi and Vercelli, 2003).

Thus, it is important to consider both the territorial and footprint-based perspectives when looking at historical progress in decoupling, and when looking at potential for decoupling in the future. Both perspectives are examined in Chapter 7.

6 Is GDP a good measure of well-being?

The need for a decoupling of environmental pressures from economic growth is the core of green growth. An essential element of the argument for green growth is that economic growth is necessary to increase human well-being. Economic growth has become an ideological panacea that helps appease society by promising that current inequalities and injustices will be resolved at some point in the future (Daly, 1974).

Some authors argue that while growth may indeed bring increased well-being for citizens in low income countries, once a certain economic threshold has been reached, further economic growth does not bring further increases in well-being. Hoekstra (2019) argues that GDP has only been loosely coupled with well-being in OECD countries over the last 40 years. A growing number of critics have identified that human happiness, well-being and life satisfaction have stalled (or reversed) even as economic output has grown (Jackson, 2009; Victor 2010; Skidelsky & Skidelsky, 2012; Wilkinson & Pickett, 2009).

Jackson (2017) argues that GDP is simply a measure of the 'busy-ness' of the economy and that GDP as an indicator has implicitly made some normative judgements on the value of different kinds of busy-ness. Firstly, by counting only the monetary value of things exchanged in the economy, and secondly by assuming that all of these monetary values are equivalent. As an example of the first factor, positive activities like household work, care of family members and voluntary work do not contribute to GDP because they are not connected to any economic exchange. With respect to the second, GDP does not distinguish between activities that contribute to human well-being such as healthcare spending and those that arguably detract from well-being such as sales of cigarettes.

Many authors propose alternative indicators to GDP that can better represent economic progress while taking into account human well-being, environmental health and resilience.

These include the Index of Sustainable Economic Welfare (ISEW, Daly and Cobb, 1989), the Genuine Progress Indicator (GPI, Cobb et al., 1995); the Sen-Stiglitz-Fitoussi-report (Stiglitz et al., 2009). Hoffrén (2006) suggests the use of the Environmentally adjusted Domestic Product of the United Nation's SEEA handbook, the UN Human Development Index and the Index for Sustainable Economic Welfare while Aşici (2013) proposes the Environmental Sustainability Index (WEF, 2001); Environmental Performance Index (Bohringer and Jochem, 2007); Environmental Vulnerability Index (Singh et al., 2012), Index of Sustainable and Economic Welfare (CES, 2000); Green Net National Product (UNEP, 2000); Ecological Footprint (Rees, 1992; Wackernagel et al., 1999), and; Adjusted Net Savings (ANS) (Hamilton and Clemens, 1999).

A study of developments in one of these alternative measures, the Genuine Progress

Indicator², Kubiszewski et al. (2013) found that in most countries the GPI has been coupled to GDP until a particular threshold, after which GDP continues to grow, while GPI flattens and, in some cases, declines. The authors draw on Max-Neef (1995) to interpret this threshold as the point at which the social and environmental costs of GDP growth become significant enough to cancel out consumption-related gains (Deaton, 2008; Inglehart, 1997).

Malmaeus (2016) argues that resource use and environmental degradation can be more easily decoupled from growth in a progress indicator that focuses on well-being than from growth in an indicator such as GDP, that only measures economic activity. Thus, some of the alternative measures of progress and national well-being may be better placed than GDP to define economic development compatible with necessary reductions of resource use and environmental degradation (Kahneman et al. 2004; Stiglitz et al. 2009).

2. The genuine progress indicator (GPI) starts with personal consumption expenditure (also the starting point for GDP) and adjusts using 26 different components, such as income distribution, environmental costs, and pollution, while adding positive components left out of GDP, such as household work. GPI was a further development of the Index of Sustainable Economic Welfare proposed by Daly and Cobb in 1989 and progressed further by a number of economists. The GPI was first established by Cobb et al (1999) and has been used widely since in a number of developed and developing countries as well as regions (e.g. individual US States) and cities since then. https://en.wikipedia.org/wiki/Genuine_progress_indicator#Development_in_the_United_States

7 Looking Backwards – decoupling (or not) to date

7.1 Evidence of decoupling in the past

19 of the reviewed papers consider quantitative evidence for, or against, decoupling in the past in European and/or OECD countries. A number of the papers find evidence of absolute decoupling having been achieved over some time periods, for some environmental pressures and by some countries when considered on a territorial perspective. However, fewer find evidence of absolute decoupling having been achieved under a footprint perspective. Most of the literature focuses on either greenhouse gas emissions or resource use.

Several articles (for example Akenji et al., 2019) refer to UNEP's assertion that almost half a century after global leaders first acknowledged the problem of unsustainable development (at the 1972 UN Conference on the Human Environment) not a single country can demonstrate that it has achieved absolute decoupling of economic growth from a comprehensive measure of environmental pressures and impacts (International Resource Panel, 2011).

Evidence for absolute decoupling seems to be stronger for GHG and other emissions to air than for material resource use, and stronger when considered from a territorial perspective rather than a footprint perspective.

According to Jackson & Victor (2019) absolute decoupling of greenhouse gas (GHG) emissions measured on a territorial basis was achieved by the EU between 1990-2017, where GHG emissions decreased by 22%, while the region's GDP increased by 58%. A large part of this reduction is likely to have been a result of carbon leakage (Jackson & Victor, 2019). Jackson (2017) found no evidence of absolute decoupling of GHG emissions at global level; despite declining energy and carbon intensities, carbon dioxide emissions from fossil fuels have increased by 80% globally since 1970. Emissions by 2017 were 40% higher than they were in 1990 – the Kyoto base year – and since the year 2000 they have been growing at over 3% per year (Jackson, 2017).

A review of 830 articles (Haberl et al., 2020) identified many studies that found evidence of relative decoupling but only a few that found evidence of absolute decoupling (Azam & Khan, 2016; Roinioti & Koroneos, 2017; Chen et al., 2018; Madaleno & Moutinho, 2018). Examples of absolute decoupling usually showed relatively small, short-term reductions in GHG emissions (Li et al., 2007). In general, absolute decoupling was identified most frequently for territorial-based GHG emissions and footprint-based TPES (Total primary energy supply) for high income countries.

A similar review of 179 papers by Vadén et al (2020), identified 170 that presented evidence of relative decoupling and 97 of absolute decoupling of environmental pressures from economic growth. Out of the 97 cases of absolute decoupling, 74 concerned decoupling of GHG and SOx emissions and other types of environmental pressures from economic growth, while 23 found evidence of absolute decoupling of

material resource use from economic growth. Vadén et al do conclude, that temporally and geographically limited decoupling is easier to achieve than economy-wide, continuous and global decoupling.

It should be noted that in both reviews, the relative frequency of decoupling in GHG emissions compared to decoupling of material resource use may reflect the high political and academic focus on climate issues, rather than being indicative that decoupling has been more readily achieved in GHG emissions than material use or other environmental pressures.

Global material resource extraction grew by a factor of eight during the 20th century while global GDP rose 23-fold (International Resource Panel, 2011). In other words, only relative decoupling had been achieved (Malmaeus et al., 2016). A key driver in the increase in material resource extraction has been the demand for physical infrastructure. The annual extraction of construction materials grew nearly 50% more rapidly than GDP, growing by a factor of 34 during the 20th century (International Resource Panel, 2011).

Similarly, Schaffartzik et al. (2014) found that Austria's material resource footprint (measured as RMC³) was only relatively decoupled from GDP between 1995 and 2007: RMC grew by approximately 16% compared to 36% increase in GDP. Of the four main material groups (metals, non-metallic minerals, biomass and fossil fuel carriers) only biomass saw an absolute decoupling.

Looking closer to home, Stoknes and Rockström (2018) looked for empirical evidence of decoupling of territorial-based GHG emissions in the Nordic countries in the period 2003–2014 and found that while Finland, Denmark and Sweden achieved absolute decoupling, Norway only achieved relative decoupling.

Other authors find similar evidence for absolute decoupling in Nordic countries when only taking a territorial perspective. Sweden reduced its carbon intensity by 72% between 1990 and 2010 leading to a reduction in territorial GHG emissions despite strong economic growth leading many in Sweden and abroad to declare decoupling an overwhelming success, one worthy of international replication (Swedish Environmental Protection Agency, 2012; TCO, 2012).

However, when a footprint perspective is used, progress is considerably slower. A study of decoupling of GHG emissions from GDP in EU-28 countries between 1993 and 2010 found that footprint related GHG emissions are much more closely correlated to GDP than territorial GHG emissions (Liobikiene and Dagiliūtė, 2016). Whereas many countries achieved absolute decoupling and all the remaining countries achieved relative decoupling in territorial-based emissions only three countries achieved absolute decoupling in footprint-based emissions (Denmark, Estonia and Germany). Four countries (Croatia, Italy, Portugal and Spain) didn't even achieve relative decoupling in footprint-based emissions. The fastest widening of the gap between footprint and territorial-based GHG emissions was observed in Sweden at no less than 6 percentage points per year. Here the territorial-based emissions decreased, while footprint-based emissions increased. By 2010, Sweden's carbon footprint was 2.5 times higher than territorial emissions (Liobikiene, & Dagiliute, 2016).

Clarke et al. (2017) revealed, with Iceland as their case study, that even practically

3. RMC = Raw Material Consumption and is a footprint-based indicator for materials consumed globally through a country's demand for resources and products

100% decarbonised stationary energy production does not guarantee a low carbon footprint for affluent countries with high import levels. Giljum et al. (2015) showed similar leakage effects for material consumption: even though *domestic* material consumption has decoupled from economic growth in some developed countries, the total raw material consumption (including materials embodied in imports) may increase at the same time.

Palm et al. (2019) found a different result for Sweden but for a more recent period: 2008-2014. They found that during this period, although Sweden's global emissions, water and land footprints were larger outside national borders than inside, the total size of these footprints had not increased. Absolute decoupling had, in other words been achieved for GHG emissions, most air pollutants, water use and land use. Notably, and similar to evidence found elsewhere (see earlier), absolute decoupling was not achieved for material footprints.

The achievement of absolute decoupling of footprint-based GHG emissions by Sweden between 2008-2014, compared to only relative decoupling in the period 1992-2010 as observed by Liobikiene and Dagiliūtė (2016), may indicate that Sweden's relatively recent environmental objective of reducing pressures it causes in other countries is being addressed through focused policy.

7.2 Evidence (or not) for the Environmental Kuznet curve

The Environmental Kuznet curve theory argues that the absolute environmental impacts of an economy will naturally reduce after economic growth reaches a certain threshold (see Box 3). Evidence on whether or not this has occurred is strongly connected to the evidence of decoupling having been achieved in general (see above) but is worth considering in a separate sub-section, since it to a certain extent considers the mechanisms behind potential decoupling.

One of these potential mechanisms is the slowing down of material use by the economy as the demand for buildings and other physical structures reaches saturation

Bleischwitz et al (2018) investigated trends in the consumption of four materials – steel, cement, aluminium and copper – in five large economies (USA, Japan, Germany, UK and China) and found evidence for saturation levels in all four materials, although for aluminium these thresholds were yet to be reached apart from in the US. From the point of saturation onwards, consumption of these materials stayed constant despite further economic growth. In other words, a steady state had been reached where injections of new materials were only needed to maintain existing stock of buildings, machines and other infrastructure (Bleischwitz et al, 2018).

Box 3: The Environmental Kuznet's curve

The Environmental Kuznets Curve (EKC) hypothesis is a theory on the natural development of industrial and post-industrial economies. It proposes that in its early stages, economic growth leads to rapid increases in environmental impacts due to an increase in heavy industrial activities and the growth in material throughput but in later stages of development, society begins to improve its relationship with the environment and levels of environmental degradation reduces. It is argued that this reduction is caused by improved technology, improved control and legislation of industry, a saturation in material use and a shift to a more service-orientated economy.

The Environmental Kuznets Curve refers to an illustration of this theory via an upside-down u-shaped curve of environmental impacts plotted against growth in GDP/capita.

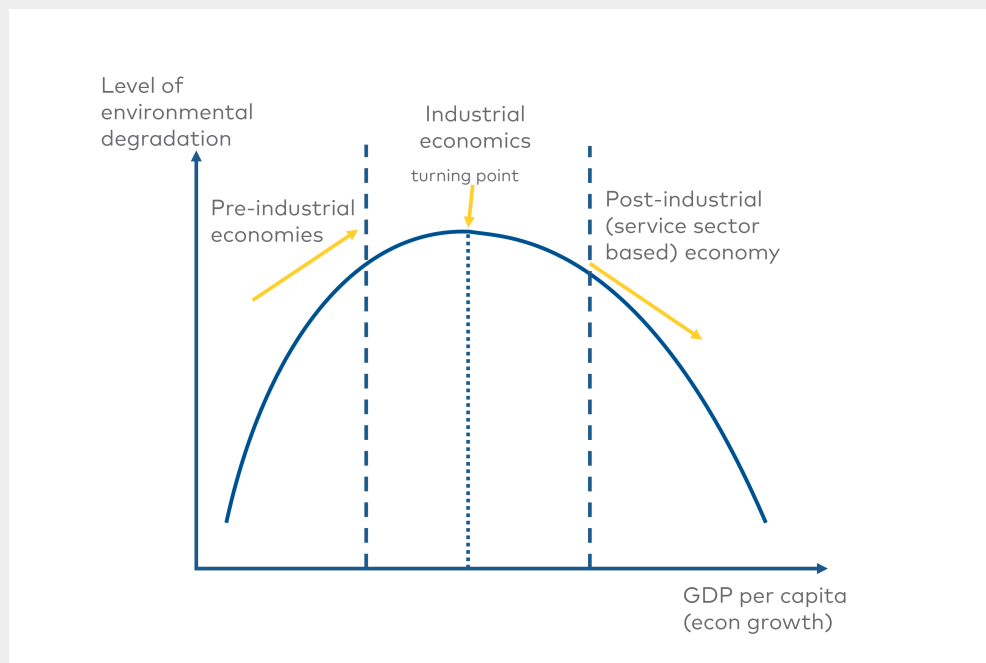


Figure 5: The Environmental Kuznet's Curve, showing the relationship between environmental degradation and GDP/capita

Source: Adapted from Pettinger (2019)

Albert (2020), also refers to saturation and notes that a number of 'ecomodernists' highlight trends in wealthier countries toward reforestation, reduced air pollution, plateauing meat consumption, and saturating demand for material-energy intensive goods (e.g. cars) (Asafu-Adjaye et al., 2015). This shift is often attributed to the transition from manufacturing to service-based economies in these countries, which are thought to promote 'de-materialization' by relying on less material and energy

intensive services to create economic value (Asafu-Adjaye et al., 2015). However, the suggestion is also that it is not only the composition of production in those countries that has dematerialized e.g. shifted from (the manufacture of) goods to services, but that consumption has also followed such a pathway.

However, other studies find no such saturation of material throughput or environmental impacts. Aşici, (2013) investigated the relationship between per capita income and pressures on nature within 213 low, middle and high-income countries, between 1970 and 2008 and found that increasing prosperity leads to more consumption and thereby higher environmental pressures. The exception was forestry where countries at higher income levels showed trends towards reforestation of some of the lost forest areas.

According to Antal and Van Den Bergh (2013) research has identified examples of Environmental Kuznets curve for local and less important environmental problems, but only when territorial pressures are considered and shifting of environmental problems from one environmental domain another (for example, reducing climate impacts through increasing use of biomass for energy, increasing pressures on land use and thereby increasing pressures on biodiversity) are ignored (Peters et al., 2011). Antal and Van Den Bergh go on to argue that this could change in the future, but only with the help of strong decoupling policy and not as a natural economic development process (see later).

As an example, Bhowmik (2019) found some fairly weak evidence for the development of CO₂-emissions following the Environmental Kuznet curve in the Nordic countries between 1970 and 2016, but he also identifies that this has largely been a result of clear climate policy since the 1990s with a shift towards renewable energy and the adoption of emissions taxes. In other words, the reductions in emissions have not been an automatic result of economic growth.

Shao (2020) identifies a number of studies that have reviewed the evidence for the Environmental Kuznet curve and only changes in human health appears to have followed the curve in some cases (Stern 2004) e.g. that human health has increased along with GDP. Otherwise economic growth continues to be associated with biodiversity loss, climate change, and the undermining of human livelihoods at commodity frontiers⁴ (Shao, 2020). In the 30-year update of Limits to Growth, the authors warned that, despite advances in energy efficiency technologies, many environmental policies, and increasing public awareness of climate change, humanity is still under threat (Meadows et al. 2004).

Contrary to the Environmental Kuznet curve argument where economic growth in the long term is good for environmental protection, Bowen et al. (2009) argue that global carbon emissions would be 50% higher today if it wasn't for several periods of economic recession (GDP growth < 1% per year) since 1950. Even if Bowen et al's concrete figures may be questioned, it can be argued that recession not growth has contributed to dampening of environmental pressures. Carbon energy and material requirements tend to be dampened by recession, only to increase again during economic recovery (see for example, Official Statistics of Finland, 2014).

Hickel (2019) argues that even if aggregate growth did allow improvement of efficiency this would be a very blunt tool for achieving decoupling. According to

4. Commodity frontiers refer to areas where land and people are appropriated as new and cheap reserves of natural resources and labour (Moore, 2000)

Hickel, if the objective is to achieve specific kinds of technological innovation, it would make more sense to invest in those directly, or incentivize innovation with policy measures (e.g., caps on carbon and resource use), rather than to grow the whole economy indiscriminately and hope for a specific outcome.

7.3 What factors have enabled the decoupling that was achieved?

Decoupling of resource use and environmental pressures from economic growth can be achieved through a range of different changes in the economy. These can be largely grouped into the following types:

1. **Structural changes in the economy:** e.g. from an industrial to a service-based industry
2. **Dematerialization:** reduction in resource use per product, or changes from consumption of 'things' to consumption of services
3. **Substitution:** changes in the type of material and/or energy used for production. For energy this would typically comprise a transition from fossil fuels to renewable energy. For materials it could comprise a substitution from bricks to wood for buildings.
4. **Efficiency:** reduction in wastage in the value chain, end-of-pipe solutions to remove emissions, increases in energy efficiency of processes, buildings, vehicles etc.

The first type of decoupling is important in relation to the geographical boundaries discussed earlier. If a structural change from an industrial to service-based economy has been caused by an increased outsourcing of heavy industry and resource extraction to other countries without any change in consumption patterns, then this will only lead to a decoupling of territorial emissions and not footprint-based emissions (e.g. leakage of environmental pressures from one geographic region to another). In fact, footprint-based emissions could increase if the heavier industries have been outsourced to countries with less stringent environmental regulations and more fossil-fuel based economies (Aşici, 2013; Borghesi and Vercelli, 2003).

If, on the other hand, the structural change reflects a change in *consumption patterns* as indicated by element 2, then this may lead to decoupling of both territorial *and* footprint-based emissions.

The relative importance of the various components of decoupling can be analysed through decomposition analysis. However, very few of the reviewed articles had carried out such analysis. Changes in the economy responsible for decoupling were in general either only loosely identified or not at all.

Stoknes & Rockström (2018) identify a number of factors which have enabled absolute decoupling of territorial GHG emissions from economic growth in Nordic countries. Structural transitions (factor 1 above) from manufacturing to service economies has been a key factor. Renewable energy substitutions (factor 3) for fossil energy and energy efficiency increases both in generation (widespread transition to combined heat and power) and use (for example in the building sector, manufacturing, metal production) have also been key factors. Stoknes & Rockström argue that Norway failed to achieve absolute decoupling in GHG emissions due to

rapid growth in transport demand.

Wenzlik et al (2015) carried out a structural decomposition analysis to identify the main causes of decoupling of Austria's material footprint - measured as Raw Material Consumption (RMC)⁵ - between 1995 and 2007. The economy saw an increased material efficiency of production (factor 4) and a dematerialization of consumption (e.g. a higher share in consumption of services and low material goods) (factor 2) in this period but these factors in combination could not entirely offset the factor of increased consumption expenditure, and thus only relative decoupling was achieved (with the exception of biomass).

Relative decoupling in the *metals* and *non-metallic minerals*, was principally caused by a shift in consumption towards less material-intensive products and services (factor 2). The *fossil fuel* footprint on the other hand, saw relative decoupling through improvements in technology and energy source substitutions from fossil to renewable sources (factor 3). None of these changes were sufficient to offset growth in expenditure on products and services. The absolute decoupling of the Austrian *biomass* footprint was achieved almost exclusively by technology/ efficiency increases (factor 4) (Wenzlik et al., 2015).

7.4 Have rebound effects been observed to date?

Where decoupling is achieved through technological/efficiency measures (see above), the decoupling may be smaller than otherwise might have been expected due to the so-called *rebound effect* (see Box 4). Rebound effects describe situations where efficiency improvements lead to an increase in consumption that partially offsets any reductions in environmental pressures gained by the efficiency improvement itself (Antal et al., 2013).

The logic is as follows: Increased resource efficiency lowers the price of the given resource, and the money, which consumers save, is used to consume more of the same good (direct rebound effect), consume more of other goods (indirect rebound effect) or lead to an increase in consumption in society as a whole due to stimulus of the direct and indirect rebound effects (economy-wide rebound effects) (Rosenbaum, 2017; Scott et al., 2019). When technologies, providing greater resource efficiency, lead to a greater resource footprint, it is also called the "Jevons' paradox" (Hickel, 2019).

The rebound effect is best illustrated by an example. An increase in fuel efficiency decreases the costs of driving a car. It may imply that consumers are driving more (income-based direct rebound effect), or that more consumers are buying their own car rather than using public transportation or biking (substitution based direct rebound effect).

5. Raw Material Consumption (RMC) is a Material Flow Analysis indicator, accounts for the physical quantity of materials required along the supply chains of all goods and services finally consumed in a country – the so-called "raw material equivalents" (RME). RMC is calculated as the sum of domestic extraction and the imports measured in RME minus the exports in RME. It is an MFA measure of the global material footprint of a country's consumption of goods. <http://www.materialflows.net/the-concept-of-material-consumption/>

Box 4: Rebound Effects

Rebound effects are when the expected effect of an initiative to reduce resources are partially or wholly offset due a decrease in price, which eventually leads to an increase in consumption. Three types of rebound effects have been identified:

1. **Direct rebound effects:** When the lowered price due to an increase in resource efficiency results in more consumption of the same resource.
2. **Indirect rebound effects:** When the lowered price due to an increase in resource efficiency results in more consumption of other types of good.
3. **Structural rebound effects:** When the lowered price due to an increase in resource efficiency results in a higher and different consumption pattern on the macro level.

Source: Rosenbaum (2017)

Moreover, an increase in energy efficiency might spark productivity and thus economic growth, which lead to an increase of consumption at macro-level (economy-wide rebound effects). Even if the consumers, owning a car, are not changing their mobility behaviour, they will save money on fuel, which they may use to consume other goods such as clothing or to travel more (indirect rebound effect) (Rosenbaum 2017). The lowered running costs of cars resulting from increased efficiency can in the long run create a strong incentive to drive a car rather than to choose public transportation or bikes (lock-in).

Proponents of green growth often refer to the development of green and clean technologies and efficiency gains as the means to achieve green growth. However, clean and sustainable technologies offer new products and services, which constitute an economic stimulus that can lead to increases in energy- and resource footprints (Rosenbaum 2017). Arvidsson et al. (2015) identify that growing consumption tends to outpace efficiency improvements, and that rebound effects have offset or limited the resource-saving potential of efficiency gains (see Hertwich, 2005; Kojima and Aoki-Suzuki, 2015). This agrees with standard economic theory that efficiency gains stimulate higher economic growth, which in turn is associated with higher levels of resource use and emissions. This is in part related to the current economic model. According to Nørgård & Xue (2016), it is the growth ideology and the structural necessity of growth in a market economy that constantly converts efficiency gains into drivers of further economic growth.

The rebound effect is especially significant in the energy industry. It is evident that energy efficiency has increased across the globe. Yet, overall energy consumption has also increased over the same period of time with the exception of periods of economic recession (Santarius et al., 2016).

Rebound effects dilute the benefits of higher energy efficiency on overall energy use and on environmental impacts (Pesch, 2018). A review of empirical household studies by the IPCC (2014a) concluded that end-consumer rebound in energy consumption in

developed countries typically erode 20%–45% of expected energy savings from energy efficiency improvements. In the Nordic countries, Parrique et al. (2019) observed a strong rebound effect in household energy consumption in Denmark and Finland between 2000–2011.

Brockway et al., (2017) looked beyond rebound effects at the end consumer to longer term rebound in the structure of the economy resulting from energy efficiency improvements in US, UK and China during the period 1980–2010. Rebound effects in the UK and US undermined between 13% and 50% of potential energy reductions resulting from efficiency improvements depending on model assumptions. In China, rebound effects were even higher, ranging from 100% to 208%. In other words, energy efficiency improvements have actually increased energy consumption rather than only undermining efficiency-led savings. The authors propose that developed countries who have outsourced their energy-intensive manufacturing industries to emerging economies like China, are also outsourcing energy-efficiency led rebound effects (Brockway et al, 2017).

Rebound effects are not limited to energy efficiency and have also been observed with respect to material efficiency. A case-study from Austria showed that increased material efficiency did not lead to absolute decreases in consumption of resources due to rebound effects. According to Wenzlik (2015), absolute decoupling between economic growth and material footprint can only take place if rebound effects are addressed.

All kinds of interventions aiming to promote sustainability can lead to rebound effects as aspects of sustainability are interlinked. Decreased working hours, which have been promoted as a means to reduce environmental impacts of the economy without increased unemployment, are also associated with a rebound, if people use their extra spare time to engage in more resource intensive consumption activities such as long-distance travel. This was identified by Buhl & Acosta (2016) in a German case study. This does not mean that decreased working hours lead to an *overall increase* in that person or household's resource consumption. Rather, that the reduction in material resource use resulting from the decrease in income is not as great as one would expect, because the composition of the consumption becomes more resource intensive.

Despite all these findings, rebound effects are seldom taken into account when raising the argument of efficiency leading to green growth (Aşici 2013). Font Vivanco et al. (2016) found only three examples in OECD countries of energy and climate policy that has taken account of rebound effects when planning energy efficiency improvements. Rebound is mostly absent from energy policy: for example, there is no mention of rebound in the European Commission's Energy Directive (Brockway et al, 2017). There are exceptions, however. In Sweden over the past decade, growing recognition that efficiency improvements are being rapidly outpaced by growth in the emissions associated with household consumption has led to an increased policy emphasis on educating for individual consumer responsibility and sustainable lifestyles (Matti, 2009, Isenhour, 2010a,b).

8 Looking Forward – the potential for sufficient decoupling

8.1 Planetary boundaries, the doughnut economy and 'fair share' of responsibility

8.1.1 The Planetary Boundaries and necessary reductions in pressures

The reviewed articles and books are in general agreement that the growth in pressures that human society exerts on the environment cannot continue at its current rate. The framework of planetary boundaries provides a set of thresholds which can be used to assess the degree to which growth in pressures needs to be slowed down, or reversed, if these are not to be exceeded.

The framework of planetary boundaries (see Box 5) was developed by the Stockholm Resilience Centre, and defines a safe operating space for humanity that respects ecological and geophysical systems (Watkins et al., 2016).

Box 5: The current status of the nine planetary boundaries

The planetary boundaries, first developed by the Stockholm Resilience Centre, demonstrate that human activity affects the functioning of the earth systems. To maintain the functionality of the earth systems, the planetary boundaries define a 'safe operating space' for human activity.

The planetary boundaries framework consists of nine systems, which are interlinked, defining a threshold for each one of them. Four of the planetary boundaries have already been crossed:

1. Stratospheric ozone depletion (Safe)
2. Biodiversity loss and extinction (High risk)
3. Chemical pollution (No data)
4. Climate change (increasing risk)
5. Ocean acidification (Safe)
6. Freshwater consumption (Safe)
7. Land use change (Increasing risk)
8. Nitrogen and phosphorus flows (High risk)
9. Atmospheric aerosol (No data).

Source: Watkins et al. (2016)

The Stockholm Resilience Centre assesses that four planetary boundaries are at high risk of being crossed in the near future including climate change, biodiversity, land-use change and nitrogen and phosphorus flows (Watkins et al., 2016). (See Box 5).

With respect to climate change, the time-bound targets are relatively well-defined (Akenji et al., 2016). Keeping global temperature increases to below 1.5 °C was adopted as the key climate target by the signatories to the Paris agreement. According to Jackson and Victor (2019) to meet this target cumulative future GHG emissions need to be kept below 420 Gt of CO₂-eq., a budget that will be used up within a decade under business-as-usual trends (ibid). For a 2 °C target, Alfredsson and Malmaeus (2019) estimate a global budget of 600 Gt CO₂-eq., under which a twenty-year perspective would allow a global release of 30 Gt CO₂-eq/year; 23% lower than current global emissions.

By ascribing all humanity equal rights to environmental services, it is argued that people in affluent countries, such as USA, the EU, and Japan, would need to reduce their emissions to around one tenth of present emissions by 2050 to meet this target (Schmidt-Bleek, 2001). In the longer term, the IPCC (2014b) warns that emissions of CO₂ and other greenhouse gases must be reduced to net zero by 2100 if we even have a chance of keeping global warming below even 2° C.

Stoknes & Rockström (2018) estimate that a 5% global average increase in carbon productivity (GDP per unit CO₂-eq. emissions) would ensure that global average temperature increases are kept under 2° C and 7-9% would keep temperature increases below 1.5° C. In the Nordic countries with relatively low GDP growth rates of around 1.5% per year, a 5% carbon productivity increase would result in an absolute reduction in emissions of 3.5% per year (Stoknes & Rockström, 2018). In emerging economies with high economic growth rates, a 5% carbon productivity increase would allow GHG emissions to increase, at least in the short term, e.g. a relative decoupling of GHG emissions from GDP (see Box 7 later).

With respect to the Nordic countries, Palm et al. (2019) find that whilst Sweden may be on an encouraging pathway towards international goals, many of the pressures still remain high above what is required to meet international targets for reducing climate change, which requires approximately a halving of GHG-emissions per decade (Rockström et al., 2017).

Alfredsson & Malmaeus (2019) underline this finding from the perspective of investments in infrastructure. The Swedish equitable share of the global carbon budget is 780 million tonnes CO₂-eq. If the budget is to last for 20, 50 or 200 years the Swedish annual carbon budget would be 39, 16 or 3.9 million tonnes respectively. Total Swedish domestic CO₂-eq. emissions in 2017 were 52 million tonnes. With a 50-year perspective the current level of emissions due to capital investments in infrastructure would exceed the total allowable carbon budget on its own, allowing no emissions budget for household or government consumption.

Sala et al., (2020) estimated overshoot by EU citizens of their fair share of allowable 'budgets' related to a range of planetary boundaries using life cycle assessment (LCA) methods. For this purpose, Sala et al translated the Stockholm Resilience Centres planetary boundaries into LCA impact categories. They estimated that the environmental impact per capita of EU citizens, exceeds the allowable impact per global citizen⁶ by sixty times for land use and eight times for particulate matter and

6. Assuming convergence e.g. that all citizens have equal access to the allowable global budget for impacts

climate change. The values of global impacts in three planetary boundary-related LCA impact categories (fossil resource depletion, freshwater eutrophication, and mineral resources depletion) were assessed as lying within the zone of uncertainty.

It is particularly difficult to derive planetary boundaries for material resource use⁷ because the use of at least some materials may not be directly associated with physical limits or irreversible losses (Akenji et al. 2016). Laakso & Lettenmeier (2014) estimated, however, that an 80% reduction in material resource use is required for citizens in industrialised countries from over 40 tonnes/capita/year down to what they consider to be a sustainable threshold of 8 tonnes per capita. Out of 45 studied Finnish households, only one very low-income household complied with the 8 tonnes per capita threshold (Laakso & Lettenmeier, 2014).

Akenji et al. (2016) warn of attempts to address planetary boundaries one-by-one. They consider that isolating single strands in a vastly complex socio-ecological system underestimate dangers. According to Akenji et al, society is yet to fully understand the interlinkages across resource use patterns. As an example, there is a strong nexus between food, water and energy, which is often associated with global resource conflicts (Akenji et al. 2016). There is increasing incidence of droughts and floods, and shortage and pollution of water. Agriculture is heavily dependent on water, consuming about 70% of global freshwater demand. Food production and water demand are projected to increase, owing to growing world population and changes in diets towards increasing meat consumption. Moreover, energy to power the world economy competes with agriculture for water, which is needed in extraction, transport, and processing of oil, gas and coal (Akenji et al., 2016).

The 'ecological footprint' approach⁸, partially attempts to tackle the interconnection between different types of resource use and environmental pressures, by combining a range of pressures into a single impact factor with a unit given in hectares. Fauré et al. (2016) used an ecological footprint approach to estimate that Sweden's global ecological footprint needs to be halved to comply with a global available ecological footprint boundary of 1.24 hectares/capita by 2050.

Shao (2020) notes another weakness with the planetary boundary concept; some boundaries are inefficiently transmitted from local to global levels (Mace et al. 2014), and certain factors, such as chemical pollution, transgress the boundaries, making pollution control measures insufficient (Diamond et al. 2015).

An additional issue that needs to be considered carefully when defining planetary boundaries and identifying needed reductions in pressures, is that for many types of resources and environmental services there is a long time-lag between over-exploitation and serious negative effects (Hertwich et al., 2010).

7. Consumption of biomass, metals, non-metallic minerals and fossil fuels

8. The Ecological Footprint method involves the translation of various kinds of pressures such as GHG-emissions and use of certain material resources into indirect land-use which they then add to direct land-use for urban development, transport, agricultural production etc. The apparent land use of a country or region is then compared to the available land use within that country or region. Alternatively, land use per capita of a country or region is compared to available land per capita, globally.

8.1.2 Improving well-being within planetary boundaries

While the planetary boundaries can, at least partially, help to define a safe working space of the economy that respect ecological limits, there is a need to include well-being in this framework by asking how prosperity can be increased within these planetary boundaries (Jackson, 2017).

Kate Raworth has developed a concept that she calls the doughnut economy (DEAL, 2021). The doughnut economy is built up with the planetary boundaries demarking the outer limits of the dough. The inner limits of the dough are the social boundaries related to ensuring a good life for all. These social boundaries include access to basic needs, equality, political participation, education, network, peace and justice (Shao, 2020).

Box 6: The doughnut economy

The doughnut economy asks how humanity can thrive within the planetary boundaries.

In the doughnut economy, the planetary boundaries represent the outer circle of the doughnut, while minimum acceptable standards of living represent the inner circle, together forming a safe and just space for humanity.

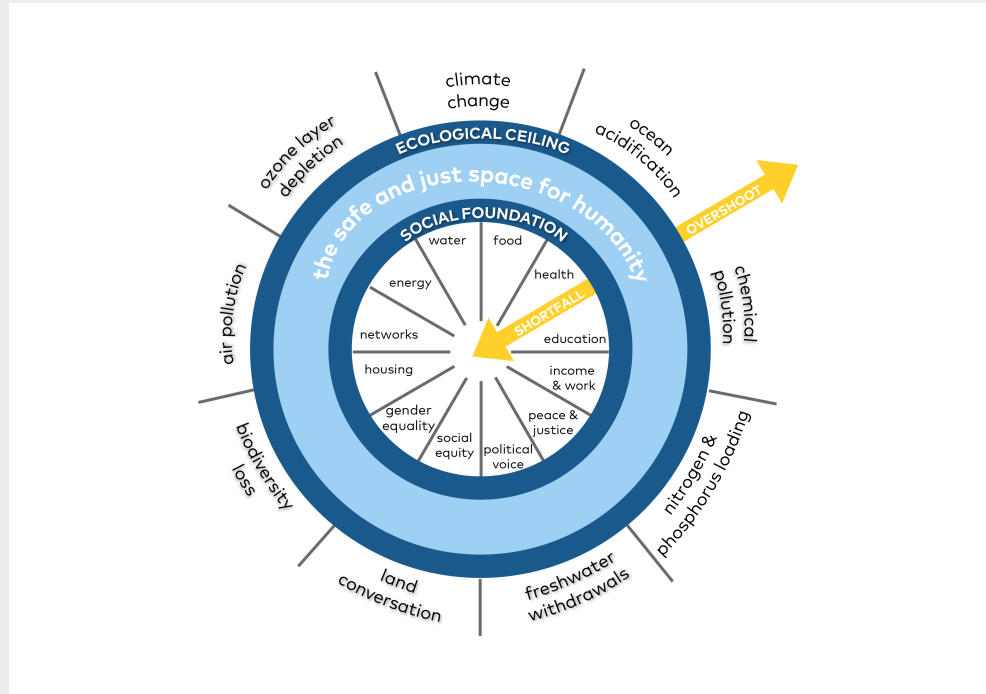


Figure 6: The doughnut economy

Source: Adapted from DEAL (2021)

The proposition of the doughnut economy is to maximise social well-being within the planetary boundaries.

The aim of Sustainable Development Goals (SDG) are also to respect environmental limits while increasing social well-being and economic growth. The SDGs were launched in 2015 and aim to guide the development towards a sustainable global society by 2030. All the Nordic countries, and many municipalities, companies and organisations have taken up the SDGs as a common language to focus and communicate their work on sustainable development.

However, critical voices of the SDG's point to the fact that many of the goals are conflicting and that the economic goal of 3% annual growth in GDP is incompatible with reductions in environmental pressures (see more under 8.3.3 later).

8.1.3 Who has responsibility for ensuring that planetary boundaries aren't exceeded?

Section 8.1.1 briefly described planetary boundaries, the budget that remains before (some of) these boundaries are exceeded and what kind of decoupling would be needed at global level to ensure that society keeps to these budgets. For some impact types, it does not matter where the pressures take place, for example, for climate change. For others such as water pollution, locality is key. Planetary boundaries are harder to define for these impact types (Mace et al., 2014; Lewis, 2012).

Under both circumstances it is important to discuss who has responsibility for reducing pressures and similarly who has the 'right' to make use of the remaining emissions or resource budget to improve welfare such that as high a share of the global population live within the dough of Kate Raeworth's doughnut economy as possible e.g. living well within planetary boundaries.

Several authors argue that rich developed countries (including the Nordics) have already long overshoot their fair share of available resource and emissions budgets and need to reduce their emissions and resource use (Alfredsson & Malmaeus, 2019; Fauré et al., 2016) while developing economies should be given opportunities to raise welfare through higher growth rates and perhaps only achieve relative decoupling of pressures (Stocknes & Rockström, 2018). Fauré et al. (2016) warns that the average living standards in Europe and North America using current technologies should not be the inspiration for developing countries because this would also lead to considerable overshoot of planetary boundaries.

Wijkman & Rockström (2012) argue that developed countries should invest in developing countries to support a global sustainable development, while Aşici (2013) argues that trade policy should take environmental and social considerations into account and not focus solely on liberalizing trade and removing trade barriers.

Several authors (Scott et al, 2019; Isenhour & Feng, 2016; Jackson & Victor, 2019; Aşici, 2013; Mair et al., 2014) take this a step further and argue that developed countries should not only take responsibility for the direct environmental pressures exerted by national entities (e.g. a territorial perspective) but also for the resource use, waste production and emissions in other countries connected with their citizens' consumption (e.g. a footprint perspective). The argument is that developed countries can meet territorial emissions targets by outsourcing heavy industries abroad, while

maintaining a carbon-intensive consumption and this would lead to no net reduction in actual global emissions (but only so-called carbon leakage in the case of GHG emissions).

Indeed Aşici (2013) found that increasing trade, all else equal, actually increases pressure on nature, and Mair et al. (2014) found that burden-shifting is particularly problematic using the case of textile production. Mair et al found that the carbon intensity of textile production in the countries to which production had been shifted is much higher than in the developed countries who had outsourced their production. According to Mair et al the carbon intensity of textile production in BRIC countries between 2002 and 2007 was greater than the carbon intensity of Western European textile production in 1995. Although these findings are for a single industry they lend support to a *race-to-the-bottom* hypothesis.

Box 7: Genuine Green Growth and a universal carbon productivity target

Stoknes & Rockström (2018) advocate a so-called Genuine Green Growth approach to reducing global GHG emissions to limit global warming. The authors estimate that a 5% annual increase in global carbon productivity (unit GDP/unit GHG emissions) would be sufficient to keep global temperature increases over pre-industrial levels to below 2 °C and that a 7–9% carbon productivity increase per year should keep temperature increases to under 1.5 °C.

They argue that all countries should aim to meet the same (5% or 7–9% depending on the temperature target selected) carbon productivity increase per year, regardless of the level of economic growth that they have achieved.

In the Nordics and other developed countries with relatively low GDP growth rates of around 1.5 % per year, this would lead to an absolute decoupling rate of 3.5% per year. In emerging economies with economic growth rates higher than 5%, resulting decoupling would be relative. This would give them room to increase welfare during their catch-up period. They also argue that each individual economic sector within a country should adopt the same carbon productivity target. Such an approach would minimize the risk of rebound effects by requiring that all sectors meet the target.

They further argue that only territorial emissions should be taken account of. Including emissions embedded in imported goods would result in double accounting – both in the importing country and the exporting country. They advocate sticking with reporting on territorial emissions, while simultaneously working to ensure that more and more entities across the globe adopt a common carbon productivity target.

These arguments are encapsulated in Sweden's overarching environmental goal 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 Sweden's borders" (Swedish Environmental Protection Agency, 2012). Because Sweden, as a small country, is dependent on the rest of the world for

trade to meet its population's consumption demands, the country must take considerable action to reduce its footprint abroad in line with the environmental objective.

Nevertheless, such political will has not been widespread. According to Sato (2012) attempts in public policy to deviate away from the conventional production-based carbon accounting approach to account for emissions embodied in trade had (up to that point) been met with hard opposition. This opposition is as diplomatic as it is ideological, given the challenges of influencing global supply chains without violating sovereignty or trade agreements (Isenhour & Feng, 2016).

Strikingly, however, Stoknes and Rockström (2018) argue that attempts to include GHG emissions from elsewhere in national carbon accounts will result in double counting. They further argue that carbon 'leakage' should not be perceived as a problem under what they call a genuine green growth (GGG) approach because under such an approach all entities would only be responsible for the emissions occurring within their own territory/operations (see Box 7 for an explanation).

Santarius et al. (2016) argue that global population growth is a critical element of the debate and argue for a need to reduce global population growth in order to prevent the safe operating space per capita from further reducing. They also note that this has been excluded from environmental debates due to the sensitivity of the topic. The sensitivity is rooted in liberal mind-sets that it is a human right to reproduce, as well as social justice theory that developing countries have the right to the same level of material wealth as achieved in industrial countries, with the population growth that follows.

8.2 The optimistic, agnostic and pessimistic perspectives on the potential for decoupling

Chapter 8.1, amongst other things, briefly outlined the reductions in environmental pressures that will be needed over the next decades in order to respect planetary boundaries, where these can be defined. Academics and politicians alike differ in their assessment of how reductions in environmental pressures can be achieved. Note that far from all commentators take their starting point in the planetary boundaries, although those that concern greenhouse gases almost all take 1.5 °C or 2 °C global temperature increases as the upper limits, guiding necessary reductions in GHG emissions.

Several articles are optimistic that pressures can be reduced while global and national economies continue to grow. In other words, that absolute decoupling can be achieved looking forward. Others are pessimistic and argue that economic growth is not compatible with reduced environmental pressures and that we need to look for ways to increase and maintain human well-being in shrinking or stable economies. A third group, broadly defined as agnostic or pragmatic lies somewhere between the two. These groups are often described as *Pro-growth*, *De-growth* and *A-growth*.

The optimistic point of view believes that absolute decoupling is possible through technological development and through the force of the market. This is often the

point of view of pro-growth economists who contend that an economic growth of approximately 3% per year is necessary to ensure stability and survival of the economy.

According to this group of economists, without economic growth, investments decrease, debt cannot be repaid, and unemployment rises (Randers, 2012; Jackson, 2017). Economic growth is measured in monetary value, and pro-growth economists believe that GDP can thus be decoupled from material throughput (Jackson and Victor, 2019).

The pessimistic point of view argues that limiting environmental pressures to comply with Earth's planetary boundaries is incompatible with long-term economic growth and that therefore economic growth should be rejected as a political target. Some economists argue that due to the way that GDP is defined it is strongly dependent on resource use, and therefore efforts to decouple resource from GDP cannot succeed (see Box 8). Alternative definitions of welfare are needed, which can more readily be decoupled from resource use (Malmaeus, 2016). See also Chapter 6.

The pessimistic view encompasses the so-called de-growth movement whose core point of view is that economic growth does not lead to increased well-being. Some commentators believe that neither academics nor politicians dare to challenge the neo-liberal paradigm despite its weaknesses, because of the strong resistance of business and financial sectors that rely heavily on economic growth (Santarius et al. 2016; Nørgård & Xue, 2016). De-growth in its turn is criticized due to the risk that it will depress investments in cleaner technologies and renewables, thus risk slowing down the green transition (Shao, 2020) and will lead to a significant increase in unemployment and social unrest (Jackson, 2017).

Box 8: Is decoupling of resource use from GDP impossible by definition?

Malmaeus (2016) argues that the way in which GDP is defined, limits the possibility for decoupling of resource use from GDP, because resource use is a key element of GDP. Malmaeus' argument begins by demonstrating, using empirical macro-economic data from OECD countries, that GDP growth is well explained by inputs of labour and physical capital in line with classical economic theory and in particular the labour theory of value. The empirical data shows, in particular, a very strong correlation between long-term growth and physical capital accumulation.

Malmaeus argues further that increasing productivity and efficiency can only increase value without increasing labour or resource use at the micro-level, but not at the full economy. Thus, that absolute decoupling of capital formation from GDP is not possible. For a single business there is no contradiction between productivity in terms of increasing resource efficiency and in terms of increasing revenue. In the system as a whole, however, the reduction of input to one firm must mean a reduction of output (and income) somewhere else in the economy. In a closed system, the net effect of the productivity gain will be exactly zero in terms of aggregate income. Productivity gains may increase output in terms of quantity but not in terms of value added. In terms of value, the notion of productivity is thus primarily relevant as a microeconomic concept.

According to Malmaeus the key question is therefore, *whether or not capital accumulation can be decoupled from the use of materials and energy*. This will determine the possibility of decoupling of GDP growth from the use of natural resources and other environmental impacts. He argues that as long as capital is made of materials, and given the strong relationship between capital and energy use, absolute decoupling between GDP growth and environmental impacts remains problematic by definition.

Between the optimistic and the pessimistic perspective, lies a more pragmatic point of view, which acknowledges that humans' current economic activity risks crossing planetary boundaries in the near future, and that growth in richer countries needs to be moderated to maintain a safe operating space. However, proponents of a pragmatic view think that some growth can be achieved through an increase in the share of the service sector, through innovation, and through a radical behavioural change.

A-growth proponents (e.g. Van Den Bergh, 2017) argue that both pro-growth and de-growth paradigms jeopardize environmental and social goals: a pro-growth stance because it limits the search for environmental policy to that which doesn't threaten economic growth; a de-growth stance because it risks a level of GDP that is insufficient to support a minimum level of essential public goods and risks lower levels of employment and social instability (Jackson 2017).

As Jackson puts it there are two ways out of this growth dilemma: "One is to make growth sustainable; the other is to make de-growth stable. Anything else invites either economic or ecological collapse" (ibid.).

In the following sections we consider briefly the academic opinion on whether

(sufficient) decoupling can be achieved to allow long-term continued economic growth and under what circumstances, and if not, what conditions would allow a stable de-growth.

8.3 Is sufficient decoupling possible?

8.3.1 Components of decoupling

Copeland and Taylor, (2013) point to several potential components of decoupling in rich economies that together may or may not be sufficient to achieve absolute decoupling: *scale effects* (more production leads to more pollution but at a decreasing rate), *composition effects* (a change in the basket of products and services that are produced and consumed favouring those with lower pressure intensities), and *technological effects* (ways of producing and/or consuming the same product or service with lower impacts). These are similar to decoupling components discussed earlier in the beginning of Chapter 7.3, where efficiency and substitution combined are similar to the *technological effects* described by Rosenbaum. Technological effects enjoy most popularity among policy makers, as they are believed to be more effective than scale effects and composition/dematerialization effects (Rosenbaum, 2017).

8.3.2 Potential of technological improvements

According to Jackson and Victor (2019) countries have not yet been able to harness green technologies rapidly enough to achieve absolute decoupling. There is still a long way to go to achieve a full decarbonised energy system.

As already described in Section 7.1.1, keeping within a 2 ° C increase in global temperature compared to pre-industrial levels would under a fair distribution of responsibility require industrial countries to reduce their per capita carbon footprint by 67% (Krausmann et al. 2020) by 2050. According to Jackson and Victor (2019) this requires a 14% reduction in carbon intensity (GHG emissions per unit GDP) each year, while Stoknes and Rockström (2018) argue that 5% might be sufficient given current economic growth rates.

So far, the highest yearly reductions in carbon intensity seen to date have been just under 3%, observed in developed countries, while the global average is less than 1% (Jackson and Victor, 2019). The International Energy Agency (2016) reported that global carbon intensity had reduced by an average of 1.4% per year over recent decades.

Therefore, regardless of whether the annual carbon productivity improvements required to keep global temperature change under 2 ° C is 5% or 14%, it will clearly require significantly more rapid technological transitions than have been seen to date.

Vadén et al. (2020) argue that claims of the potential for absolute decoupling in the future needs further support from sources other than empirical research literature. The claim needs to be supported by detailed and concrete plans of structural change that delineate how the future will be different from the past. Otherwise the onus of

the claim will rest on the abstract possibility of decoupling; an abstract possibility that no empirical evidence can disprove but that in the absence of robust empirical evidence or detailed and concrete plans rests, in part, on faith.

As discussed earlier, innovation and technology development can themselves lead to increased growth and thus increased consumption. In other words, rebound effects risk offsetting potential decoupling as a result of technology development. Even a high-efficiency scenario leads to no absolute decoupling as a result of efficiency improvements, when rebound effects are included in the model (Hickel and Kallis, 2019).

Carbon capture and storage (CSS) technologies - where carbon emissions are captured from power- or industrial plants and stored underground - have received great attention as possible mid-term enablers of decoupling of carbon emissions (Haberl et al. 2020). The technology was developed back in the 1980's. However, it is still very expensive and energy intensive and needs to be further matured for large-scale deployment. Several research and pilot projects deploying CSS are taking place across the Nordic countries⁹.

One hundred of the 116 climate change mitigation scenarios modelled by IPCC rely on so-called 'negative emissions', brought about through bioenergy with carbon capture and storage (BECCS) technologies (Hickel, 2019). Anderson and Peters (2016) conclude that "BECCS remains a highly speculative technology" and that relying on it is "an unjust and high-stakes gamble"; if it is unsuccessful, "society will be locked into a high-temperature pathway." This conclusion is shared by a growing number of scientists (e.g., Fuss et al., 2014; Vaughan and Gough, 2016; Larkin et al., 2017; Van Vuuren et al., 2018), and by the European Academies Science Advisory Council (2018).

Albert (2020) identifies the Fourth Industrial Revolution as having potential to decarbonize and dematerialize the economy. According to Falk et al. (2018) these technologies have potential to reduce carbon emission by 15% in 2030 without lowering economic growth or material standards. Falk et al (2018) conclude that internet of things and machine learning will increase energy efficiency and eventually enable electricity storage. It will improve the mobility-, energy- and infrastructure sector. Nano-technologies can likewise contribute to higher energy efficiencies such as a ten-fold reduction in vehicle mass and double the efficiency of engines (Drexler, 2013). 3D printing, meanwhile, can contribute to local and on-demand printing, which is less dependent on global supply chains (Falk et al. 2018).

With respect to material resource use, Jänicke (2012), argues that investments in green technologies should be able to provide material productivity gains of 1% per year but not much more than that. These green investments should target material productivity over labour productivity to avoid triggering unemployment. A green tax reform can further support a priority of material productivity over labour productivity (Jänicke, 2012).

For some planetary boundaries, such as biodiversity and ecosystem services, technology and increased efficiency cannot be the solution. It is rather a land use priority to leave more space for wild nature, which need to be ensured through regulation (Jänicke, 2012).

9. Nordic Energy Research, 2020, Carbon Capture, Utilization and Storage: An essential technology for facilitating carbon neutrality

8.3.3 How critical is the *level* of economic growth?

The degree to which absolute decoupling can be achieved, for example via technology and efficiency improvements as outlined above, is highly dependent on the rate of economic growth. According to Jänicke (2012) a 1% per annum growth rate over 70 years gives a doubling in the size of the economy. A 5% per annum increase over 70 years would give a 30-fold increase and would be the death sentence for environmental strategy.

These simple calculations challenge economic growth rates called for under the Sustainable Development Goals (SDGs). Projections by Hickel (2019) predict that a global growth of 3% per year as called for by SDG Target 8.1 would render it empirically infeasible to achieve reductions in CO₂ emissions rapidly enough to stay within the carbon budget for 2°C. Moreover, it would not allow *any* reduction in aggregate global material resource use, at resource efficiency improvement rates achieved to date.

According to Hickel, if the resource efficiency trends of the 21st century continue, a 3% annual global GDP growth will drive material footprint up from 87 billion tons in 2015 to 167 billion tons in 2030, overshooting sustainability thresholds for material use by a factor of three. If we achieve the somewhat higher resource efficiency trends achieved globally between 1980 to 2002, a 3% annual GDP growth will still drive the global material footprint to 119 billion tons per year by 2030, overshooting the sustainability threshold by a factor of two.

Stoknes & Rockström (2018) view a slowing down in GDP growth as a natural progression as countries become richer and shift to service economies. The closer a developed economy is to economic stagnation, the easier it ought to be to achieve absolute reductions in environmental pressures (Stoknes and Rockström, 2018).

Jänicke (2012) argues, for example, that growth in developed countries (including the Nordics) should be limited to 1% per year to achieve absolute decoupling through investments in green technologies. It is argued that 1% growth will allow absolute decoupling while at the same time not leading to increased unemployment. Spangenberg (2010), similarly argues that the only solution within the logic of the present market system is for moderate GDP growth (at least in wealthy countries) coupled with a massive increase in eco-innovation and a physical de-growth process.

8.3.4 What is the role of infrastructure and capital investment?

Several of the articles consider that trends and approaches to accumulation and design of the stock of physical infrastructure play a critical role in the question of whether absolute decoupling can be achieved.

Decarbonisation of energy generation infrastructure is viewed as a key enabler of decoupling between economic growth and carbon emissions, but will be difficult to achieve. Akenji et al. (2016) argue that current energy infrastructure is designed to use fossil fuels, and huge investments in renewable infrastructure will be needed to decarbonize the sector. The International Energy Agency has identified that 80% of carbon emissions are locked-in in current power plants, factories and buildings (Akenji 2016).

The growth in stock (buildings and infrastructure) is seen as presenting a major challenge to achieving GHG emission reductions required to mitigate climate

change. According to Krausmann et al. (2020) if current trends in investments in building stock continue, the building and use of buildings will rapidly eat up the entire GHG emissions budget available to meet the 2.0° C target, leaving no carbon budget for other consumption activities.

Alfredsson and Malmaeus (2019), similarly note that the current level of material and energy investments in all types of physical infrastructure in Sweden are such that the country is close to exceeding its fair share of the global budget of materials and carbon emissions. They also argue that investments in energy-efficient buildings will lock-in long term reductions in energy use, but that this needs to be weighed up against the considerable initial energy needed to replace the current building stock (Alfredsson and Malmaeus, 2019).

Krausmann et al. (2020) argue that the ability to decouple GHG emissions from GDP towards and beyond 2050 is strongly dependent on the degree by which *growth* in physical infrastructure, buildings, machinery etc. (e.g. capital growth) can be decoupled from population growth and from GDP, in combination with rapid decarbonisation of energy systems. Krausmann et al. also argue that per capita building stock in less developed countries cannot emulate existing levels of building stock per capita in the richer countries without hugely overshooting global GHG targets. To meet the 1.5° C target, building stock per capita in industrialised countries would need to be reduced by 67% (returning it to 1970 levels), combined with total decarbonisation of energy systems already by 2030. This will require significant new approaches to how buildings and infrastructure are designed and used.

Malmaeus (2016) takes this a step further and argues that GDP growth is very closely correlated to capital growth (see Box 8 earlier). According to Malmaeus, the key question is, therefore, whether or not capital accumulation *itself* can be decoupled from the use of materials and energy. Otherwise, according to Malmaeus, reducing building stock as proposed by Krausmann et al would also reduce GDP. Physical capital has historically been the most important form of value preservation. If capital accumulation can, through strong intervention, be decoupled from the use of materials and energy this would potentially allow GDP growth while reducing the use of material resources and other environmental impacts. On the other hand, as long as capital is made of material resources, and given the strong relationship between capital and energy use (Ayres and Voudouris, 2014) absolute decoupling between GDP growth and environmental impacts remains problematic by definition.

This argument that GDP and capital formation are closely linked, links also to Bleischwitz et al. (2018)'s assessment (see earlier) that some key construction materials have already reached saturation levels in several modern economies. This saturation of capital formation may then at least partially explain why GDP growth in post-industrial economies are generally low compared to emerging economies. This is critical for absolute decoupling as described in 8.3.3 above.

8.3.5 Is the circular economy a key component of decoupling?

More than 100 definitions of a circular economy (CE) can be found, illustrating that there is no common understanding of the term (Giampietro, 2019). Typically however, it is understood to comprise an extension of the active lifetimes of products through design for circularity, regular maintenance and repair, reuse and finally

material recycling of the products when they no longer are fit for use.

Academia and practitioners generally view the circular economy as a possible means to achieve decoupling of environmental impacts by looping resources in the economy while generating growth (Lonca et al., 2019). By avoiding extraction of resources and further production, a circular economy also theoretically has reduced carbon emissions compared to a non-circular economy. Less resource extraction can further lead to more areas set aside for nature, which can, in theory, have a positive impact on biodiversity.

Giampietro (2019), however, argues that circular economy strategies need to change radically to deliver decoupling. Most circular economy strategies currently focus on recycling which allows a continuation of a linear production and consumption flow. Waste will still be a key element of the circular economy, as material losses occur when products flow through the economy, especially when downgraded through recycling cascades. Moreover, a circular product is still heavily reliant on materials and energy, implying that the resource footprint of circular produced products might be smaller than a conventional product, but is still present (Giampietro 2019; Akenji et. al 2016).

Lonca et al. (2019) agree, arguing that, all other things being equal, a circular economy will only lead to relative decoupling because circular systems and processes are heavily reliant on energy. They argue that a simultaneous decarbonization of energy systems will be necessary if a circular economy is to result in absolute decoupling of carbon emissions from economic growth. According to Lonca et al., material efficiency (material/product) improvements and implementation of Best Available Technologies (BAT) in steel, plastics, aluminium and cement can potentially reduce carbon emissions in the EU by 178Mt CO₂/yearly. Circular business models (such as product as a service models and leasing) can reduce emissions by a further 56Mt CO₂/year (Lonca et al, 2019). Lonca et al warn, however, that indirect rebound effects and spill-overs can significantly reduce these savings.

Stratford (2020) views a shift from ownership models to rental and leasing models as a means to both achieving decoupling and improving democratic equity. Increased levels of renting of products will intensify the use of products and stocks, which can moderate consumption growth. According to Stratford, if the surplus from rental systems is used to improve production, such production investments will stimulate growth but at lower rates than for ownership-based economies because the surplus will be lower. Also, it is key that policies that promote rental and the sharing economy address inequality and financial instability (Stratford, 2020).

Haberl (2020) argues that the global reliance on natural resources will not change, as the implementation of carbon-neutral infrastructure and technologies require resources. As already noted in the previous section the growth in buildings and infrastructure is seen as one of the greatest barriers to decoupling between economic growth and resource use (Palm et al., 2019).

In general, there is uncertainty on whether the circular economy will lead to significant decoupling between economic growth and resource use and by when; and whether it will at best only lead to relative decoupling. Most articles agree that circular economy is a necessary element of decoupling but will not be sufficient on its own to achieve the reduction in resource use and environmental pressures needed.

8.4 De-growth, reduced consumption and social consequences

As already noted in the previous chapters, many of the reviewed articles are not optimistic concerning the potential for long-term decoupling that would allow economic growth in developed countries to continue whilst also respecting planetary boundaries in the long term. Some of these conclude that either economies will naturally see a stagnation in economic growth or that stagnated or reduced growth should be planned (e.g. Stocknes & Rockström, 2017; Jackson & Victor, 2019; Jackson, 2017; Jänicke, 2012; Spangenberg, 2010). Even agnostic observers conclude that large rapid absolute reductions of resource use and GHG emissions cannot be achieved through observed decoupling rates, and propose that decoupling policy is complemented by sufficiency-oriented strategies (Van Den Bergh, 2017; Haberl, 2020).

The proponents of de-growth and sufficiency orientated strategies are, in general, aware that this can potentially lead to some negative social consequences and make proposals for how these could be addressed.

According to Jackson (2017), the neoliberal understanding of well-being is closely linked to economic activity and employment. Whenever the economy slows down, people lose their jobs. The neoliberal paradigm also assumes that well-being and consumption are closely linked: more consumption translates to increased well-being.

According to Stratford (2020) the need for economic growth is closely related to the interaction of rent-seeking with debt-based monetary systems and the Too-Big-To-Fail limited liability model of banking. According to Stratford, these factors dampen prospects for economic growth and create a political growth imperative (Richters and Siemoneit, 2019) whereby governments are compelled to pursue growth in output, regardless of its environmental consequences, in order to prevent debt, poverty and unemployment from becoming politically destabilising.

Several authors argue that we are locked-in to mechanisms of growth, be it cognitively, culturally or economically (Spangenberg, 2010; Loiseau et al., 2016; Fuchs and Lorek, 2005; Storm, 2009) and are thus incapable of choosing not to grow, either politically or mentally (Van den Bergh, 2012; Berg and Hukkinen, 2011). According to Pesch (2018), this lock-in finds its roots in the institution of ownership since a property-based economy can only be sustained by growth; the credibility of the return of investment has to be present before any investment in resources that allow production will be made. In turn, these investments can only be based on capital that is borrowed at a positive interest rate.

Stratford (2020) argues that concentrations of rentier power, and certain forms of rent-seeking pose a significant threat to the de-growth scenario of going 'slower by design, not disaster' (Victor, 2008). Stratford argues that by trying to impose environmental protection without first preventing any actions to pursue rent extraction (e.g. avoiding that production and labour capital is owned by the elite), we are likely to experience increasing inequality and financial instability.

Stratford (2020) argues that de-growth will lead to a zero-sum game, where one's increase in income leads to another's loss. If production was limited by environmental protection, people striving for wealth would claim the ownership of production in the form of resource grabbing, intensified exploitation of workers, financial speculation and aggressive use of intellectual property.

Haapanen and Tapio (2016) also acknowledge that a decrease of consumption levels in the developed world will lead to a feeling of deprivation, even if basic needs are met. As a result of this analysis, policies should be designed to avoid exploitation of the production apparatus (Stratford, 2020).

Some authors propose that reduced working hours per person can be one solution to some of the potential social risks of *de-growth by design*, by allowing GDP to be lowered without triggering unemployment to rise (Jackson, 2017; Knight et al., 2013). Fewer working hours per person is also expected to increase well-being and public health (Vita et al., 2019). The Western world has even been diagnosed with a “social recession” due to its symptoms of structural depressions and inequality, and reduced working hours can be part of the treatment (Jackson, 2017).

While fewer working hours per person will lead to lower income and expenditure, the resulting reductions in environmental footprint might be less than expected due to rebound effects; more leisure time can lead to more carbon-*intensive* consumption due to increased travel (Shao, 2020; Buhl & Acosta, 2016). Therefore, fewer working hours also need to be combined with a simpler life styles to ensure significant reductions in environmental pressures (Jackson, 2017).

Lamb and Steinberger (2017) argue that after a certain standard of living is achieved, consumption does not increase well-being. There are certain areas of consumption which are important to increase well-being including health-care services, education and participation. Other types of consumption are only a means to acquire social status. Therefore, consumption should only be decreased for those consumption areas that do not directly lead to increased well-being (Lamb and Steinberger 2017).

Finally, with respect to decoupling rather than de-growth, Ottelin et al. (2018) argue that environmental policies aimed at decoupling impacts, risk increasing inequality within a society. A carbon tax, for example, will increase prices of basic goods such as energy and food, negatively affecting lower income groups while having little effect on the well-being or behaviour of the middle- and upper-class. The latter may therefore not reduce their carbon footprint as a result of a carbon tax. Ottelin et al. (2018) argue that carbon taxes should be designed progressively such that they don't disproportionately affect people on lower incomes.

8.5 Can policy interventions provide absolute decoupling in the future?

8.5.1 The need for and resistance to decoupling policy

As already identified under Chapter 6.2, there is little evidence to date that economies grow and develop in such a way that environmental pressures begin to reduce, following a period of growth e.g. the Environmental Kuznet curve has not been seen. As such, strong policy will be needed to achieve the Paris Agreement targets and to respect other planetary boundaries.

Yet according to Haberl et al. (2020) global environmental governance has historically been characterized by incremental change, rather than a comprehensive transformative change. A review of evidence on decoupling to date, concluded that

environment and climate policies have at best achieved relative decoupling between GDP, GHG emissions and resource use respectively (Kemp-Benedict, 2018; Haberl et al., 2019).

Distelkamp and Meyer (2019) identify the general lack of political action as a main barrier towards absolute decoupling. They demonstrate through a simulation model, that absolute decoupling can be achieved globally, *if* global cooperation is fulfilled and if a strong policy mix is implemented, including carbon taxes as well as policies that deliver a total decarbonization of the energy system, a phasing out of fossil-based mobility, improved recycling, and rapid greening of building stock. If global cooperation and action is not achieved, and the EU acts alone, the union can realise increased growth by exporting clean technologies but global planetary boundaries will not be met.

There are strong reasons why regulation that could deliver such transformations have not been put in place. Regulation measures have in general been limited by a strong lobby against transformative change of the economic system (Rosenbaum, 2017). Across the world, the growth paradigm dominates and whenever economic growth and climate mitigation policies are in conflict, economic growth is prioritised (Randers, 2012).

Governments are dependent on economic growth to ensure tax revenue, employment, and legitimacy. Especially in period of economic recessions, expansive financial policy measures based on public investments are taken into use to ease the decrease in economic growth and thus reduce unemployment. Citizens expect that governments work to ensure a high level of employment, as part of their moral imperative. Degrowth is therefore a challenge to the legitimacy of liberal contemporary democracies (Antal, 2013; Jackson, 2017).

As such it is hard to eradicate the growth imperative of the market economy; any policy aiming at, e.g. slowing down productivity, curbing the demand for consumption, redirecting the technology towards use value and durability, will meet resistance from business and financial sectors (Nørgård and Xue, 2016).

Fedrico-Fazio et al. (2016) argue that policies can contribute to absolute decoupling if these are based upon an integration of planetary limits and thresholds and contain concrete targets, where decoupling is translated into the given sectoral context. Policies could directly link indicators of the impact on the environment (e.g. carbon emissions, resource use, loss of biodiversity) with concrete actions, such that, if a planetary limit has been exceeded, it will trigger a pre-defined policy action constraining further exceedance (Watkins et al. 2016).

Ottelin et al. (2018) believe that there is considerable potential for green public investments to lead to decoupling, particularly in welfare states such as the Nordic countries, since policy frameworks already exist to set environmental taxes and channel these into green investments. Green investments are seen as of particular interest due to the high carbon and resource footprint of infrastructures and potential for reductions thereof.

Thombs (2020) on the other hand, believes that countries (like the Nordics) with high levels of political equality are challenged in achieving absolute reductions in CO₂ emissions. This is because welfare redistribution can increase the incomes of the working-class thus stimulating overall demand in the economy, and thereby, carbon emissions and resource use (Stiglitz, 2016).

8.5.2 Policy aimed at consumption and consumers

Consumption and the consumer are increasingly seen as the key factors in reducing environmental pressures from economic activities. In Sweden, this has grown from a recognition of the fact that efficiency improvements are being rapidly outpaced by growth in emissions associated with household consumption. This has led to an increased policy emphasis on educating for individual consumer responsibility and sustainable lifestyles (Matti, 2009; Isenhour, 2010a,b). According to Isenhour and Feng (2016), the Swedish EPA has recognized that technology will not be enough to achieve absolute decoupling without comprehensive and complementary life-style changes – a trend reversal that calls for political resolve (Swedish Environmental Protection Agency, 2012).

Several of the articles discuss whether policy should target structural frameworks that enable green consumption or focus on influencing individuals through provision of information etc. One article recommends a focus on behavioural change by rewarding environmentally sound behaviour and penalizing actions that harm the environment guided by clear policy objectives (Watkins et al. 2016). Isenhour & Feng, (2016) on the other hand point to several studies that show that there are no significant differences in the environmental footprint of environmentally engaged and unengaged consumers, respectively. They argue that policies should aim at enabling *all* consumers to reduce their environmental footprint rather than placing the burden at a few by addressing the underlying and structural reasons for resource and carbon-intensive products (Isenhour & Feng, 2016).

When designing policies, it is important to differentiate between areas that can be addressed individually and those which are beyond the control of the individual. A green transition requires a combination of behavioural change and supportive framework conditions. Policy should be designed to reflect lock-ins and apply a systemic approach and spill-overs should be tackled (Akenji et al., 2016). A systemic assessment of the impact of a policy should therefore be made before the intervention is implemented in order to identify rebound effects, spill-overs as well as other unintended effects (Lonca et al., 2019).

Scott et al. (2019) argue that policy needs to address those consumption areas that lead to highest environmental pressures. By not linking emissions to the goods and services they become embodied in, these emissions and materials do not enter decision-making processes. For example, while only 9% of emissions produced in the EU are directly emitted from the service and manufacturing sectors – and therefore would not normally be highlighted as a priority for mitigation – they indirectly embody 22% and 26% of emissions caused by EU consumption; they are significant procurers of GHG-intensive materials and products along their supply chains (Scott et al., 2018)

Vita et al. (2019) identify some consumption areas which are strong candidates for policy approaches that would both reduce territorial impacts in developed countries and reduce footprints abroad. At least half of the environmental pressures caused by European consumption of food and clothing take place in other regions. Changes in European diets and fashion would relieve land and water resources in producing countries, which are typically more climate vulnerable (Tukker et al., 2014). Reducing meat and clothing consumption would also benefit Europeans by reducing domestic carbon and toxicity due to less processing, packaging and shipping. Sustainable

housing and improving the efficiency of appliances and electronics, on the other hand, would mostly reduce environmental pressures within Europe resulting from electricity generation and local sourcing of fuels.

International cooperation for sustainability could prioritize the lifestyle changes that yield most bi-lateral benefits (Haberl et al., 2007; Keohane and Victor, 2016).

9 Key messages for the Nordics

In this final chapter we take a recap of the findings in the literature and draw out some key messages and recommendations for the Nordic countries. Some of the recommendations come directly from reviewed papers. Others have been formulated by us, but with a basis in findings and conclusions from the reviewed papers. We have attempted to only include recommendations where many authors are in relative agreement on an issue. However, we also recognise that there are conflicting arguments from different authors on a number of issues.

To take account of this we have formulated recommendations so that they concern carrying out further study and/or that policy-makers should take account of a particular risk or issue when formulating policy.

The aim of this report is to encourage policymakers and others to question what they may earlier have accepted as a truth; that the solution to growing climate, biodiversity and other environmental crises is simply a question of decoupling of environmental pressures from economic growth. The aim is not to provide all the answers.

Another important observation is that Nordic policymakers work within the EU policy framework. Some of the recommendations given here concern the wider EU context rather than national efforts. Finally, it should be recognised that reducing environmental pressures to lie within planetary limits is a global challenge that no country can solve alone. That said, each country can take on responsibility for ensuring that environmental pressures resulting from national activities lie within a *fair share* of remaining budgets that respect planetary boundaries. Care should be taken, however, to ensure that national policy does not have the effect of pushing environmental problems elsewhere. These issues amongst others are dealt with in the text below.

Target-setting and planetary boundaries

The choice of policy targets and associated instruments for achieving them is closely connected to the choice of indicators to assess the state of affairs and measure progress. This task is challenged by the need to ensure compliance with global environmental boundaries, which often defy traditional geographical and political frontiers (Rosenbaum, 2017; Shao, 2020; Mace et al. 2014; Lewis 2012) and moreover, with respect to material resource use are difficult to define as these are not associated with physical limits or irreversible losses (Akenji et al. 2016).

Nevertheless, authors argue that environmental, resource efficiency and green growth policy targets should be carefully aligned with one or more of the science-based planetary boundary thresholds (Stoknes and Rockström, 2018; Jackson, 2017) and that planetary thresholds should be implemented in policy making and economic models to define a safe operating space for economic activity (Jackson, 2017; Wijkman and Rockström, 2012; Sala et al., 2020). One approach might be to allocate the global planetary boundaries to a territorial level in accordance with the population of a country (Sala et al., 2020).

In addition, for planetary limits for which green technologies and efficiency are not the primary solution (such as biodiversity and environmental services) strict regulation, including set aside of significant areas of land and sea for wilderness and nature conservation, might be needed (Jänicke, 2012).

There are currently very few targets globally for absolute reductions in material resource use. Those targets that do exist are only for resource efficiency improvements and likely to only lead to relative decoupling (Meyer et al., 2018). Absolute decoupling ought to be an explicit policy objective both in the Nordic countries (Meyer et al., 2018; Haberl et al., 2020) at EU level and globally and any related action plans should take rebound effects into account (Meyer et al., 2018; Lonca et al, 2019; Santarius et al, 2016).

Many authors (e.g. Krausmann et al, 2020; Jackson, 2017; Haberl et al, 2020; Akenji et al. 2016; Alfredsson & Malmaeus, 2019; Fauré et al., 2016) agree that absolute reductions of environmental pressures are needed in the richer countries of the world, including the Nordics, if planetary boundaries are to be respected globally whilst freeing up resources for developing countries and emerging economies to increase the welfare of their citizens. If further growth in welfare is something that the Nordics and other rich countries aspire to, then this entails an absolute decoupling of environmental pressures from growth. Relative decoupling will not be sufficient.

Recommendations for Nordic countries:

- Engage in, and promote further development of, the science concerning the quantification and fair allocation of emissions and resource use budgets that respect planetary boundaries
- Investigate how resource efficiency and/or green growth policy targets can be developed that are based on a fair share allocation approach
- Engage in discourse and agreement at EU and international level on material resource reduction targets with potential for compensation to balance winning and losing regions in terms of economic development

Limited evidence for absolute decoupling to date

The reviewed articles find limited evidence for absolute decoupling having been achieved to date and certainly not at the rates needed to respect planetary boundaries by mid-century. Evidence for absolute decoupling seems to be strongest for GHG and other emissions when considered from a territorial perspective, but there is evidence that this has been a result of carbon leakage e.g. outsourcing of heavy industrial production to other regions, without corresponding changes in consumption.

In the Nordic countries, Finland, Denmark and Sweden achieved absolute decoupling of *territorial* emissions (Stoknes and Rockström; 2018) but only Denmark achieved absolute decoupling of *footprint-based* emissions (Liobikiene and Dagiliūtė, 2016). Carbon leakage due to increasing imports to the Nordic countries from other regions is clearly a challenge. Evidence from Iceland suggests that even 100% decarbonized energy production does not guarantee a low carbon footprint (Clarke et al, 2017).

Burden-shifting can be particularly problematic, due to some evidence that the carbon intensity of industrial production in the countries to which production has been outsourced is higher than the carbon intensity of these industries in the outsourcing countries (Mair et al, 2014).

Denmark was in fact one of only 3 EU countries to have achieved absolute decoupling in global GHG emissions related to consumption (Liobikiene and Dagiliūtė, 2016) although a further study (Palm et al., 2019) found that Sweden had achieved absolute decoupling in its carbon footprint in more recent years, as well as other air pollutants, water and land use. However, the rates of absolute decoupling in GHG emissions in neither case were sufficient to meet absolute reductions to respect a 2° C global warming threshold.

The recent reductions in Sweden's environmental footprint abroad may have resulted from an increased policy focus on curbing environmental footprints related to consumption (Matti, 2009, Isenhour, 2010a,b). This policy focus has resulted from Sweden's overarching environmental goal 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 Sweden's borders"* (Swedish Environmental Protection Agency, 2012). Other Nordic countries might do well to adopt similar goals and subsequent consumption-focused policy.

For material resource use, the picture is even gloomier. A few cases of absolute decoupling of material resource use were identified but mostly for material indicators that do not include the full material rucksack of imported goods (Giljum et al, 2015). At global level material extraction increased 8-fold during the 20th Century, while GDP grew 23-fold e.g. only relative decoupling has been achieved (International Resource Panel, 2011). This is of considerable concern given the strong interconnection between material resource use and other pressures and impacts; material resource extraction is estimated to have been responsible for half of greenhouse gas emissions and 90% of biodiversity loss to date (International Resource Panel, 2019)

Recommendations for Nordic countries:

- Consider the adoption of targets and policy for clear reductions in a range of environmental pressures, rather than, or supplementary to, targets for increased productivity (for example carbon or resource productivity)
- Consider the adoption of targets and implementing policy for reducing environmental footprints abroad related to domestic consumption, and investigate the consequences of such policy
- Develop measurement systems in collaboration with Eurostat or across the Nordic countries (using multi-regional input output analysis or otherwise) to allow regular monitoring of environmental pressures abroad caused by national consumption similar to those developed in Sweden

New measures of progress needed

Many authors argue, either based on the historical evidence (Haberl et al., 2020; Jackson, 2017; Jackson & Victor, 2019; Krausmann et al, 2020) or from a theoretical point of view (Wiedenhofer et al, 2020; Jackson & Victor, 2019), that absolute decoupling will not be possible at the rate needed to respect planetary boundaries, if we continue to use GDP as a measure of progress.

Some theorists argue that GDP is strongly linked to material resource use, such that any reductions in material resource use will necessarily lead to reductions in GDP. This is due to the strong coupling of GDP to capital growth which itself is strongly linked to material use through the construction of infrastructure, machinery and building stock (Malmaeus, 2016; Krausman et al, 2020). In order to maximize benefits in society, using a gauge (GDP) that essentially measures costs is probably ineffective.

Many (Jackson, 2017; Jackson and Victor, 2019; Vadén et al., 2020; Antal and Van den Bergh, 2017; Malmaeus, 2016) argue for new, or supplementary measures of progress and prosperity. It is argued that beyond a certain level of GDP, further increases in GDP do not guarantee increases in well-being and therefore more direct measures of progress in well-being are needed (Hoekstra, 2019; Jackson, 2009; Skidelsky & Skidelsky, 2012; Wilkinson & Pickett, 2009).

It is also argued that new measures of progress may be better placed to define economic development compatible with necessary reductions of resource use and environmental degradation. In other words, absolute decoupling of environmental pressures can be more readily achieved from growth measured according to indicators that include human well-being at their core (Malmaeus, 2016; Jackson & Victor, 2019; Kubiszewski et al. 2013).

A large number of candidates for alternative measures have been proposed and are discussed briefly by the authors (Hoffrén 2006; Stiglitz et al., 2009; Aşici 2013; Bohringer and Jochem, 2007) but there appears to be no consensus, as yet, on which of these is most promising. Many governments are caught in ambiguous notions such as 'beyond GDP' and 'beyond growth' without having a true understanding of what these notions entail.

Recommendations for Nordic countries:

- Work within Nordic, EU and international monitoring fora towards alternative measures of progress to GDP, that focus on human prosperity and well-being and move towards achieving consensus on these at international level
- Encourage debates and discussions on the shortcomings of GDP in education, and particularly in economics and business management studies in higher education

Reconsidering the 'growth at any cost' economic model

If alternative measures of progress are adopted this can open the door for economic models that do not rely on economic growth as the key route towards ecological sustainability and human wellbeing (Vadén et al., 2020) but rather focus on increased financial and fiscal prudence (Jackson, 2017). Challenging the grow or die philosophy of the market-based economy may reduce resistance from business and financial sectors towards policy aiming at slowing down productivity, curbing material consumption demand, or redirecting technology towards functional value and durability of goods (Nørgård and Xue, 2016). Any mainstream assumption of green growth should be questioned since a categorical pro-growth strategy risks obstructing implementation of good climate policies (Albert, 2020). Instead, being neutral about growth can facilitate the acceptance of serious climate policy (Van den Bergh, 2017).

An a-growth strategy can be argued as a means to facilitate an economic restructuring in Nordic and other OECD countries in order to achieve a more just distribution of economic welfare between rich and poor countries, and a substantial absolute reduction of environmental pressures (Van den Bergh, 2017; Shao, 2020). New policies may be needed to maximize social and environmental well-being. These could include resource caps, reduction of working hours, public transportation and lowering energy demand (Thombs, 2020).

The growth-at-any-cost mentality is partly a result of the reliance of current economic models on debts and rentier power e.g. where a (small) number of organisations and individuals own and rent out capital to businesses and individuals who then need to increase their productivity in order to repay debts Stratford, 2020. Debate is needed on whether and how such rentier power could be diffused and rents redistributed such that a-growth or de-growth strategy do not risk increasing debts and unemployment (Stratford, 2020; Randers, 2012). A part of this discussions should include consideration of whether redistribution of rents would need to go hand-in-hand with tough resource caps and environmental protections in order to counter boosts in demand and higher levels of resource consumption and environmental pressures that might otherwise result (Stratford, 2020). A combination of pre-emptive environmental protections alongside checks on rentier power would allow the economy to 'go slower by design, not disaster' (Victor, 2008).

In the meantime, several authors argue that if economic growth is to continue to be a policy imperative, debate is also needed on appropriate targets for this growth. The rate of economic growth has a significant effect on carbon emissions, compared with other driving forces. Therefore, the slower the growth and the earlier transition to a steady state economy are, the more effective the efforts toward absolute decarbonization are likely to be (Shao, 2020). De-growth risks depressing investments, increases in unemployment and social unrest (Shao, 2020; Jackson, 2017). Modest economic growth rates of 1% or less, on the other hand, may allow absolute decoupling while reducing risk of widespread unemployment (Hickel, 2019; Jänicke, 2012). Evidence for this has been found in Sweden between 1997 and 2007, and Germany between 2000 and 2010 (Jänicke, 2012). Modest growth rates also appear to be more realistic for post-industrial countries such as the Nordics (Stoknes and Rockström, 2018).

An a-growth approach may need to be accompanied by an employment strategy to

reduce risks of negative effects such as increasing unemployment. Employment can potentially be ensured in a low-growth economy, through replacing labour taxes with environmental taxes, and promotion of circular businesses such as repair, maintenance and refurbishment (Antal and Van Den Bergh, 2014; Jänicke, 2012). Potential rebound effects due to more leisure time must also be considered and prevented through carefully chosen policy (Shao, 2020).

Recommendations for Nordic countries:

- Stimulate debate in politics and wider society about the relevance of, and means for stepping outside the pro-growth versus anti-growth frame
- Stimulate debate on which mechanisms lie behind the growth imperative and how these mechanisms might be tackled without causing societal instability
- Consider reducing economic growth targets to 1% or less to more readily allow absolute reductions in environmental pressures and investigate whether and how this could be achieved without risking increasing unemployment
- Investigate the potential benefits of reducing working hours to reduce unemployment risks from low growth and simultaneously reduce levels of material consumption

Green technologies, eco-efficiency, the circular economy and the rebound effect

There was a general recognition in the literature that green technologies, improved resource efficiency and the circular economy are essential elements of decoupling of pressures from growth but that these in general only allow relative decoupling of environmental pressures, particularly at higher levels of growth (Lonca et al. 2019; Rosenbaum 2017; Jackson & Victor, 2019; Aşici 2013). Rebound effects were identified as a key factor in the lack of reductions in pressures being achieved through technical solutions (Parrique et al, 2019; Brockway et al., 2017; Lonca et al, 2019; Pesch, 2018; Wenzlik, 2015; Hickel and Kallis, 2019).

Nevertheless, green investments ought to be a central element of policy for reducing environmental pressures even if they can't achieve absolute decoupling on their own. Indiscriminate growth cannot be expected to lead to necessary efficiency improvements since evidence for the Environmental Kuznet curve is very weak (Hickel, 2019). Moreover, direct investments in efficiency and innovation may be necessary since the best clean technologies are not always profitable in economic terms (Ottelin et al., 2018; Hickel, 2019).

One of the best means for encouraging and funding technological improvements to reduce energy use and the use of material resources, may be by raising the price of natural resources and energy (Hoffren, 2006). This approach can also counter direct and indirect rebound effects that result from price elasticities, since improvements in efficiency will have the effect of offsetting increased costs rather than decreasing unit costs for the consumer (Hickel, 2019).

The Nordic countries have large public sectors and the tax regimes needed for funding such green investments (Ottelin et al., 2018). Moreover, the Nordic countries can profit from being frontrunners in the green transition, as the development and

implementation of green technologies can be exported to other parts of the world (Distelkamp and Meyer, 2019). Shifting the emphasis of taxation from labour to GHG and resource-intensive production, products and consumption can drive technology in the right direction. However, such taxes should be implemented carefully to ensure that the poor aren't affected disproportionately (Ottelin et al., 2018) and effort needs to be made to ensure that higher taxation doesn't drive resource-intensive industries to relocate elsewhere.

Some authors (Albert, 2020; Falk et al., 2018; Drexler, 2013) argue that the Fourth Industrial Revolution in terms of nano-technology, the internet of things and machine learning have considerable potential to decarbonize and dematerialize the economy. However, more study is needed on this potential as the evidence seems rather weak.

Circular economy strategies need to move away from a focus on recycling which allows a continuation of a linear production and consumption flow (Giampietro, 2019; Akenji et al. 2016). Policy needs to focus on the inner circles of circularity through encouraging long product lifetimes, repair and refurbishment (Giampietro, 2019; Lonca et al, 2019; Antal & Van den Bergh, 2013; Scott et al., 2019). Planned obsolescence needs to be addressed via eco-design standards adopted for a wide range of products (Watkins et al., 2016) along with capacity support to designers in creating longer-lasting products with lower material footprints (Scott et al., 2019).

Furthermore, promoting circularity in an individual company or industrial sector does not guarantee reductions in resource use across the whole economy due to cross-sectoral rebound effects (Arnsperger and Bourg, 2016). Nordic governments need to be made aware that the circular economy in general will only support relative decoupling and that any decoupling can be offset by rebound effects. Policy makers should be assisted in taking a whole economy viewpoint that considers cross-sectoral rebound effects of circular economy measures such that these can be closed off. This is not the responsibility of individual businesses for whom these measures make economic sense but rather for national governments (Lonca et al., 2019).

Finally, policy-makers need to be better informed on the various types of rebound mechanisms, in order to reduce the negatives associated with them while maximizing the merits (Santarius et al., 2016; Giampietro, 2019). Sociological and anthropological studies of changes in behaviour in response to energy and material efficiency improvements can significantly improve this understanding and the development of mitigation measures (Santarius et al, 2016).

Recommendations for Nordic countries:

- Invest in/subsidise green technologies and material productivity in order to increase competitive, export markets etc.
- Consider the benefits of and means for a green tax reform to shift taxes from labour to resource use and environmental emissions. This should take account of the potential regressive nature of such taxes and the potential for carbon leakage effects. Means for mitigating these effects should be investigated.
- Identify means to better promote circular businesses such as repair, maintenance and refurbishment through tax breaks, investments, regulating against planned obsolescence, changes to consumer law concerning product guarantees, rights to repair and other assisting policy measures

- Develop a better understanding of rebound effects and mechanisms, in part through anthropological studies, to allow more effective mitigation measures
- Consider how price elasticity-based rebound effects can be countered by ensuring that efficiency improvements are accompanied by increases in resource and emissions taxes to ensure stable costs of consumption
- Investigate the potential of the Fourth Industrial Revolution (nano-technology, the internet of things and machine learning etc.) to reduce material use in the economy, including consideration of associated rebound effects

Decouple material resource use from capital investments

Several argue that one of the key reasons why the use of material resources has only been decoupled to a limited extent from economic growth is the continued growth in building stock and infrastructure (Palm et al., 2019; Alfredsson and Malmaeus, 2019). Resource use for capital investments in Sweden will rapidly use up Sweden's entire fair share of material resources leaving no resource budget for consumption (Alfredsson and Malmaeus, 2019). The situation may be similar in other Nordic countries.

Alternative building materials and processes, for example in cement production, may reduce CO₂ emissions from investments. Materials footprints, meanwhile, can potentially be reduced through improved building standards and policy that encourage flexible design, material substitutions, more efficient use of space, more sharing of space between firms/families, less single living, more community living and more efficient transport infrastructure. This can be combined with carbon-neutral or carbon-positive buildings and infrastructure to avoid lock-in, for example through strict building standards (Krausmann et al., 2020; Alfredsson and Malmaeus, 2019; Pesch, 2018).

One paper argues that growth in capital investment in the future needs to be decoupled from material resource use if absolute decoupling of resource use from economic growth is to be feasible (Alfredsson and Malmaeus, 2019). Physical capital has historically been the most important form of value preservation and research is needed to explore how such decoupling can take place (Malmaeus, 2016). One means might be through a higher share of ICT in capital investments at the expense of buildings and infrastructure (Alfredsson and Malmaeus, 2019). As an example, increased flexibility in working between the home and the office that has been made necessary by the COVID-19 pandemic, and allowed through investments in ICT for virtual meetings, has reduced demands for office space per worker. Such developments could be supported via carefully thought out policy (OECD, 2020b).

In particular Keynesian stimulation of an economy for economic recovery after a recession should be carried out with dematerialisation and low energy use in mind (Wenzlik et al., 2015).

Recommendations for Nordic countries:

- Investigate the use of building standards and a range of related policies that would encourage flexible design of buildings, material substitutions in construction, more efficient use of space, more sharing of space between firms

and between citizens; encouraging less single living in favour of more community living

- Identify ways to divert capital investments away from resource intensive buildings and infrastructure development and into alternative less-intensive investments such as ICT
- Identify policy measures for ensuring that capital investments in buildings and infrastructure are channelled into low energy using structures stock to avoid long-term lock-ins in energy use
- Ensure that any economic stimulation, for example following a recession, is fully integrating with dematerialization and decarbonization policies

Changing the social logic through broadly accepted policies

Most existing climate policies focus on the energy sector. While this is an essential element of decarbonization, policies are also needed at consumer level through reducing demand for materials and products (Scott et al., 2019). To reach the targets of the Paris agreement, and to reduce resource use significant changes in life styles are needed. Sustainability scenarios rely heavily on mainstreaming sustainable lifestyles and identifying and supporting these is key for current mitigation and adaptation challenges (Vita et al., 2019; Jackson, 2017).

Policies for lifestyle changes require citizen engagement and approval to succeed. Even benevolent policies that do not resonate with the target group can generate resistance. Sustainability transformation requires innovative technologies as well as innovative lifestyles and engaged and well-informed citizens (Vita et al., 2019). Using positive language is one means for gaining acceptance. GHG emissions reductions can, for example, be defined in terms of increased carbon productivity rather than decreased carbon intensity. This linguistic approach can increase public support of a green transition, as it promises win-win frameworks. It is easier to gain public support for a positive development (Stoknes and Rockström, 2018).

The Nordic countries should identify lifestyles that are both environmentally sound and can, through careful policy design and communication, be socially accepted (Vita et al., 2019). The social logic can be addressed through reducing working hours, addressing inequality, strengthening social capital, and dismantling the culture of consumerism, bringing a range of social benefits (Weiss and Cattaneo, 2017; Thombs, 2020; Jackson, 2017).

Consumption is increasingly seen as the key factor in reducing environmental pressures. In Sweden, this has grown from a recognition that efficiency improvements are being rapidly outpaced by growth in consumption. This has led to an increased policy emphasis on educating for individual consumer responsibility and sustainable lifestyles (Matti, 2009; Isenhour, 2010a,b). A green transition requires a combination of behavioural change and supportive framework conditions. Policy should aim at changing the frameworks within which consumers operate, reflect and reduce lock-ins and spill-over effects such that *all* consumers reduce their environmental footprint and not just those that are the environmentally-engaged (Isenhour & Feng, 2016; Akenji et al., 2016).

Ownership norms can be challenged through promotion of sharing and leasing models (Antal & Van den Bergh, 2013; Scott et al., 2019). This can increase democratic equity (Stratford, 2020) as well as reduce resource demand. However, consumers' risk-perceptions of leasing and sharing models need to be addressed through appropriate policy/regulation, before such models can be mainstreamed (Scott et al., 2019).

Public spending has significant carbon and material footprints particularly in welfare states such as the Nordics. Adjusting public spending to be less impact-intensive is an important element of greening consumption (Ottelin et al., 2018). State spending is a powerful instrument with the power to redirect investment to sustainable projects and redistribute resources to marginalised groups.

Recommendations for Nordic countries:

- Identify lifestyles that are both environmentally sound and can be socially acceptable through careful policy design and communication
- Develop policy that changes the framework conditions that guide consumption, including addressing 'lock-ins, social norms, price structures and more to ensure that all consumers reduce their environmental footprint
- Consider the adoption of regulation that ensures a fair allocation of risks and responsibilities in leasing and other sharing models to accelerate a shift to non-ownership models
- Consider the potential benefits and risks of reducing working hours
- Encourage societal debate on how inequality can be reduced and social capital strengthened
- Develop positive win-win language for use when promoting greener lifestyles

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11 Appendix A: Detailed methodology

The literature study comprised three overall phases. First, a long list of relevant literature on decoupling with relevance to the Nordic countries, was identified based on a systematic search strategy. The second phase comprised a first analysis and filtering of the long-list to provide a short-list of approximately 50 articles and books that were most relevant to the research questions included in the objectives, such that all themes would be addressed. The final phase comprised a systematic analysis of the selected literature guided by an analytical framework that was developed with starting point in the research questions. The methodology is described below.

11.1 Collating a long-list of relevant literature

This project phase aimed at identifying a long-list of relevant literature published after 2005. 2005 was selected as a watershed, at which point decoupling was firmly cemented into EU environmental policy with the publication of the Thematic Strategy on the Sustainable Use of Natural Resources under the EU Commission's 6th Environmental Action Program.

The long-list was compiled making use of two, complementary databases and associated search engines:

- **Scopus**, which is Elsevier's own database of primarily peer-reviewed articles from more than 5000 publishers covering both science, technology, social science and humanities
- **The Danish Royal Library's REX Database**, containing all materials of the Royal Library including books and popular articles, which are not covered by Scopus.

Stage 1 – identifying relevant key-words

The following key words were identified for use in literature searches within these search engines. These include commonly used concepts and theories within or related to the general concept of decoupling or otherwise related to the research questions posed in the objectives of this report:

- **Decoupling**: breaking the connection between economic growth/human well-being and environmental pressures (resource use, greenhouse emissions etc.).
- **Planetary boundaries**: nine quantitative planetary boundaries related to climate change, land use change, biodiversity, water use, ocean acidification, ozone depletion, nitrogen and phosphorous, as well as air pollution.
- **Doughnut economics**: Builds upon the planetary boundaries by defining the necessary social foundation of health, food, education, quality etc. to define a safe and just space for humanity to operate within the planetary boundaries.
- **Degrowth or post growth**: Refer to a criticism of capitalism and the economic

growth imperative. These prioritise social and ecological well-being rather than economic growth.

- **Limits to growth:** the title of the landmark report on the issue published by Club of Rome in 1972, which has been ground-breaking in the environmental limits of growth.
- **Prosperity without growth:** Is the title of Tim Jackson's watershed report on decoupling, which created a foundation for the discussion of decoupling accessible to laymen.
- **Welfare without growth:** a variation of the above
- **Green growth:** fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies (OECD, 2020a).
- **The Environmental Kuznet Curve:** a theory on the natural development of economic and associated environmental pressures. According to the theory, environmental degradation increases as GDP rises and an economy develops until a turning point is reached, where the economy has reach a middle-income level, from which point environmental degradation will decrease as GDP rises further.

Stage 2 – Iterative use of queries in search engines

A number of queries were trialled iteratively using these key words with a range of Boolean operators (e.g. "AND", "OR", "NOT") with the goal of focussing the query and narrowing the results to a size that could be reasonably handled in subsequent steps.

The numbers of results for various query types used in the **SCOPUS** search engine is given in Table A.1. The table illustrates the vast number of publications that have some potential relevance to the field. The final result in the table includes a further filtering through selection of the most relevant 'themes' under which articles in Scopus are grouped.

We carried out the same final String 4 search using Swedish translations of the keywords to identify whether additional articles of relevance were found. No additional titles were identified.

String 4 as identified above for SCOPUS was also used in the REX database search engine. This gave over 900 results. REX, does not include 'themes' as SCOPUS does, but does have a function that allows the titles to be listed in order of relevance to the search words, based on the number of times that the search words appear and on whether they appear in the abstract or only in the main text. We included the first 200 'most relevant' titles in our first REX long-list.

Table A.1: results of successive queries of the SCOPUS search engine

Iterative search string number	Query	Number of results
String 1	"planetary boundaries" OR "doughnut economics" OR "de-growth" OR "prosperity without grown" OR "welfare without growth" OR "limits to growth" OR "post-growth"	68.612
String 2	Decoupl* AND ("green growth" OR "ecological"* OR "environmental" OR "resource")	133.170
String 3	"Environmental Kuznets curve"	4.267
String 4	("planetary boundaries" OR "doughnut economics" OR "environmental Kuznets curve" OR "degrowth" OR "prosperity without growth" OR "welfare without growth" OR "limits to growth" OR "post-growth") AND Decoupl* AND ("green growth" OR "environmental" OR "resource")	3.250
String 4 combined with selection of specific 'themes' which is another type of field filled in for each entry	As String 3 above but combined with following 'themes' which were thought most likely to include relevant publications: Sustainable Development, Sustainability, Economic Growth, Growth, Environmental Economics. Themes such as Temperature, Meteorology and Atmospheric Science, Clouds, Turbulence, Simulation were also available and considered to have	575

Stage 3 – Removal of duplicates

We programmed Excel to identify duplicates between the 200 most relevant REX results and the 575 SCOPUS results and removed these from the list.

Stage 4 – filtering based on title of article/book

We carried out a visual review of titles and removed those that were focused on non-OECD countries. We also removed those articles that on the basis of the title had a narrow thematic focus e.g. reduction in smog in a given city, improvements in a water basin or the consumption of a single resource such as copper or phosphorous. This reduced the SCOPUS long-list to just under half at 248 publications and reduced the REX non-duplicate list to 42 publications giving 290 titles in total. This was viewed as the limit of any filtering that could be carried out based on title only and from here on abstracts would need to be read.

11.2 Selection of short-list for detailed analysis

The selection of the short list from the 290 titles in the long-list was made through a review of abstracts.

Stage 1 – characterization and judgement of relevance/usefulness

Using the abstract each publication was characterised in terms of its relevance to various elements that could be drawn from the objectives of the project (see Box A.1 below).

Based on this categorisation, a judgement on the level of relevance of the publication to the study according was made to the following hierarchy (*Must have, Very Useful, Useful, Partly Useful, Not relevant*). Account was also taken of whether the publication had brought something new to the discussions. Review papers were also given a high weighting

Box A.1: Categorisation of articles

1. Does the article focus on the Nordic region?
2. Is the article a review paper or original research?
3. Is the information in the article based on empirical evidence or theoretical arguments?
4. Does the article focus on dematerialisation, substitution or technological development?
5. Does the article compare production and consumption perspectives?
6. Does the article take the planetary boundaries into account?
7. Which type of decoupling - resource use and/or environmental impacts from GDP and/or well-being – does the article consider?
8. Is the article optimistic, agnostic or pessimistic?

Stage 2 – ensuring a balanced and sufficient coverage of themes

A final step was taken to ensure that the final short-list covered all relevant dimensions of the themes in Box A.1 but without excessive overlap.

Publications that had been identified as *"Must-have"* and *"Very Useful"* were re-evaluated to ensure that all types and contributing components of decoupling were covered, that the short list included a balance of pessimistic, agnostic and optimistic standpoints, and that key issues such as rebound effects, shifting of impacts, consideration of well-being indicators other than GDP, and potential policy for encouraging decoupling were covered.

Where, several publications in the *"Very Useful"* group overlapped with respect to coverage, those with the fewest citations (only possible for SCOPUS results not

REX) were then degraded to "*Useful*".

Where any of the components were *not* seen to be covered by the initial short list, the publication classified as "*Useful*" were reconsidered again to fill any gaps and upgraded to "*Very Useful*". The result was 12 *Must haves*, 10 of which are review papers on various issues, and 36 *Very Usefuls*. This gives 48 publications in total. The short list was reviewed by the consortium including the two academic experts associated with the project.

A full list of the reviewed publications is given in Appendix B.

11.3 Analytical framework

An analytical framework was developed to guide the review and analysis of each publication in the short list. The main aims of the analytical framework were to 1) to allow a characterization of papers, and 2) ensure that all elements of potential interest in answering the research questions given in the Objectives were covered.

The analytical framework (Table A.2) is divided into four main areas (distinguished by colour in the table):

- **Characterisation** of the paper/document, who wrote it and in what context
- **Backward-looking elements** that consider historical evidence for decoupling, shifting of impacts and rebound effects
- **Forward-looking elements** concerned with planetary boundaries, potential for and constraints to further decoupling and the potential negative social consequences of decoupling
- **Conclusions and key messages** with particular importance for the Nordic countries, including relevant recommendations found in the articles

The analytical framework was set up and filled out in an excel sheet, which enabled a filtering and comparisons of specific themes and positions to guide the analysis.

Table A.2: Analytical framework for analysis of the short-list of 48 papers

	Parameter	Guiding questions (with explanation)	Information needed
CHARACTERISATION OF THE PAPER AND SUBJECT MATTER	Basic details		Title, Authors, Date, publisher/ journal
	Abstract	What is the background and overall findings?	Provide an abstract/summary max 150 words. This should be taken from the document itself if it already had a summary/ abstract
	Type of paper	What type of document/content is it? (Changes how we treat it, whether we need to treat it with caution due to an element of bias, or whether it is an objective review of evidence. This is also closely related to previous question)	Choose one or more of options below: - Primary research - A review of primary research - A strategy/policy document
	Forward- or backward looking	Is the document forward looking (e.g., what needs to be done?) or backward looking (what happened in the past?)	Choose one or more of options below: - Backward looking - Forward looking
	Type of decoupling referred to	What type(s) of decoupling are identified/discussed?	Identify which type(s) of decoupling the paper focuses on/ discusses: - Environmental impact from economic growth - Resource use from economic growth - Well-being from economic growth - Environmental degradation from resource use
	Well-being indicators	Does the paper criticize GDP as a well-being indicator and/or propose other indicators of well-being?	Describe and identify alternative indicators
BACKWARD LOOKING – EVIDENCE TO DATE		Does the document provide evidence/arguments for decoupling or for lack of decoupling to date?	Choose one of below and elaborate: Qualitative: In-depth data collected from one or a few cases Quantitative: Empirical data collected from a large number of cases, or from national statistics Theoretical: Economic/ environmental theory

	Timeframe	Is the identified decoupling considered to be short term or long-term?	Choose one of below and describe briefly: Temporary: The evidence of decoupling presented in the article is temporary Long-term: A permanent decoupling is observed
	Shifting of impacts to date	What is the geographical context presented by the document and within which decoupling is reviewed?	Choose one of below and describe briefly: Only territorial: Resources and environmental degradation from production Only footprint-based: Resources and environmental degradation from consumption Both perspectives
		Does the document mention/ provide evidence for carbon leakage or other kinds of geographical leakage that undermines decoupling?	Describe the findings in terms of shifting of impacts to date
	Components of decoupling to date	Does the paper differentiate between different components that have been responsible for decoupling to date? If so, is evidence provided for the relative importance of each type in any decoupling seen to date? Describe this. Are any of these forms of decoupling judged to be more short-lived than others?	1) Structural changes in the economy: e.g. from an industrial to a service-based industry (this can often be a result of 'outsourcing' see below) 2) Dematerialization: reduction in resource use per product, or changes from consumption of 'things' to consumption of services 3) Substitution: changes in the type of material and/or energy used for production 4) Efficiency: reduction in wastage in the value chain, end-of-pipe solutions to remove emissions etc.
	Rebound effects to date	Does the paper present evidence for rebound effects that have undermined decoupling to date?	Describe the empirical evidence and/or main mechanisms for rebound effects that have been observed and the degree to which they have reduced decoupling

FORWARD LOOKING

Potential for further decoupling	Does the paper identify potential for (or against) further decoupling?	Yes, no or partial Briefly describe
Constraints to further decoupling	Does the paper identify key constraints to decoupling? These can for example be lack of potential for further technological development, lock-in resource	Briefly describe the key constraints identified if there are any

	/energy demand effects caused by infrastructure and existing stocks or rebound effects.	
Negative social consequences	Does the paper envisage that decoupling, degrowth and/or resource restrictions will lead to negative social consequences? Such as increased inequality, unemployment	Briefly describe consequences if mentioned
Planetary limits/tipping points	Does the paper consider decoupling with respect to planetary limits, and is decoupling seen as being able to respect these? Which planetary limits present most constraints to further growth in well-being (in developed countries)?	Briefly describe which planetary limits are referred to and whether or not the paper considers that these can be respected Describe which are considered to be most problematic if any such evaluation is made

CONCLUSIONS AND KEY MESSAGES		
Conclusions	What is the concluding (or starting) position and does this have political bias?	Pro-growth and/or optimistic: Economic growth can (or should) be pursued. Technology can solve all environmental issues if brought to bear in the correct way. Pragmatic: Economic growth can continue, but negative impacts on the environment will occur although these will not be critical De-growth and/or pessimistic: Growth should be avoided if we are to stop the critically impacting the eco-systems
Recommendations	Does the paper include recommendations on future policy/action?	Describe briefly
Messages for Nordics	How relevant are the results/ position to the Nordic region and what take-home messages are there?	Describe how relevant the results are to Nordics in terms of similar economic context, similar structure of government and economy, similar geographical context etc. Briefly name any conclusions/ messages that are directly relevant and should be considered by the Nordic countries
Additional remarks	Other notes; Useful quotes	

12 Appendix B: List of reviewed literature

Selected articles for assessment						Type of decoupling considered				Type of evidence		
	Primary research	Review of primary research	Strategy/ policy document	Backward looking	Forward looking	Env. impact from economic growth	Resource use from economic growth	Well-being from economic growth	Env. degradation from resource use	Qualitative	Quantitative	Theoretical
Akenji, L., Bengtsson, M., Bleischwitz, R., Tukker, A. and Schandl, H., 2016. Ossified materialism: introduction to the special volume on absolute reductions in materials throughput and emissions. <i>Journal of Cleaner Production</i> , 132, pp.1–12.		x	x		x	x	x	x	x		x	
Albert, M.J., 2020. The dangers of decoupling: earth system crisis and the 'Fourth Industrial Revolution'. <i>Global Policy</i> , 11(2), pp.245–254		x			x	x	x		x			
Alfredsson, E.C. and Malmaeus, J.M., 2019. Real capital investments and sustainability- The case of Sweden. <i>Ecological Economics</i> , 161, pp.216–224.	x			x	x	x	x		x		x	x
Antal, M. and Van den Bergh, J.C., 2013. Macroeconomics, financial crisis and the environment: Strategies for a sustainability transition. <i>Environmental Innovation and Societal Transitions</i> , 6, pp.47–66.		x		x	x	x						x
Aşıcı, A.A., 2013. Economic growth and its impact on environment: A panel data analysis. <i>Ecological indicators</i> , 24, pp.324–333.	x			x		x			x		x	
Banks, M., 2018. Creative economies of tomorrow? Limits to growth and the uncertain future. <i>Cultural trends</i> , 27(5), pp.367–380.		x								x		
Bleischwitz, R., Nechifor, V., Winning, M., Huang, B. and Geng, Y., 2018. Extrapolation or saturation-Revisiting growth patterns, development stages and decoupling. <i>Global environmental change</i> , 48, pp.86–96.	x			x			x				x	

Bhowmik, D. (2019). Decoupling CO2 Emissions in Nordic countries: Panel Data Analysis. SocioEconomic Challenges 3(2): 15–30				x		x				x	
Distelkamp, M. and Meyer, M., 2019. Pathways to a resource-efficient and low-carbon Europe. Ecological Economics, 155, pp.88–104.	x				x	x	x			x	
Fauré, E., Svenfelt, Å., Finnveden, G. and Hornborg, A., 2016. Four sustainability goals in a Swedish low-growth/degrowth context. Sustainability, 8(11), p.1080.			x		x	x	x				x
Fedrico-Fazio, D., Schweitzer, J.P., Ten Brink, P., Mazza, L., Ratliff, A. and Watkins, E., 2016. Evidence of absolute decoupling from real world policy mixes in Europe. Sustainability, 8(6), p.517.	x			x	x		x		x		
Giampietro, M., 2019. On the circular bioeconomy and decoupling: implications for sustainable growth. Ecological economics, 162, pp.143–156.		x		x	x	x					x
Haapanen, L. and Tapio, P., 2016. Economic growth as phenomenon, institution and ideology: a qualitative content analysis of the 21st century growth critique. Journal of Cleaner Production, 112, pp.3492–3503.		x		x	x	x		x		x	
Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., Fishman, T., Hausknost, D., Krausmann, F., Leon-Gruchalski, B. and Mayer, A., 2020. A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. Environmental Research Letters, 15(6), p.065003.	x	x		x		x	x		x		x
Hickel, J., 2019. The contradiction of the sustainable development goals: Growth versus ecology on a finite planet. Sustainable Development, 27(5), pp.873–884.		x		x	x	x	x				x
Hoffren, J., 2006. Reconsidering quantification of						x	x		x		x

eco-efficiency: Application to a national economy. Progress in Industrial Ecology, an International Journal, 3(6), pp.538–558.										
Isenhour, C. and Feng, K., 2016. Decoupling and displaced emissions: on Swedish consumers, Chinese producers and policy to address the climate impact of consumption. Journal of Cleaner Production, 134, pp.320–329.	x	x		x	x	x	x		x	x
Jackson, T. and Victor, P.A., 2019. Unraveling the claims for (and against) green growth. Science, 366(6468), pp.950–951.		x		x		x	x		x	
Jackson, T. 2017. Prosperity Without Growth: Foundations for the Economy of Tomorrow. Abingdon: Routledge.			x	x	x	x	x	x	x	x
Jänicke, M., 2012. "Green growth": From a growing eco-industry to economic sustainability. Energy Policy, 48, pp.13–21.		x			x	x				
Knight, K.W., Rosa, E.A. and Schor, J.B., 2013. Could working less reduce pressures on the environment? A cross-national panel analysis of OECD countries, 1970–2007. Global Environmental Change, 23(4), pp.691–700.	x			x	x		x		x	x
Krausmann, F., Wiedenhofer, D. and Haberl, H., 2020. Growing stocks of buildings, infrastructures and machinery as key challenge for compliance with climate targets. Global Environmental Change, 61, p.102034.	x						x			
Lamb, W.F. and Steinberger, J.K., 2017. Human well-being and climate change mitigation. Wiley Interdisciplinary Reviews: Climate Change, 8(6), p.e485.		x		x	x			x		x
Liobikienė, G. and Dagiliūtė, R., 2016. The relationship between economic and carbon footprint changes in EU: the achievements of the EU sustainable consumption and production policy implementation.	x			x		x				

Environmental Science & Policy, 61, pp.204–211.											
Lonca, G., Bernard, S. and Margni, M., 2019. A versatile approach to assess circularity: The case of decoupling. Journal of Cleaner Production, 240, p.118174.	x				x		x		x		x
Malmaeus, J.M., 2016. Economic values and resource use. Sustainability, 8(5), p.490.	x			x	x	x	x				
Meyer, M., Hirschnitz-Garbers, M. and Distelkamp, M., 2018. Contemporary Resource Policy and Decoupling Trends—Lessons Learnt from Integrated Model-Based Assessments. Sustainability, 10(6), p.1858.					x						
Nørgård, J. and Xue, J., 2016. Between green growth and degrowth: Decoupling, rebound effects and the politics for long-term sustainability. In Rethinking Climate and Energy Policies (pp. 267-284). Cham: Springer.		x	x	x	x	x	x	x	x	x	x
Ottelin, J., Heinonen, J. and Junnila, S., 2018. Carbon and material footprints of a welfare state: Why and how governments should enhance green investments. Environmental Science & Policy, 86, pp.1–10.	x			x	x	x	x				x
Palm, V., Wood, R., Berglund, M., Dawkins, E., Finnveden, G., Schmidt, S. and Steinbach, N., 2019. Environmental pressures from Swedish consumption—A hybrid multi-regional input-output approach. Journal of Cleaner Production, 228, pp.634–644.	x			x		x	x				
Pesch, U., 2018. Paradigms and paradoxes: The futures of growth and degrowth. International Journal of Sociology and Social Policy		x			x		x	x			x
Randers, J., 2012. The Real Message of The Limits to Growth A Plea for Forward-Looking Global Policy. GAIA-Ecological Perspectives for Science and Society, 21(2), pp.102–105.			x	x		x	x		x		
Rosenbaum, E., 2017. Green		x				x					

Growth—Magic Bullet or Damp Squib?. Sustainability, 9(7), p.1092.										
Sala, S., Crenna, E., Secchi, M. and Sanyé-Mengual, E., 2020. Environmental sustainability of European production and consumption assessed against planetary boundaries. Journal of environmental management, 269, p.110686.	x			x		x				
Santarius, T., Walnum, H.J. and Aall, C., 2016. Introduction: Rebound research in a warming world. In Rethinking Climate and Energy Policies (pp. 1–14). Cham: Springer.					x	x				
Scott, K., Giesekam, J., Barrett, J. and Owen, A., 2019. Bridging the climate mitigation gap with economy-wide material productivity. Journal of Industrial Ecology, 23(4), pp.918–931.			x		x	x			x	
Shao, Q., 2020. Paving ways for a sustainable future: a literature review. Environmental Science and Pollution Research, 27(12), pp.13032–13043.		x				x	x	x	x	x
Stoknes, P.E. and Rockström, J., 2018. Redefining green growth within planetary boundaries. Energy Research & Social Science, 44, pp.41–49.	x			x	x	x				x
Stratford, B., 2020. The threat of rent extraction in a resource-constrained future. Ecological Economics, 169, p.106524.				x	x	x	x	x	x	x
Thombs, R.P., 2020. In-and-Beyond State Power: How Political Equality Moderates the Economic Growth-CO2 Emissions Relationship, 1990-2014. The Sociological Quarterly, pp.1–20.	x			x		x				x
Vadén, T., Lähde, V., Majava, A., Järvensivu, P., Toivanen, T., Hakala, E. and Eronen, J.T., 2020. Decoupling for ecological sustainability: A categorisation and review of research literature. Environmental Science & Policy, 112, pp.236–244.		x				x				x
Van Den Bergh, J.C., 2017. A third option for climate policy		x			x	x		x		x

within potential limits to growth. Nature Climate Change, 7(2), pp.107–112.										
Vita, G., Lundström, J.R., Hertwich, E.G., Quist, J., Ivanova, D., Stadler, K., Wood, R. 2019. The Environmental Impact of Green Consumption and Sufficiency Lifestyles Scenarios in Europe: Connecting Local Sustainability Visions to Global Consequences. Ecological Economics, Volume 164.	x			x		x		x		x
Watkins, E., Ten Brink, P., Schweitzer, J. P., Rogissart, L., and Nesbit, M. 2016. Policy mixes to achieve absolute decoupling: An ex ante assessment. Sustainability, 8(6), pp.528.		x		x	x	x			x	
Weiss, M. and Cattaneo, C., 2017. Degrowth–taking stock and reviewing an emerging academic paradigm. Ecological Economics, 137, pp.220–230.		x		x		x	x	x	x	x
Wenzlik, M., Eisenmenger, N. and Schaffartzik, A., 2015. What drives Austrian raw material consumption?: A structural decomposition analysis for the years 1995 to 2007. Journal of Industrial Ecology, 19(5), pp.814–824.	x			x		x				x
Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Streeck, J., Pichler, M., Mayer, A., Krausmann, F., Brockway, P., Schaffartzik, A. and Fishman, T., 2020. A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part I: bibliometric and conceptual mapping. Environmental Research Letters, 15(6), p.063002.		x				(x)	x			x
Wijkman, A. and Rockström, J., 2012. Bankrupting nature: Denying our planetary boundaries. Abingdon: Routledge.	x			x	x	x		x		x

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